Remember…

- Four basic types of tissue
  - Epithelium – epidermis
  - Connective tissue - dermis
  - Muscle tissue
  - Nervous tissue

The Integumentary System

Skin, and its Appendages

(hair, hooves, horn, claws, and various skin-related glands)

The Integumentary System

- Integument is skin
- Skin and its appendages make up the integumentary system
- A fatty layer (hypodermis) lies deep to it
- Two distinct regions
  - Epidermis
  - Dermis

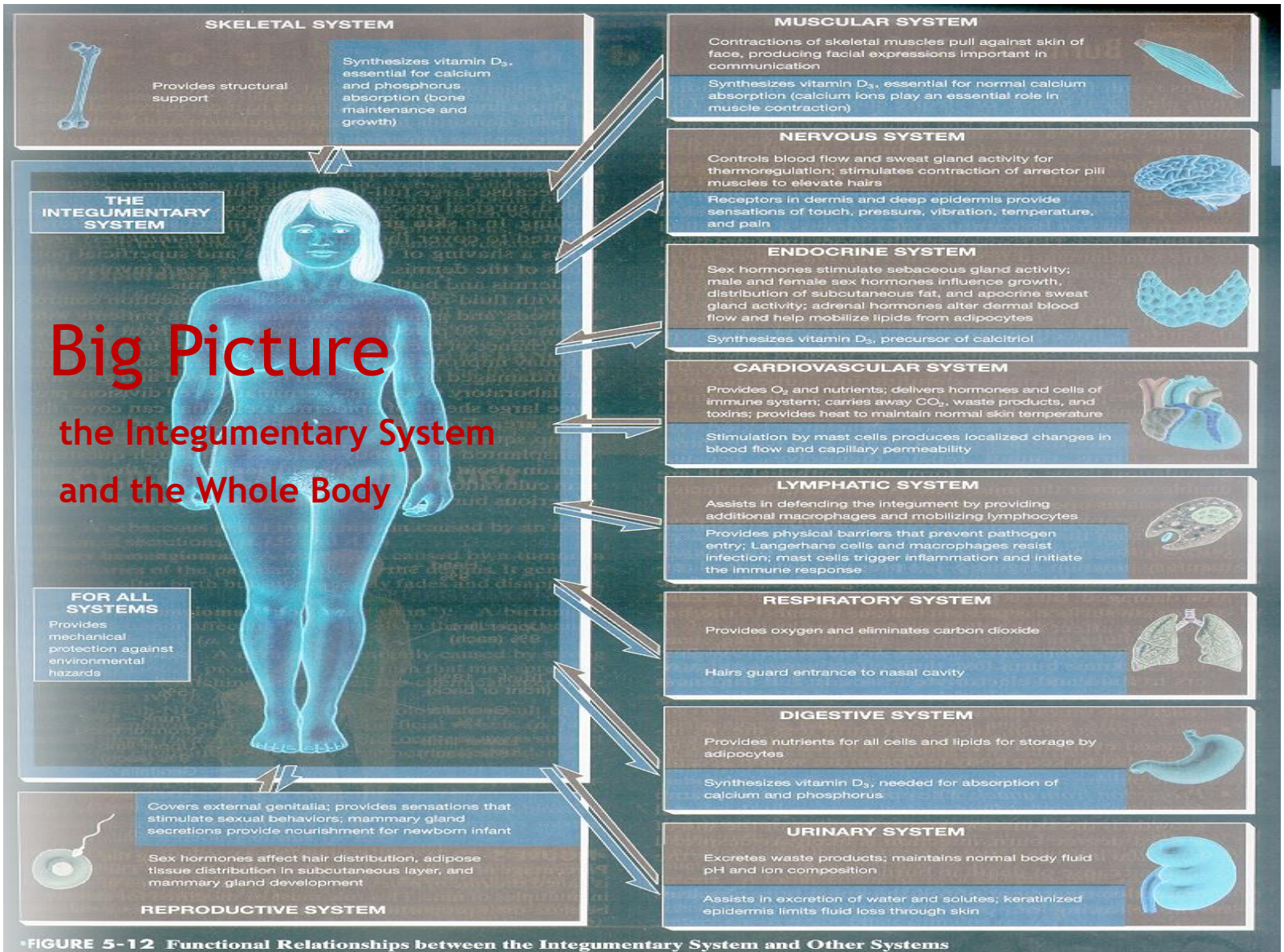
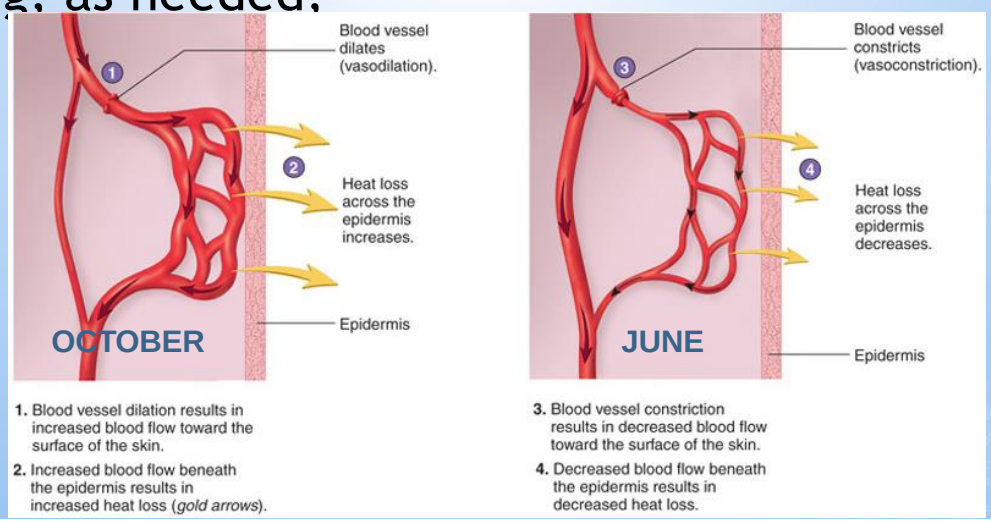


FIGURE 5-12 Functional Relationships between the Integumentary System and Other Systems

Functions of Skin and subcutaneous layer

- ***Protection*** of underlying tissues and organs against shocks, abrasion, and chemical attack;
- ***Excretion*** of salts, water, and organic wastes by integumentary glands;
- ***Thermoregulation*** *(Maintenance* of normal body temperature) through either insulation or evaporative cooling, as needed;



1. Blood vessel dilation results in increased blood flow toward the surface of the skin.
2. Increased blood flow beneath the epidermis results in increased heat loss (*gold arrows*).
3. Blood vessel constriction results in decreased blood flow toward the surface of the skin.
4. Decreased blood flow beneath the epidermis results in decreased heat loss.

Functions of Skin and subcutaneous layer

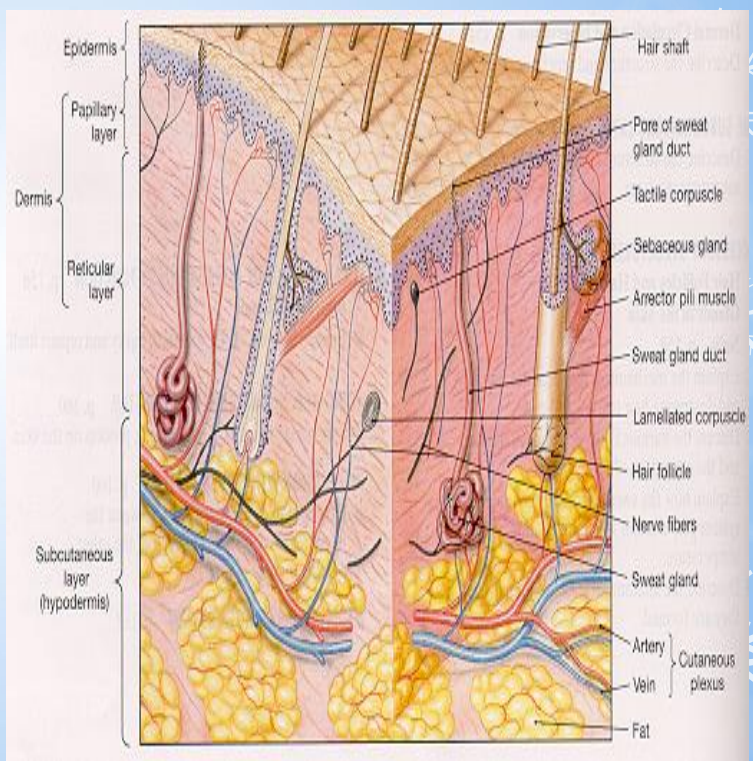
- ***Synthesis*** of vitamin D_3;
- ***Storage of nutrients***: lipids are stored in adipocytes in the dermis and in adipose tissue in the subcutaneous layer;
- ***Sensation*** *(Detection)* of touch, pressure, pain, and temperature stimuli and relay of that information to the nervous system.

Functions of skin

- Protection
  - Cushions and insulates and is waterproof
  - Protects from chemicals, heat, cold, bacteria
  - Screens UV
- Synthesizes vitamin D with UV
- Regulates body heat
- Prevents unnecessary water loss
- Sensory reception (nerve endings)

Histological Structure of Skin

- Skin:
  - Epidermis: keratinized stratified squamous epithelium forms an outer waterproof shield. Is avascular;
  - Dermis: a tough, leathery layer of dense fibroelastic connective tissue. Is vascular.
- Subcutaneous layer (hypodermis): primarily adipose tissue (a thermo-insulator and a mechanical shock absorber). Often not considered a part of the integument.



Cells of the Epidermis

- Keratinocytes: produce keratin (a tough, fibrous, waterproof protein but gives skin its resiliency and strength).
  - Keratinization: the normal formation of keratin by the stratified squamous epithelia of skin. As the epithelial cells mature, they fill with granules filled with keratin and at the same time give up vital organelles; ultimately become lifeless sheets of keratin. In human, an entirely new epidermis forms every 7-8 weeks.
- Melanocytes: produce melanin (a dark pigment) which is ultimately absorbed by keratinocytes to protect UV rays.
- Langerhans' cells: macrophages specific to the epidermis which phagocytize microorganisms and other invaders.
- Merkel cells: associated with a sensory nerve ending and may aid in the sensation of tough.

Cells of the Epidermis

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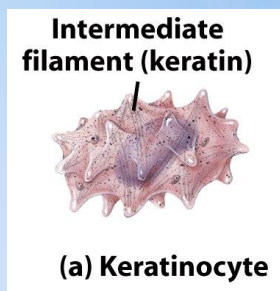
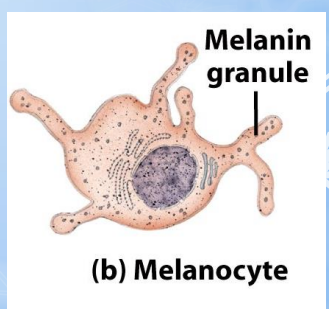
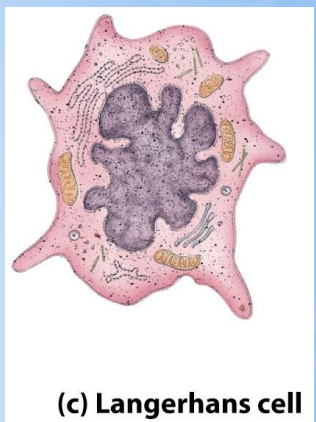


- **Melanocytes:** produce melanin (a dark pigment) which is ultimately absorbed by keratinocytes to protect against UV rays (skin colour alteration).

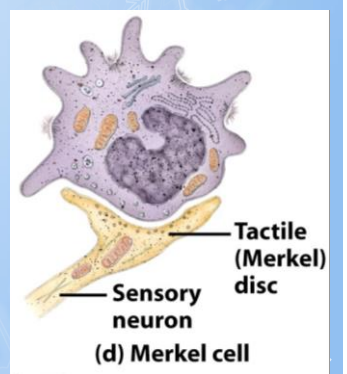


Cells of the Epidermis

- Langerhans' cells: macrophages specific to the epidermis which phagocytize microorganisms and other invaders.

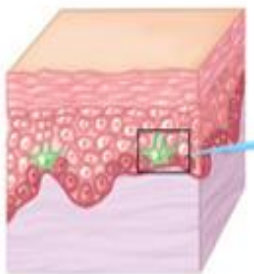

(c) Langerhans cell

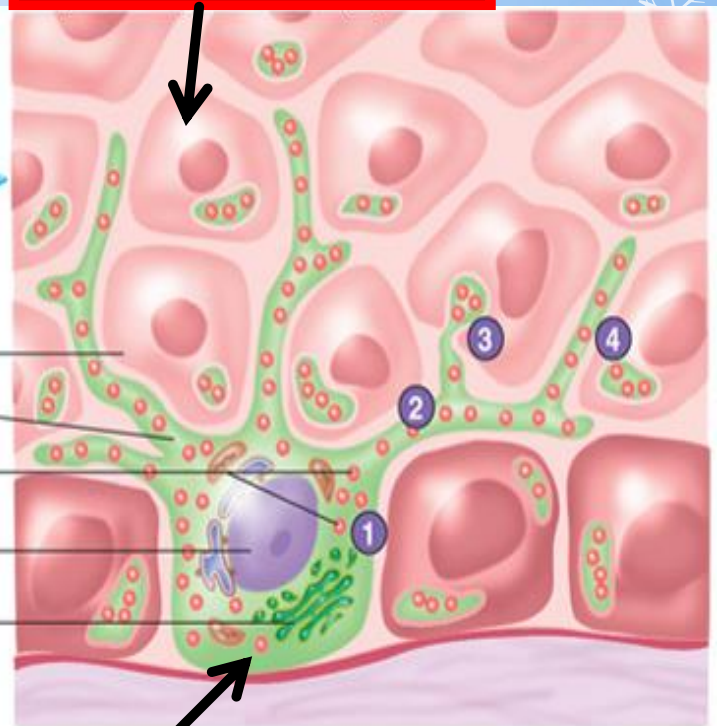
- Merkel cells: associated with a sensory nerve ending and may aid in the sensation of touch.
- !!!!!



