UNIT 1

INTEGUMENTARY SYSTEM

Structure

1.1 INTRODUCTION

The integument is the outermost covering of an animal. It is a composite organ that includes the skin and everything derived from or contained in it, forming an essential and dynamic integumentary system. The surface is the **epidermis,** below it is the **dermis** and between them lies the **basement membrane.**

The integument is the largest organ of the human body. In humans it makes up some 15 per cent of the weight. Epidermis and dermis together form some of the most varied structures found within vertebrates. The epidermis produces hair, feather, baleen, claws, nails, horns, beak and some types of scales. The dermis gives rise to dermal bones and osteoderms of reptiles. Collectively epidermis and dermis form teeth as well as denticles and skin of fish.

As the critical border between the organism and its environment, the integument has a variety of specialized functions. It forms part of the exoskeleton and thickens to resist mechanical injury. The integument helps hold the shape of the animal. Osmotic regulation and movement of gases and ions to and from the circulation are aided by the integument in conjunction with other systems. Skin gathers needed heat or radiates the excess and houses sensory receptors. Skin pigments block some of the sunlight, hence protect the body from harmful UV radiation.

Objectives

After studying this unit, you should be able to:

- ❖ describe the components that make up the structure of integument,
- ❖ explain the basic functions of the integument,
- ❖ compare the integument of fishes and tetrapods, and
- ❖ discuss the specialized derivatives of integument.

1.2 EMBRYONIC ORIGIN

Neurulation is a stage in the development of vertebrates during which nervous tissue is separated from the ectoderm which separates the skin tissue.

Let us begin by examining the embryonic origin and development of skin.

By the end of neurulation in the embryo, most skin precursors are delineated. The single layered surface ectoderm proliferates to give rise to the multilayered epidermis. The deep layer of the epidermis, the **stratum basale** rests upon the basement membrane. Through active cell division, the basement membrane replenishes the single layer of outer cells called the **periderm** (Fig. 1.1a).

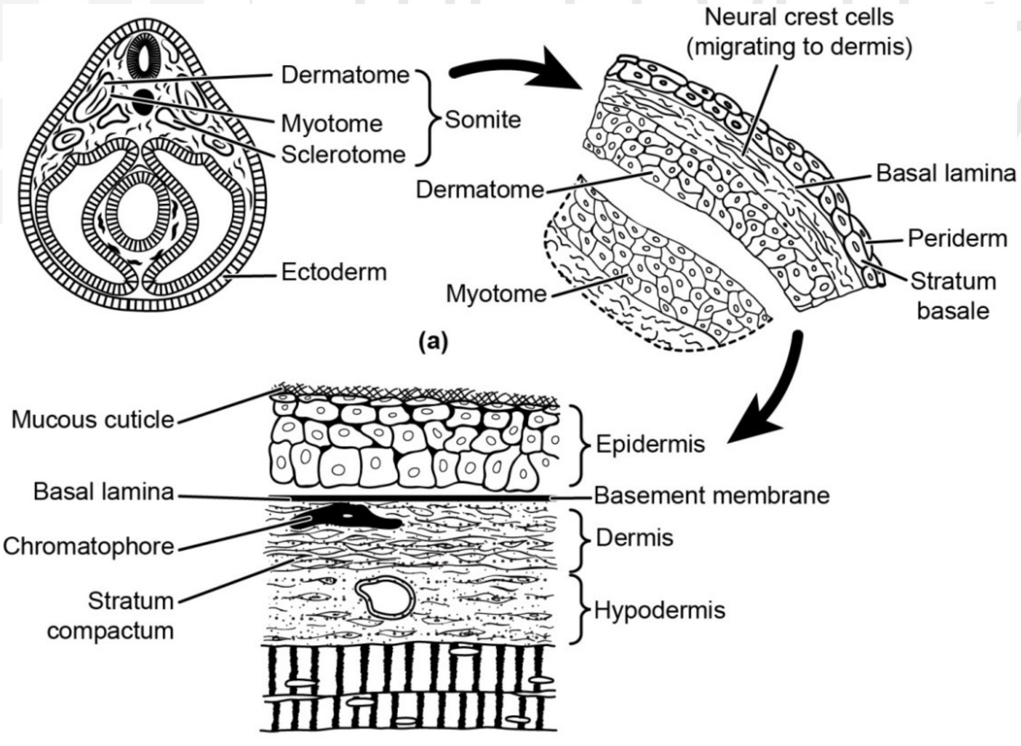

Fig. 1.1: Embryonic development of the skin. (a) Cross section of a representative vertebrate embryo. (b) The epidermis differentiates into a stratified layer that has cuticle on the surface.

The dermis arises from several sources, principally from the dermatome. Fundamentally, the integument is composed of two layers, epidermis and dermis, separated by the basement membrane. Vascularization and innervations are added, along with contributions from the neural crest. Interaction between epidermis and dermis stimulates specializations such as teeth, feathers, hair and scales of several varieties (Fig. 1.2).

A dermatome is the area of the skin of the human anatomy that is mainly supplied by branches of a single spinal sensory nerve root.

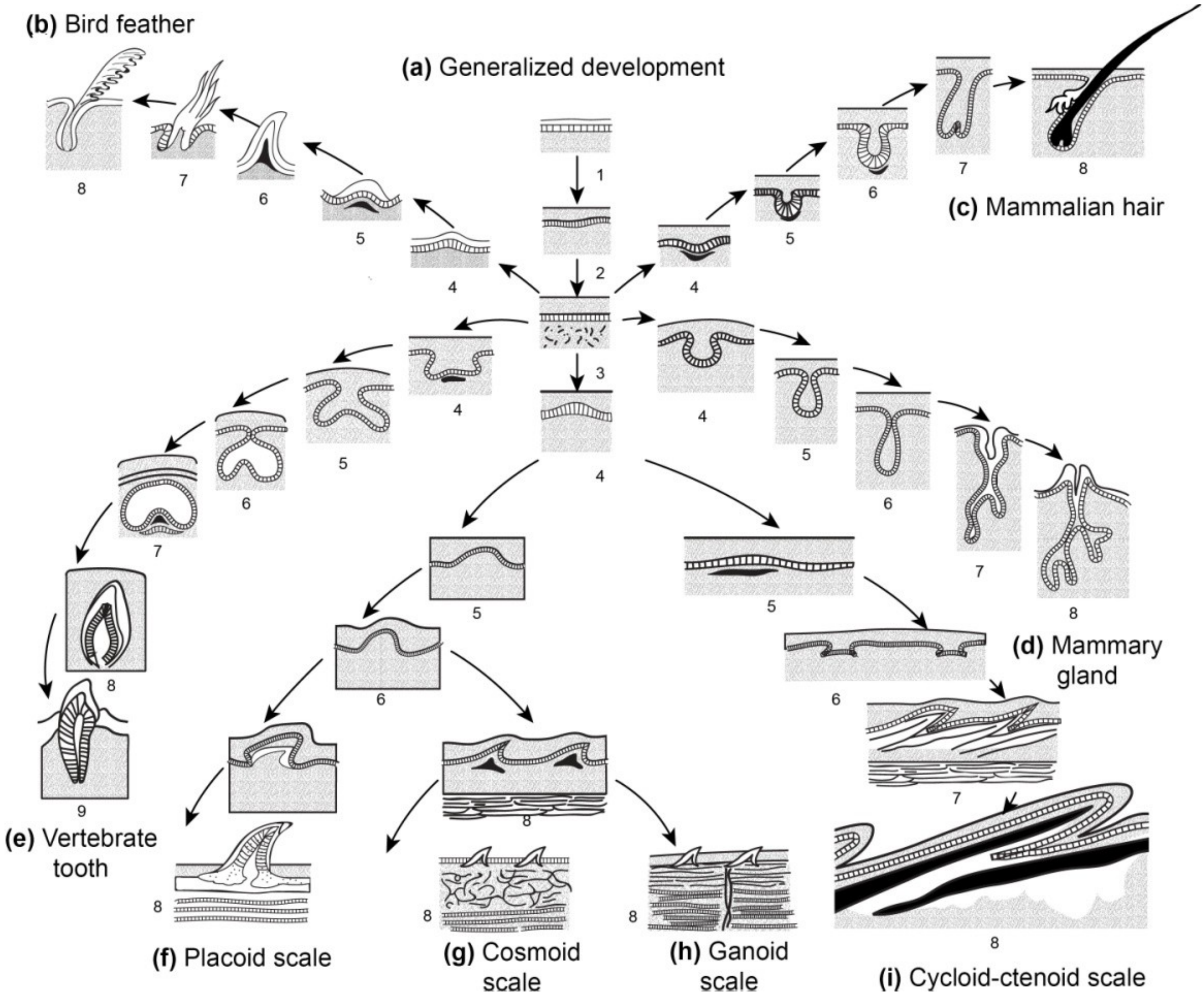

Fig. 1.2: Skin derivatives. (a) Out of the simple arrangement of epidermis and dermis, with a basement membrane, a great variety of vertebrate integuments develop. (b) Interaction of epidermis and dermis gives rise to feathers in birds. (c & d) Hair and mammary glands in mammals. (e) teeth in vertebrates. (f) Placoid scales in chondrichthyans and (g, h and i) Cosmoid, ganoid and ctenoid scales in bony fishes.

1.3 GENERAL FEATURES OF THE INTEGUMENT

Although we do not think of the integument in a vertebrate as an organ, it is made up of cells and tissue that work together as a single structure to perform very important functions in the body. The integument is made up of several layers of cells and can be divided as the outer layer of epithelial tissue forming the epidermis, below which is the region of tissue called the dermis and a third region below the dermis called the hypodermis which separates the skin from deeper tissue.

1.3.1 Epidermis

The epidermis in most animals is multilayered but thin. In many vertebrates it produces mucus to moisten the surface of the skin. In fishes, mucus seems to afford some protection from bacterial infection and helps ensure the laminar flow of water across the body surface. In amphibians, mucus probably serves similar roles and additionally keeps the skin from drying during the animal's sorties onto land.

In terrestrial vertebrates the epidermis covering the body often forms an outer **keratinized** or **cornified** layer, the **stratum corneum**. This layer is composed of mostly differentiated dead cells. New epidermal cells are formed by mitotic division, primarily in the deep epidermal layer **stratum basale.** These cells push more superficial ones towards the surface, where they tend to self destruct in an orderly fashion. During this process, various protein products accumulate and collectively form **keratin** (a water insoluble protein) in a process called **keratinization.** Keratin helps the skin to maintain a barrier against bacteria and gives some protection against injury.

