

# Integumentary System (Skin)



## Chapter Outline

- Skin
- Appendages of skin
- Functions of skin
- Thermoregulation

### SKIN

Skin is the general covering of the entire external surface of the body. It is continuous with the mucous membrane at the orifices of the body (Fig. 4.1). It has sensory nerve endings that help in perceiving pain, touch, hot or cold, etc. Because of the presence of sweat glands, it helps the body in temperature regulation.

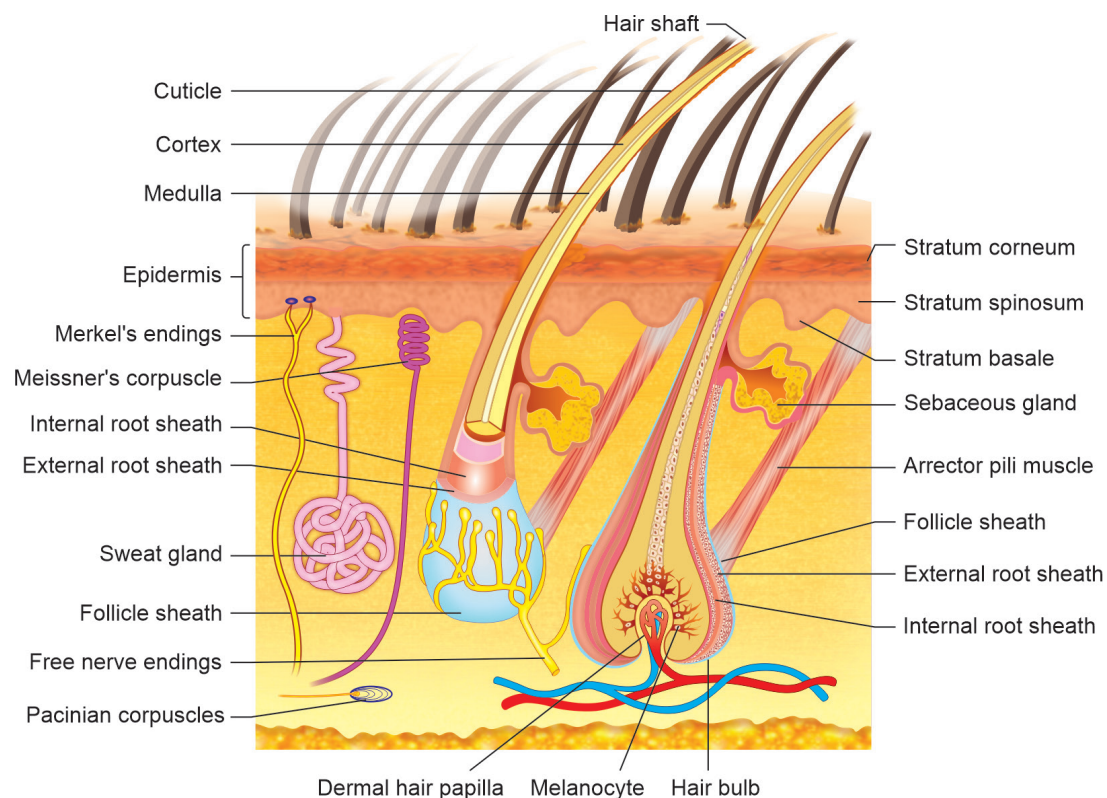
### Surface Area

In an adult, the surface area of the skin is 1.5–2 (average 1.7) sq. meters.

**Du Bois formula:** The surface area of an individual can be calculated by Du Bois formula. Therefore,

$$A = W \times H \times 71.84$$

where  $A$  = Surface area in sq. cm,  $W$  = weight in kg and  $H$  = height in cm.



**Fig. 4.1:** Histology of thin skin with nerve endings

### Pigmentation of Skin

The color of the skin is determined by at least five pigments present in it.

- Melanin (brown), present in the germinative zone of the epidermis.
- Melanoid (resembles melanin), present diffusely throughout the epidermis.
- Carotene (yellow to orange), present in stratum corneum and the fat cells of dermis and superficial fascia.
- Hemoglobin (purple).
- Oxyhemoglobin (red), present in the cutaneous vessels.

### Thickness

The thickness of the skin varies from about 0.5–3 mm.

The skin is composed of two distinct layers, epidermis and dermis.

- **Epidermis:** It is the superficial, avascular layer of stratified squamous epithelium. It is ectodermal in origin and gives rise to the appendages of the skin, namely hair, nails, sweat glands and sebaceous glands.

Structurally, the epidermis is made-up of a deep germinative zone, comprising stratum basale, stratum spinosum and stratum granulosum (Fig. 4.2).

Superficial cornified zone: Stratum lucidum and stratum corneum.

### The germinative zone contains:

- ‘dopa’ positive *melanocytes* of neural crest origin, which synthesize melanin.
- Langerhans cells, which are phagocytic in nature.
- Merkel’s cells which are sensory receptor cells in stratum basale.
- **Dermis or corium:** Dermis or corium is the deep, vascular layer of the skin, derived from mesoderm.