(d) Merkel cell

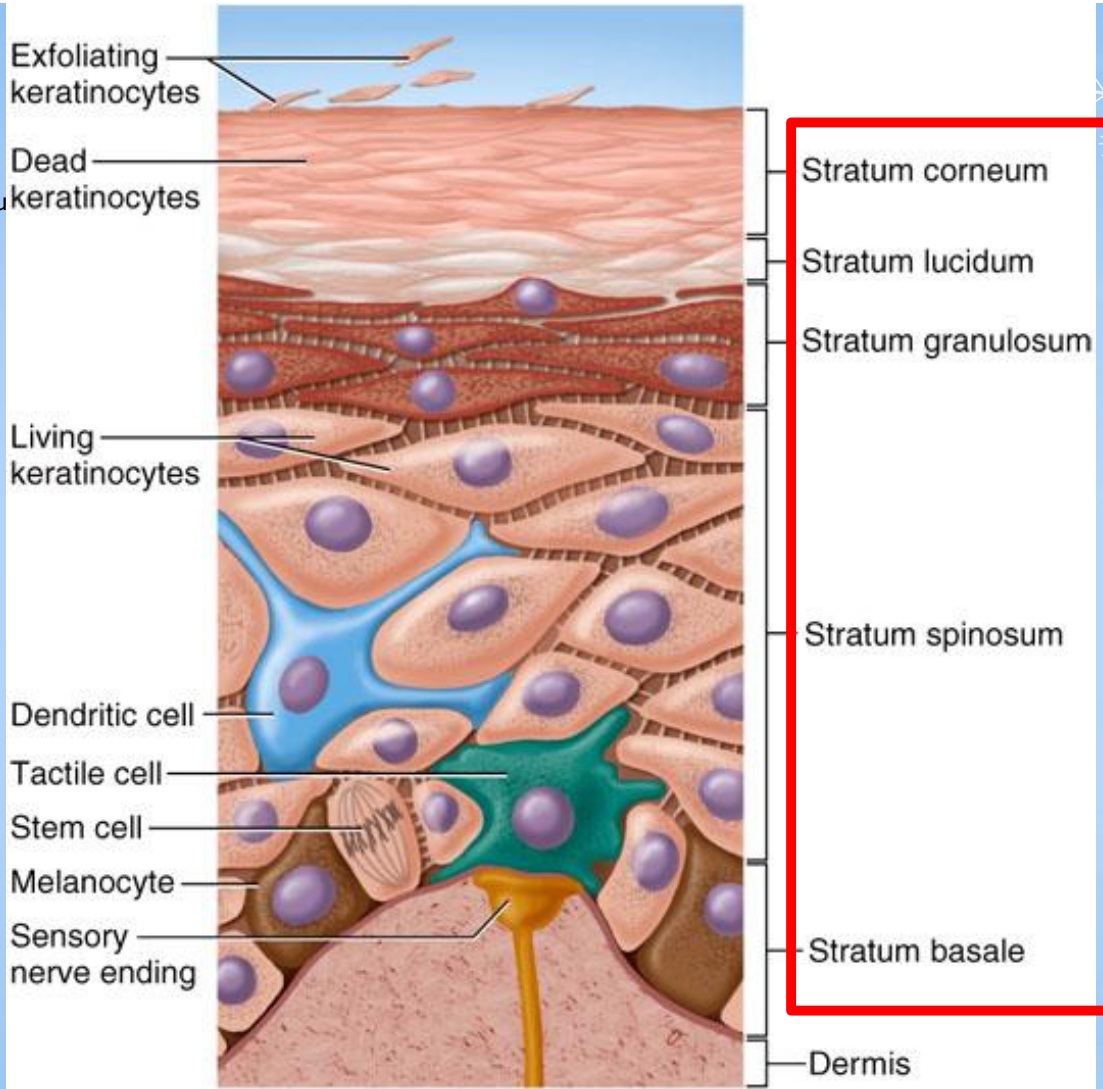
1. Melanosomes are produced by the Golgi apparatus of the melanocyte.
2. Melanosomes move into melanocyte cell processes.
3. Epithelial cells phagocytize the tips of the melanocyte cell processes.
4. The melanosomes, which were produced inside the melanocytes, have been transferred to epithelial cells and are now inside them.





6-12

Figu


Exfoliating keratinocytes
Dead keratinocytes
Living keratinocytes
Dendritic cell
Tactile cell
Stem cell
Melanocyte
Sensory nerve ending
Stratum corneum
Stratum lucidum
Stratum granulosum
Stratum spinosum
Stratum basale
Dermis
Dermal papilla
(a)

6-13

QUIZ 2

Q1. Name four adaptations of the respiratory system

Q2. Name two functional cells of physiological significance to the respiratory system

Q3. Name four functions of the respiratory system.

Zambia Take a Leaf! Ivory Coast Bans Skin Lightening Creams

BY EDITOR – POSTED ON MAY 7, 2015

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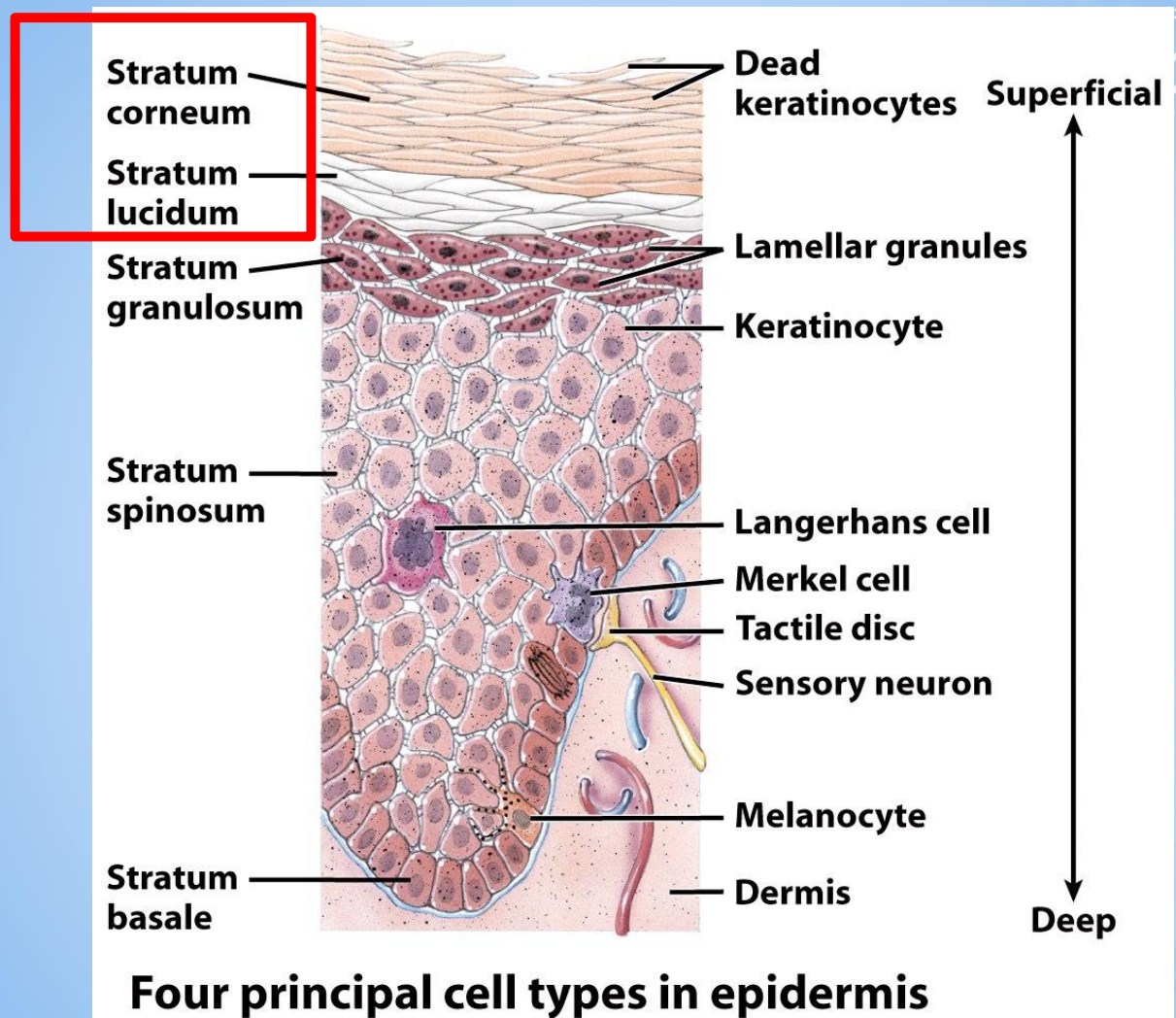
6-15

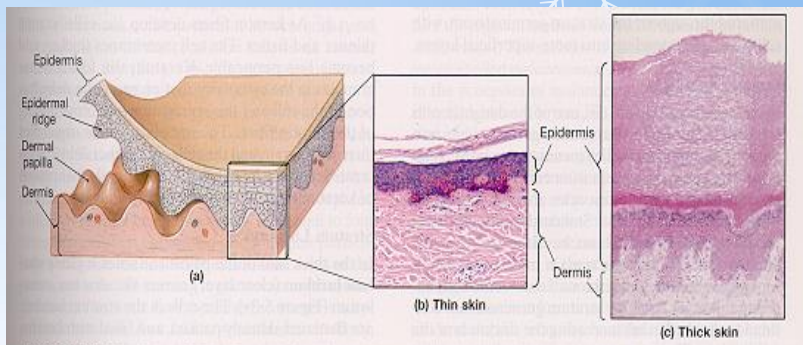


Four principal cell types in epidermis

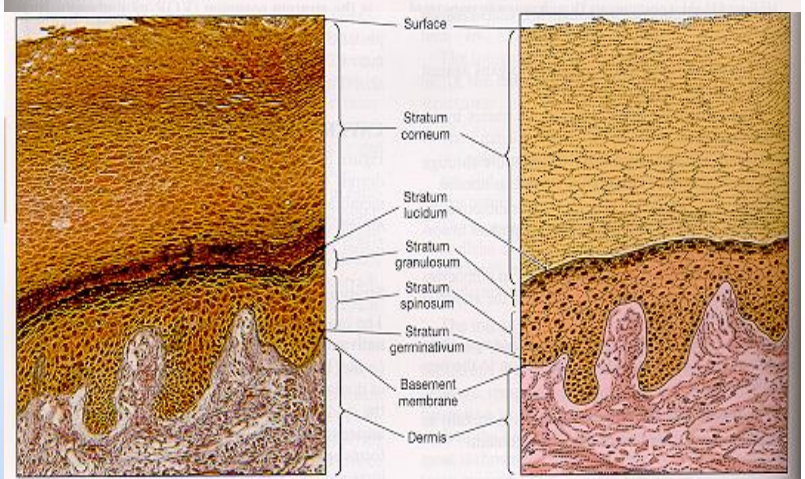
6-16

Layers of the Epidermis

- stratified squamous epithelium from the deepest toward the free surface
  - *Stratum germinativum (stratum basale):* a single row of keratocytes attached to basement membrane; Stem cells
  - *Stratum spinosum (spiny layer):* 8-10 layers of keratocytes bound by desmosomes.
  - *Stratum granulosum (granular layer):* 2-4 layers of flattened, diamond-shaped keratocytes which begins to fill with keratin, keratohyline and lamellated granules (glycolipids).
  - *Stratum lucidum (clear layer):* only in thick skin. A translucent layer composed of a few rows of flattened dead cells filled with karetin.
  - *Stratum corneum (horny layer):* dominates the epidermis, 20-30 rows of dead, keratinized keratocytes.



•**FIGURE 5-2 Thin Skin and Thick Skin.** **(a)** The basic organization of the epidermis. The proportions of the various layers vary with the location sampled. **(b)** Thin skin covers most of the exposed body surface. (LM × 144) **(c)** Thick skin covers the surfaces of the palms and soles. (LM × 154)



•**FIGURE 5-3 The Structure of the Epidermis.** A portion of the epidermis in thick skin, showing the major stratified layers of epidermal cells. Langerhans cells cannot be distinguished in standard histological preparations. (LM × 210)

Cells from stratum germinativum to stratum corneum take 15-30 days and stay for an additional 2 weeks.

Epidermis of Hairy Skin

- Most mammals are covered with fur. Unlike the epidermis of human, skin covered with fur usually consisted of three epidermal layers rather than five:
  - Stratum basale
  - Stratum spinosum
  - Stratum corneum
- Surface is covered in scalelike folds. Hair emerges from underneath the scales, clusters of three follicles per scale in dog.
- Tactile elevation (epidermal papilla): knoblike elevation throughout the surface, important in the perception of tough.

