Structure of Skin

■ INTRODUCTION

Skin is the **largest organ** of the body. It is not uniformly thick. At some places it is thick and at some places it is thin. The average thickness of the skin is about 1 to 2 mm. In the sole of the foot, palm of the hand and in the interscapular region, it is considerably thick, measuring about 5 mm. In other areas of the body, the skin is thin. It is thinnest over eyelids and penis, measuring about 0.5 mm only.

■ LAYERS OF SKIN

Skin is made up of two layers:

I. Outer epidermis
II. Inner dermis.

■ EPIDERMIS

Epidermis is the outer layer of skin. It is formed by stratified epithelium. Important feature of epidermis is that, it does not have blood vessels (Fig. 60.1). Nutrition is provided to the epidermis by the capillaries of dermis.

Layers of Epidermis

Epidermis is formed by five layers:

1. Stratum corneum
2. Stratum lucidum
3. Stratum granulosum
4. Stratum spinosum
5. Stratum germinativum.

■ 1. STRATUM CORNEUM

Stratum corneum is also known as **horny layer.** It is the outermost layer and consists of **dead cells,** which are called **corneocytes.** These cells lose their nucleus due to pressure and become dead cells. The cytoplasm is flattened with fibrous protein known as **keratin.** Apart from this, these cells also contain phospholipids and glycogen.

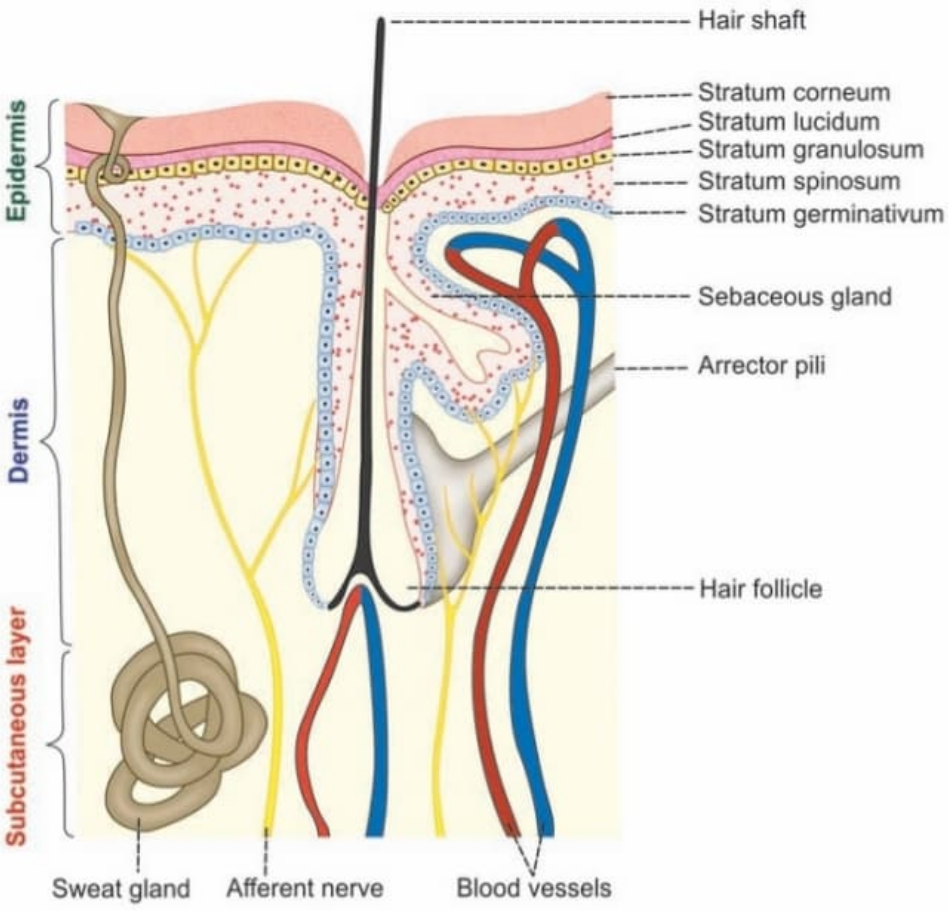

FIGURE 60.1: Structure of skin

■ 2. STRATUM LUCIDUM

Stratum lucidum is made up of flattened epithelial cells. Many cells have degenerated nucleus and in some cells, the nucleus is absent. As these cells exhibit shiny character, the layer looks like a **homogeneous translucent zone.** So, this layer is called stratum lucidum (lucid = clear).