Keratinisation and formation of **stratum corneum** also occur when friction or direct mechanical abrasion insult the epithelium. The stratum corneum may be differentiated into hair, hooves, horn sheaths or other specialized confined structures. Other epidermal cells may produce glands or they may be isolated glandular cells.

Scales form within the integument of many aquatic and terrestrial vertebrates. Scales are basically folds in the integument. If dermal contributions predominate, the fold is called a **dermal scale.** An epidermal fold produces an **epidermal scale.**

1.3.2 Dermis

The most conspicuous component of dermis is the fibrous connective tissue composed mostly of collagen fibres. The upper layer lies directly below the basal membrane that separates it from epidermis. It is composed of loosely packed cells. The layer below it has more tightly packed cells and is called stratum compactum. The dermis attaches the skin to the musculature lying below. It also includes nerves, blood vessels and pigment cells, bases of feathers, hair and its erector muscles and other associated structures. The dermis of many vertebrates produces plates of bone directly through intramembranous ossification. Because of their embryonic source and initial position within the dermis, these bones are called **dermal bones.** They are prominent in ostracoderm fishes but appear secondarily even in derived groups, such as in some species of mammals.

1.3.3 Functions of Integument

The integument is the first surface of the organism that comes in contact with the environment:

- It protects the internal soft tissue and organs from damage, microbes and abrasions. It is the first defence in the immune system against infections for instance, in our skin there are tiny oil glands that enhance the barrier function. It also protects against UV radiations.

- It receives and conducts external stimuli like touch, chemicals and temperature to the nervous system.
- Regulates the temperature of the body in most vertebrates. For instance the skin regulates the internal body temperature in most mammals by sweating.
- Protects against dehydration and water loss in terrestrial vertebrates.
- It helps in respiration in many aquatic vertebrates, may be the only respiratory organ in some aquatic vertebrates.
- Imparts colour which may be protective or for camouflage.

Let us now learn about the different forms of integument seen in the various groups of vertebrates. Though the fundamental pattern is the same, the skin is modified according to the environment in which they live.

1.4 PHYLOGENY

1.4.1 Integument of Fishes

With few exceptions, the skin of most living fishes is non-keratinized and covered instead by mucus. Exceptions include keratinized specializations in a few groups. The "teeth" lining the oral disc of lampreys, the jaw coverings of some herbivorous minnows, and the friction surface on belly skin of some semi terrestrial fish are all keratinized derivatives. However, in most living fishes, the epidermis is alive and active on the body surface, and there is no prominent superficial layer of dead, keratinized cells.

Two types of cells occur within the epidermis of fishes: epidermal cells and specialized unicellular glands. In living fishes, including cyclostomes, prevalent epidermal cells make up the stratified epidermis. Epidermal cells are tightly connected through cell junctions and contain numerous secretary vesicles that are released to the surface where they contribute to the mucous cuticle.

Unicellular glands are single, specialized and interspersed among the epidermal cell population. There are several types of unicellular glands. The club cell is an elongate, sometimes binucleate unicellular gland (Fig. 1.3).

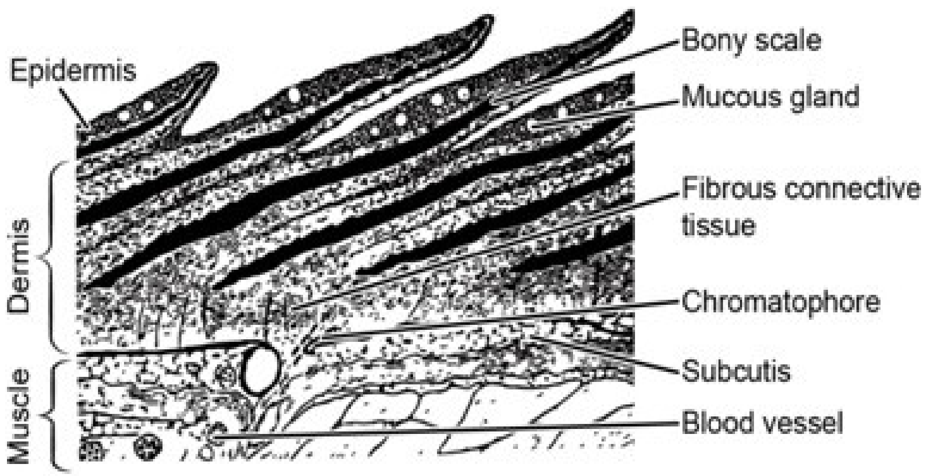

Fig. 1.3: Section of fish skin.

Collagen within the stratum compactum is regularly organized into plies that spiral around the body of the fish, allowing the skin to bend without wrinkling. In some fishes, the dermis has elastic properties. When a swimming fish bends its body, the skin on the stretched side stores energy that helps unbent the body. The fish dermis often gives rise to dermal bone, and dermal bone gives rise to dermal scales. In addition, the surface of fish scales is sometimes coated with a hard, acellular enamel of epidermal origin and a deeper dentinelayer of dermal origin.

Primitive Fishes

In ostracoderms and placoderms, the integument produced prominent body plates of dermal armor that encased their bodies in an exoskeleton. Dermal bones of the cranial region were large, forming the head shields, but more posterierly along the body, the dermal bones tended to be broken up into smaller pieces, the dermal scales. The surface of these scales was often ornamented with tiny, mushroom shaped tubercles. These tubercles consisted of a surface layer of enamel or an enamel like substance over an inner layer of dentine.

Agnatha

The skin of living hagfishes and lampreys departs considerably from that of primitive fossil fishes. Dermal bone is lost, and the skin surface is smooth and without scales (Fig. 1.4). The epidermis is composed of stacked layers of numerous living epidermal cells throughout. Interspersed among them are unicellular glands, namely, the large granular cells and elongate club cells. In addition, the skin of hagfishes includes **thread cells** that discharge thick cords of mucus to the skin surface when the fish is irritated. The dermis is highly organized into regular layers of fibrous connective tissue. Hagfishes also possess multicellular slime **glands** that release their products through ducts to the surface.

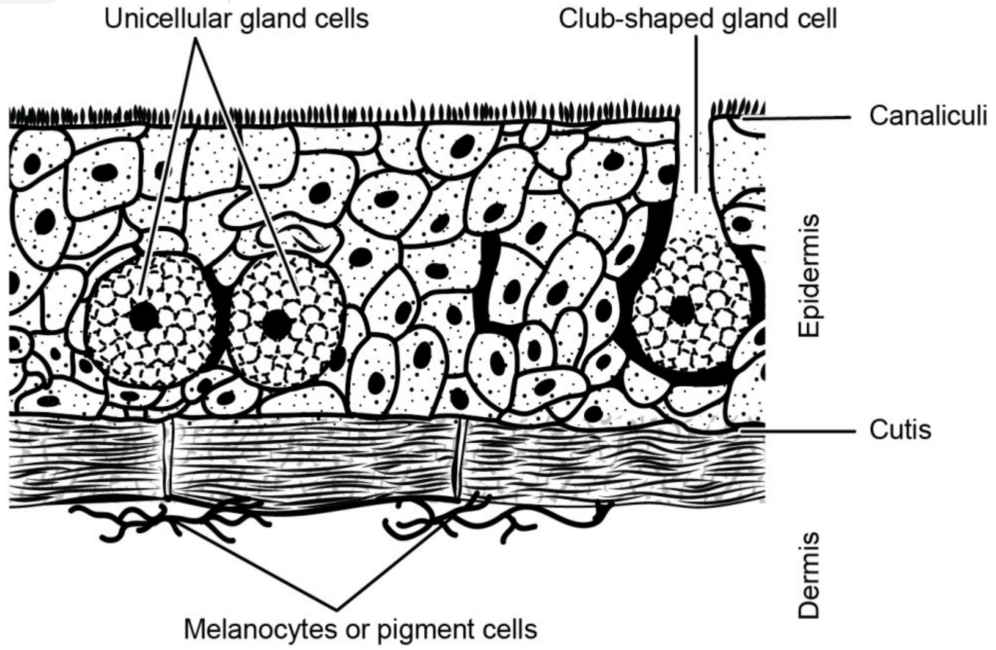

Fig. 1.4: Skin of larval cyclostomes in V.S.

Chondrichthyes

In cartilagenous fishes, dermal bone is absent, but surface denticles, termed **placoid scales**, persist. These scales give the rough feel to the surface of the skin (Fig. 1.5 a).

Recent evidence suggests that these tiny placoid scales favourably affect the water flowing across the skin as the fish swim forward to reduce friction drag. Numerous secondary cells are present in the epidermis as well as stratified epidermal cells. The dermis is composed of fibrous connective tissue, especially elastic and collagen fibres, whose regular arrangement forms a fabric like warp and weft in the dermis. This gives the skin strength and prevents wrinkling during swimming.

The placoid scale develops in the dermis but projects through the epidermis to reach the surface. A cap of enamel forms the tip, dentine lies beneath and pulp cavity resides within (Fig. 1.5 a, b).

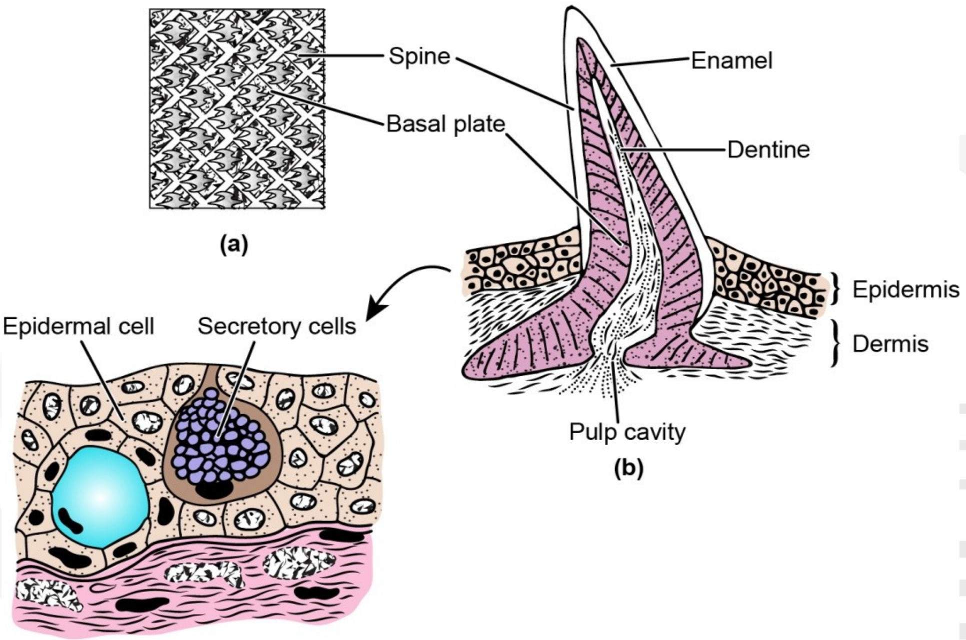

Fig. 1.5: Shark skin. (a) Surface view of the skin showing regular arrangement of projecting placoid scales. (b) Section through a placoid scale of shark.