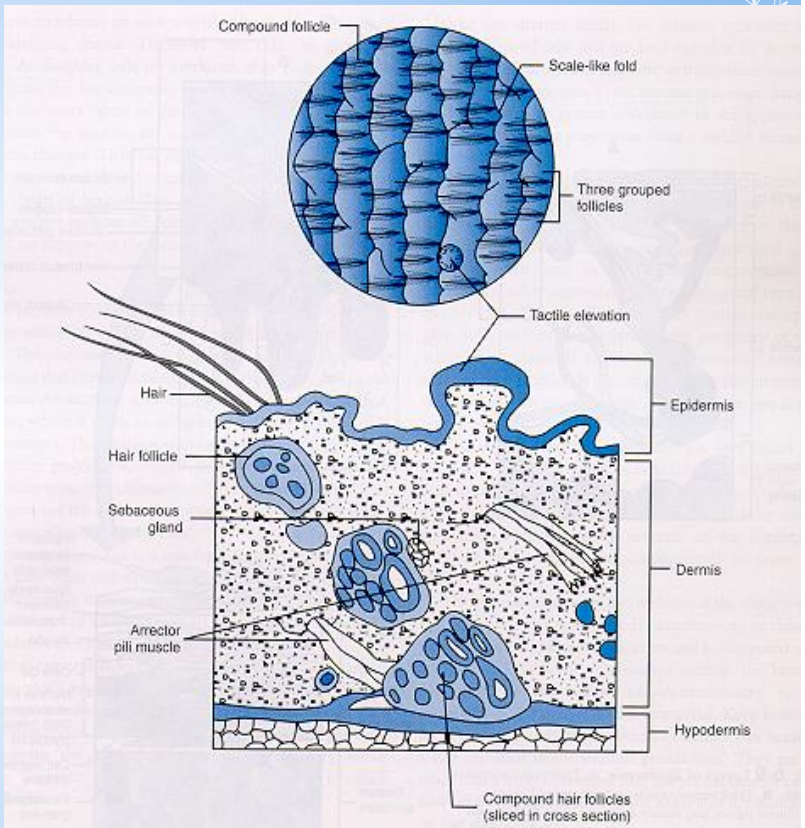


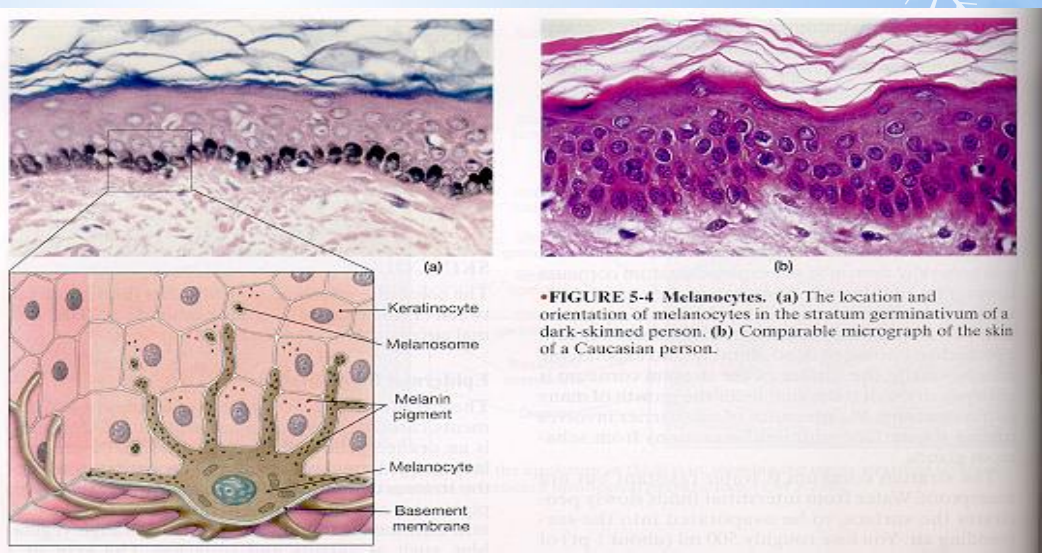
FIGURE 6-3 **Tactile Elevation and Tylotrich Hair.** Compound hairs, in the dog, are organized into groups of three. Interspersed among these groups are tactile elevations, which are prominent, knoblike extensions of epidermis. They are found in most mammalian species and often are associated with specialized sensory hairs called *tylotrich hairs*. Hair may be found medial, lateral, cranial, or caudal to tactile elevation. It is thought that this arrangement enables animals to detect subtle pressure, such as the light touch and movement of insects on skin.

Epidermis

- Skin color: determined by:
  - Epidermal pigmentation:
    - Two pigments:
      - Carotene: orange-yellow, normally accumulated in epidermal cells. Can be converted to Vitamin A.
      - Melanin: brown, yellow-brown or black, produced by melanocytes.
    - Melanocytes:
      - Location: stratum germinativum, squeezed between or deep to epithelial cells.
      - Manufacture melanin: tyrosine → melanin → packed in melanosome → transferred to keratinocytes → fuse with lysosomes and destroyed:
        - » In Caucasian: transfer occurs in deeper layers;
        - » In dark skinned people: melanosomes are bigger and transfer may occur in more-superficial layers.
    - Pigment acts to protect the keratocytes from UV rays.
  - Dermal circulation

Blood contains red cells filled with the pigment hemoglobin which binds and transports oxygen:

+ oxygen → light red
- Oxygen → darker red



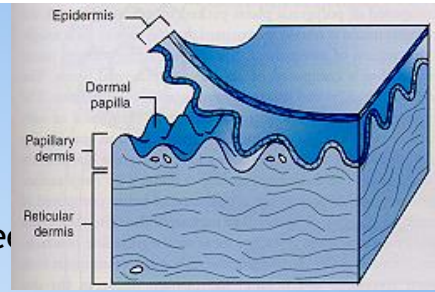
•**FIGURE 5-4 Melanocytes. (a)** The location and orientation of melanocytes in the stratum germinativum of a dark-skinned person. **(b)** Comparable micrograph of the skin of a Caucasian person.

The Epidermis and Vitamin D_3

- When exposed to ultraviolet radiation, epidermal cells in the stratum spinosum and stratum germinativum convert a cholesterol-related steroid into Vitamin D_3, or cholecalciferol.
- The liver converts vitamin D_3 into an intermediary product used by the kidney to synthesize the hormone calcitriol, Calcitriol is essential for normal absorption of calcium and phosphorus by the small intestine.

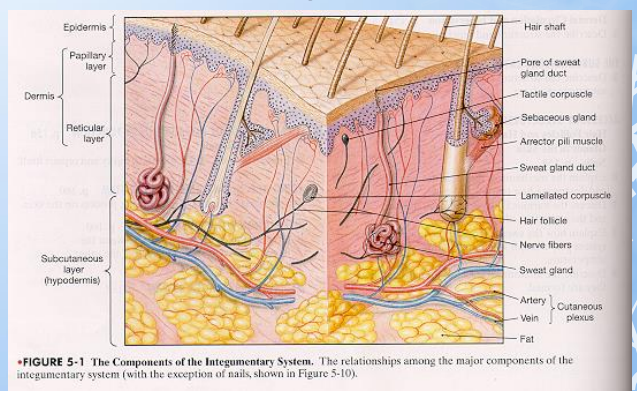
  → limited exposure to sunlight is very beneficial.

Dermis and Subcutaneous Layer



- Dermis organization: two major components:
  - Papillary layer:
    - Consists of areolar tissue. Dermal papillae project betwe ridges;
    - Contains the capillaries and sensory neurons. Tactile (Meissner's) corpuscles: touch receptors sensitive to light tough.
  - Reticular layer, 80% of dermis
    - Consists of an interwoven meshwork of dense irregular connective tissue. The majority of fibrous bundles tend to run parallel to one another and their orientation depends on the direction of the stress placed on them (for surgeons, a incision is better to be made parallel to the direction of the collagen fibers for best healing).
    - Contains all cells of connective tissue proper, networks of blood vessels, lymph vessels and nerve fibers, and accessory organs of epidermal origin. Lamellated (Pacinian) corpuscle: touch receptor sensitive to heavier pressure and vibration.
- Subcutaneous Layer (hypodermis):

  A thick, loose layer of areolar and adipose tissue, rich with adipose, blood and lymphatic vessels, and nerves.



•FIGURE 5-1 The Components of the Integumentary System. The relationships among the major components of the integumentary system (with the exception of nails, shown in Figure 5-10).

Special Features of the Integument

- Paw Pads:
  - Bear the weight of animal and provide a tough, protective surface on which animals walk.
  - Composed of all five epidermal layers: the outermost stratum corneum is thicker than all of the others combined.
  - Minute conical papillae cover the entire pad.
  - Multiple footpads:
    - Carpal pads: on the caudal surface of the “wrist”;
    - Metacarpal pads: the central weight-bearing pads;
    - Digital pads: protect each digits

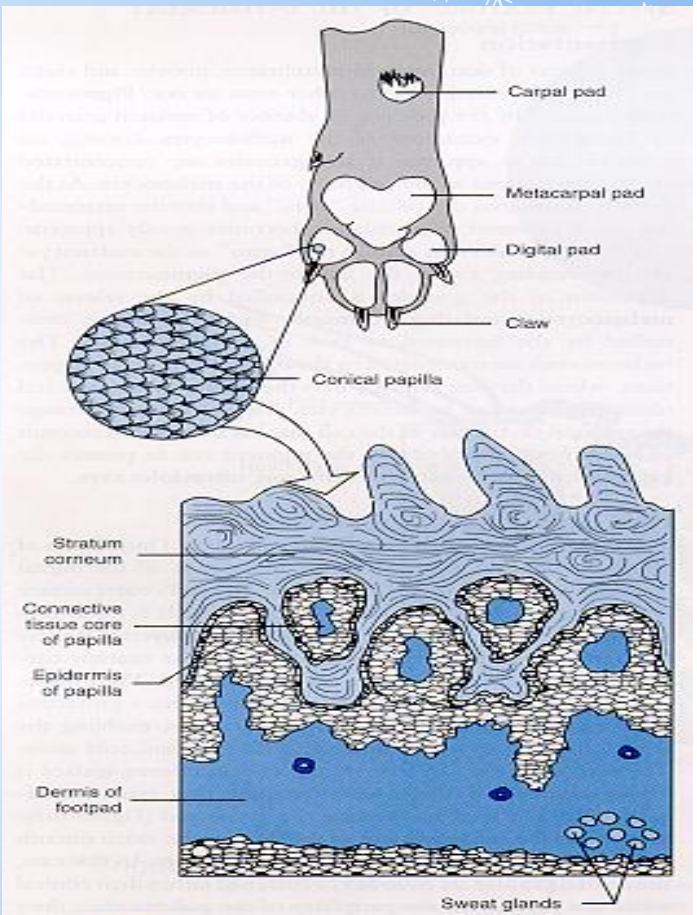
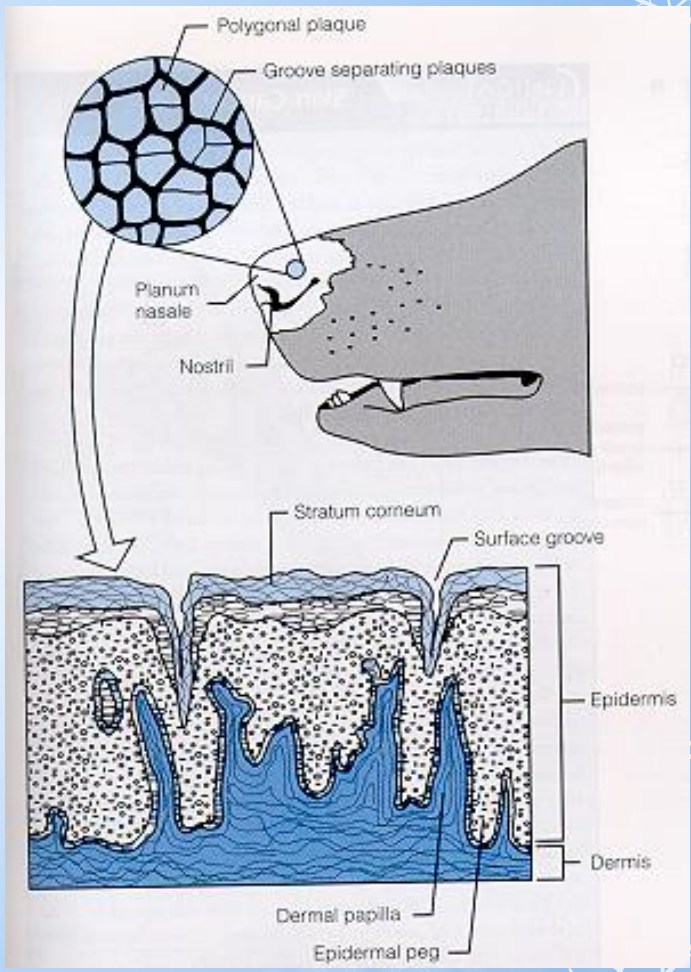


FIGURE 6-5 **Paw Pads.** Paw pads provide a tough, protective surface on which animals walk. Outer layer of pad is the thickest skin in the body and is composed of thousands of conical papillae. Papillae arise from stratum corneum, the outermost layer of epidermis.

Special Features of the Integument

- Planum Nasale:
  - The top of nose: planum nasale in cats, pigs, sheep and dogs; planum nasalabiale (muzzle) in cow and horse.
  - In dog, only three epidermal layers: stratum basale, stratum spinosum, stratum corneum. The stratum corneum is composed of only 4-8 layers of cells.
  - The epidermal surface is divided by deep surface grooves → polygonal plaque.
  - Although abnormalities in the appearance of the planum nasale can indicate certain illnesses, its wetness or dryness is usually not an indicator of the health status of the animal as a whole.



Accessory Structures of Integument: Hair

- Hair Follicles:
  - Hair is anchored by the hair follicle.
  - Hair follicle is an invagination of the epidermis that extends from the skin surface to the dermis or, occasionally, hypodermis.
  - Structure:
    - Papilla: a peg of connective tissue containing capillaries and nerves at the base;
    - Matrix: rapidly dividing epithelial cells covering papilla. As cells divide, older cells are pushed upward into the tunnel away from papilla (hair gets longer) and become keratinized as they lose contact with nutrition → develop hair;
    - Follicles wall:
      - Internal epithelial root sheath;
      - External epithelial root sheath;
      - Glassy membrane
      - Dermal or connective tissue root sheath.
  - Compound follicles: multiple hair strands emerge from a single pore, but each has its own follicle and bulb.