■ 3. STRATUM GRANULOSUM

Stratum granulosum is a thin layer with two to five rows of flattened **rhomboid cells.** Cytoplasm contains granules of a protein called **keratohyalin.** Keratohyalin is the precursor of **keratin.**

■ 4. STRATUM SPINOSUM

Stratum spinosum is also known as **prickle cell layer** because, the cells of this layer possess some spine-like protoplasmic projections. By these projections, the cells are connected to one another.

■ 5. STRATUM GERMINATIVUM

Stratum germinativum is a thick layer made up of polygonal cells, superficially and columnar or cuboidal epithelial cells in the deeper parts. Here, new cells are constantly formed by mitotic division. The newly formed cells move continuously towards the stratum corneum. The stem cells, which give rise to new cells, are known as **keratinocytes.**

Another type of cells called **melanocytes** are scattered between the keratinocytes. Melanocytes produce the pigment called **melanin.** The color of the skin depends upon melanin.

From this layer, some projections called **rete ridges** extend down up to dermis. These projections provide anchoring and nutritional function.

■ DERMIS

Dermis is the inner layer of the skin. It is a connective tissue layer, made up of dense and stout collagen fibers,

fibroblasts and histiocytes. Collagen fibers exhibit elastic property and are capable of storing or holding water. Collagen fibers contain the enzyme collagenase, which is responsible for wound healing.

Layers of Dermis

Dermis is made up of two layers:

1. Superficial papillary layer
2. Deeper reticular layer.

■ SUPERFICIAL PAPILLARY LAYER

Superficial papillary layer projects into the epidermis. It contains blood vessels, lymphatics and nerve fibers. This layer also has some pigment-containing cells known as **chromatophores.**

Dermal papillae are finger-like projections, arising from the superficial papillary dermis. Each papilla contains a plexus of capillaries and lymphatics, which are oriented perpendicular to the skin surface. The papillae are surrounded by rete ridges, extending from the epidermis.

■ RETICULAR LAYER

Reticular layer is made up of reticular and elastic fibers. These fibers are found around the hair bulbs, sweat glands and sebaceous glands. The reticular layer also contains mast cells, nerve endings, lymphatics, epidermal appendages and fibroblasts.

Immediately below the dermis, subcutaneous tissue is present. It is a loose connective tissue, which connects the skin with the internal structures of the body. It serves as an insulator to protect the body from excessive heat and cold of the environment. Lot of smooth muscles called **arrector pili** are also found in skin around the hair follicles.

■ APPENDAGES OF SKIN

Hair follicles with hair, nails, sweat glands, sebaceous glands and mammary glands are considered as appendages of the skin.

■ COLOR OF SKIN

Color of skin depends upon two important factors:

1. Pigmentation of skin
2. Hemoglobin in the blood.

■ PIGMENTATION OF SKIN

Cells of the skin contain a brown pigment called **melanin,** which is responsible for the color of the skin. It is synthesized by **melanocytes,** which are present mainly in the stratum germinativum and stratum spinosum of epidermis. After synthesis, this pigment spreads to the cells of the other layers.

Melanin

Melanin is the skin pigment and it forms the major color determinant of human skin. Skin becomes dark when melanin content increases. It is protein in nature and it is synthesized from the amino acid tyrosine via dihydroxyphenylalanine (DOPA).

Deficiency of melanin leads to **albinism** (hypopigmentary congenital disorder).

■ HEMOGLOBIN IN THE BLOOD

Amount and nature of hemoglobin that circulates in the cutaneous blood vessels play an important role in the coloration of the skin.