It is made-up of connective tissue (with variable elastic fibers). The connective tissue is arranged into a superficial *papillary layer* and a deep *reticular layer*.

The papillary layer forms conical, blunt projections which fit into reciprocal depressions on the undersurface of the epidermis. The reticular layer is composed chiefly of the white fibrous tissue arranged mostly in parallel bundles.

The direction of the bundles, constituting flexure or *cleavage lines* (Langer’s lines), is longitudinal in the limbs and horizontal in the trunk and neck (Fig. 4.2).

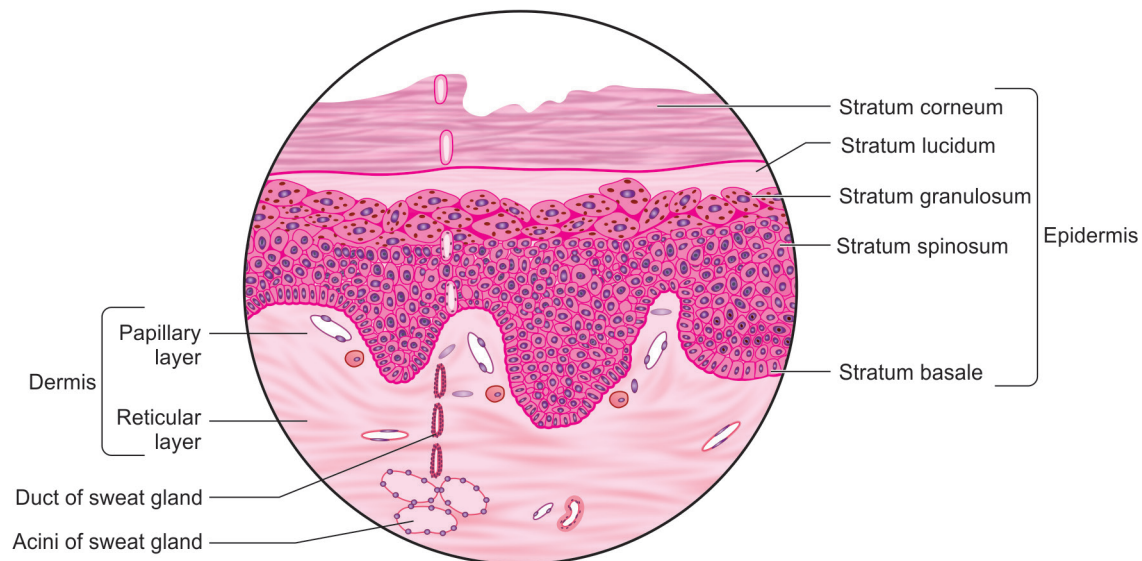
Dermis is the real skin, because when dried it makes hide and when gets tanned it looks like leather.

### Blood Supply

The dermis is vascular while epidermis is avascular.

### Nerve Supply

There are motor and sensory nerves. The motor nerve fibers are autonomic nerve fibers which are sudomotor,



#### FACTS TO REMEMBER

1. Columnar cells of stratum basale rest on the basement membrane
2. Stratum spinosum, stratum granulosum, stratum lucidum and stratum corneum form the succeeding layers
3. Stratum corneum is the waterproof layer

Fig. 4.2: Histology of thick skin

pilomotor and vasomotor. The sensory nerve endings in the skin are of the following types:

- Free nerve endings, Merkel's disc, Meissner's corpuscles
- Pacinian corpuscles, Ruffini's endings, Krause's bulbs

### Surface Irregularities of the Skin

Skin is marked by three types of surface irregularities:

1. **Tension lines:** These lines to some extent correspond to variations in the pattern of fibers in the dermis.
2. **Flexure lines (skin creases or skin joints):** These are certain permanent lines along which the skin folds during habitual movements of the joints.
3. **Papillary ridges (friction ridges):** They are confined to palms, soles and their digits. They form narrow ridges separated by fine parallel grooves, arranged in curved arrays. They correspond to patterns of dermal papillae. Their study constitutes a branch of science, called dermatoglyphics (fingerprints).
  - Three major patterns in the human fingerprints include loops, whorls and arches (Fig. 4.3).
  - These patterns and many other minor features are determined genetically by multifactorial inheritance.
  - These do not change throughout life, except to enlarge. This serves as a basis for identification through fingerprints or footprints.

Skin of palm and sole is thick, rest of the body has thin skin. Table 4.1 compares the two types of skin.

### APPENDAGES OF SKIN

#### Nails

Nails are hardened keratin plates (cornified zone) on the dorsal surface of the tips of fingers and toes. Each nail has the following parts.

- Root is the proximal hidden part which is buried into the nail groove and is overlapped by the nail fold of the skin (Figs 4.4A and B).
- Body is the exposed part of the nail which is adherent to the underlying skin; root and body together form nail's plate.
- Free border is the distal part free from the skin. It is attached to the under surface by hyponychium.