Bony Fishes

The dermis of bony fish is subdivided into a superficial layer of loose connective tissue and a deeper layer of dense fibrous connective tissue Chromatophores are found within the dermis. The most important structural product of the dermis is the scale. In bony fishes, dermal scales do not actually pierce the epidermis, but they are so close to the surface they give the impression that the skin is hard (Fig. 1.6 a, b). These scales grow at the margins and over the lower surface which are lines of growth and represent the number of seasons the fish have lived. The dermis is vascular and permeable and in some small fish participates in gas exchange. The epidermis (Fig.1.6 b) contains many mucous glands; mucous helped reduce friction and prevent bacterial and fungal infections. Some fishes have poison glands, or granular glands that secrete poisonous/ irritating alkaloids. Some bony fishes have photophores and most have chromatophores that help in attracting prey or defence.

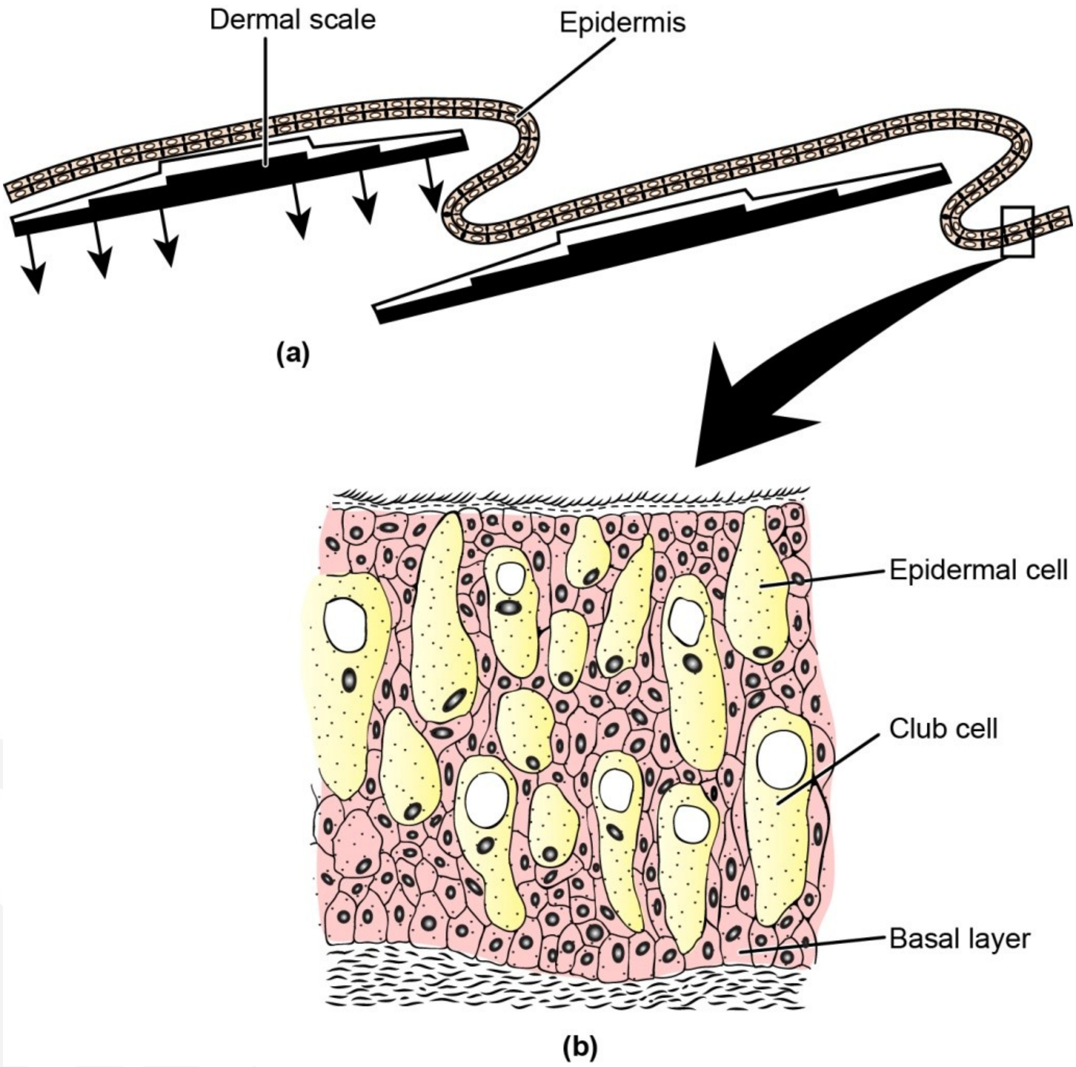

Fig. 1.6: Bony fish skin. (a) Arrangement of dermal scales within the skin of teleost fish. (b) Enlargement of epidermis.

On the basis of their appearance, several types of scales are recognized among bony fishes. The **cosmoid** scale, seen in primitive sarcopterygians resides upon a double layer of bone, one layer of which is vascular and the other lamellar. On the outer surface of this bone is a layer that is now recognized as dentine and spread superficially on the dentine is a layer now recognized as enamel.

The **ganoid** scale is characterized by the prevalence of a thick surface coat of enamel, without an underlying layer of dentine. Dermal bone forms the foundation of the ganoid scale, appearing as a double layer of vascular and lamellar bone or single layer of lamellar bone. Ganoid scales are shiny, overlapping and interlocking.

The **teleost scale** lacks enamel; dentine and vascular bone layer. Only lamellar bone remains, which is acellular and mostly non-calcified. Two kinds of teleost scales are recognized. One is **cycloid scale,** composed of **circuli.** The other is **ctenoid scale** with a fringe of projections along the posterior margin (Fig. 1.7).

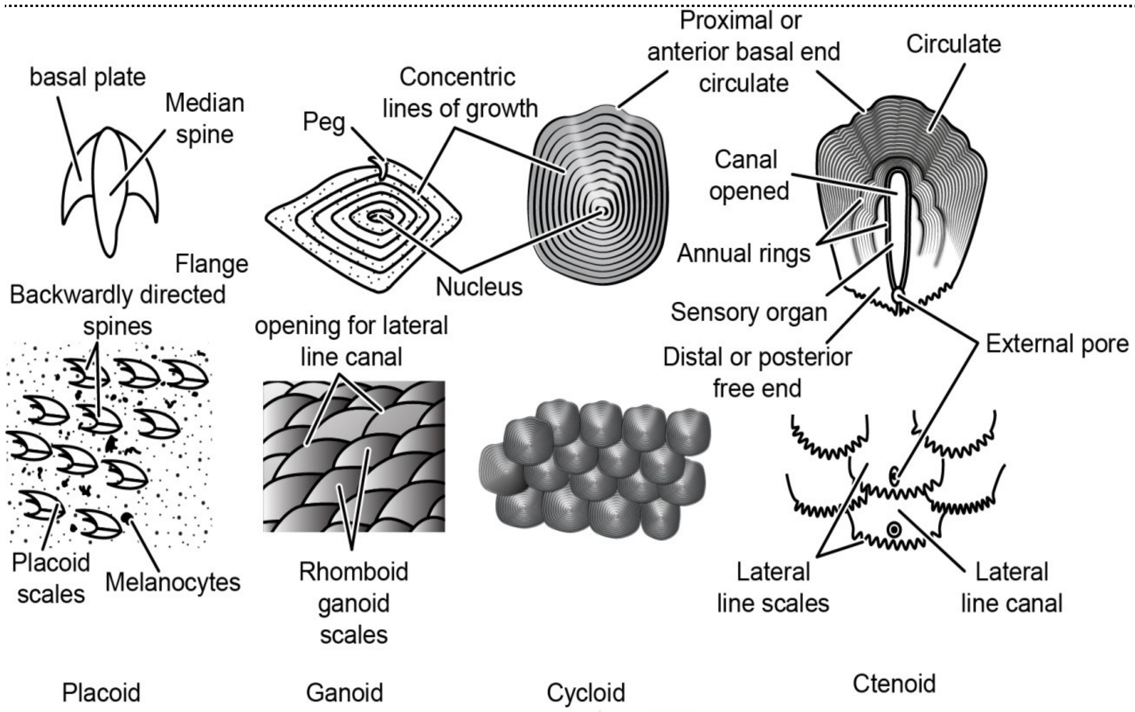

Fig. 1.7: Different types of dermal scales found in fishes. Lower row shows parts of skin with numerous scales. Upper row shows single scales.

SAQ 1

a) Which type of scales are present in cartilaginous fishes?

b) Bony fishes are characterised by which type of scales?

1.4.2 Integument of Tetrapods

Keratinization is a major feature of integument among terrestrial vertebrates. Extensive keratinization produces a prominent outer cornified layer, the stratum corneum, that resists mechanical abrasion. Lipids are often added during the process of keratinization or spread across the surface from specialized glands. The cornified layer along with these lipids increases the resistance of the tetrapod skin to desiccation. Multicellular glands are more common in the skin of tetrapods than in the skin of fishes. In fishes, the mucous cuticle and secretion of the unicellular gland at or near the surface of the skin. In contrast, among tetrapods, multicellular glands usually reside in the dermis and reach the surface through common ducts that pierce the cornified layer.