Skin becomes:

i. Pale, when hemoglobin content decreases
ii. Pink, when blood rushes to skin due to cutaneous vasodilatation (blushing)
iii. Bluish during cyanosis, which is caused by excess amount of reduced hemoglobin.

Functions of Skin

■ FUNCTIONS OF SKIN

Primary function of skin is protection of organs. However, it has many other important functions also.

■ 1. PROTECTIVE FUNCTION

Skin forms the covering of all the organs of the body and protects these organs from the following factors:

i. Bacteria and toxic substances
ii. Mechanical blow
iii. Ultraviolet rays.

i. *Protection from Bacteria and Toxic Substances*

Skin covers the organs of the body and protects the organs from having direct contact with external environment. Thus, it prevents the bacterial infection.

Lysozyme secreted in skin destroys the bacteria. Keratinized stratum corneum of epidermis is responsible for the protective function of skin. This layer also offers resistance against toxic chemicals like acids and alkalis. If the skin is injured, infection occurs due to invasion of bacteria from external environment.

During injury or skin infection, the keratinocytes secrete:

a. **Cytokines** like interleukins, α-tumor necrosis factor and γ-interferon, which play important role in inflammation, immunological reactions, tissue repair and wound healing
b. Antimicrobial peptides like β-defensins, which prevent invasion of microbes.

ii. *Protection from Mechanical Blow*

Skin is not tightly placed over the underlying organs or tissues. It is somewhat loose and moves over the underlying subcutaneous tissues. So, the mechanical impact of any blow to the skin is not transmitted to the underlying tissues.

iii. *Protection from Ultraviolet Rays*

Skin protects the body from **ultraviolet rays** of sunlight. Exposure to sunlight or to any other source of ultraviolet rays increases the production of **melanin** pigment in skin. Melanin absorbs ultraviolet rays. At the same time, the thickness of stratum corneum increases. This layer of epidermis also absorbs the ultraviolet rays.

■ 2. SENSORY FUNCTION

Skin is considered as the **largest sense organ** in the body. It has many nerve endings, which form the specialized cutaneous receptors (Chapter 139).

These receptors are stimulated by sensations of touch, pain, pressure or temperature sensation and convey these sensations to the brain via afferent nerves. At the brain level, perception of different sensations occurs.

■ 3. STORAGE FUNCTION

Skin stores fat, water, chloride and sugar. It can also store blood by the dilatation of the cutaneous blood vessels.

■ 4. SYNTHETIC FUNCTION

Vitamin D3 is synthesized in skin by the action of ultraviolet rays from sunlight on cholesterol.

■ 5. REGULATION OF BODY TEMPERATURE

Skin plays an important role in the regulation of body temperature. Excess heat is lost from the body through skin by radiation, conduction, convection and evaporation. Sweat glands of the skin play an active part in heat loss, by secreting sweat. The lipid content of sebum prevents loss of heat from the body in cold environment. More details are given in Chapter 63.

■ 6. REGULATION OF WATER AND ELECTROLYTE BALANCE

Skin regulates water balance and electrolyte balance by excreting water and salts through sweat.

■ 7. EXCRETORY FUNCTION

Skin excretes small quantities of waste materials like urea, salts and fatty substance.

■ 8. ABSORPTIVE FUNCTION

Skin absorbs fat-soluble substances and some ointments.

■ 9. SECRETORY FUNCTION

Skin secretes **sweat** through **sweat glands** and **sebum** through **sebaceous glands.** By secreting sweat, skin regulates body temperature and water balance. Sebum keeps the skin smooth and moist.

Body Temperature

■ INTRODUCTION

Living organisms are classified into two groups, depending upon the maintenance (regulation) of body temperature:

1. Homeothermic animals
2. Poikilothermic animals.

■ HOMEOTHERMIC ANIMALS

Homeothermic animals are the animals in which the body temperature is maintained at a constant level, irrespective of the environmental temperature. Birds and mammals including man belong to this category. They are also called **warm-blooded animals.**

■ POIKILOTHERMIC ANIMALS

Poikilothermic animals are the animals in which the body temperature is not constant. It varies according to the environmental temperature. Amphibians and reptiles are the poikilothermic animals. These animals are also called **cold-blooded animals.**

■ BODY TEMPERATURE

Body temperature can be measured by placing the **clinical thermometer** in different parts of the body such as:

1. Mouth (oral temperature)
2. Axilla (axillary temperature)
3. Rectum (rectal temperature)
4. Over the skin (surface temperature).