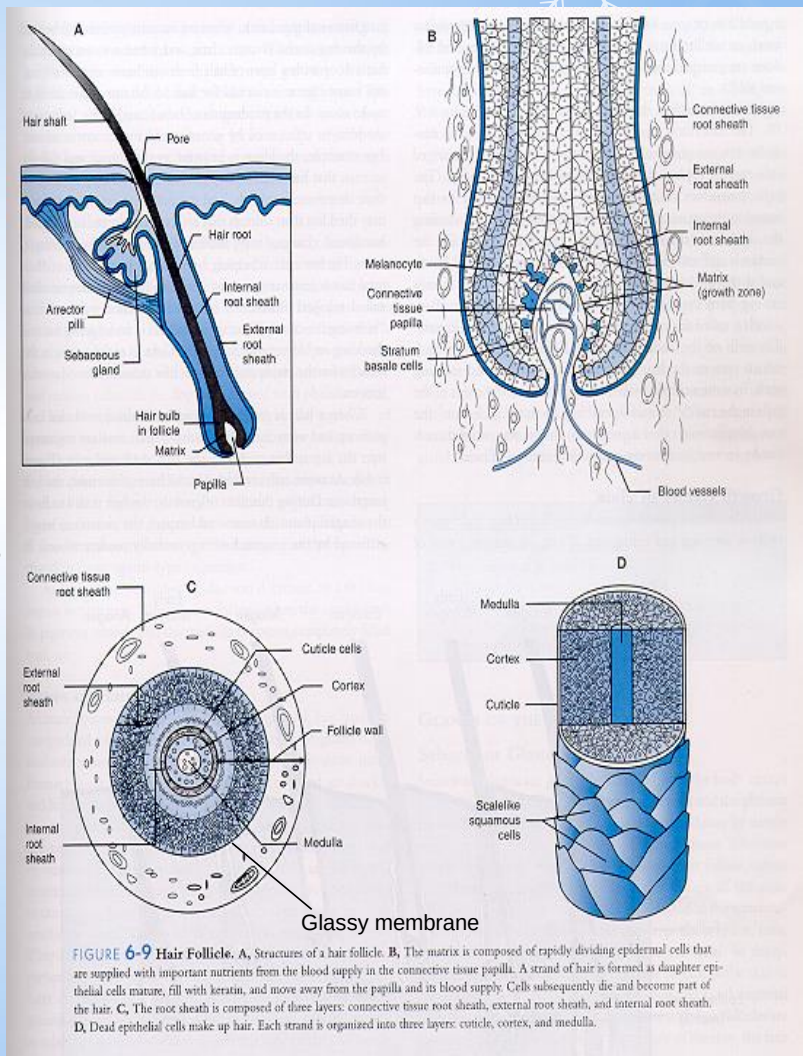


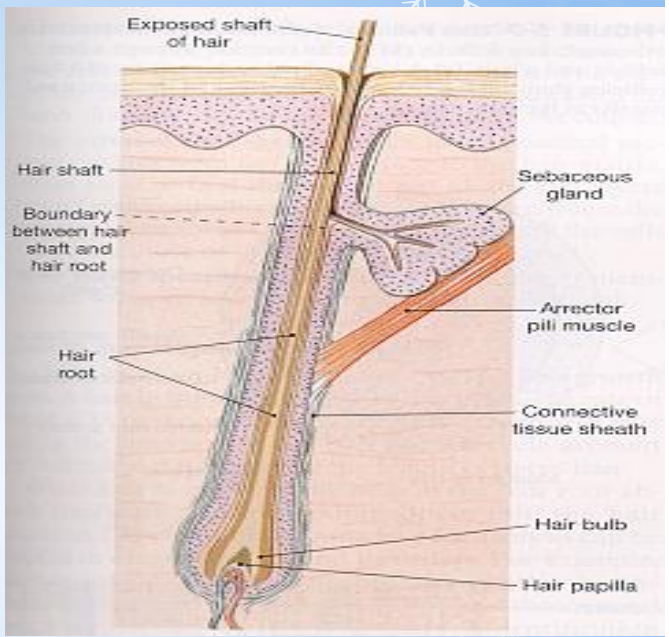
FIGURE 6-9 **Hair Follicle.** **A,** Structures of a hair follicle. **B,** The matrix is composed of rapidly dividing epidermal cells that are supplied with important nutrients from the blood supply in the connective tissue papilla. A strand of hair is formed as daughter epithelial cells mature, fill with keratin, and move away from the papilla and its blood supply. Cells subsequently die and become part of the hair. **C,** The root sheath is composed of three layers: connective tissue root sheath, external root sheath, and internal root sheath. **D,** Dead epithelial cells make up hair. Each strand is organized into three layers: cuticle, cortex, and medulla.

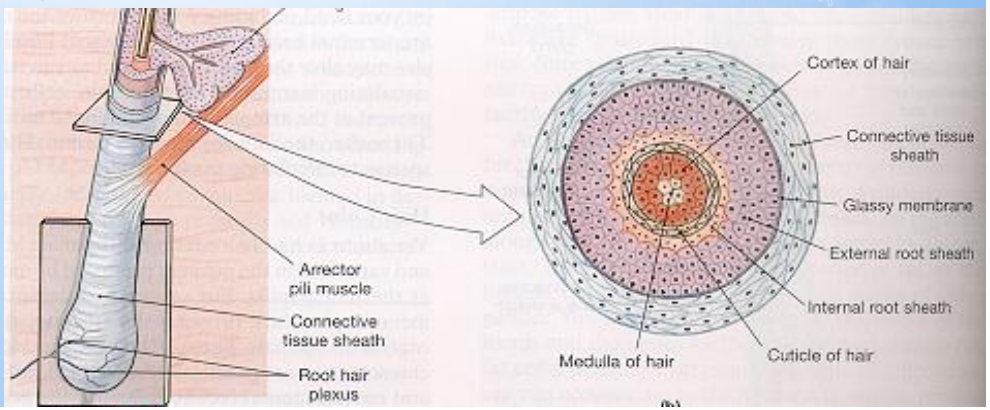
Accessory Structures of Integument: Hair

- Hair:
  - Plays important role in maintaining body temperature.
  - Nonliving structures produced in hair follicles.
  - Structure:

    Anatomy:
    - Hair bulb: base of hair
    - Hair root: portion anchoring hair to skin
    - Hair shaft: visible part

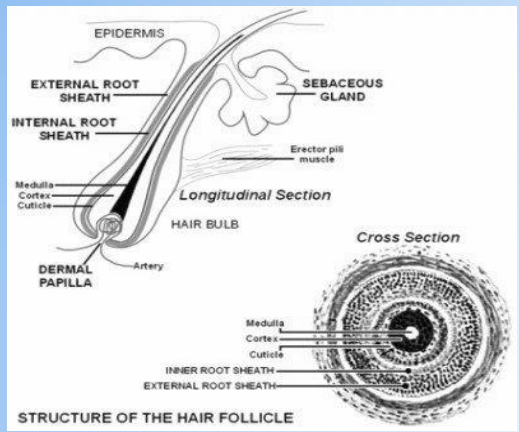
    Structure: three concentric layers
    - Cuticle: outer layer of shaft consisting of a single layer overlapped dead, keratinized cells containing hard keratin.
    - Cortex: cells contain hard keratin.
    - Medulla: 2-3 layers of loosely arranged cells containing soft keratin.

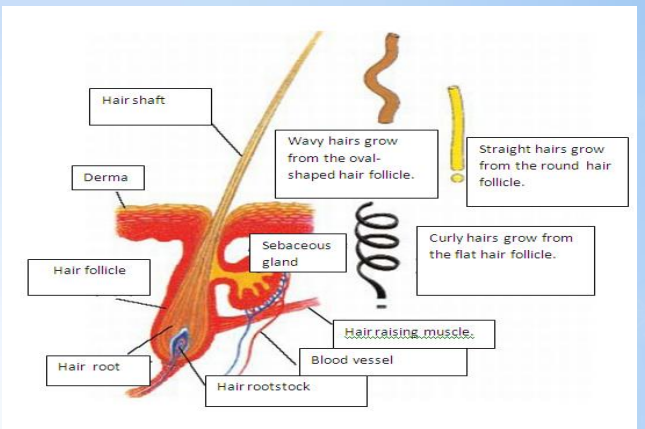




Hair structure

•Hair consists of the shaft, which grows and rises above the skin surface, and the root, which is located in the small fossa within the derma thickness and is anchored into a special follicle (hair follicle).





The hair has two part namely:

•HAIR FOLLICLE

•The hair follicle is the point from which the hair grows. It is a tiny cup-shaped pit buried in the fat of the scalp.

•HAIR SHAFT

•The part of the hair seen above the skin is called the hair shaft. The hair shaft is made up of dead cells that have turned into keratin and binding material, together with small amounts of water. This structure explains why we do not feel any pain while our hair is being cut.

Accessory Structures of Integument: Hair

- Growth cycles of Hair:
  - Hair growth cycle (grow and falling out) is determined by genetic and environment. In the scalp of human: 2-5 years, 0.33 mm per day.
  - Three phases:
    - Anagen phase: a time of hair growth when the follicle is longest;
    - Catagen phase: appearance of a thick glassy membrane and a shortening of the hair follicle. The thickening of basement membrane in the matrix separates epidermal cells from the dermal papilla;
    - Telogen phase (a resting phase): hair follicle is very short and dermal papilla is separated from the bulb. Hair strand is rounded and resembles a club. Can last from weeks and years.
- Hair color:
  - Hair color depends on the quantity and the type of melanin in the cortex and medulla:
    - Horse: only one type melanin
    - Dog: pheomelanin (reddish) and tyrosine melanin (brown)
  - As animals age, melanin production decreases and hear → gray. When cortex loses pigment and medulla filled with air → white.

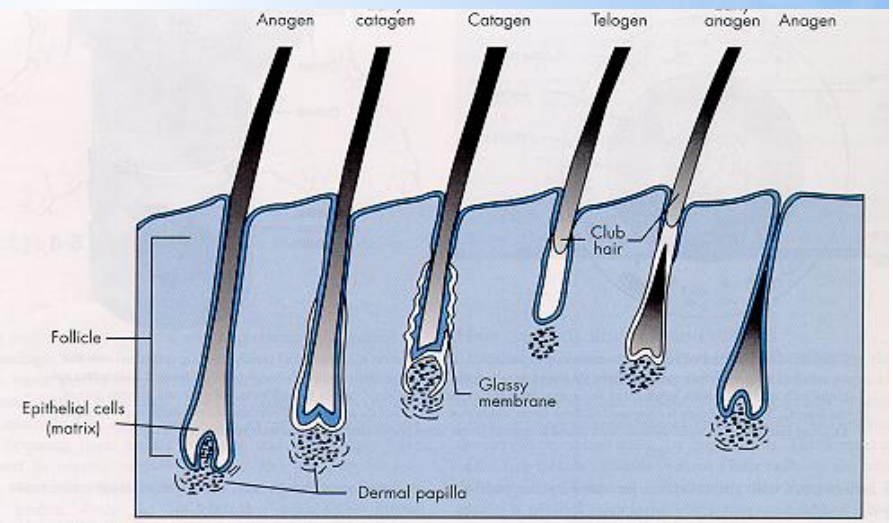


FIGURE 6-10 **Growth Cycles of Hair.** Three phases take place in the hair growth cycle. The *anagen* phase is a time of hair growth when the follicle is longest. The *catagen* phase occurs with the appearance of a thick glassy membrane and a shortening of the hair follicle. In addition, thickening of the basement membrane in the matrix separates epidermal cells from the dermal papilla. In the *telogen* phase, the hair follicle is very short, and the dermal papilla is separated from the bulb. The hair strand is rounded and resembles a club (therefore called *club hair*).

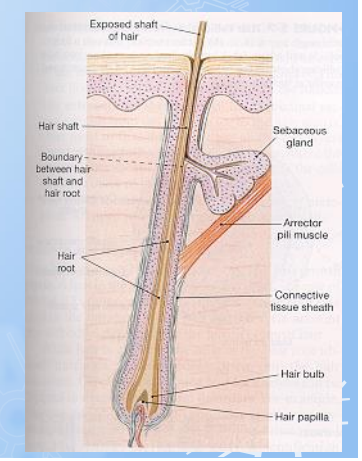
Accessory Structures of Integument: Hair

- Types of Hair:
  - Primary or guard hairs:
    - Generally straight or arched; thicker and longer.
    - Dominant hairs in a complex hair follicle: a complex hair follicle in the dog consists of one primary hair surrounded by numerous secondary hairs.
  - Secondary or wool-type hairs:
    - Soft and shorter, forms the fleece of sheep.
    - Lacks a medulla, the connective-tissue portion of the follicle is sparse.
  - Tactile or sinus hairs:
    - Used as probes or feelers: well supplied with sensory nerve endings.
    - A large blood sinus is located in the connective portion of the follicle.
- Arrector pili muscle:
  - Implantation angle: the degree of hair erection.