Amphibians

Amphibians are of special interest because during their lives they usually metamorphose from an aquatic form to a terrestrial form. Phylogenetically, amphibians are also transitional between aquatic and terrestrial vertebrates. The epidermis is composed of several layers of cells and amphibians are the first among the vertebrates to have a dead layer of cells, the stratum corneum. This layer is best developed in amphibians that spend most of their time on land. The dermis is thin, composed of two layers, the outer is loose stratum spongiosum and the inner more compact stratum compactum. Blood vessels, nerves and glands are located in the stratum compactum. In most modern amphibians, the skin is also specialized as a respiratory surface across which gas exchange occurs with the capillary beds in the lower epidermis and deeper dermis. In fact, some salamanders lack lungs and depend entirely on **cutaneous respiration** to meet their metabolic needs.

The most primitive amphibians had scales like the fishes from which they arose. Dermal scales are present only as vestiges in some species of tropical caecilians. Frogs and salmanders lack all traces of dermal scales (Fig. 1.8 a). In salamanders, the skin of the aquatic larvae includes a dermis of fibrous connective tissue. Scattered throughout are large Leydig cells to secrete substances that resist entry of bacteria or viruses. In terrestrial adults, the dermis is similarly composed of fibrous connective tissue. During the breeding season **nuptial pads** may form on digits of limbs of male salamanders or frogs. Nuptial pads are raised calluses of cornified epidermis that help the male hold the female during mating.

Generally, the skin of frogs and salamanders includes two types of multicellular glands, **mucus** and **poison glands** (Fig. 1.8 b). Chromatophores may occasionally be found in amphibian epidermis but most reside in the dermis.

Box 1.1: Poison Arrows and Poison Frogs

The skin of most amphibians contains glands that secrete products that are distasteful or even toxic to predators. In tropical region of the New World live a group of frogs, the poison arrow frogs, with especially toxic secretions. Native people of the region will often gather these frogs, hold them on sticks over a fire to stimulate release of these secretions and then collect the secretions on the tips of their arrows. Game shot with these toxin-laced arrows are quickly tranquilized or killed.

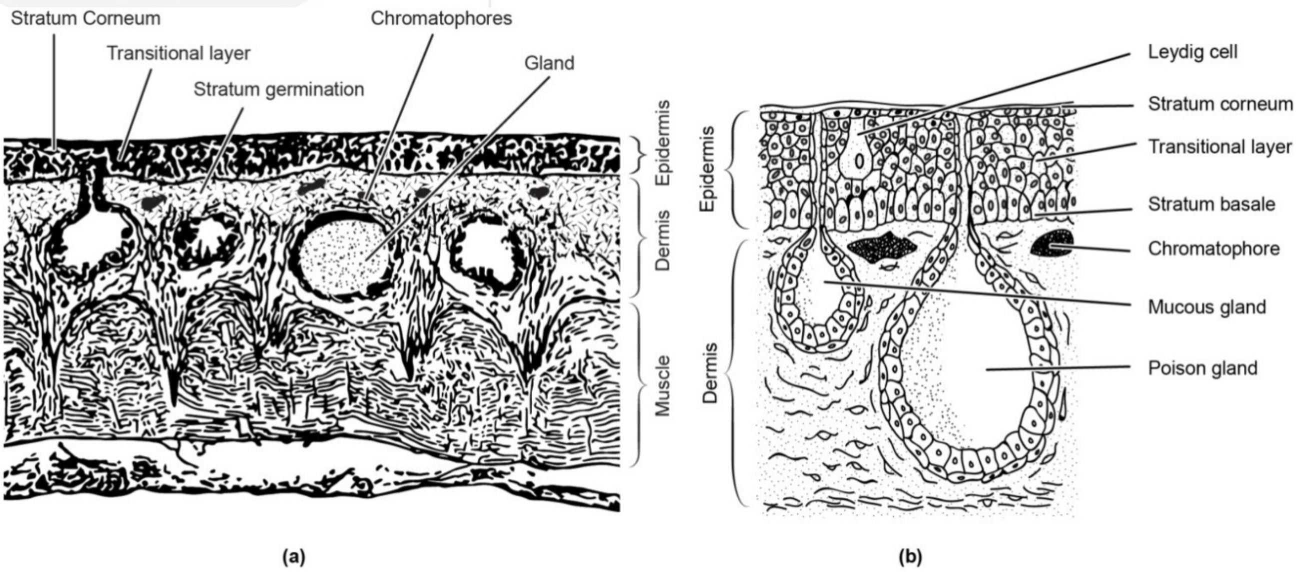

Fig. 1.8: Amphibian skin. a) Section through an adult frog skin. A basal stratum basale and a thin, stratum corneum are present. b) Diagrammatic view of amphibian skin showing mucous and poison glands that empty their secretions through short ducts to the surface of the epidermis.

Reptiles

The skin of reptiles reflects their greater commitment to a terrestrial existence. The epidermis has a well developed stratum corneum. Keratinization is much more extensive, with very few skin glands which is an adaptation to prevent loss of moisture. Horny scales are present, but these are fundamentally different from the dermal scales of fishes, which are built around bone of dermal origin. The reptilian scale usually lacks the bony undersupport or any significant structural contribution from the dermis. Instead it is a fold in the stratum corneum, hence it is an epidermal scale (Fig. 1. 9 a). If the epidermal scale is large and platelike, it is termed **scute**. Additionally, epidermal scales may be modified into crests, spines or hornlike processes.

Dermal bone is present in many reptiles. Where dermal bones support the epidermis, they are called **osteoderms;** plates of dermal bone located under the epidermal scales. Osteoderms are found in crocodilians, and some lizards. The dermis of reptilian skin is composed of fibrous connective tissue. In turtles and crocodiles, sloughing of skin is modest, in comparison to birds and mammals, in whom small flakes fall off at irregular intervals. But in lizards and in snakes, shedding of cornified layer, termed molting or **ecdysis** results in removal of extensive sections of epidermis (Fig. 1.9 b).

Integumental glands of reptiles are restricted to certain areas of the body. Many lizards possess rows of femoral glands along the underside of the hind limb in the thigh region. Crocodiles and turtles have scent glands. Most integumental glands of reptiles play a role in reproductive behavior.

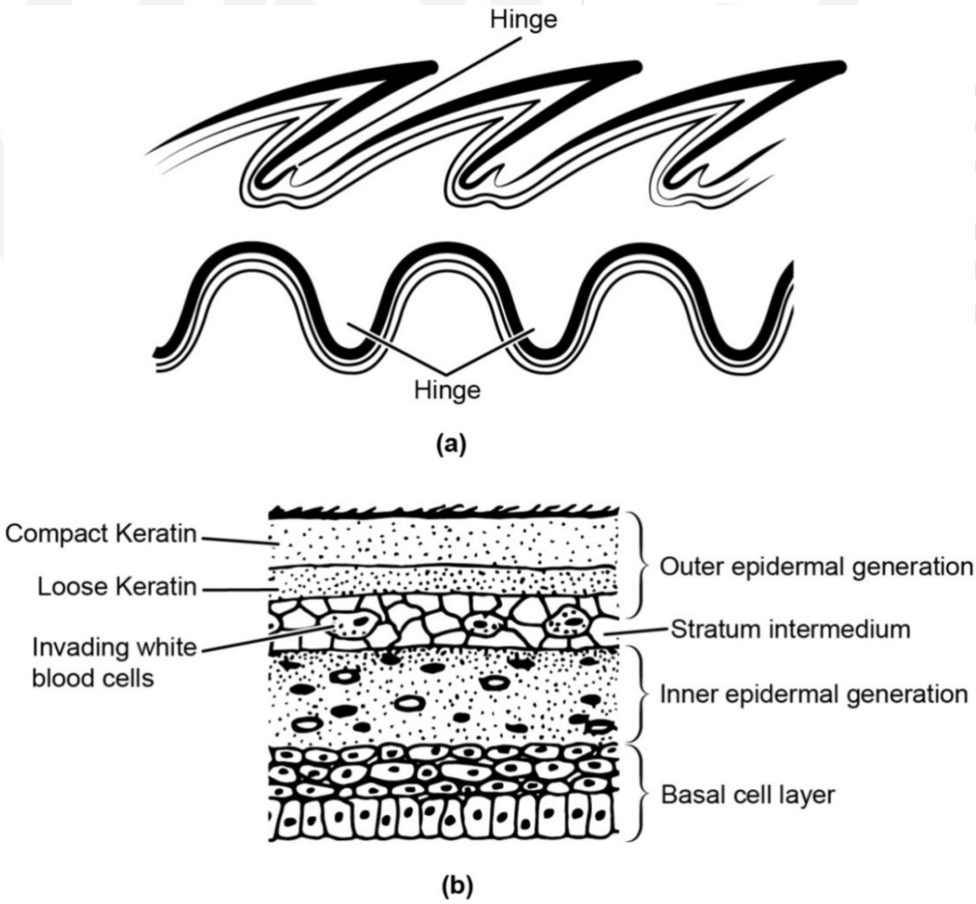

Fig. 1.9: Reptile skin. a) Epidermal skin scales. Extent of projection and overlap of epidermal scales varies among reptiles and even along the body of same individual. b) Section through epidermis of reptilian skin showing ecdysis.

Birds

The feathers of birds have been referred to as 'nothing more than reptilian scales'. This oversimplifies the homology, but probably not much. The dermis of bird skin, especially near the feather follicles, is richly supplied with blood vessels and sensory nerve endings. During brooding the dermis in the breast of some birds becomes vascularized, forming a **brood patch** in which warm blood can come in close association with incubating eggs.

The epidermis comprises the stratum basale and stratum corneum. Between them is the transitional layer of cells that gets transformed into the keratinized surface of stratum corneum (Fig. 1.10 a, b).