■ NORMAL BODY TEMPERATURE

Normal body temperature in human is 37°C (98.6°F), when measured by placing the clinical thermometer in the mouth (oral temperature). It varies between 35.8°C and 37.3°C (96.4°F and 99.1°F).

■ TEMPERATURE AT DIFFERENT PARTS OF THE BODY

Axillary temperature is 0.3°C to 0.6°C (0.5°F to 1°F) lower than the **oral temperature.** The **rectal temperature** is 0.3°C to 0.6°C (0.5°F to 1°F) higher than oral temperature.

The superficial temperature (skin or surface temperature) varies between 29.5°C and 33.9°C (85.1°F and 93°F).

Core Temperature

Core temperature is the average temperature of structures present in deeper part of the body. The core temperature is always more than oral or rectal temperature. It is about 37.8°C (100°F).

■ VARIATIONS OF BODY TEMPERATURE

Physiological Variations

1. *Age*

In infants, the body temperature varies in accordance to environmental temperature for the first few days after birth. It is because the temperature regulating system does not function properly during infancy. In children, the temperature is slightly (0.5°C) more than in adults because of more physical activities. In old age, since the heat production is less, the body temperature decreases slightly.

2. *Sex*

In females, the body temperature is less because of low basal metabolic rate, when compared to that of males. During menstrual phase it decreases slightly.

3. *Diurnal variation*

In early morning, the temperature is 1°C less. In the afternoon, it reaches the maximum (about 1°C more than normal).

4. *After meals*

The body temperature rises slightly (0.5°C) after meals.

5. *Exercise*

During exercise, the temperature raises due to production of heat in muscles.

6. *Sleep*

During sleep, the body temperature decreases by 0.5°C.

7. *Emotion*

During emotional conditions, the body temperature increases.

8. *Menstrual cycle*

In females, immediately after ovulation, the temperature rises (0.5°C to 1°C) sharply. It decreases (0.5°C) during menstrual phase.

Pathological Variations

Abnormal increase in body temperature is called **hyperthermia** or **fever** and decreased body temperature is called **hypothermia** (Refer applied physiology in this Chapter).

■ HEAT BALANCE

Regulation of body temperature depends upon the balance between heat produced in the body and the heat lost from the body.

■ HEAT GAIN OR HEAT PRODUCTION IN THE BODY

Various mechanisms involved in heat production in the body are:

1. Metabolic Activities

Major portion of heat produced in the body is due to the metabolism of foodstuffs. It is called **heat of metabolism.**

Heat production is more during metabolism of fat. About 9 calories of heat is produced during metabolism of fats, when 1 L of oxygen is utilized. For the same amount of oxygen, carbohydrate metabolism produces 4.7 calories of heat. Protein metabolism produces 4.5 calories/L.

Liver is the organ where maximum heat is produced due to metabolic activities.

2. Muscular Activity

Heat is produced in the muscle both at rest and during activities. During rest, heat is produced by muscle tone. Heat produced during muscular activity is called **heat of activity.** About 80% of heat of activity is produced by skeletal muscles.

3. Role of Hormones

Thyroxine and adrenaline increase the heat production by accelerating the metabolic activities.

4. Radiation of Heat from the Environment

Body gains heat by radiation. It occurs when the environmental temperature is higher than the body temperature.

5. Shivering

Shivering refers to shaking of the body caused by rapid involuntary contraction or twitching of the muscles as during exposure to cold. Shivering is a compensatory physiological mechanism in the body, during which enormous heat is produced.

6. Brown Fat Tissue

Brown adipose tissue is one of the two types of adipose tissues, the other being white adipose tissue.