    eg. in dog: 30-40 degree
  - Implantation angle beyond normal when frightened

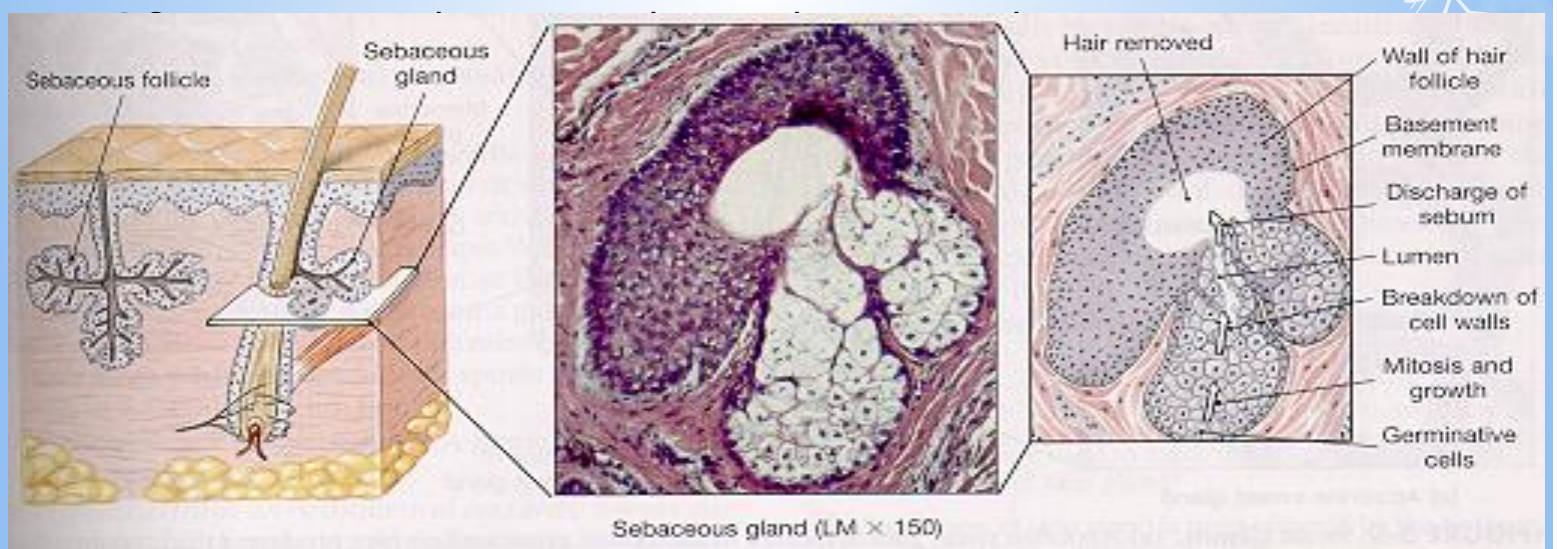
    or cold ← due to arrector pili muscle contraction

    → Defense mechanism to make animal appear bigger



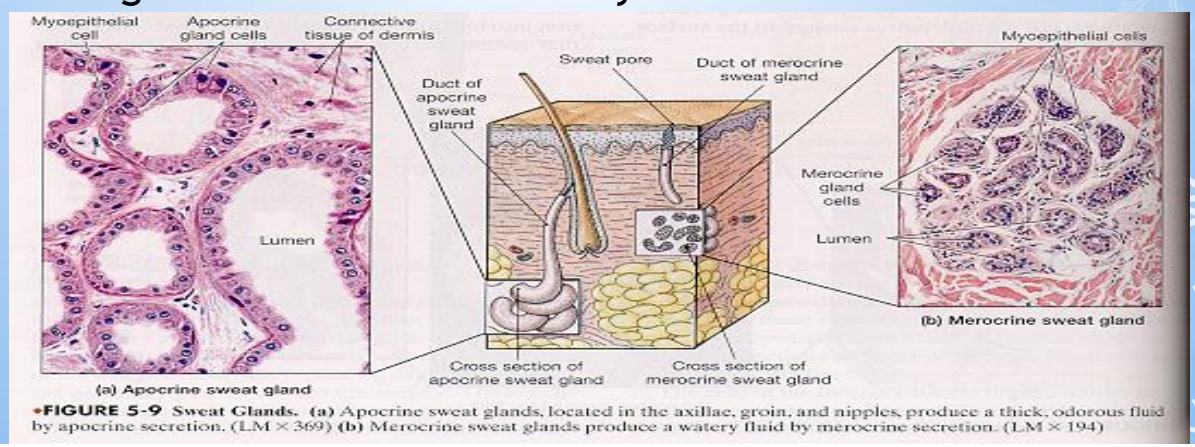
Accessory Structures: Glands of the Skin

- Sebaceous *[si'beiʃəs]* (oil) glands
  - Holocrine glands that discharge a waxy, oily secretion into hair follicles: produce large quantities of lipids and release them through holocrine secretion.
  - Secretion (sebum *['si:bəm]*) enters hair follicle and onto the surface of the skin: inhibits bacteria growth; lubricates and protects the keratin of the hair shaft and conditions the surrounding skin.
  - A single branched alveolar glands or sebaceous follicles: large sebaceous glands (complex gland) that is not associated with hair follicles and discharges sebum directly onto the epidermis.



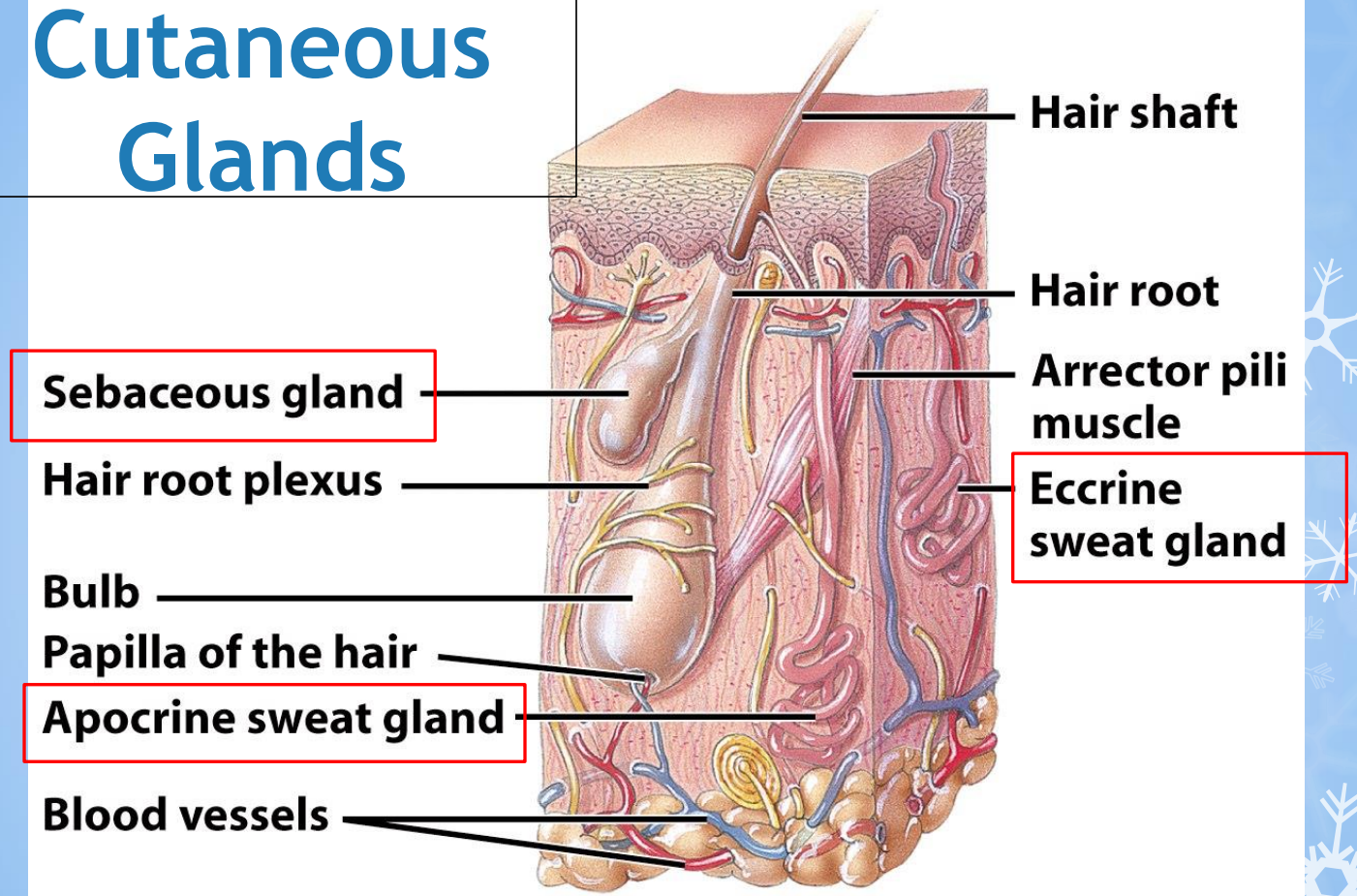
Accessory Structures: Glands of the Skin

- Sweat glands (sudoriferous *[ˌsju:dɔ'rifərəs]* glands)
  - Produce sweat, a watery transparent liquid that helps cool the body through evaporation;
  - Are a simple coiled, tubular glands.
  - Two types (both rely on merocrine secretion):
    - Apocrine sweat glands: secrete their products into hair follicles, also by merocrine method.
    - Merocrine (Eccrine *['ekrin]*) sweat glands: main type, smaller, discharge their secretion directly onto the surface of the skin.



•**FIGURE 5-9 Sweat Glands.** **(a)** Apocrine sweat glands, located in the axillae, groin, and nipples, produce a thick, odorous fluid by apocrine secretion. (LM × 369) **(b)** Merocrine sweat glands produce a watery fluid by merocrine secretion. (LM × 194)

Cutaneous Glands

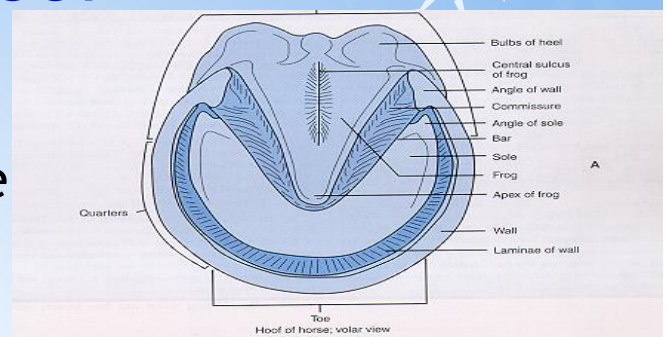


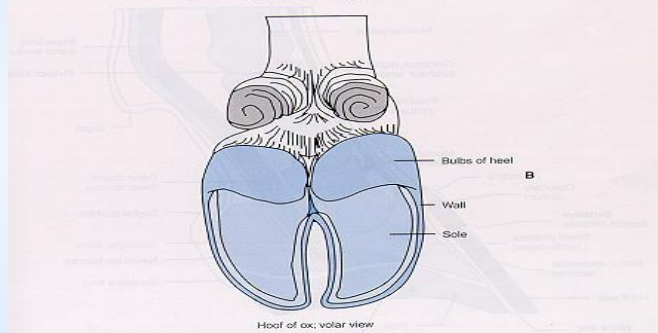
Hair and surrounding structures

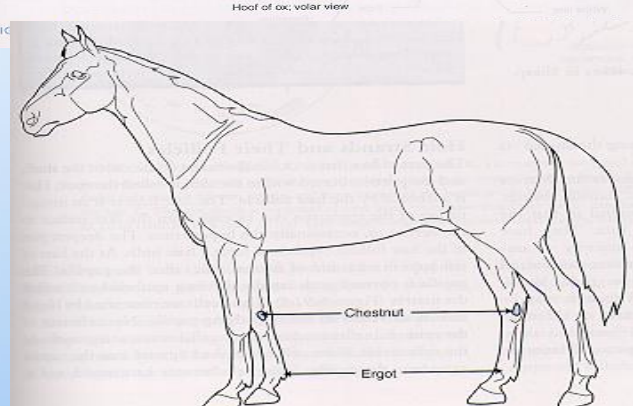
- Functions of hair
  - Warmth – less in man than other mammals
  - Sense light touch of the skin
  - Protection - scalp
- Parts
  - Root imbedded in skin
  - Shaft projecting above skin surface
- Make up of hair – hard keratin
- Three concentric layers
  - Medulla (core)
  - Cortex (surrounds medulla)
  - Cuticle (single layers, overlapping)

Accessory Structures: The Hoof

- Hoof = ungula *['ʌŋgulə]*; Hoofed animals = ungulates
- Ruminants (cow, goat, sheep) have four hooves per foot. Each one covers a digit, only two carry weight.
  - 1st digit ("thumb") disappeared
  - 2nd ("index finger") & 5th ("pinky") digits regressed → dewclaw *['dju;clɔ:]*.
  - 3rd & 4th digits carry weight
- Horse has only one hoof = 3rd digit. Splint bones, ergot *['ə:gət]* and chestnuts are remaining vestiges of ancestral digits.

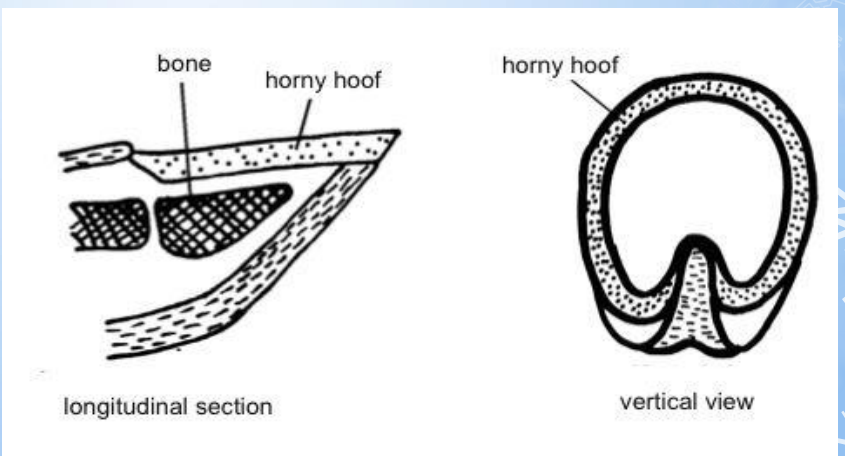






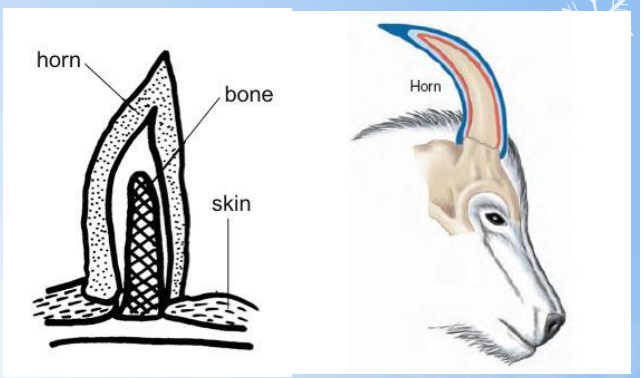
HOOFS

•**Hoofs** are found in sheep, cows, horses etc. otherwise known as **ungulate mammals**. These are animals that have lost toes in the process of evolution and walk on the “nails” of the remaining toes. The hoof is a cylinder of horny material that surrounds and protects the tip of the toe .

