MJC 3 (Comparative Anatomy)

Integument: Its derivatives and functions

The integument (or skin) is a composite organ. On the surface is the epidermis, below it is the dermis and between them lies the basement membrane. The integument is one of the largest organs of the body, making up some 15 per cent of the human body 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, 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 an organism. Osmotic regulation and movement of gases and ions to and from the circulation are aided by the integument in conjunction wit11 other systems. Skin gathers needed heat or radiates the excess and houses sensory receptors. It holds feathers for locomotion, hair, for insulation and horns for defense. Skin pigment blocks full sunlight.

There is nothing more conspicuous about an organism than its skin. It is our primary means of identifying the organism, and is what defines the boundary of its body. Skin is also the primary means through which an organism interacts with its environment.

Basic structure of the integument:

The integument consists primarily of the skin and its derivatives. Skin is a functional unit composed layers of fairly distincy epidermis (derived from ectoderm) and dermis (derived from the dermatome of somites) that are separated by the basement membrane.

Epidermis

- is relatively thin in most animals
- the upper layer composed of mostly dead, differentiated cells (stratum corneum) with a lot of keratin which helps the skin maintain some protection against water loss and bacteria
- continually produced by the most basal layer of the epidermis (stratum germinativum) and consists of cuboidal cells that are generalized and move toward the upper layer as they differentiate
- as the cells move outward, most synthesize keratin, a water-insoluble protein, the cells become flattened, die, and are sloughed off. Other epidermal cells form multicellular glands or isolated glandular cells.
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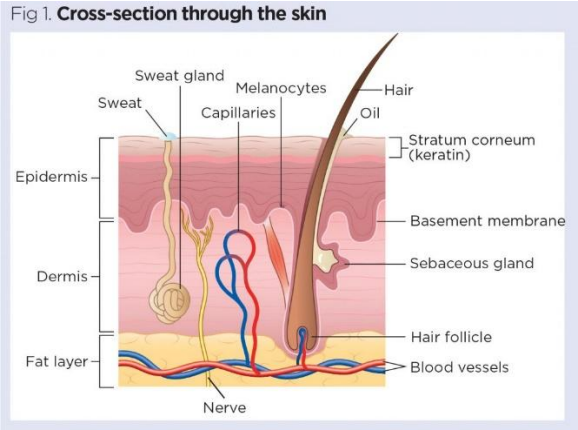
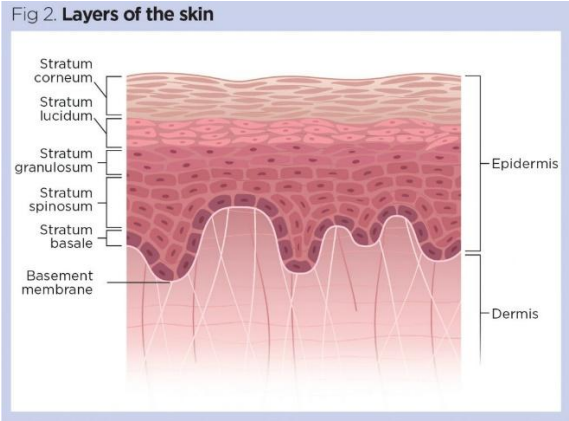
Dermis

- is more of a connective tissue than protective
- irregularly-shaped connective tissue cells that produce the extracellular matrix, including collagen and elastic fibers
- the upper layer (stratum laxum) lies directly below the basement membrane and is mostly loosely-packed cells
- the stratum compactum lies below and contains more tightly-packed cells
- the presence of elastin in the dermis is a synapomorphy of Gnathostomata - in part, the dermis anchors the skin to the underlying musculature

- also includes dermal scales, blood vessels, nerves, pigment cells, the bases of feathers and hairs, and their associated erector muscles.





Integument of the vertebrate classes

If we again tour through the different taxa that we discussed previously, we find many different forms of integument, based on the different environment that each organism inhabits.

Amphioxus

It has an epidermis with a single layer of cells. A synapomorphy of Craniata is the presence of a stratified (multilayered) epidermis. The horny teeth of lampreys are keratin - most other fishes have little or no keratin in the skin.