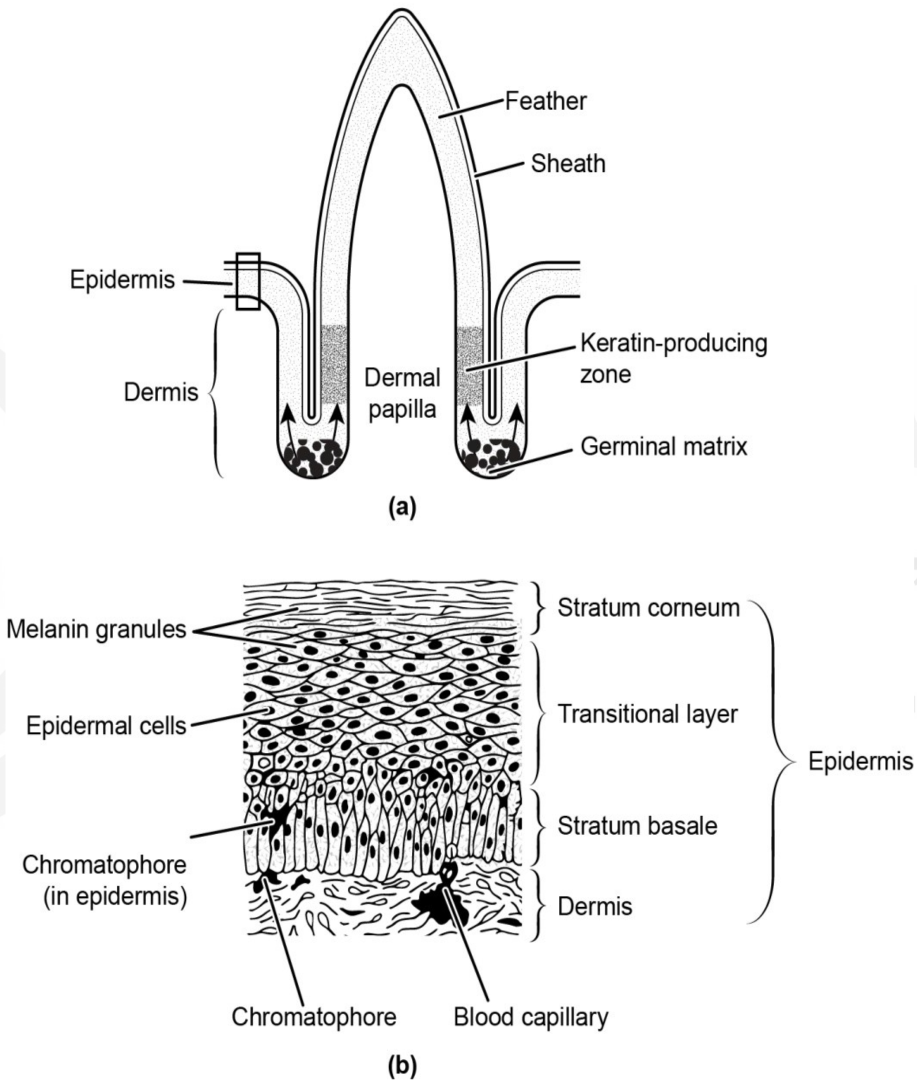

Fig. 1.10: Bird skin. (a) Growth of a feather follicle. The feather forms within a sheath, that is a keratinised derivative of epidermis. (b) Section of skin showing the stratum basale and keratinized surface layer, stratum corneum.

At least one bird has feathers and skin lightly coated with a toxin thought to deter predators. The brightly coloured bird, called a **hooded pitohui**, lives in New Guinea and is about the size of a blue jay. The poison works by repelling snakes, hawks, or other predators tasting one of the feathers. The bright plumage of the pitohui may represent a warning colouration to predators.

Bird skin is devoid of glands except the **uropygial gland,** located at the base of the tail (Fig. 1.11 b) secretes a lipid and protein product that birds collect on the sides of their beak and then smear on their feathers. The other gland located on the head of some birds, **salt gland,** is well developed in marine birds. Salt glands eject excess salt obtained when these birds ingest marine foods and sea water.

Feathers distinguish birds from all other vertebrates. Feathers can be structurally elaborate and come in a variety of forms. Yet feathers are nonvascular and non-nervous products of the skin, principally of the epidermis and the keratinizing system. They are laid out along distinctive tracts, termed pterylae, on the surface of the body (Fig. 1.11 b). Feathers develop embryologically from *feather follicles,* invaginations of the epidermis that dip into the underlying dermis.

The feather itself grows outward in the sheathed case. Within the sheath, the central axis is divided into a distal *rachis* that bears barbs with interlocking connections, termed barbules and a proximal *calamus* that attaches to the body.

There are several types of feathers (Fig. 1.11 b). *Contour feathers* lie close to skin as thermal insulation. *Filopumes* are often specialized for display and *flight feathers* constitute the major aerodynamic surface.

Flight feathers are characterised by a long *rachis* and *prominent vane* (Fig. 1.11 c). Their primary function is locomotion. Most feathers receive sensory stimuli and carry colours for display during courtship. Chromatophores are absent in birds, instead they have only one kind of pigment cells the melanocytes, just like mammals. These occur within the epidermis, and their pigments are carried into the feathers to give them colour.

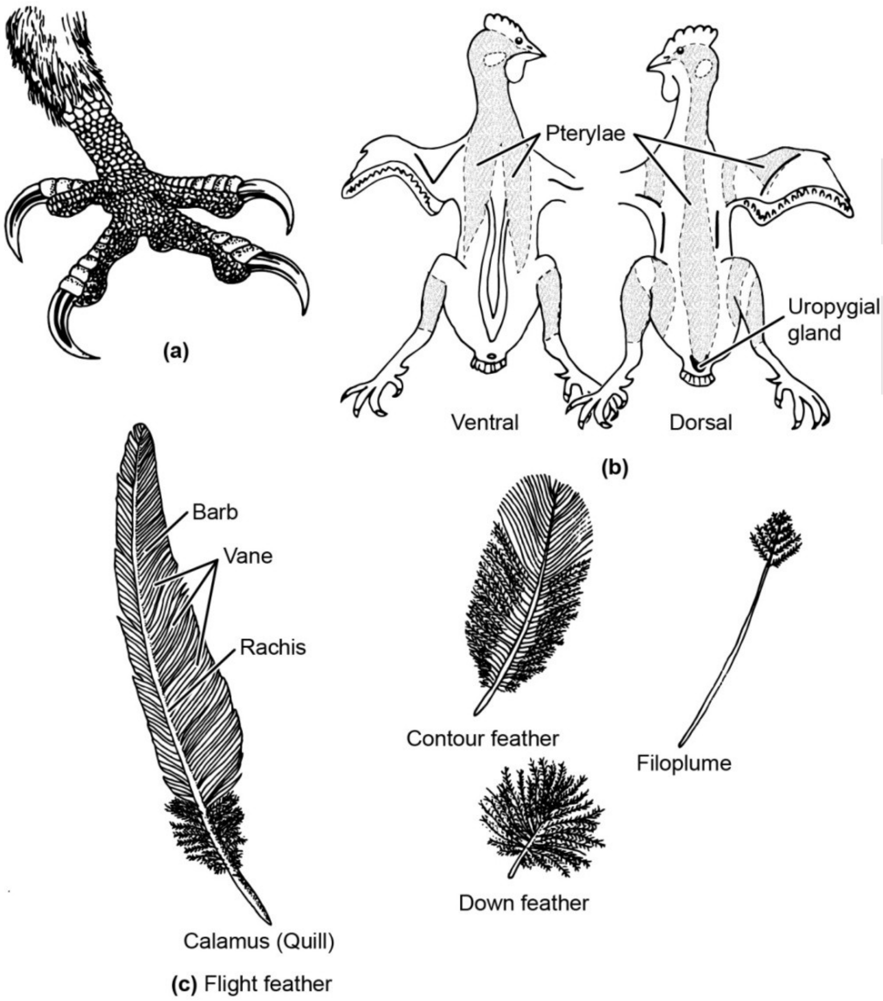

Fig. 1.11: Epidermal derivatives in the bird. (a) Epidermal scales are present on the feet and leg on birds. (b) Feathers arise along specific pteiylae tracts. (c) Feather types.

Mammals

As in other vertebrates, the two main layers of mammalian skin are epidermis and dermis which join and interface through the basement membrane. Beneath the dermis lies the hypodermis, composed of *connective tissue* and fat.

Epidermis

The epidermis may be locally specialized as hair, nails or glands. It is made up of stratified squamous epithelial tissue and has no blood vessels. Normal 'thin skin' has 4-5 layers of epithelial cells. From deep to superficial the layers are: *stratum basale* (also known as stratum germinativum) *stratum spinosum*, *stratum granulosum* and *stratum corneum* (Fig. 1.12). Epithelial cells of the epidermis are keratinocytes except the cells of stratum basale and belong to the keratinizing system that forms the dead superficial cornified layer of the skin. The surface kerantinized cells are replaced by cells arising primarily from the stratum basale cells. Cells within the basale divide mitotically. As they are displaced to higher levels, they pass through keratinization stages.