It produces enormous body heat, particularly in infants. Refer Chapter 47 for details.

■ HEAT LOSS FROM THE BODY

Maximum heat is lost from the body through skin and small amount of heat is lost through respiratory system, kidney and GI tract. When environmental temperature is less than body temperature, heat is lost from the body. Heat loss occurs by the following methods:

1. *Conduction*

Three percent of heat is lost from the surface of the body to other objects such as chair or bed, by means of conduction.

2. *Radiation*

Sixty percent of heat is lost by means of radiation, i.e. transfer of heat by infrared electromagnetic radiation from body to other objects through the surrounding air.

3. *Convection*

Fifteen percent of heat is lost from body to the air by convection. First the heat is conducted to the air surrounding the body and then carried away by air currents, i.e. convection.

4. *Evaporation – Insensible Perspiration*

When water evaporates, heat is lost. Twenty two percent of heat is lost through evaporation of water.

Normally, a small quantity of water is continuously evaporated from skin and lungs. We are not aware of it. So it is called the insensible perspiration or insensible water loss. It is about 50 mL/hour. When body temperature increases, sweat secretion is increased and water evaporation is more with more of heat loss.

5. *Panting*

Panting is the rapid shallow breathing, associated with dribbling of more saliva. In some animals like dogs which do not have sweat glands, heat is lost by evaporation of water from lungs and saliva by means of panting.

■ REGULATION OF BODY TEMPERATURE

Body temperature is regulated by hypothalamus, which sets the normal range of body temperature. The set point under normal physiological conditions is 37°C.

Hypothalamus has two centers which regulate the body temperature:

1. Heat loss center
2. Heat gain center.

■ HEAT LOSS CENTER

Heat loss center is situated in **preoptic nucleus** of anterior hypothalamus. Neurons in preoptic nucleus are heat-sensitive nerve cells, which are called **thermoreceptors** (Fig. 63.1).

Stimulation of preoptic nucleus results in cutaneous vasodilatation and sweating. Removal or lesion of this nucleus increases the body temperature.

■ HEAT GAIN CENTER

Heat gain is otherwise known as heat production center. It is situated in **posterior hypothalamic nucleus.** Stimulation of posterior hypothalamic nucleus causes shivering. The removal or lesion of this nucleus leads to fall in body temperature.

■ MECHANISM OF TEMPERATURE REGULATION

When Body Temperature Increases

When body temperature increases, blood temperature also increases. When blood with increased temperature passes through hypothalamus, it stimulates the thermoreceptors present in the heat loss center in preoptic nucleus. Now, the heat loss center brings the temperature back to normal by two mechanisms:

1. Promotion of heat loss
2. Prevention of heat production

1. *Promotion of heat loss*

When body temperature increases, heat loss center promotes heat loss from the body by two ways:

i. By increasing the secretion of sweat: When sweat secretion increases, more water is lost from skin along with heat

ii. By inhibiting sympathetic centers in posterior hypothalamus: This causes cutaneous vasodilatation. Now, the blood flow through skin increases causing excess sweating. It increases the heat loss through sweat, leading to decrease in body temperature.

2. *Prevention of heat production*

Heat loss center prevents heat production in the body by inhibiting mechanisms involved in heat production, such as shivering and chemical (metabolic) reactions.

When Body Temperature Decreases

When the body temperature decreases, it is brought back to normal by two mechanisms:

