

# Temperature

## Heat

The thermal condition of the body is called heat.

## Temperature

The degree of hotness and coldness of the body is called temperature.

### Normal body temperature

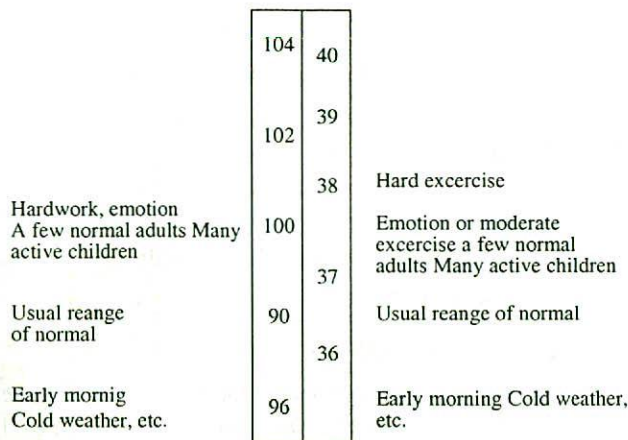
Range : 97-99 °F or

: 36.0-37.5 °C

Average : 98.6 °F or 37 °C

1. Oral temp : 98.0 °F - 98.6 °F (36.7-37 °C)
2. Rectal : (98.0 + 1) °F = 99.0 °F
3. Axillary : (98.0-1) °F = 97.0 °F

(Ref. Guyton & Hall 11th edition)



Estimated range of body temperature in the normal persons (From Dubois Fever Springfield, iii., Charles C Thomas)

Fig. 15-1. Estimated range of body temperature.

**Core temperature** : The temperature of the interior of the body is called core temperature.

**Shell Temperature** : The temperature of the skin or tissues immediately undrlying the skin is called shell temperature.

### Difference between core and shell temperature

Core temperature	Shell temperature
1. Core temperature remains almost exactly constant. It varies within $\pm 1$ °F.	1. Shell temperature rises and falls with the temperature of the surroundings.
2. It is determined by measuring i. Rectl and	2. It is determined by measuring i. Oral and

Core temperature	Shell temperature
ii. Esophageal tempera- ture.	ii. axillary or groin temperature.
3. Genereally temperture is more than shell temperature.	3. Generally the tempera- ture is less than core temperature.

### Q. How the heat is conducted from the core of the body to the skin?

Ans. Blood vessels penetrate the subcutaneous insulator tissues and are distributed profusely in the subpapillary portions of the skin. Indeed immediately beneth the skin is a continuous venous plexus that is supplied by inflow of blood. In the most exposed areas of the body- the hands, fet and ears blood is supplied through direct arterivenous anastomoses, from the arterioles to the veins. Therefore the flow of blood to the skin is the most of effective mechanism of heat transfer from the body core to the skin.

(Ref. Guyton & Hall 11th edition)

## Thermal balance

It is the state of condition when the rate of heat production is exactly equal to the rate of heat loss. The thermal balance is maintained by thermogenesis and thermolysis.

**Thermogenesis** : It is the process of heat production of the body.

## Mechanism of heat gain

We gain heat by two ways :

A. **Heat production within the body** : It occurs in the follwing ways :

1. **Metabolism** : Oxidation of food materials produces large amount of heat in the body.
2. **Physical activity** : The skeletal muscles produce about 1/2 of the body heat during exercise, walking, running and other form of physical activity.
3. **Metabolic activity** of liver, heart etc. produce heat.
4. **Action of some hormones** : Such as thyroxine, epinephrine and enzyme also produce heat.
5. **Peristaltic activity** of intestine during digestion also produce heat.

B. **Heat gain from environment** :

1. By directly from sun and heated substance.
2. Ingestion of hot foods and drinks.

**Thermolysis** : It is the process of heat loss from the body.



## Mechanism of heat loss from the body

Heat is lost from the body by :

1. **Radiation** : Transfer of heat from one object to another without the contact with each other. Heat is transferred by radiation in the form of electro- magnetic waves. Due to the difference of temperature existing between body and envirmint about 60% of total body heat is lost by radiation.
2. **Conduction** : Transfer of heat from atom to atom or molecule to molecule by change of Kinetic energy (KE). When the temperature of the air is low, about 18% of heat is lost in this process, 15% of the heat is conducted to the air and 3% is lost by direct conduction from the surface of the body to other objects.