There are three major types of hard tissue associated with skin:

Enamel

- the hardest tissue in the body
- made of hydroxyapatite and has no cells or tubules within it; only about 3% of it is organic
- ectodermal in origin and is produced by accretion of layers
- generally it is the most superficial of hard tissues and is found on teeth and the outer layers of denticles, scales and dermal armor - one type of enamel is ganoine

Dentine

- is softer than enamel and has about 25% organic fibers
- usually contains tubules occupied by the processes of the mesodermal cells
- found on the same structures as enamel, but is always deep to the enamel layer
- some types of dentine are osteodentine, orthodentine, and cosmine, the last of these has characteristic types of canals

Bone

- has about the same level of organic component as dentine
- may have osteons (Haversian systems) as does osteodentine, or may be deposited in layers like orthodentine
- unlike enamel and dentine, bone may undergo drastic reorganization

Agnathans

The skin of living agnathans lacks dermal bone or scales, but the earliest craniate fossils (Ostracoderms) are known from tiny scales of dermal bone found in the Cambrian period. These scales had

- a deepest, thin layer of lamellar bone,
- a thick layer of spongy (vascular) bone,
- another layer called dentine,
- a surface coat of enamel-like material, often called ganoine.

There was a pore-canal system that likely functioned in electroreception

Chondrichthyes

The skin is covered with denticles or placoid scales with layers of dense lamellar bone, dentine, and enamel. Teeth are modified placoid scales.

Bony fishes

Integument of fish is characterized by structures that help the organism maintain its water balance

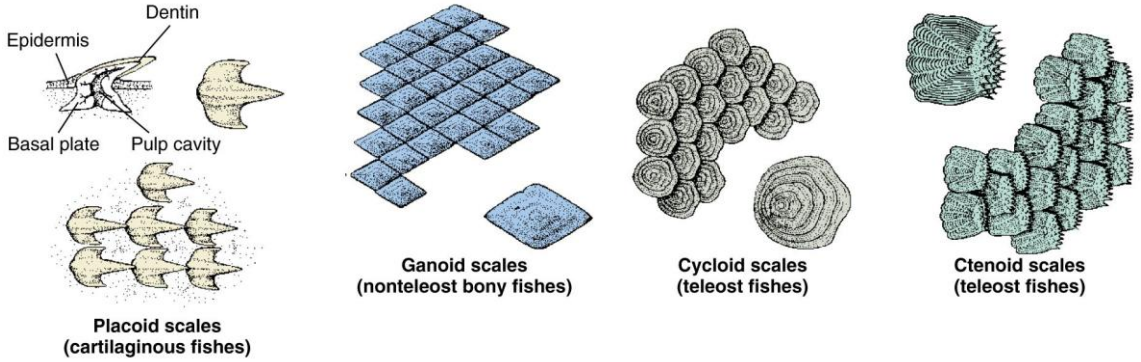
- generally characterized by thin epidermis, with little or no keratinized cells at the stratum corneum
- mucus secreted from fish's skin which seals out water and also prevents invasion by ectoparasites and fungus
- glands are unicellular - derived from a single epidermal cell

Structures associated most with the fishes are scales:

- composed of three basic compounds: bone, dentine and enamel (moving from inside to outside); the outside layer, enamel, is the hardest tissue in the body, and therefore can be very protective
- perform a more protective function, although the protectiveness of the scale is determined by the thickness of the bone
- because they contain compounds that are similar to those in teeth, scales are often compared to teeth

Basal types of scales include

cycloid scale – thin bony scale having a smooth surface and rounded margins
ctenoid scale – thin bony scale having comblike processes on its outer part and a serrate margin
placoid scale – scaly outgrowth of the skin, that is thicker and more embedded in the skin
cosmoid (ganoid) scale – thick bony plates that are embedded into the skin, that act more like a bony armor



Amphibians

The earliest tetrapods had dermal scales, which probably functioned as armor. Among living amphibians, caecilians have tiny dermal scales called osteoderms. Their homology with dermal armor is not clear.

Amphibians mark the transition between the aquatic and terrestrial environment. Skin remains similar to its aquatic roots and resembles the skin of the fish; however, scales are not present. To prevent water loss, amphibians utilize mucus, which is a similar mechanism that fish use to prevent taking on additional water. However, the mucus in amphibians is secreted by multicellular glands rather than the unicellular glands in fish.

Because the integument of amphibians makes them somewhat vulnerable, many amphibians also secrete toxins that prevent them from being eaten by other organisms. The primary gland responsible for the secretion is the parotid gland, located behind the ear of amphibians.