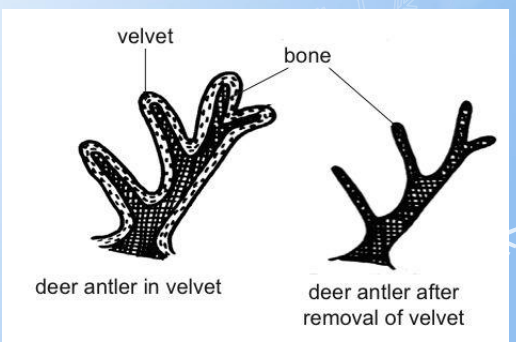


Horns And Antlers

•**True horns** are made of keratin and are found in sheep, goats and cattle. They are never branched and, once grown, are never shed. They consist of a core of bone arising in the dermis of the skin and are fused with the skull. The horn itself forms as a hollow cone-shaped sheath around the bone



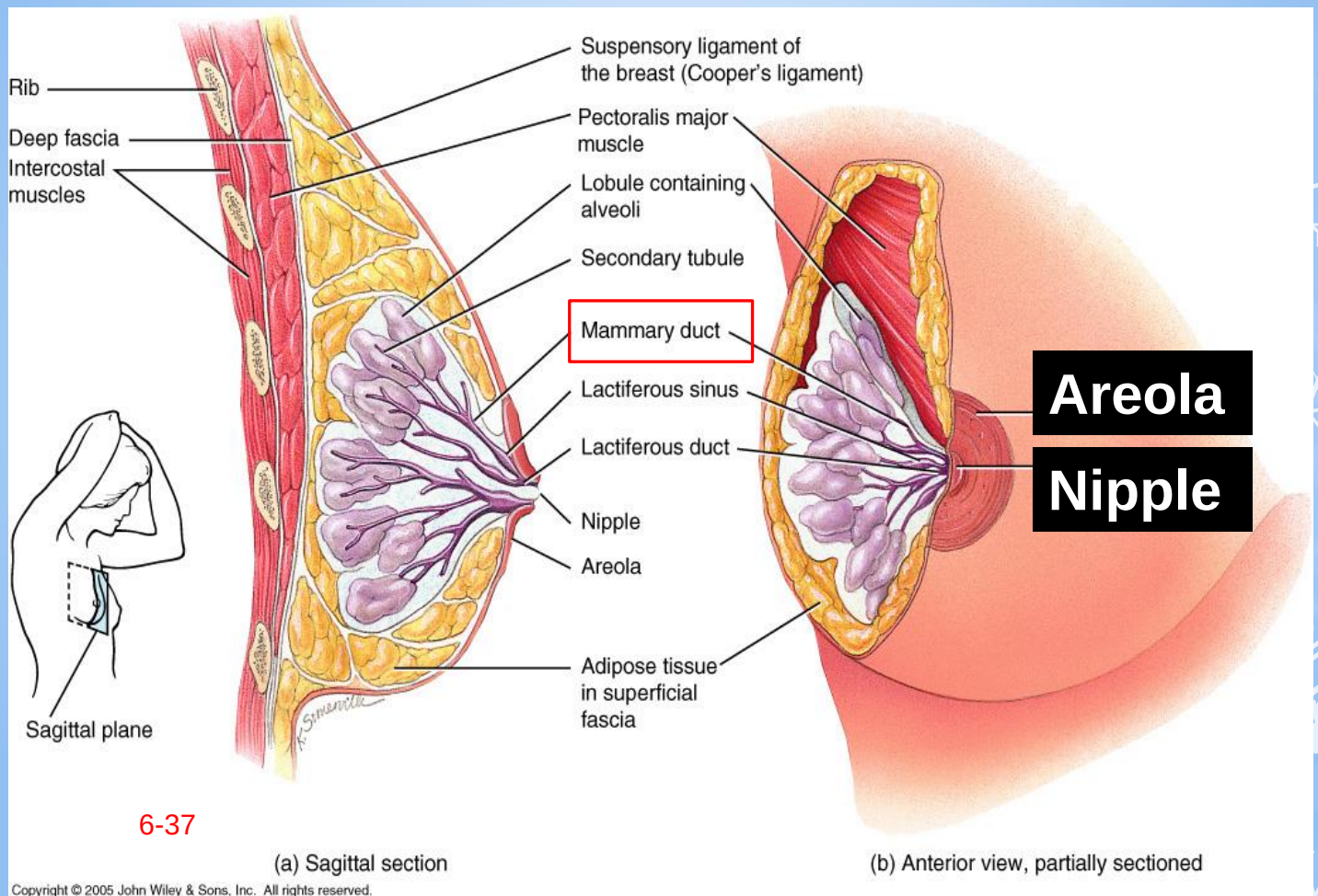
•The **antlers** of male deer have quite a different structure. They are not formed in the epidermis and do not consist of keratin but are entirely of bone. They are shed each year and are often branched, especially in older animals. When growing they are covered in skin called **velvet** that forms the bone. Later the velvet is shed to leave the bony antler. The velvet is often removed artificially to be sold in Asia as a traditional medicine



Accessory Structures:
Mammary Gland

- The mammary glands are anatomically related to apocrine sweat glands.

Mammary Glands – Compare human



Mammary Glands

1. Breasts of both sexes rarely contain mammary glands
   - secondary sexual characteristic of females
2. Mammary glands (within female breast)
   - produce milk--during lactation and pregnancy
- Mammary ridges or milk lines
  - Mammals-- 2 rows of mammary glands
  - Primates-- kept only anteriormost glands
- Additional nipples (polythelia)
  - may develop along milk line

6-38

6-38

Accessory Structures:
Horns and Antlers

- Provision for defense as animals sought to defend themselves in fights either for life or dominion over mates.

- May be permanent or deciduous, simple or branched

The Poultry Integumentary System

- The fowl's skin has been modified for special functions:
  - The **feathered** skin.
  - The **scale** covered skin on the lower legs and feet.
  - The **hard, horny** areas of the beak and toenails.
  - The **pad** of the foot (or plantar).
  - The skin of the **comb and wattles**.

The Poultry Integumentary System

- The uropygial or preen gland
- Is a two-lobed, pea-sized structure that develops from the epidermis
- At the base of the tail above the pygostyle or last vertebra.
- It produces and discharges a fatty secretion through a duct opening on a small papilla or pimple located on the surface of the skin.

2. BIRDS

•**integumentary system** consists of the skin, the feathers and the appendages (claws and beak)

•the integumentary system is very important in providing protection to the bird from a number of potentially dangerous situations.

The

The fowl's skin is divided into a number of separate areas where the skin has been modified to some extent to be able to carry out special functions. These areas are:

•The feathered skin.

•The scale covered skin on the lower legs and feet.

•The hard, horny areas of the beak and toenails.

•The pad of the foot (or plantar).

•The skin of the comb and wattles.

The feathered skin is also divided into a number of special areas or tracts – those where feathers actually do grow and other areas where they do not grow but which appear as such because they are covered by feathers. The areas where they do grow are called **pterylae** and the areas where they do not grow are called **apteria**.

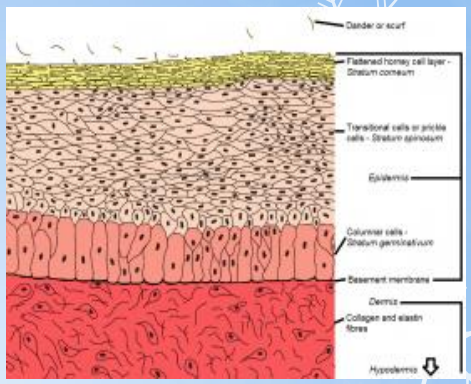
Cross-section of bird skin

Structure

The skin is composed, in the main, of two different tissues:

•Connective tissue of the dermis and hypodermis where the cells are widely spaced.

•Cellular stratified epithelium of the epidermis, which make up the horny outer layer of the skin and forms the feathers.



a. The hypodermis connect with air sacs of the respiratory system thus enhancing the ability to fly. different skin types contain different amounts and distribution of special compounds mainly **collagen**,**elastin** and **keratin**.

•***Epidermis***

The epidermis consists of three separate layers:

A.The flattened, horny cell layer – the outermost layer.

B.The transitional layer – joins the outer layer to the inner layer. It is here that the cells formed in the third innermost layer are transformed into the hard, horny type found in the outermost layer.

C.The columnar cell layer – this is the innermost layer of the epidermis and is the germinative layer where the cells of the epidermis are formed.

b. Dermis

•The dermis is relatively thin and shows a uniform, microscopic structure. This is different to many other animals that have both densely packed and loose layers of cells. The main component of the dermis is collagen with a small amount of elastin.

•***Hypodermis***

•The hypodermis contains fewer cells and is more loosely arranged than the dermis. Fat is stored here in special adipose cells (adipose tissue is fat tissue). Air spaces found in the

FEATHERS

•The lightness and stiffness of keratin is also a key to bird flight. In the form of feathers it provides the large airfoils necessary for flapping and gliding flight. In another form, the light fluffy down feathers,also made of keratin, are some of the best natural insulators known. This superior insulation is necessary to help maintain the high body temperatures of birds.

•Five types of feathers:

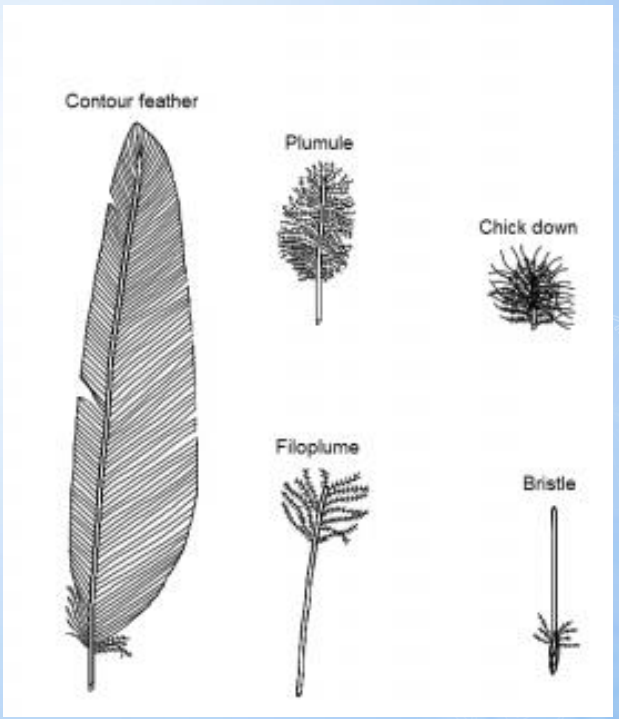
a. Contour Feather

b. Down Feather

c.Pin or Filoplumes Feather

d.Plumules

e.Bristles



a. Contour Feather

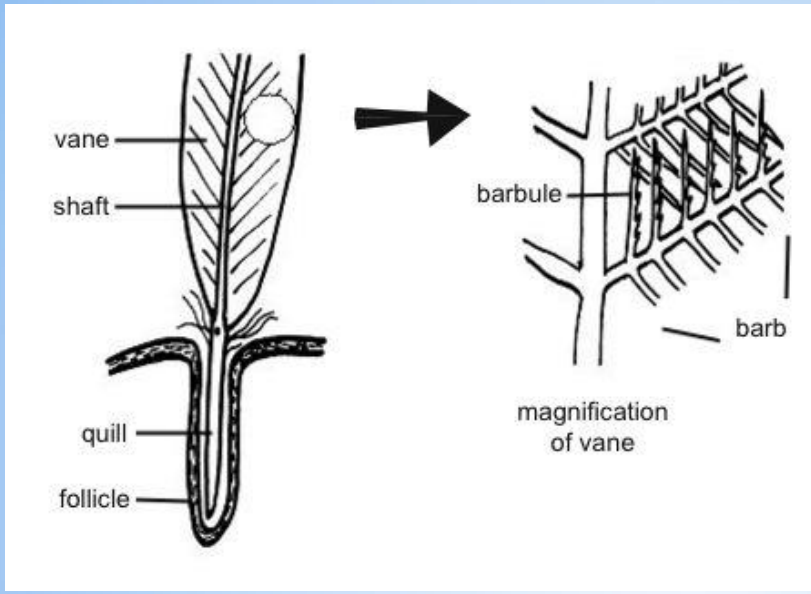


Diagram 5.7 - A Contour Feathera

•**Countour feathers** are large feathers that cover the body, wings and tail. They have an expanded **vane** that provides the smooth, continuous surface that is required for effective flight.

b. Down Feather

Diagram 5.8 - A Down Feather

•Down feathers are the only feathers covering a chick and form the main insulation layer under the contour feathers of the adult. They have no shaft but consist of a spray of simple, slender branches (see diagram 5.8).

c.Pin or Filoplumes Feather

Diagram 5.9 - A Pin Feather

•Pin feathers have a slender hair-like shaft often with a tiny tuft of barbs on the end. They are found between the other feathers and help tell a bird how its feathers are lying (see diagram 5.9).