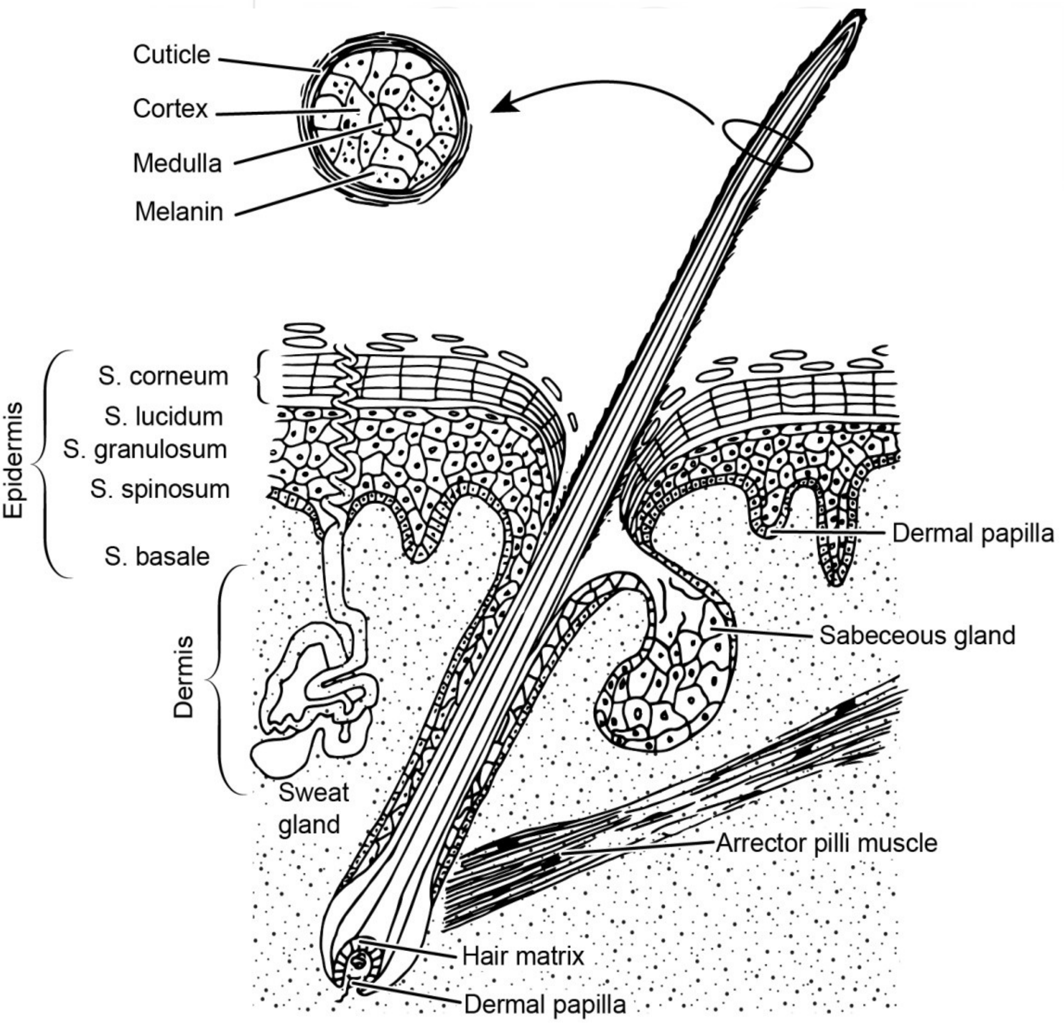

Fig. 1.12: Mammalian skin. The epidermis is differentiated into distinct layers. As in all other vertebrates, the deepest is stratum basale. The dermis pokes up dermal papillae that give the overlying epidermis an undulating appearance. Sweat glands, hair follicles and sensory receptors lie within the dermis.

The process of keratinization is most distinct in the regions of the body where the skin is thickest: as in the soles of the feet and palms. Elsewhere, these layers may be less apparent. Stratum corneum protects the delicate underlying cells of the epidermis from microbes, abrasions and water loss.

Though keratinocytes are the most prominent cell types of the epidermis, other cells are recognised although their functions are less clearly known. The *Langerhans Cells* are stellate cells dispersed throughout the upper part of stratum spinosum*.* These cells play a role in cell mediated action of immune system. The *Merkel cells*, originating from neural crest and associated with nearby sensory nerves, respond to stimulation that the brain perceives as touch. Merkel cells are more abundant in hands and feet. *Melanocytes* arise from embryonic neural crest cells. These secrete granules of the pigment *melanin***,** which are passed directly to epithelial cells. Melanin imparts hair and skin its colour (Skin colour arises from a combination of yellow *stratum corneum,* the red underlying blood vessels and dark pigment granules secreted by melanocytes).

Dermis

The mammalian dermis is double layered. The outer *papillary layer* pushes finger like projections, called *dermal papillae* into the overlying epidermis. Dermal papillae increase the strength of the epidermis-dermis connection they also contain blood vessels, receptors, some adipocytes and phagocytes. The deeper *reticular* layer includes irregularly arranged fibres, connective tissue, blood vessels; nerves and smooth muscles occupy the dermis but do not reach the epidermis. The mammalian dermis produces dermal bones, but these contribute to the skull and pectoral girdle and rarely form dermal scales in the skin.

Hair follicles and glands project inward from the epidermis (Fig. 1. 12). The dermis is usually composed of irregularly arranged fibrous connective tissue that is often impregnated with elastic fibres to give it some stretch but return it to its original shape. As a person ages, this elasticity is lost and the skin sags.

Hypodermis

Mammalian skin has another layer below the dermis; the hypodermis. It is made up of loose connective tissue, adipose tissue and skeletal muscles. The adipose tissue stores fat which gives a cushion for the internal organs. The skeletal muscles move the skin to some extent.

Hair

Hair are slender, keratinous filaments. The base of a hair is the root. Its remaining length, constitutes the *shaft*. The outer surface of the shaft often forms a *cuticle.* Beneath this is the *hair cortex* and at its core is the *hair medulla* (Fig. 1.12).

The hair shaft projects above the surface of the skin but it is produced within an epidermal hair follicle rooted in the dermis.

At its expanded base the follicle receives a small tuft of the dermis, *hair papilla.* Melanocytes in the follicle contribute pigment granules to the hair shaft to give it further colour. The *arrector pili* muscle, a thin band of smooth muscle anchored in the dermis, is attached to the follicle and makes the hair stand erect in response to cold, fear or anger.

Some hair are specialized. Sensitive nerves are associated with the roots of *vibrissae* or *whiskers* around the snouts of many mammals. These are common in nocturnal mammals and in mammals that live in burrows with limited light. The quills of porcupines are stiff, coarse hairs specialized for defense.

Glands

Principally, there are two main types of glands in mammals, *sebaceous* and *sweat* glands. Derived from them are *scent* and *mammary glands.*

The *sebaceous glands* are present all over the body and produce an oily secretion *sebum,* that is released on the skin and mostly into hair follicles in order to condition and help waterproof fur. Sebaceous glands are absent from the palms of hands and soles of feet, but they are present without associated hair, at the angle of the mouth, on the penis, near vagina and next to mammary nipples The *wax glands* of outer ear canal, which secrete ear wax and *Meibomian glands* of the eye lid, which secrete on oily film over the surface of the eye ball are modified sebaceous glands.

The *sweat glands* produce a watery product called perspiration or *sweat.* Two types are usually recognized by the viscosity of their secretion (viscous or thin), by their association (with or without hair follicles) and by their functional onset (at puberty or before). One type called eccrine sweat gland produces thin sweat, and is found all over the body and more abundant on the palms, feet and forehead. It is not associated with hair follicles. It is a coiled gland present deep in the dermis and its mouth opens on the surface of epidermis. Its products are mostly water with some salt, antibodies, antimicrobial peptides and traces of metabolic waste; function in regulation of body temperature. The other apocrine sweat gland produces viscous sweat, is associated with hair follicles, and begins functioning at puberty. Apart from water and salt it secretes organic compounds that are decomposed by bacteria and this is responsible for body odor.

Sweat glands are not found in all mammals, and their distribution varies. Chimpanzees and human have the greatest number of sweat glands, including some on the palms and soles. In the duckbill platypus, sweat glands are limited to the snout. In deer, they are present at the base of tail. In elephants, sweat and sebaceous glands are absent entirely.

The *scent glands* are derived from sweat glands and produce secretions that play a part in social communication. Secretions of these glands are used to mark territory, identify the individual and communicate during courtship.

The *mammary glands* are also thought to be derived from sweat glands or perhaps from sebaceous glands. Functional only in the female, they produce milk and watery mixture of fats, carbohydrates and proteins that nourish the young. The number of mammary glands varies among species. Release of milk to suckling is *lactation.* Mammary glands consist of numerous lobules. Each lobule is a cluster of secretary alveoli in which milk is produced. The alveoli open into a common duct that, in turn, opens to the surface through a raised epidermal papilla or *nipple*. The nipple is surrounded by circular pigmented area of skin called *aerola.* Alveolar ducts open into a common chamber or cistern within a long collar of epidermis called *teat* (1.13 a, c). Adipose tissue can build up beneath the mammary glands to produce *breasts*.

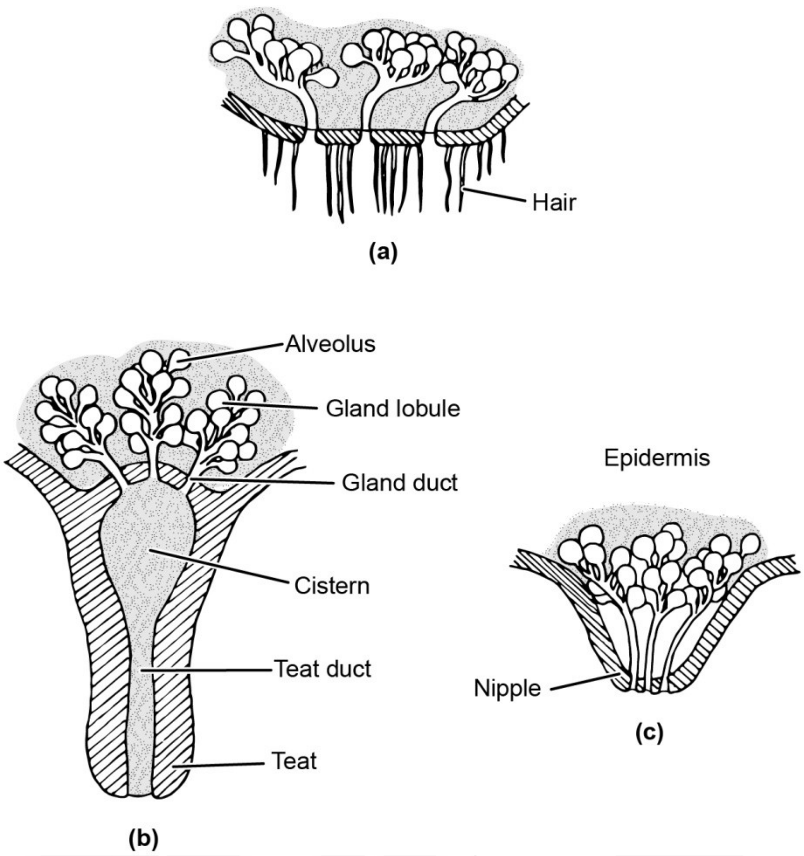

Fig. 1.13: Mammary glands. a) In monotremes, the mammary glands open to the unspecialized skin surface, and the young press their snout to skin where these glands open. b) In some marsupials, the mammary ducts open through specializations of the integument, c) The nipple is a raised epidermal papilla around which the supple lips of the infant fit to drink the milk.

In *monotremes, nipples* and *teats* are absent and breasts do not form. Milk is released from ducts into the flattened milk patch or aerola on the surface of the skin (Fig. 1.14 a). The point of infant's snout is shaped to fit the surface, permitting vigorous sucking. At sexual maturity adipose tissue builds up under the mammary glands to produce breast from which milk is released. In common language, this is termed *let down*.

SAQ 2

Fill in the blanks.

a) Dermal bones are most prominent in ……………….. .

b) In fishes and aquatic vertebrates, collagen fibres of the dermis are arranged to form ……………….. layer of the integument.

c) In terrestrial vertebrates, the epidermis covering the body often forms a keratinized layer called as ………………… .

d) Epidermal fold, in the form of thickened keratinized layer produces …………………… .

e) *Stratum basale,* the deepest layer of epidermis rests upon……………… .