Reptiles

Reptiles show more advanced integumental adaptations to the terrestrial environment because they are more far-removed from the water. In contrast, the cells are more highly keratinized. The integument is modified into horny scales in snakes and lizards. In snakes, the scales on the ventral surface can be further modified into scutes, which can be used in locomotion.

In turtles the epidermis is strongly modified into plates that cover the shell, and because they increase in diameter each year, they can be used to age the animals.

Birds

The integument of birds reflects some reptilian ancestry and some new developments of the class. Scales are present on the legs and feet of most birds, and the bill is covered in a tough skin that is highly keratinized. The remaining skin is relatively thin.

The defining characteristic of bird integument is feathers:

- derived originally from scales, so that scales and feathers are homologous
- function in flight (flight feathers) as well as temperature regulation (contour feathers)
- basic structure of feather calamus, rachis and vane, which are derived from a feather follicle.
- The vane is composed of barbs that help to hold the shape of the feather and can be put back into place during preening.

Birds are not always completely covered in feathers - instead, feathers usually grow along tracts called pterylae, and bare spots are called aptera

Some feathers are modified to perform different functions

- down feathers are softer feathers because they lack all the barbs of flight feathers
- bristles and filoplumes are specially modified feathers that are used in catching prey (e.g., bristles around the bill of swallows and flycatchers) and display (filoplumes of grouse)

Mammals

Mammals generally have skin that conforms to the basic structure described previously, with the epidermal layers of the skin being especially thick in areas such as the soles and the palms of the feet, where proection is needed.

Hair is the distinctive characteristic of mammals, and it provides insulation as well as some additional protection to the animal

- grow in folllicles derived from the stratum germinativum of the epidermus but are rooted in the dermis
- hair growth continues until the mitosis in the root stops - individuals in which mitosis completely stops at the hair root are usually the ones that go bald.

The fine structure of an individual hair consists of three layers: medulla, cortex and cuticular scale (which contain a lot of keratin). Softer hairs (such as our fine body hairs) lack a medulla, whereas our scalp hair contains a medulla and is usually very strong.
Modifications of hair include guard hairs (that protect the undercoat hair), quills (such as in hedgehogs and porcupines) and vibrissae (the tactile whiskers on the snouts of mammals). Other modifications of mammalian skin includes blubber, which is found in many cetaceans and marine mammals. Blubber is a highly thickened subcutaneous fat layer that adds to the insulation of marine mammals and also acts as a food source for the body.

Glands of the skin

Glands associated with the skin that help to protect the skin and its associated structures, aid in heat regulation, and give off scent.
Include:

- sebaceous glands which lubricate and waterproof hairs - special case in birds the uropygial gland located at the base of the tail which secretes a waxy substance that is used to waterproof and clean feathers.
- two types of sweat glands in mammals aid in heat regulation: eccrine and apocrine sweat glands
- eccrine sweat glands secrete a watery solution that assists in evaporative cooling on the entire body
- apocrine sweat glands have thicker secretions that contain more odor, and are sometimes modified into scent glands in some species to use for scent marking (dogs) or defense (skunks); also the wax gland, which secretes the wax in mammalian ears.
- the mammary gland (related to sebaceous glands) which contain fatty tissue in addition to secretory cells that produce milk; usually only become active under hormonal influences, such as the secretion of prolactin by the body that occurs in females during pregnancy and lactation.

Nails, claws, hoofs, horns and antlers:

All are integumental derivatives.

- nails grow from the nail bed located in the epidermis at the distal part of the phalanges; the nail is higly cornified in ungulates whereas in clawed animals the nail is elongated and thickened for defense or predation
- horns are supported by a bony structure growing out from the skull; surrounding the bony core is a highly keratinized layer of the epidermis which is generally permanent
- antlers are not present throughout the year, and are shed during the non-breeding season; develop under a protective covering of skin (velvet), which is lost as the antlers mature
- rhinoceros horns are simply hairlike keratin fibers that are woven together without a bony core - similar to baleen in whales that is used for feeding