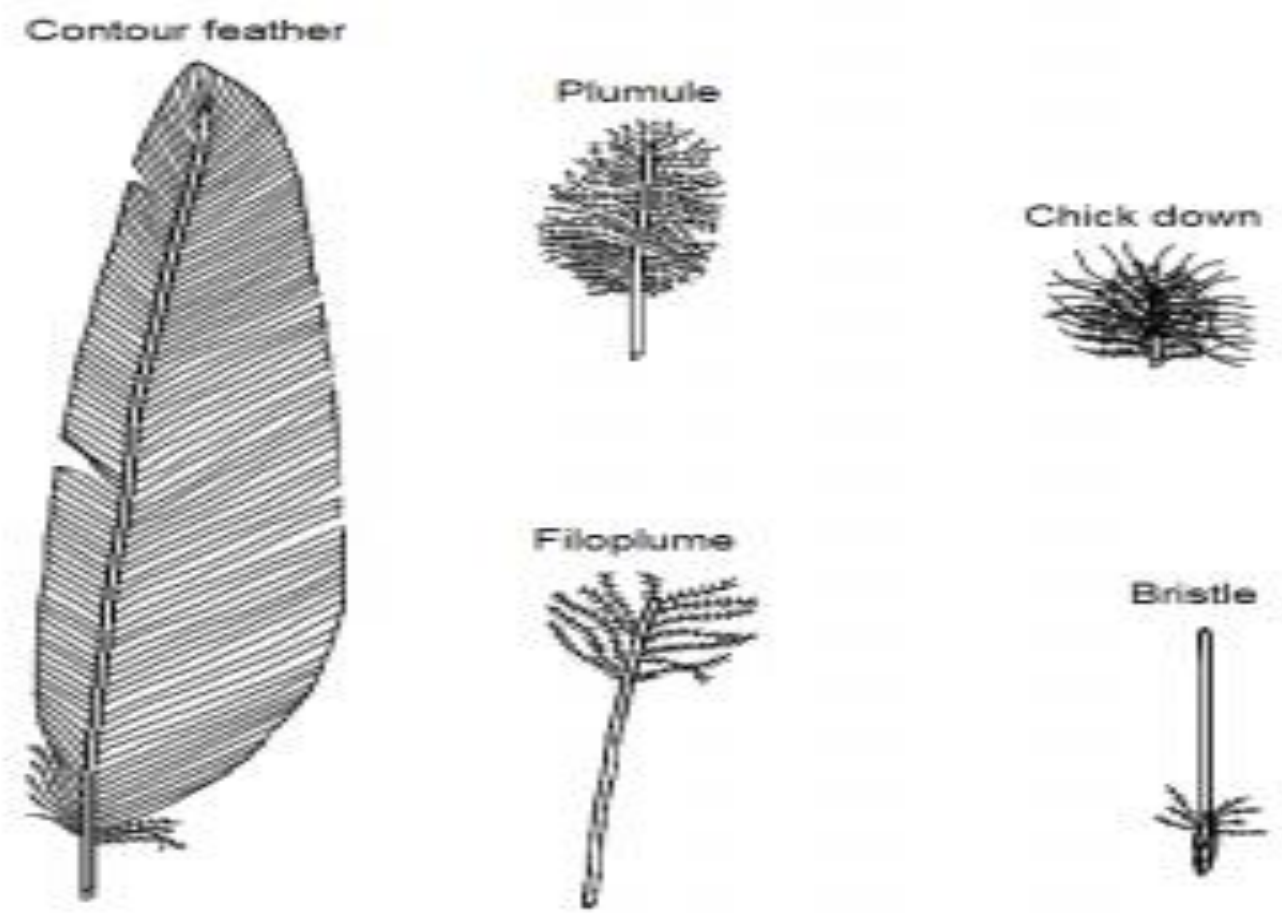
d.Plumules

•Plumules are found beneath the contour feathers where they form a soft, downy undercoat. They have a short shaft with radiating, free barbs and barbules. They have no interlocking hooklets or barbicels. These feathers provide the depth to the coat and play a large part in trapping the air and holding it still – thus improving their ability to conserve warmth.

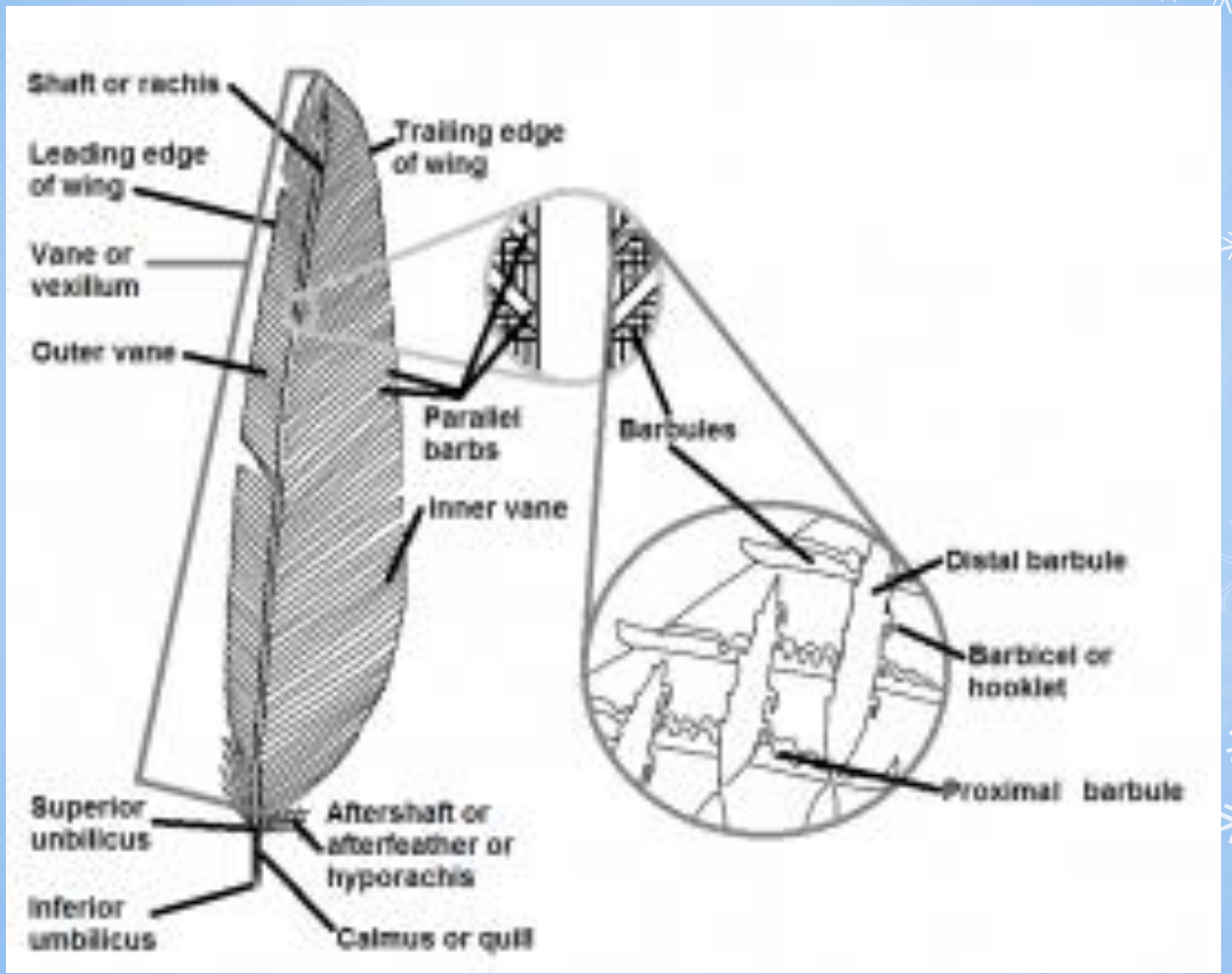
e.Bristles

•Bristles are found around the mouth and eyes of chickens and are thought to be primarily used to aid the sensory ability of birds and protect sensitive areas. A comparison between bird bristles and mammalian eylashes could be used here.

The Poultry Feathers



The Poultry Feathers



Thermoregulation

- Homeotherm- warm blooded (mammals and birds)
- Poikilotherm- cold blooded (reptiles and amphibians)
- I. Body Temperature
- A. Gradients of Temperature
  - 1. different temperatures in different body tissues
- B. Diurnal Temperature
  - 1. time of day
    - a. animals that are active during the day tend to have lower temps in the morning than in the afternoon
    - b. nocturnal animals have higher temps in afternoon than in the morning
  - 2. heat storage-camel
    - a. water conservation technique - heat increases during day and is dissipated at night

This thermal balance is expressed by the equation:

$$M - E_E \pm E_R \pm E_C \pm E_G \pm S = 0$$

where:

M	=	Metabolic heat production
E_E	=	Heat loss from the skin and respiratory passages by **evaporation**
E_R	=	Heat lost or gained through **radiation**
E_C	=	Heat lost or gained by direct contact between the body and surrounding surfaces, i.e. **conduction**
E_G	=	Heat lost or gained by **convection** due to contact between the air and skin, and air and the linings of the respiratory passages
S	=	Heat lost or gained to bring ingested food and water to body temperature

Regulation of Heat Production by Effectors

As air temperature falls, the rate of heat production must increase to compensate for an increased rate of heat loss.

Increased activity of muscle contraction produces more body heat. This activity is under voluntary control.

Shivering**:** This is an autonomic response to the cold. During shivering, both flexor and extensor muscles simultaneously contract at high frequency in a rhythmic fashion.

Non-shivering thermogenesis**:** Heat production can occur in the body, but that is not attributable to shivering of skeletal muscle. termed nonshivering thermogenesis (NST).. Brown Adipose Tissue (BAT) calorigenic role in NST cannot shiver. Thus NST is the main form of heat production).

Thermoregulation –
Physiologic Responses to Heat and Cold

- A. Responses to Heat
- 1. Circulatory Adjustments
  - a. blood vessels dilate
  - b. increased surface area increases heat loss
  - c. controlled by the brain (hypothalamus) temperature
- 2. Evaporative Heat Loss
  - a. evaporation = cooling
  - b. defined as insensible water loss

Thermoregulation –
Physiologic Responses to Heat and Cold

- Includes water lost from:
  - a. skin surface (sweat)
  - b. through exhaled air
  - c. sweating and panting
- Heat loss due to sweating varies wide between species
  - most effect in humans
  - eccrine sweat glands
    - 1. most common in humans
    - 2. in dogs and cats found on the footpad for lubrication

Thermoregulation –
Physiologic Responses to Heat and Cold

apocrine sweat gland

- 1. found in most domestic species
- 2. proteinaceous in nature in the dog
- 3. usefulness in heat regulation (thermoregulatory function)
  - a. horse - most b. cattle
  - c. sheep d. dog
  - e. cat f. swine - least

Thermoregulation –
Physiologic Responses to Cold

1. Reduction of Heat Loss
   - a. Is activated by blood temperature
   - b. reduced exposed surface area
   - c. piloerection of hair
   - d. blood supply
     - i. vasoconstriction of peripheral vessels
     - ii. counter-current blood supply of legs

Thermoregulation –
Physiologic Responses to Cold

- C. Brown Fat verses White Fat
  - 1. cells have faster metabolic rate (MR)
    - a. contains more mitochondria
    - b. high oxygen consumption rate
    - c. high oxygen consumption and MR lead to increased heat to warm body
  - 2. brown fat also found in new born

Thermoregulation –
Physiologic Responses to Cold

- 2. Increase of Heat Production
  - a. critical temperature - temperature which triggers heat generation
  - b. shivering - 75% of muscle movement "lost" as heat
  - c. epinephrine and norepinephrine- brown fat metabolism
  - d. thyroid hormone – affects Basal Metabolic Rate

Thermoregulation –
Physiologic Responses to Cold

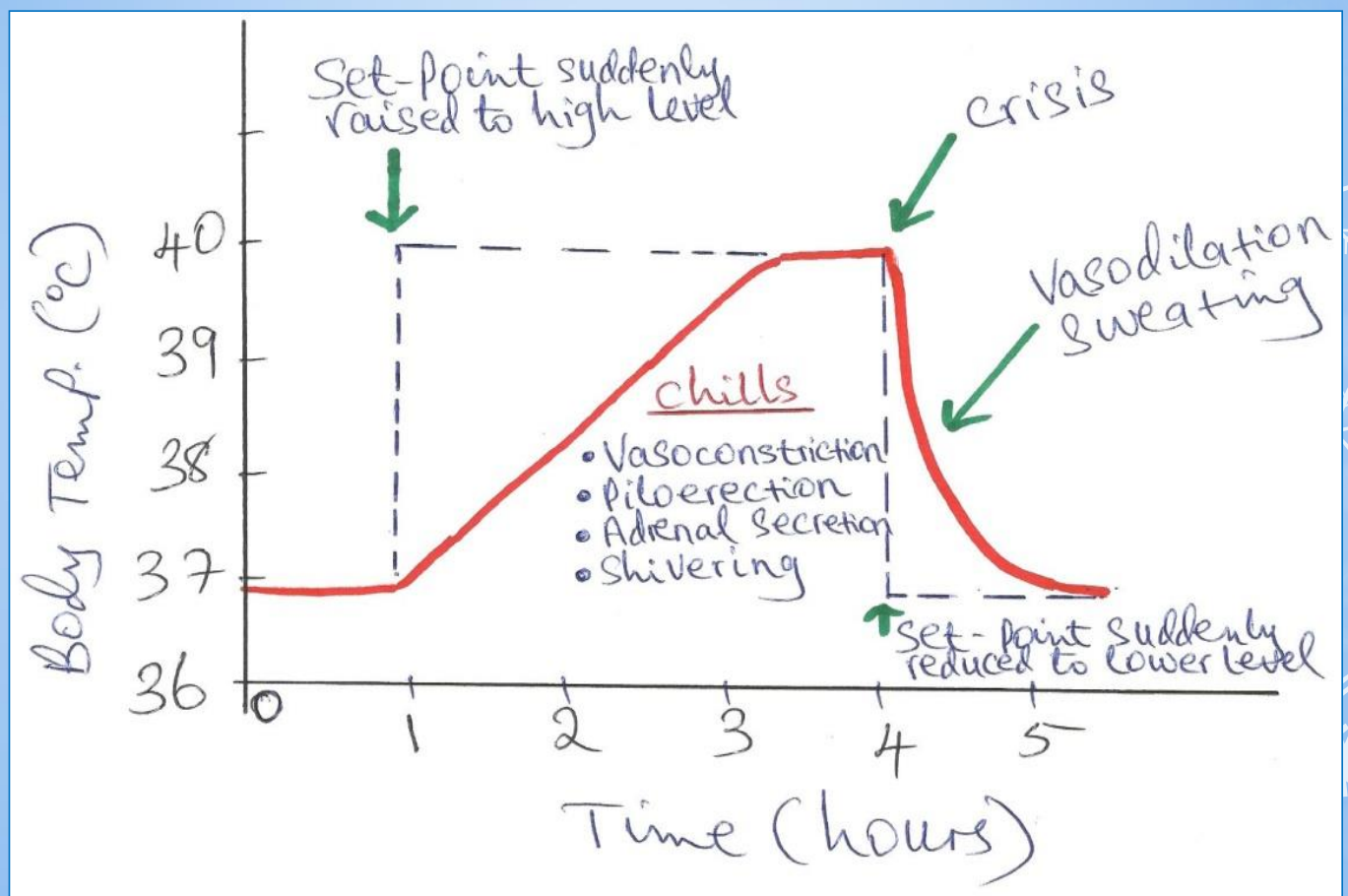
C. Responses to Extreme Environmental Temperatures