SAQ 3

Match the following:

i)	Femoral glands	a)	Birds
ii)	Uropygial glands	b)	Crocodiles
iii)	Scent glands	c)	Lizards
iv)	Mammary glands	d)	Eye lids of mammals
v)	Meibomian glands	e)	Female mammals
vi)	Sebaceous glands	f)	Mammals

SAQ 4

Answer the following in one or two words:

a) Two types of cells present within the epidermis of fishes.

b) Surface denticles present in chondrichthyes.

c) Scales, characterized by prevalence of thick enamel, present in bony fishes.

d) Skin is specialized as a respiratory surface in these tetrapods.

e) In these reptiles, osteoderms are found.

f) The presence of major structure which distinguishes birds from all other vertebrates.

SAQ 5

a) Which are the four successive layers present in the integument of mammals?

b) Which muscle is attached to the hair follicle of human beings and makes hair stand erect?

1.5 SPECIALISED DERIVATIVES OF THE INTEGUMENT

Up to now you have studied comparative account of vertebrate skin. Let us now look at the special derivatives of skin in different vertebrates.

1.5.1 Nails, Claws, Hooves

Nails are plates of tightly compacted, cornified epithelial cells on the surface of fingers and toes, thus, they are products of the keratinizing system of the skin. The nail matrix forms new nail at the nail base by pushing the existing nail forward to replace that worn or broken at the free edge. Nails protect the tips of digits from inadvertent mechanical injury. They also help stabilize the skin at the tips of the fingers and toes, so that on the opposite side the skin can establish a secure friction grip on objects grasped.

Only primates have nails (Fig. 1.14 a). In other vertebrates, the keratinizing system at the terminus of each digit produces claws or hooves (Fig. 1.14 b, c). *Claws* or *talons* are curved, laterally compressed keratinized projections from the tips of digits. They are seen in some amphibians and in most birds, reptiles and mammals. *Hooves* are large keratinized plates on the tips of the ungulate digits.

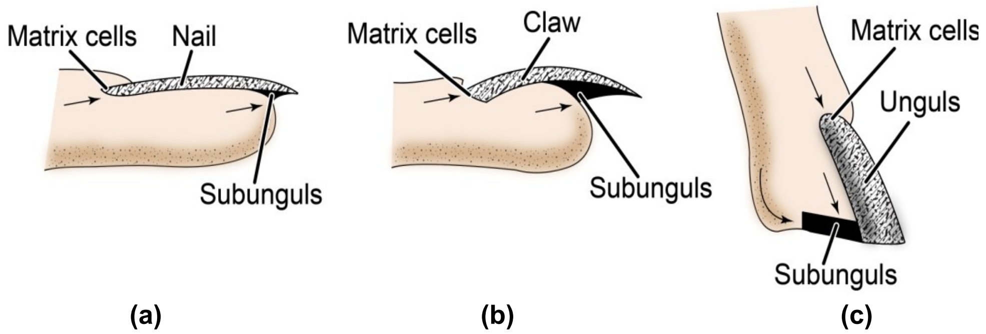

Fig. 1.14: Epidermal derivatives. (a) The nail is a plate of cornified epithelium growing outward (arrows) from proliferating matrix cells at its base and from subunguis. (b) Claw (c) Hoof.

1.5.2 Horns and Antlers

Horned lizards have processes extending from behind the head that look like horns but are specialized, pointed epidermal scales. Mammals are the only vertebrates with true horns or antlers.

The skin, together with the underlying bone contributes to both true horns and antlers. As these structures take shape, the underlying bone rises up, carrying the overlying integument with it. In horns, the associated integument produces a tough, cornified sheath that fits over the bony core (Fig. 1.15 a). In antlers, the overlying living skin (called 'velvet') apparently shapes and provides vascular supply to the growing bone. Eventually the velvet falls away to unsheathe the base bone, the actual material of the finished antlers (Fig. 1.15 b).

True antlers occur only in members of the *Cervidae* (e.g. deer, elk, moose). Typically, only males have antlers, which are branched and shed annually. There are notable exceptions. In deer, the antler usually consists of a main beam from which branch shorter points.

The annual cycle of antler growth and loss in the white-tail deer for example, is under hormonal control. In spring, increasing length of daylight stimulates the pituitary gland to release hormones that stimulate antlers to sprout from sites on the skull bones. By late spring, the growing antlers are covered by velvet. By fall, hormones produced by the testes inhibit the pituitary and the velvet dries.

Among mammals, true horns are found among members of the family Bovidae (e.g. cattle, antelope, sheep, goats, bison). Commonly horns occur both in males and females, are retained year round, and continue to grow throughout the life of the individual. The horn is unbranched and formed of a bony core and a keratinized sheath.

Unlike true horns of bovids, horns of the pronghorn, family Antilocapridae, are forked in adult males. The rhino horn does not include a bony core, so it is exclusively a product of the integument. It forms from compacted keratinous fibres.

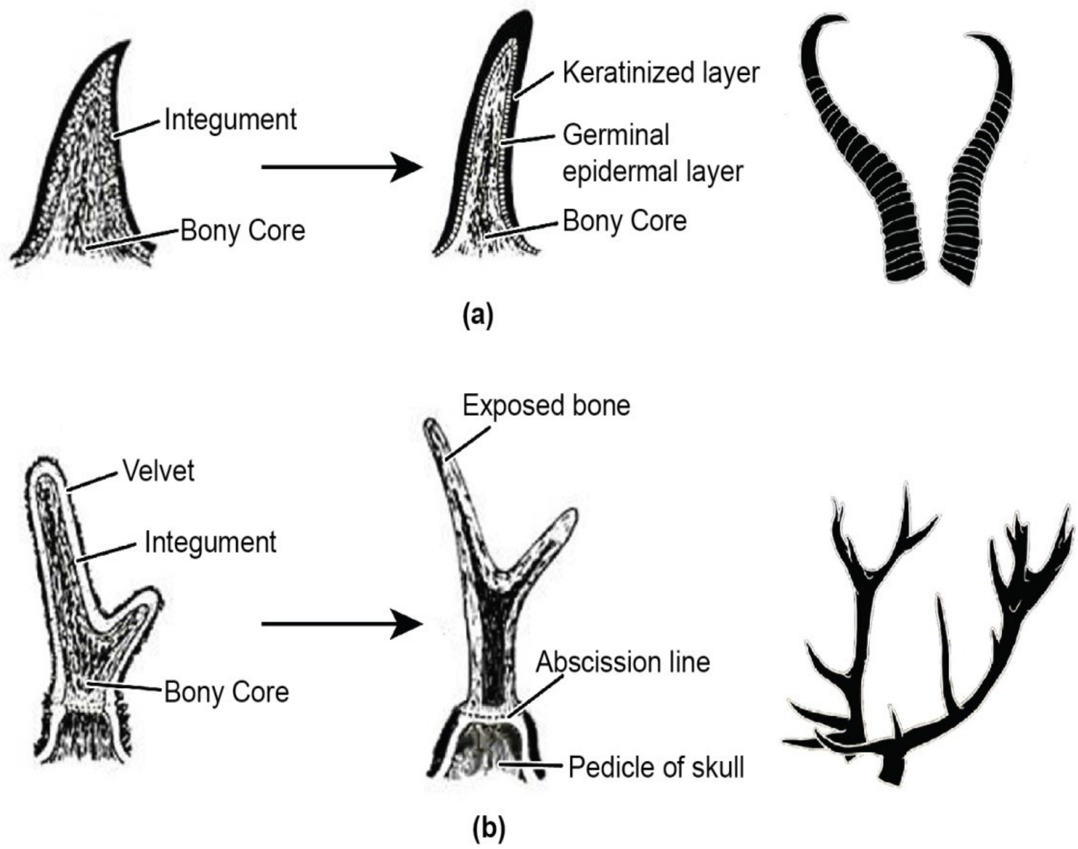

Fig. 1.15: Horns and Antlers. a) Horns appear as outgrowth of skull beneath the integument, which forms a keratinized sheath. b) Antlers also appeal as outgrowth of the skull beneath the overlying integument, which is referred to as 'velvet' because of its appearance.

1.5.3 Baleen

The integument within the mouths of Mysticete whales forms plates of *baleen* that act as strainers to extract krill from water gulped in the distended mouth. Although, it is sometimes referred to as “whalebone”, baleen contains no bone. It is a series of keratinized plates that arise from the integument. During its formation, groups of dermal papillae extend and lengthen outward, carrying the overlying epidermis. The epidermis forms a cornified layer over the surface of these projecting papillae. Collectively, these papillae and their covering of epidermis constitute the plates of baleen (Fig. 1.16).