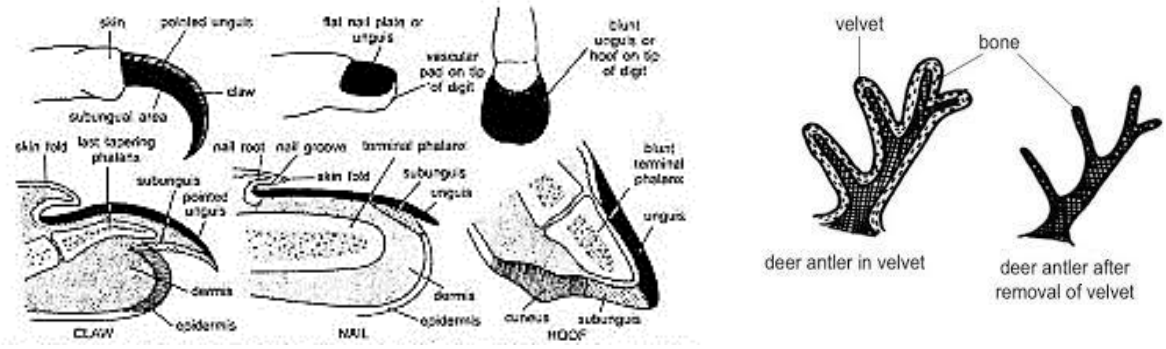


Fig: Relation between Nails, claws, hoofs, horns and antlers

Integument coloration - Pigment cells

Pigment cells (chromatophores) are derived from neural crest cells that break off from the ectoderm during neural tube formation and are usually found in the dermis.

- In the epidermis of mammals and birds, the pigment cells are usually melanophores which contain the pigment melanin. Melanin is red or blackish brown. Melanophores in the epidermis are usually responsible for slow color change, such as that related to aging or seasonal changes.
- in groups other than mammals and birds the chromatophores are mostly in the dermis:
- melanophores are like those of the epidermis
- iridophores have organelles that contain platelets of guanine pigment, which reflects or scatters light
- xanthophores and erythrophores have yellowish pteridine pigments and reddish carotenoid pigments
- dermal chromatophores are responsible for rapid, physiological color change. Coloration can be of many types, including **cryptic** (providing blend into the environment) and **aposematic** (warning coloration, that occurs in some snakes).

Functions of the skin

The skin has three main functions:

- Protection;
- Thermoregulation;
- Sensation.

Within this, it performs several important and vital physiological functions, as outlined below (Graham-Brown and Bourke, 2006).

Protection

The skin acts as a protective barrier from:

- Mechanical, thermal and other physical injury;
- Harmful agents;
- Excessive loss of moisture and protein;
- Harmful effects of UV radiation.

Thermoregulation

One of the skin's important functions is to protect the body from cold or heat, and maintain a constant core temperature. This is achieved by alterations to the blood flow through the cutaneous vascular bed. During warm periods, the vessels dilate, the skin reddens and beads of sweat form on the surface (vasodilatation = more blood flow = greater direct heat loss). In cold periods, the blood vessels constrict, preventing heat from escaping (vasoconstriction = less blood flow = reduced heat loss). The secretion and evaporation of sweat from the surface of the skin also helps to cool the body.

Sensation

Skin is the 'sense-of-touch' organ that triggers a response if we touch or feel something, including things that may cause pain. This is important for patients with a skin condition, as pain and itching can be extreme for many and cause great distress. Also touch is important for many patients who feel isolated by their skin as a result of colour, disease or the perceptions of others as many experience the fact that they are seen as dirty or contagious and should not be touched.

Immunological surveillance

The skin is an important immunological organ, made up of key structures and cells. Depending on the immunological response, a variety of cells and chemical messengers (cytokines) are involved. These specialised cells and their functions will be covered later.

Biochemical functions

The skin is involved in several biochemical processes. In the presence of sunlight, a form of vitamin D called cholecalciferol is synthesised from a derivative of the steroid cholesterol in the skin. The liver converts cholecalciferol to calcidiol, which is then converted to calcitriol (the active chemical form of the vitamin) in the kidneys. Vitamin D is essential for the normal absorption of calcium and phosphorous, which are required for healthy bones (Biga et al, 2019). The skin also contains receptors for other steroid hormones (oestrogens, progestogens and glucocorticoids) and for vitamin A.

Social and sexual function

How an individual is perceived by others is important. People make judgements based on what they see and may form their first impression of someone based on how that person looks. Throughout history, people have been judged because of their skin, for example, due to its colour or the presence of a skin condition or scarring. Skin conditions are visible – in this skin-, beauty- and image-conscious society, and the way patients are accepted by other people is an important consideration for nurses.