The proximal part of the body presents a white opaque crescent called lunule. Each lateral border of the nail body is overlapped by a fold of a skin, termed the nail fold and the groove between nail body and nail fold is called nail groove.

The skin (germinative zone + dermis) beneath the root and body of the nail is called *nail bed*. The germinative zone of the nail bed beneath the root and lunule is thick and proliferative (germinal matrix) and is responsible for the growth of the nail. The rest of the nail bed is thin (sterile matrix) over which the growing nail glides. Under the translucent body (except lunule) of the nail, the corium is very vascular. This accounts for their pink color.

Nail of middle finger grows the fastest.

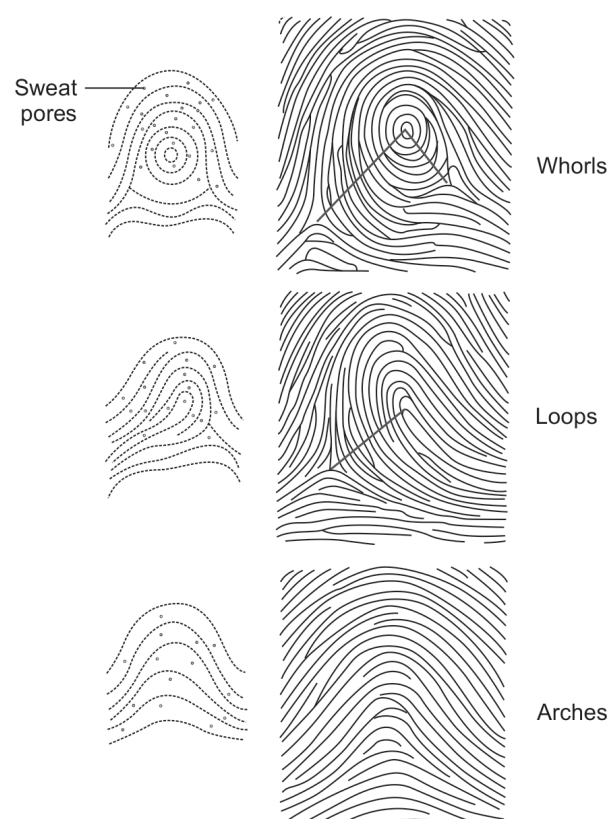
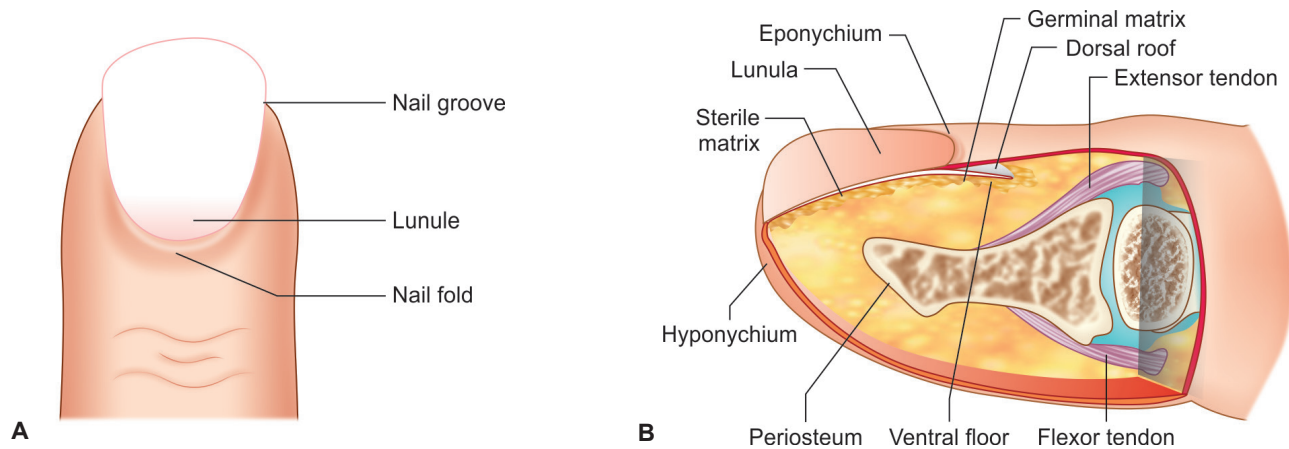