1. Prevention of heat loss
2. Promotion of heat production.

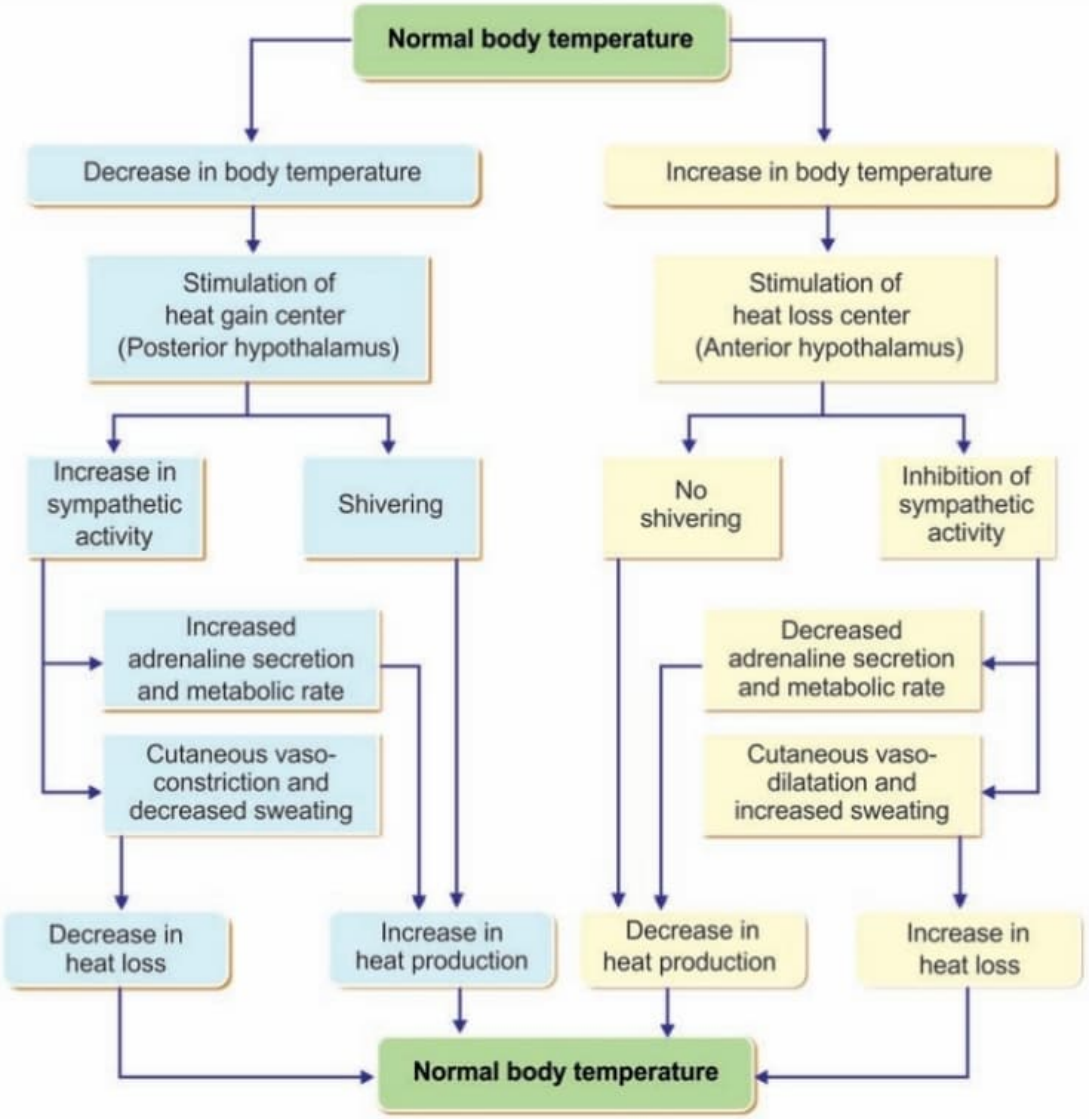

FIGURE 63.1: Regulation of body temperature

1. *Prevention of heat loss*

When body temperature decreases, sympathetic centers in posterior hypothalamus cause cutaneous vasoconstriction. This leads to decrease in blood flow to skin and so the heat loss is prevented.

2. *Promotion of heat production*

Heat production is promoted by two ways:

i. *Shivering:* When body temperature is low, the heat gain center stimulates the primary motor center for shivering, situated in posterior hypothalamus near the wall of the III ventricle and shivering occurs. During shivering, enormous heat is produced because of severe muscular activities.

ii. *Increased metabolic reactions:* Sympathetic centers, which are activated by heat gain center, stimulate secretion of adrenaline and noradrenaline. These hormones, particularly adrenaline increases the heat production by accelerating cellular metabolic activities.