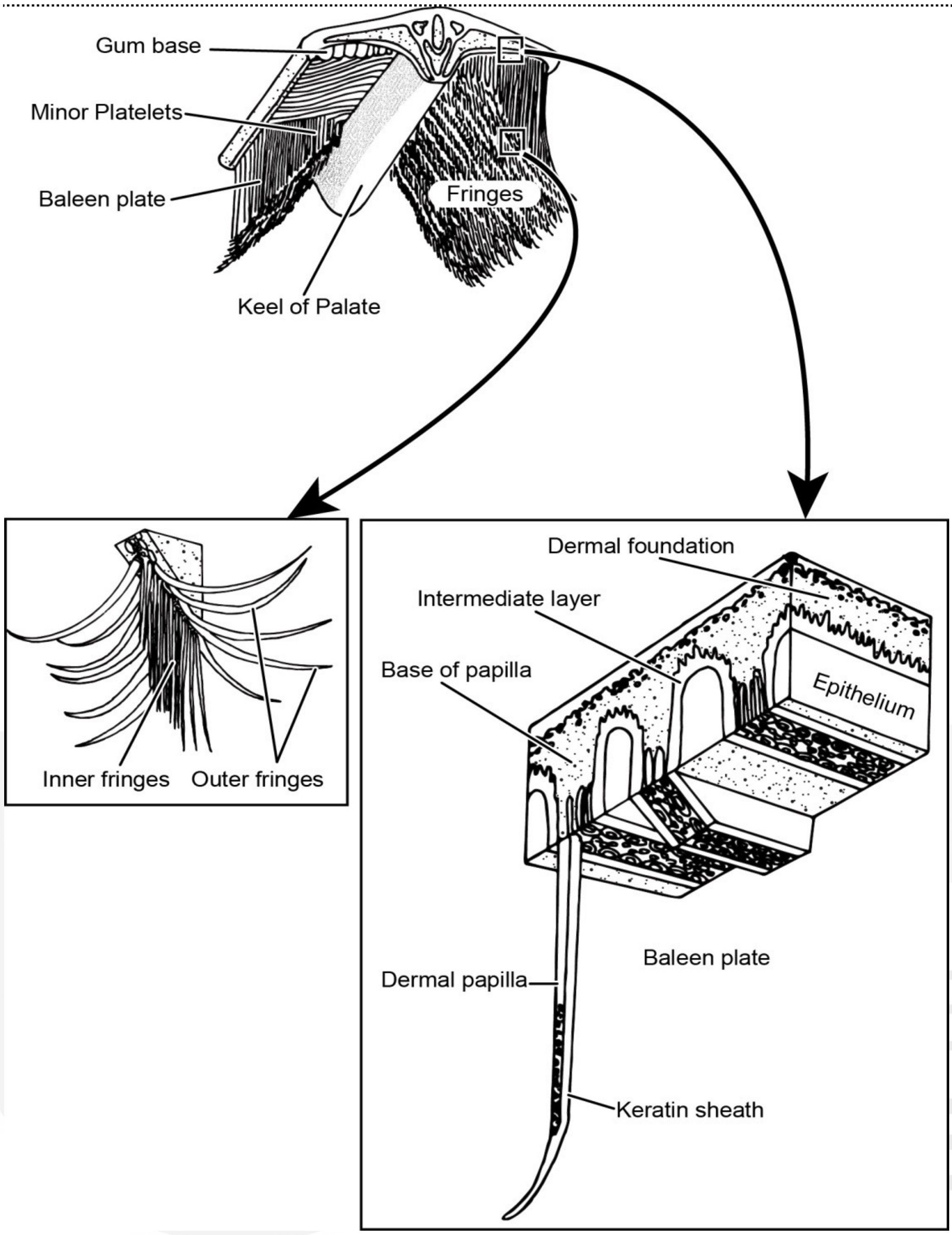

Fig. 1.16: Baleen from a whale. The lining to the mouth includes an epithelium with the ability to form keratinized structures. Groups of outgrowing epithelium become keratinized and frilly to form the baleen.

1.5.4 Scales

Scales have many functions. Both epidermal and dermal scales are hard, so when they receive mechanical insult and surface abrasion, they prevent damage to soft tissues beneath. The density of scales also makes them a barrier against invasion of foreign pathogens, and they retard water loss from the body. In sharks and fishes, scales dampen the boundary layer turbulence to increase swimming efficiency. Some reptiles regulate the amount of surface heat they absorb by turning their bodies forward or away from the sun.

1.5.5 Dermal Armor

Dermal bone forms the armor of ostracoderm and placoderm fishes. Being a product of the dermis, dermal bone has a great variety of structures. Dermal bone supports the scales of bony fishes but tends to be lost in tetrapods. It is absent in the skin of birds and most mammals. Exceptions have been noted earlier, namely, in the fossil mammal *Glyptodon* and in the skin of the living, armadillo. However, selected dermal bones take up residence in the fish skull and pectoral girdle.

The shell of turtles is a composite structure. The dorsal half of the shell is the *carapace* formed by fusion of dermal bone with expanded ribs and vertebrae. Ventrally the *plastron* represents fused dermal bones along the belly. On the surface of both carapace and plastron, keratinized plates of epidermis cover this underlying bone.

1.5.6 Mucus

Mucus produced by the skin serves several functions. In aquatic vertebrates, it inhibits entrance of pathogens and may even have slight antibacterial action. In terrestrial amphibians, mucus keeps the integument moist, allowing it to function in gas exchange. Although cutaneous respiration is prominent in amphibians, it occurs in many other vertebrates as well. For example, many turtles rely on cutaneous gas exchange as they hibernate submerged in ice-covered ponds during winter. Sea snakes may depend on cutaneous respiration for up to 30 per cent of their oxygen uptake. Similarly fishes such as the plaice, European eel and mudskipper may depend on some cutaneous gas exchange to meet their metabolic requirement.

Mucus is also involved in aquatic locomotion. As a surface coat, it smoothes the irregularities and rough surface features on the epidermis to reduce the friction met by a vertebrate swimming through relatively viscous water.

1.5.7 Colour

Skin colour results from complex interactions between physical, chemical and structural properties of the integument. Changes in blood supply can redden the skin, as in blushing in humans. The *differential scattering* of the light, referred to as *Tyndall scattering,* is the basis of much colour is nature. This is the phenomenon that makes the clear day sky appear blue. In birds, air-filled cavities within feather barbs take advantage of this scattering phenomenon to produce blue feathers of kingfishers, blue jays, and bluebirds. Many black, brown, red, orange and yellow colours result from pigments. Pigments produce colour by selective light reflection. Interference phenomena are responsible for iridescent colours.

Many of the pigments, producing colours by this variety of physical phenomena are synthesized by and held in specialized dermal cells termed chromatophores that arise from embryonic neural crest. They are responsible for generating skin and eye colour in ectotherms. On the basis of form, composition and function, four groups of chromatophores are currently recognized. The most well known of these is the melanophore that contains the pigment melanin which appears black or brown and is packaged in vesicles called melanosomes, these are distributed throughout the cell.

A second type of chromatophore is the *iridophore* which contains light reflecting, crystalline guanine plates. It is found in ectothermic vertebrates and in the iris of the eye of some birds. When illuminated by light the plates reflect the light producing iridescence. Two other types of chromatophores are the *xanthophores,* containing yellow pigments and the *erythrophore,* so called because of the red pigments. Sometimes both these pigments are found in the same cell and their ratio gives the overall colour.

Endotherms (birds and mammals) have only one class of pigment cells the melanocytes that are equivalent to the melanophores of ectotherms, to generate the skin and eye colour. You have read in the earlier sub section that melanocytes are present in the stratum basale of the epidermis and produce melanin that is built up in the keratinocytes giving the skin colour.

Sunlight can influence physiological changes in chromatophore activity. Increased exposure stimulates increased production of pigment granules, resulting in darker skin in humans over a period of days.

SAQ 6

a) Which pigment in human beings causes skin colouration?

b) Though misleadingly referred to as 'whale-bone', it contains no bone. What is it?

1.6 SUMMARY

- Integument is a composite organ. Fundamentally it is composed of epidermis, and dermis, separated by the basement membrane. It protects the animal from injury, microbes, water loss and regulates the body temperature.
- The epidermis is the outer layer of epithelial tissue and is several layers thick. The epidermis of terrestrial vertebrates forms keratinized layer, called as stratum corneum. The dermis is made up of connective tissue and in many vertebrates produces dermal bones, which is prominently seen in bony fishes.
- Living agnathans do not have scales but many mucous secreting glands in their skin while cartilaginous and bony fishes have protective scales derived from the integument.
- In cartiliginous fishes, placoid *scales* are present. Bony fishes are characterised by cosmoid *scales* and ganoid *scales.* Teleosts are characterised by two types of scales: cycloid scales and ctenoid scales.
- Skin of amphibians is specialized for respiration i.e. *cutaneous respiration. Mucous glands* and *poison glands in the dermis* are main characteristics of amphibians. Chromatophores may occasionally be found in the amphibian dermis.
- In reptiles keratinization is much more extensive. Integumental glands of reptiles are restricted to certain areas of the body. Many lizards possess *femoral glands* in the thighs. Crocodiles and turtles have *scent glands.*

- Feathers originating from dermis distinguish birds from all other vertebrates. Bird skin has no glands except *uropygial glands* at the base of tail and *salt gland* on the head.
- The epidermis of mammals is specialized as *hair, nails or glands.* Keratinocytes are the most prominent cell types of epidermis. Skin colour of mammals is due to pigment *melanin.* Principally there are two main types of glands in mammals i.e. *sebaceous* and *sweat glands.* Derived from them are *scent* and *mammary* glands.
- Baleen, claws, hooves, horns, antlers and dermal armor are specialized derivatives of the integument.

1.7 TERMINAL QUESTIONS

1. What is the difference between cycloid scale and ctenoid scale of teleosts?
2. Write two important differences between scales of reptiles and fishes.
3. What are the different types of feathers? What are their functions?
4. What is the function of sebaceous glands? Write the various types of sebaceous glands present in mammals.
5. Explain keratinization in terrestrial vertebrates.

1.8 ANSWERS

Self-Assessment Questions

1. a) Placoid scales

   b) Cosmoid and Ganoid scales.

2. a) ostracodem fishes

   b) *stratum compactum*

   c) *stratum corneum*

   d) epidermal scale

   e) basement membrane

3. i) c ii) a iii) b iv) e v) d vi) f.

4. a) epidermal cells and unicellular glands

   b) placoid scales

   c) ganoid scales

   d) amphibians

   e) crocodiles and some lizards

   f) feathers

5. a) i) *stratum spinosum*

ii) *stratum granulosum*

iii) *stratum lucidum*

iv) *stratum corneum*

b) Arrector pili.

6. a) Melanin, b) Baleen.

Terminal Questions

1. Cycloid scale is composed of concentric rings or **circuli** and ctenoid scale has a fringe of projections along its posterior margin.

2. The scales of fishes are of dermal origin. But reptilian scales lack bony undersupport or any significant structural contribution from the dermis. It is a fold in the surface epidermis.

3. There are four main types of feathers in birds: Contour feathers, down feathers, filoplumes and flight feathers. Contour feathers aerodynamically shape the surface of the bird. Down feathers lie close to the skin as thermal insulation. Filoplumes are often specialized for display and flight feathers constitute the major aerodynamic surface.

4. Sebaceous glands produce an oily secretion called sebum. The **wax glands** of outer ear canal, which secrete wax and **meibomian glands** of eyelid, which secrete an oily film on the surface of eyeball are derived from sebaceous glands.

5. Keratinocytes of epidermis form the dead, superficial cornified layer of the skin. The surface of keratinized cells are continually exfoliated and replaced by cells of stratum corneum.

Acknowledgement of Figures

Fig. 1.3: Source: General Biological Supply House