Fig. 4.3: Types of papillary ridges

Table 4.1: Differences between thick and thin skin

Thick skin	Thin skin
The skin from the palms and soles, so named because of its relatively thick epidermis	The skin from areas of the body other than the palms and soles, so named because of its relatively thin epidermis
Occurs on the soles of feet, palms of hands and the surface lining of the fingers and toes	Covers the rest of the body
Thick epidermis of five layers: <ol style="list-style-type: none"> <li>1. Stratum basale</li> <li>2. Stratum spinosum</li> <li>3. Stratum granulosum</li> <li>4. Stratum lucidum</li> <li>5. Stratum corneum</li> </ol>	Thin epidermis of three layers: <ol style="list-style-type: none"> <li>1. Stratum basale</li> <li>2. Stratum spinosum</li> <li>3. Thin stratum corneum</li> </ol>
Lacks hair follicles	Contains hair follicles
Lacks arrector pili muscles	Contains arrector pili muscles attached to hair follicles
Thin dermis	Thick dermis
Lacks sebaceous glands	Contains sebaceous glands
Has numerous, spirally coiled sweat glands	Has fewer sweat glands
Denser sensory receptors	Sparser sensory receptors
Contains both ridges and furrows on the surface	Lacks ridges and furrows on the surface
Contains regular dermal papillae	Contains irregular dermal papillae
More restricted to mechanical abrasion	Performs the other functions of the skin





**Figs 4.4A and B:** A. Parts of a nail; B. anatomy of nail

## Hair

Hairs are keratinous filaments derived from invaginations of the germinative layer of epidermis into the dermis.

These are peculiar to mammals and help in conservation of their body heat.

Hairs are distributed all over the body, except for the palms, soles, dorsal aspect of distal phalanges, umbilicus, glans penis, inner surface of prepuce, the labia minora and inner surface of labia majora.

Structure of hair: Each hair has an implanted part called the root, a bulb and a projecting part, called the shaft.

**Layers of shaft:** Innermost is the medulla, cortex is the middle one and cuticle is a single outer layer:

The root is surrounded by a hair follicle (a sheath of epidermis and dermis) and is expanded at its proximal end to form the hair bulb. Each hair bulb is invaginated at its end by hair papilla (vascular connective tissue) which forms the neurovascular hilum of the hair and its sheath.

Hair follicle surrounds the hair. Wall of the follicle comprises:

- Inner root sheath
- Outer root sheath
- Connective tissue sheath (Fig. 4.5).

The arrector pilorum muscles (smooth muscles supplied by sympathetic nerve) connect the undersurface of the follicles to the superficial part of the dermis. Arrector pili muscles are absent in a few regions like hair of face, axilla, eyelashes, eyebrows, hair of anterior nares and of external auditory meatus.

**Growth of hair:** The hairs grow at the rate of about 1.5–2.2 mm/week.

**Color of hair:** Color of hair depends upon the amount and type of melanin pigment.

## Sweat Glands

Sudoriferous or sweat glands are distributed all over the skin, except for the lips, glans penis and nail bed. These glands are of two types; *eccrine* and *apocrine* (Table 4.2).

- **Eccrine glands:** The eccrine glands are much more abundant and distributed in almost every part of the skin. The coiled part, called the body of the gland, lies in

the deeper part of corium or in the subcutaneous tissue. The straight part, called the duct, traverses the dermis and epidermis and opens on the surface of the skin.

- **Location:** The glands are large in the axilla and groin, most numerous in the palms and soles. The eccrine glands are merocrine in nature, i.e. produce thin watery secretion without any disintegration of the epithelial cells.
- **Control:** They are supplied and controlled by cholinergic sympathetic nerves.
- **Functions:** The glands help in regulation of the body temperature by evaporation of sweat and also help in excreting the body salts.
- **Apocrine glands:** Apocrine glands are confined to axilla, eyelids (Moll's glands), nipple and areola of the breast, perianal region and the external genitalia.
  - **Structure:** They are larger than eccrine glands and produce a thicker secretion having a characteristic odor. They develop in close association with hair. Ceruminous glands of the external auditory meatus are modified apocrine sweat glands.
  - **Nervous control:** The apocrine glands also are merocrine in nature, but are regulated by a dual autonomic control.
  - **Functions:** In animals, they produce chemical signals or pheromones, which are important in courtship and social behavior.

## Sebaceous Glands

- **Location:** Sebaceous glands, producing an oily secretion, are widely distributed all over the dermis of the skin.
- **Structure:** Sebaceous glands are small and sacculated in appearance, made-up of a cluster of about 2–5 piriform alveoli.
  - Most of their ducts open into the hair follicles.
  - Sebaceous glands are *holocrine* in nature.
- **Nervous control:** The secretion is under hormonal control, especially the androgens.
- **Functions:** It lubricates skin and protects it from moisture. Sebum also lubricates hair and prevents them from becoming brittle.