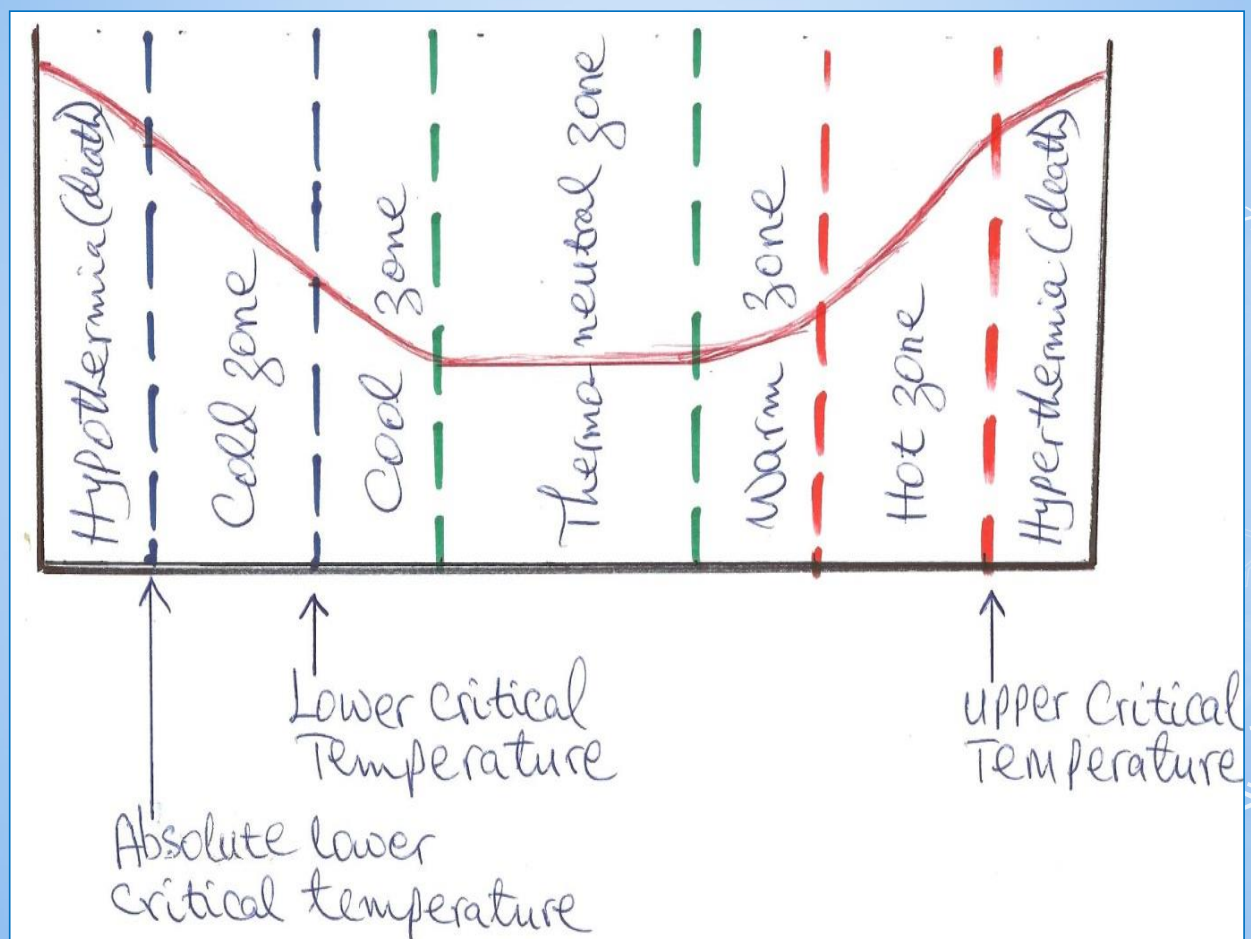
- 1.combination of heat and humidity
- 2. critical environments
  - a. pig - 35° C / 65% RH
  - b. birds - 37.8° C / 75% RH, 45°C rectal
  - c. cat- 40° C/ 65% RH
  - d. dog- 41° C rectal temp
  - e. cattle and sheep - 42.8° C / 65% RH
  - f. human- varies with physical condition

Thermoregulation –
Physiologic Responses to Cold

Hyperthermia- pathologic elevation in core body temperature

- 1. Fever
  - a. elevation of body temperature in response to a bacterial or viral infection
- 2. Heat Stroke and Impaired Evaporation
  - a. heat load exceeds cooling effects of evaporation
- 3. Hyperthermia is also associated with times of extreme fluid loss.


Set-Point suddenly raised to high level
crisis
Vasodilation
Sweating
chills
• Vasoconstriction
• Piloerection
• Adrenal Secretion
• Shivering
Set-point suddenly reduced to lower level
Body Temp. (°C)
40
39
38
37
36
0
1
2
3
4
5
Time (hours)


Hypothermia (death)
Cold zone
Cool zone
Thermo neutral zone
Warm zone
Hot zone
Hyperthermia (death)
Lower Critical Temperature
Upper Critical Temperature
Absolute lower critical temperature

Thermoneutral Zone: The animal is under neither cold stress nor heat stress when it is in this zone.

Cool Zone: The temperature falls, and the animal involves physical thermoregulatory mechanisms to conserve metabolic heat. The metabolic rate of the fed animal remains at the thermoneutral level, but the animal's maintenance requirement increases.

Cold Zone: Below the lower critical temperature lies the cold zone. Here the metabolic rate goes up to increase heat production. The lower critical temperature is a very important parameter in animal production, productivity or feed conversion efficiency suffers at such temperatures.

Intolerably Cold Zone: Hypothermia occurs here followed by death.

Warm Zone: The thermoregulatory reactions are limited to more or less passive facilitation of heat loss (sensible means).

Hot Zone: Active heat-dissipating mechanisms are invoked, e.g. panting and sweating.

Intolerably Hot Zone: An animal can no longer dissipate heat. Death occurs from hyperthermia.

SENSIBLE FORMS OF HEAT FLOW

Radiation

Occurs in the form of electromagnetic waves such as infrared heat rays. Most infrared heat rays radiating from the body have wavelengths 10 to 30 times the wavelengths of light rays.

Conduction

This type of heat flow occurs as a result of contact between two surfaces.

Convection

The removal of heat from the body by convection air currents is commonly referred to as “heat loss by convection.”

INSENSIBLE FORM OF HEAT FLOW

Evaporation

depends on the following factors:

- Air temperature
- Amount of available moisture
- Area of the evaporating surface
- Absolute humidity of air surrounding the animal
- Degree of air movement

Panting

Effects of Temperature on Animal Performance

Feed and water intake: High temperature depresses feed intake, but water intake is increased, though to some extent only. High humidity at high ambient temperatures depresses feed intake further.

Efficiency of feed utilization: Higher ambient temperature decreases the efficiency of feed utilization.

Growth: Since climatic stress depresses appetite, feed intake is obviously reduced, and affects productivity as measured by growth.

Milk Yield: Milk yield, butter fat and solids-not-fat (SNF) are depressed under high temperatures.

Effects of Temperature on Animal Performance

Reproduction: High temperatures have the following effect:

Female Animals

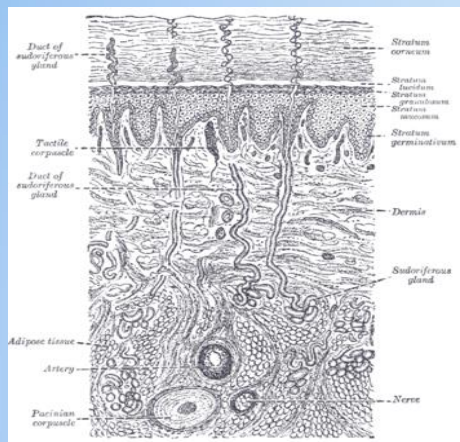
Regularity and duration of estrous cycle are affected
High incidence of abnormal ova
High embryonic mortality
High foetal death rate
Decreased foetal size

Male Animals

Decreased sexual libido
Interference with spermatogenesis

KINDS OF Glands

a. Sweat Glands or Sudoriferous



•These are **large lumen glands** associated with **hair follicles**.

•They **develop** from the same **down growths** that give rise to **hair follicles**.

•The **connection is retained** and they are **coiled tubular glands**, sometimes **branched**.

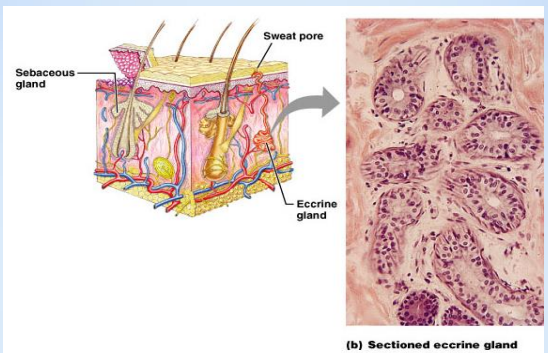
•The **secretory portion** is in the dermis or **upper** hypodermis

•The **secretory product** is **stored in the lumen**.

•**Myoepithelial cells** facilitate the **expulsion** of

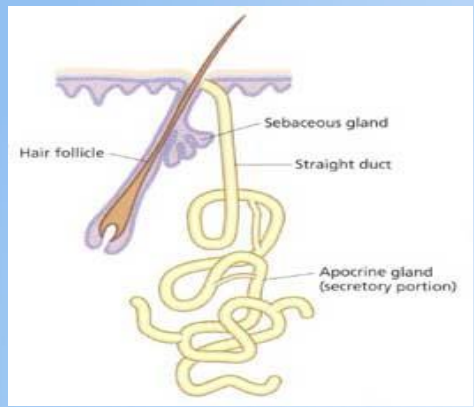
There are **2 types** of sweat glands:
•Eccrine sweat glands, all over body except **lips** and **part of external genitalia**;
•Apocrine sweat glands, only in **axilla**, **areola**, **nipple of** mammary gland, and **circumanal region** and the **external genitalia**. The **ceruminous glands of ear** and **glands of Moll** of eyelid are also apocrine.
•Both the eccrine and the apocrine sweat glands are **innervated** by the **sympathetic nervous system**.
•Eccrine glands respond differently to **heat** and **nervous state**.
•The apocrine glands respond to **emotional** and **sensory stimuli** but **not heat**.

•***Eccrine Sweat Glands***



•These are **simple coiled glands** that **regulate body temperature**.
•The **secretory segment** is deep in the dermis or **upper** hypodermis.
•Its duct leads to surface.
•In the **secretory region** there are **clear cells** that produce the **watery component** of **sweat** and **dark cells** that produce a **proteinaceous secretion**.
•There are also **myoepithelial cells** that are responsible for the **expression of sweat** from the gland.
•**Duct cells** form the **walls** from the secretory portion to the area near the surface where the epidermal cells form the wall.
•The duct is **stratified cuboidal**.
•There is both **thermoregulatory sweating** and **emotional sweating**.
•**Resorption** of **some minerals** take place in the duct.
•**Myoepithelial cells** are present in the duct.

- ***Apocrine Sweat Glands***

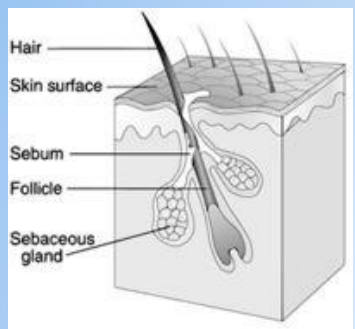


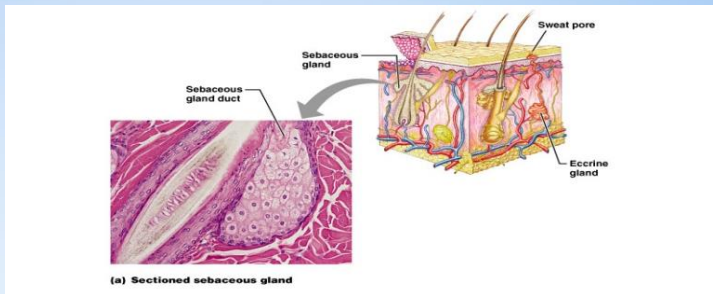
- the **secretory product** from the gland.
- The **duct** has a **narrow lumen**.
- **Apocrine**

secretions contain **protein**, **carbohydrate**, **ammonia** and **lipid**.

b. *Sebaceous Glands or Oil Glands*

•Found in the skin of mammals and these glands secrete sebum.





•**<u>sebum</u>** (Latin, meaning *fat* or *tallow*) that is made of fat (lipids) and the debris of dead fat-producing cells.
•These glands exist in humans throughout the skin except in the palms of the hands and soles of the feet.
•Sebum acts to protect and waterproof hair and skin, and keep them from becoming dry, brittle, and cracked. It can also inhibit the growth of microorganisms on skin.