Simultaneously, hypothalamus secretes thyrotropin-releasing hormone. It causes release of thyroid-stimulating hormone from pituitary. It in turn, increases release of thyroxine from thyroid. Thyroxine accelerates the metabolic activities in the body and this increases heat production.

Chemical thermogenesis: It is the process in which heat is produced in the body by metabolic activities induced by hormones.

■ APPLIED PHYSIOLOGY

■ HYPERTHERMIA – FEVER

Elevation of body temperature above the set point is called hyperthermia, fever or **pyrexia.** Fever itself is not

an illness. But it is an important sign of something going wrong in the body. It is the part of body's response to disease. Fever may be beneficial to body and on many occasions, it plays an important role in helping the body fight the diseases, particularly the infections.

Classification of Fever

Fever is classified into three categories:

1. *Low-grade fever:* When the body temperature rises to 38°C to 39°C, (100.4°F to 102.2°F)
2. *Moderate-grade fever:* When the temperature rises to 39°C to 40°C (102.2°F to 104°F)
3. *High-grade fever:* When the temperature rises above 40°C to 42°C (104°F to 107.6°F).

Hyperpyrexia

Hyperpyrexia is the rise in body temperature beyond 42°C (107.6°F). Hyperpyrexia results in damage of body tissues. Further increase in temperature becomes life threatening.

Causes of Fever

1. *Infection:* Certain substances (pyrogens) released from bacteria or parasites affect the heat-regulating system in hypothalamus, resulting in the production of excess heat and fever.
2. *Hyperthyroidism:* Increased basal metabolic rate during hyperthyroidism causes fever
3. *Brain lesions:* When lesion involves temperature-regulating centers, fever occurs.
4. *Diabetes insipidus:* In this condition, fever occurs without any apparent cause.

Signs and Symptoms

Signs and symptoms depend upon the cause of fever:

1. Headache
2. Sweating
3. Shivering
4. Muscle pain
5. Dehydration
6. Loss of appetite
7. General weakness.

Hyperpyrexia may result in:

1. Confusion
2. Hallucinations
3. Irritability
4. Convulsions.

■ HYPOTHERMIA

Decrease in body temperature below 35°C (95°F) is called hypothermia. It is considered as the clinical state of subnormal body temperature, when the body fails to produce enough heat to maintain the normal activities. The major setback of this condition is the impairment of metabolic activities of the body. When the temperature drops below 31°C (87.8°F), it becomes fatal. Elderly persons are more susceptible for hypothermia.

Classification of Hypothermia

Hypothermia is classified into three categories:

1. *Mild hypothermia:* When the body temperature falls to 35°C to 33°C (95°F to 91.4°F)
2. *Moderate hypothermia:* When the body temperature falls to 33°C to 31°C (91.4°F to 87.8°F)
3. *Severe hypothermia:* When the body temperature falls below 31° C (87.8°F).

Causes of Hypothermia

1. Exposure to cold temperatures
2. Immersion in cold water
3. Drug abuse
4. Hypothyroidism
5. Hypopituitarism
6. Lesion in hypothalamus
7. Hemorrhage in certain parts of the brainstem, particularly pons.

Signs and Symptoms

1. *Mild hypothermia*

Uncontrolled intense shivering occurs. The affected person can manage by self. But the movements become less coordinated. The chillness causes pain and discomfort.

2. *Moderate hypothermia*

Shivering slows down or stops but the muscles become stiff. Mental confusion and apathy (lack of feeling or emotions) occurs. Respiration becomes shallow, followed by drowsiness. Pulse becomes weak and blood pressure drops. Sometimes a strange behavior develops.

3. *Severe hypothermia*

The person feels very weak and exhausted with incoordination and physical disability. The skin becomes chill and its color changes to bluish gray. Eyes are dilated. The person looses consciousness gradually. Breathing slows down, followed by stiffness of arms and legs. Pulse becomes very weak and blood pressure decreases very much, resulting in unconsciousness.

Further drop in body temperature leads to death.