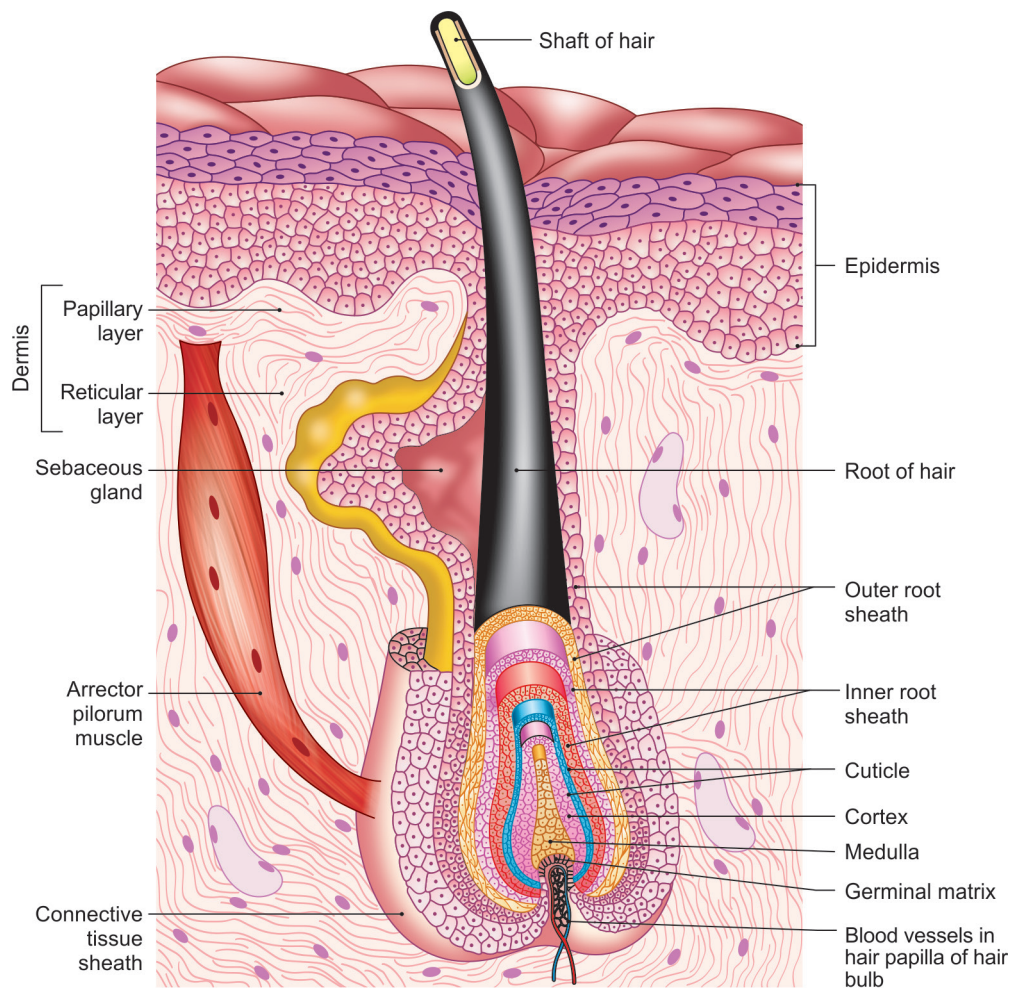


Fig. 4.5: Hair follicle with arrector pilorum muscle

Table 4.2: Difference between eccrine and apocrine sweat glands

Characteristics	Eccrine sweat gland	Apocrine sweat gland
Activity	Throughout life	Active at puberty
Opening on surface	Through the sweat pore	Around hair shaft
Function	Maintains temperature	Provides peculiar odor
Nervous control	Postganglionic sympathetic neurons, which are cholinergic	Postganglionic sympathetic neurons which are adrenergic
Secretion	Watery with salts	Viscid with lipids and proteins

## FUNCTIONS OF SKIN

- **Protection:** Skin protects the body from mechanical injuries.
  - **Physical barrier:** Due to stratum corneum, skin acts as a barrier against bacterial infections, heat and cold, wet and drought, acid and alkali.
  - **Immune properties:** Langerhans cells phagocytose antigen and take it to T lymphocytes.
  - **Reflex action:** Sensory nerve endings start reflex action against painful stimuli and prevent it from damage.
- **Regulation of body temperature:** The internal body temperature is maintained in a normal range by

homeostatic mechanisms despite wide fluctuations in environmental temperature (Fig. 4.6). Human and mammals are homeothermic, i.e. they maintain constant body temperature. Body temperature is least at 5 am and is highest in afternoon. If the rate of body heat production equals the rate of heat loss, the body maintains a constant core temperature near 98.6°F (37°C).

- Core temperature is the temperature in body structures that lie deep to the skin and subcutaneous layer.
- Shell temperature is the temperature near body surface in the skin and the subcutaneous layer. Normally, shell temperature is lower than core

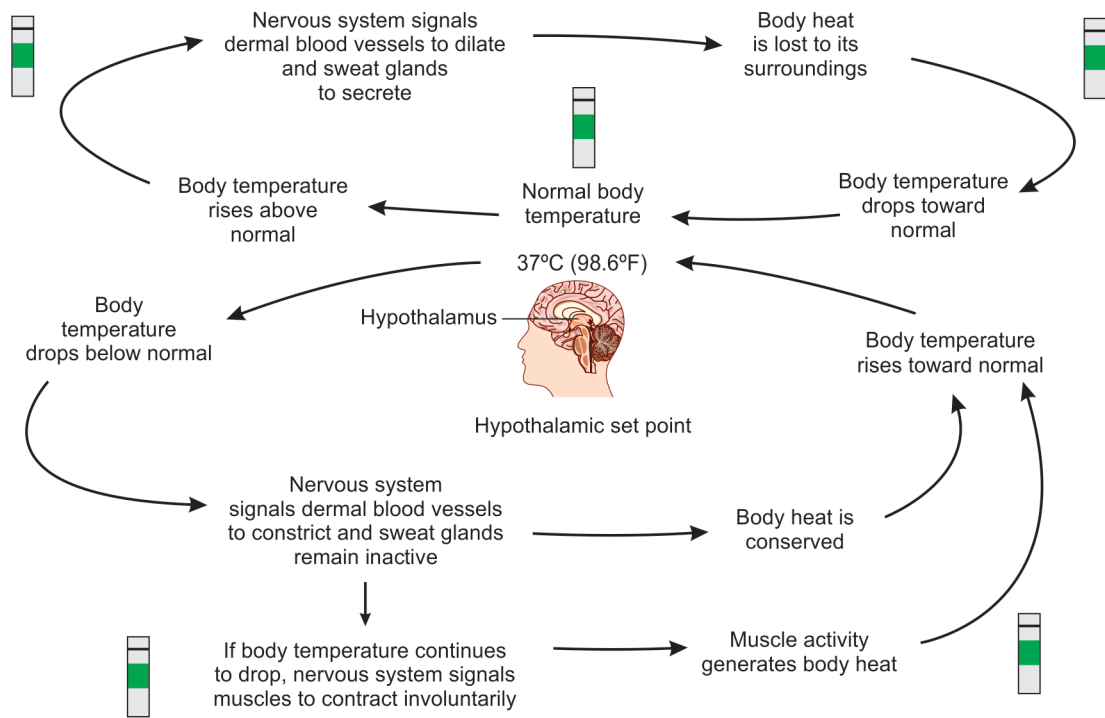


Fig. 4.6: Regulation of body temperature

temperature by 1–6°C depending on environmental temperature.

- **Heat production:** The production of body heat is proportional to metabolic rate. Factors affecting the metabolic rate are:
  - **Body temperature:** Higher the body temperature, higher is the metabolic rate. For each 1°C rise in core temperature, metabolic rate increases by 10%.
  - **Exercise:** During strenuous exercise metabolic rate may increase up to 20 times the basal metabolic rate (BMR) due to contraction of skeletal muscles.
  - **Nervous system:** Stimulation of sympathetic division of autonomic nervous system releases norepinephrine and epinephrine, both of which increase the metabolic rate.
  - **Hormones:** Thyroid hormones are the main regulators of BMR. BMR increases as blood levels of thyroid hormones rise. Growth hormone, testosterone and insulin also increase the BMR.
  - **Ingestion of food:** This activity raises the metabolic rate by 10–20% due to the increase in metabolic rate during the process of digestion, absorption and storage of nutrients. This food-induced increase in heat production is maximally seen after eating a high protein diet.
  - Metabolic rate is also affected by gender (lower in females except during pregnancy and lactation), sleep (lower) and age (higher in children).
- **Heat loss:** Normal body temperature is maintained only when heat is lost to the environment at the same rate as it is produced by metabolic reactions. Heat from the body can be lost by:
  - **Conduction:** It is the exchange of heat that occurs between molecules of two materials that are in

direct contact with each other. At rest, about 3% of body heat is lost via conduction to solid materials in contact with body such as chair and clothing. If a body is submerged in cold or hot water, heat loss or gain via conduction is much greater because water conducts heat 20 times more effectively than air.

- **Convection:** It is the transfer of heat by movement of a gas/liquid between areas of different temperature. Contact of air/water with human body results in heat transfer by both conduction and convection. When cool air comes in contact with body, it warms and become less dense; and is carried away by convection currents created as less dense air rises. At rest, about 15% of body heat is lost to air via conduction and convection.
- **Radiation:** It is the transfer of heat in the form of infrared rays between a warmer object and a cooler one without physical contact. About 60% heat loss occurs via radiation in a resting room at 21°C.
- **Evaporation:** It is the conversion of liquid to a vapor. Every milliliter of water evaporates taking with it about 0.58 calories of heat. At rest, about 22% of heat is lost through evaporation of about 700 ml water per day (300 ml in exhaled air and 400 ml from skin surface).

Heat is also lost through respiratory tract, urine and via feces.

The body temperature regulation is shown diagrammatically in Fig. 4.6.

- **Hypothalamic thermostat:** The control center that regulates the temperature is the preoptic area in the anterior hypothalamus. Nerve signals from preoptic area are transmitted to the heat losing center and heat promoting center of the hypothalamus.



## THERMOREGULATION

If core temperature declines, mechanisms that conserve heat and increase heat production to raise body temperature to normal, become active via several negative feedback mechanisms. Temperature receptors in skin and hypothalamus send nerve impulses to control centers in hypothalamus, which in turn sends impulses to heat promoting center.

These impulses also cause release of thyroid-stimulating hormone (TSH). These impulses help to raise the core temperature by:

- **Constriction of blood vessels of the skin:** Decreases heat loss through skin by decreasing flow of blood to skin. Piloerection, i.e. contraction of arrector pili muscles, which causes skin hair to stand up. These form an insulating layer to conserve heat.
- **Increased release of hormones by adrenal medulla:** These hormones bring about an increase in cellular metabolism, which increases heat production.
- **Increased TSH releases:** Increased secretion of thyroid hormones from thyroid gland, which in turn increases metabolic rate.
- **Impulses from the brain cause shivering** (skeletal muscles contract in a repetitive cycle), increasing the metabolic rate.

All the mechanisms mentioned above result in increase in body temperature.

Fever usually results from infection and is due to release of chemicals (pyrogens) from affected tissue. The pyrogens through prostaglandins act on the hypothalamic thermostat and reset it to higher tempe-

perature. The body responds by activating heat-producing mechanisms, e.g. shivering and vasoconstriction, until the new higher temperature is reached. When hypothalamic thermostat is reset to normal level due to disappearance of pyrogens, heat loss mechanisms are activated, e.g. sweating and vasodilatation, until body temperature falls to the normal. Death occurs if core temperature rises above 44–46°C (112–114°F). Heat stroke occurs with prolonged work in hot and humid atmosphere. This leads to cramps, headache and circulatory collapse due to temperature rise—till 41°C.

Rest of the functions associated with skin are:

- **Sensory:** Skin is sensory to touch, pain and temperature.
- **Regulation of body temperature:** Heat is lost through evaporation of sweat. It is conserved by the fat and hair.
- **Absorption:** Oily substances are freely absorbed by the skin.
- **Secretion:** Skin secretes sweat and sebum.
- **Excretion:** The excess of water, salts and waste products are excreted through the sweat.
- **Regulation of pH:** A good amount of acid is excreted through the sweat.
- **Synthesis:** In the skin, vitamin D is synthesized.
- **Storage:** Skin stores chlorides.
- **Reparative:** The cuts and wounds of the skin are quickly healed.
- **Water balance:** Skin does not permit water to pass in and out of the body. Thus it maintains the water balance of the body.

### Golden Points

- **Surface area:** In an adult, the surface area of the skin is 1.5–2 (average 1.7) sq. meters.
- **Pigmentation of skin:** The color of the skin is determined by at least five pigments present in it.
  - Melanin (brown), is present in the germinative zone of the epidermis.
  - Melanoid resembles melanin present diffusely throughout the epidermis.
  - Carotene (yellow to orange), is present in stratum corneum and the fat cells of dermis and superficial fascia.
  - Hemoglobin (purple)
  - Oxyhemoglobin (red), is present in the cutaneous vessels.
- **Epidermis** is the superficial, avascular layer of stratified squamous epithelium. It is ectodermal in origin and gives rise to the appendages of the skin, namely hair, nails, sweat glands and sebaceous glands.
- **Dermis or corium:** Dermis or corium is the deep, vascular layer of the skin, derived from mesoderm. It is made-up of connective tissue (with variable elastic fibers). The connective tissue is arranged into a superficial papillary layer and a deep reticular layer.

- Dermis is the real skin, because when dried it makes hide and when it gets tanned it looks like leather.
- For touch, pain, temperature and pressure there are nerve endings in the epidermis and dermis.
- Free nerve endings are in relation to hair follicles, tendons, etc. these respond to touch and temperature.
- **Merkel's endings:** The nerve fibers of these endings expand into a disc applied closely to the base of a special Merkel cell, inserted into the basal cells of epithelium of epidermis. These respond to pressure sensations.
- Ruffini's corpuscles are encapsulated nerve endings. These respond when heavy objects are gripped.
- Krause's end bulb are seen in the lips and external genitalia. It responds to thermal impulses.
- Meissner's corpuscles are found in dermis of skin of hand, feet, etc. The capsule consists of elastic fibers and flattened cells. In its core lies the nerve fiber. These are responsible for touch.
- Pacinian corpuscles are found in palms and soles. These are big about 2 mm long and 100–200 µm wide. The center of the core contains a single nerve fiber, surrounded by connective tissue fibers and cells. These are pressure receptors.
- Three major patterns in the human fingerprints include loops, whorls and arches. These patterns are determined genetically by multifactorial inheritance.

### Nails

- Nails are hardened keratin plates (cornified zone) on the dorsal surface of the tips of fingers and toes. Each nail has the following parts.
  - Root body and free border nail.
  - Part of the nail which is adherent to the underlying skin; root and body together form nail's plate.
- Nail of middle finger grows the fastest.

### Hair

- Hairs are keratinous filaments derived from invaginations of the germinative layer of epidermis into the dermis.
- These are peculiar to mammals and help in conservation of their body heat.
- Hairs are distributed all over the body, except for the palms, soles, dorsal aspect of distal phalanges, umbilicus, glans penis, inner surface of prepuce, the labia minora and inner surface of labia majora.
- **Structure of hair:** Each hair has an implanted part called the root, a bulb and a projecting part, called the shaft.
- Layer of shaft: Innermost is the medulla, cortex is the middle one and cuticle is a single outer layer:
  - The root is surrounded by a hair follicle (a sheath of epidermis and dermis) and is expanded at its proximal end to form the hair bulb.

- The arrector pili muscles (smooth muscles supplied by sympathetic nerve) connect the undersurface of the follicles to the superficial part of the dermis.
- Color of hair: Color of hairs depends upon the amount and type of melanin pigment. Grey hair occurs due to "air in the hair" and lack of melanin.

### Sweat glands

- Sudoriferous or sweat glands are distributed all over the skin, except for the lips, glans penis and nail bed. These glands are of two types: eccrine and apocrine.
- **Eccrine glands:** The eccrine glands are much more abundant and distributed in almost every part of the skin.
- **Apocrine glands:** Apocrine glands are confined to axilla, eyelids (Moll's glands), nipple and areola of the breast, perianal region and the external genitalia.

### Sebaceous glands

- Sebaceous glands, producing an oily secretion, are widely distributed all over the dermis of the skin.
- Sebaceous glands are holocrine in nature.
- Nervous control: The secretion is under hormonal control, especially the androgens.

### Clinical Aspects of Skin

- Hair loss is due to lack of blood supply. It occurs mostly in the central part of scalp. Hair transplant may be required in selected cases. Hair are taken from back of scalp.
- Greying of hair occurs due to lack of melanin pigment in the hair. It starts initially in the area above the ear. Air also gets into hair and causes it to look grey.
- Acne may be due to increased testosterone levels or increased obesity. Weight loss helps in decreasing the acne.
- Cosmetics should be used with care. Too much use only lightens the pocket with no extra benefit.
- Since cosmetics are chemicals and have a short shelf life, these should be used within the date of expiry.
- Healthy food, enough proteins give a glow which few cosmetics can match.
- Color of skin is determined genetically, too much interference can be harmful.
- In anemia, the nails are pale and white.
- In iron deficiency anemia, the nails become thin brittle and spoon-shaped (koilonychia).

Skin incisions for surgery are given along flexure lines. Thus, the incisions look "a flexure line only". Healing is better and gives cosmetic value.

- Hypertrophy of the nail bed (clubbing) occurs in chronic suppurative disease (lung abscess, bronchiectasis and osteomyelitis).
- It takes about 90–120 days for the whole nail (body) to grow. Therefore, in fungal diseases of the nails the course of treatment should last for not less than this period. The growth is faster in summer than in winter, in the fingers than in toes and in the longer fingers than in the shorter ones.
- Hairs exhibit alterations in certain diseases. In malnutrition hairs become thin, dry and sparse; in hypothyroidism they become coarse and dry.
- Excessive growth of hair (hirsutism) occurs in adrenogenital syndrome. Loss of hair is known as alopecia.
- Skin is dry in 'Dhatu' poisoning, heat stroke and diabetic coma; it is unusually moist in hypoglycaemic coma and peripheral failure.
- In ichthyosis (characterized by abnormally dry skin), the sebaceous glands are few and small and the secretion of sebum is markedly reduced. Excessive oiliness of skin, due to overactivity of sebaceous glands, is called seborrhoea. It may occur from puberty onwards, but diminishes with advancing age.



## Assess Yourself

### Long Answer Questions

1. What is thermoregulation? How it helps to regulate the body temperature?
2. What do you understand by the term 'skin'? Differentiate between thick and thin skin.
3. Discuss in detail the various functions of skin.

### Short Answer Questions

1. Enumerate the layers of epidermis of thick skin.
2. Describe the hair follicle.
3. Describe appendages of skin and their main functions.

### Multiple Choice Questions

Tick (✓) the correct option in the following:

1. The outermost layer of the skin is known as:
  - a. Cutaneous
  - b. Subcutaneous
  - c. Dermis
  - d. Epidermis

2. Layers of epidermis in thin skin from inner side to outer side are:
  - a. Stratum corneum—St. basale—St. spinosum
  - b. St. basale—St. corneum—St. spinosum
  - c. Stratum basale—St. spinosum—St. corneum
  - d. Stratum basale—St. spinosum—St. lucidum
3. Melanocytes secrete:
  - a. Sebum
  - b. Melanin
  - c. Sweat
  - d. All of the above
4. Main mechanism in thermoregulation/heat loss is:
  - a. Radiation
  - b. Evaporation
  - c. Conduction
  - d. Convection
5. Which of these layers has shedding of cells occurring continuously due to wear and tear?
  - a. Stratum corneum
  - b. Stratum lucidum
  - c. Stratum granulosum
  - d. Stratum spinosum

## Answer Key

1. d
2. c
3. b
4. a
5. a