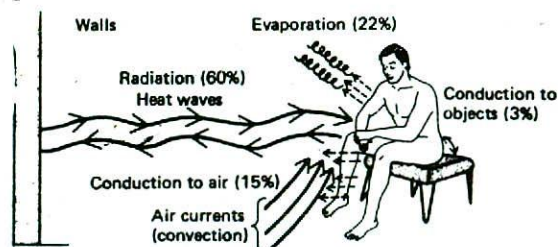


Fig. 15 - 2. Mechanism of heat loss from the body.

3. **Convection** : Transfer of heat by movement of molecule of a fluid or gass. When the temperature of the surrounding air is low, heat is lost by the skin and the molecules of air gradually get warmed and move away from the surface. A new layer of cooling air takes its place and the process is continue.
4. **Evaporation** : Heat loss occurs due to evaporation of sweat. About 22% heat is lost in this way through lung and skin. It has two types :
  - a. Insensible perspiration
  - b. Sweating.

Water evaporates insensibly from the skin and lungs, this causes continual heat loss from the body (12 to 16 cal per hour). When the temperature of the surroundings is greater than that of the skin, instead of losing heat, the body gains heat by radiation and conduction. Under this condition, the only means by which the body can rid itself of heat is by evaporation.
5. Heat is lost through feces and flatus.
6. Heat is lost through urine.

(Ref. Guyton & Hall 11th edition)

## Factors influencing body temperature

### A. Physiological :

1. **Age** : Body temprature is more in growing children but it is lower in old age.
2. **Sex** : It is more in male than female.
3. **Diurnal changes** : It is highest in the evening (4 to 6 P.M.) and lowest at the morning (3 to 5 A.M.)
4. **Diet** : Protein diet rises the temperature more compared to fat and carbohydrate. It is menifested during the process of digestion.
5. **Muscular activiy** : It rises body temperature.
6. **Climatic variation** : Temperature changes with climatic variation.
7. **Menstruation** : During menstruation temperature falls, but during ovulation temp. rises.
8. **Sleep** : Temperature fall during sleep.
9. **BMR** : Change of BMR affect the temperature.
10. **Emotion** : Rises body temperature.
11. **Miscellaneous** : Clothing, air movement, humidity etc influence the body temperature.

### B. Pathological :

1. Administration of pyrogens : It rises body temperature.
2. Endocrine disordrs :

In *thyrotoxicosis* body temperature rises.

In *myxoedema & cretinism* temperature fall. *Diabetes insipidus and pontine haemorrhage* rises the temperature, whereas *Diabetic coma, Hypopituitarism and Hypothalamic lesion* lowers the temperature.

### Hypothalamic thermostat

The overall heat controlling mechanism of the hypothalamus is called the hypothalamic thermostat.

### Temperature regulating centers :

There are two temperature regulating centers, located in the hypothalamus :

- a. Anti-rise center, located in the anterior part of hypothalamus.
- b. Anti-drop center, located in the posterior part of hypothalamus.

(Ref. Guyton & Hall 11th edition)



## Regulation of body temperature

*Body temperature is regulated by :*

1. Hypothalamic thermostat.
2. Behavioral control.
3. Local skin reflex.

**Hypothalamic thermostat :** The temperature of the body is regulated almost entirely by nervous mechanism of hypothalamic thermostat and almost all of these operate through temperature regulation centers by increasing or decreasing body temperature.

- a. **Mechanism of Reducing body temperature :** When the temperature becomes too great, thermostatic system employs three important mechanism to reduce body temperature.
  - i. Skin blood vessels of almost of all areas of the body dilated.
  - ii. Sweating is strongly stimulated.
  - iii. Shivering and chemical thermogenesis are strongly inhibited.
- b. **Mechanism of increasing body temperature :**  
In cold state, the thermostatic mechanism increasing body temperature by :
  - i. Skin vasoconstriction throughout the body.
  - ii. Pilo-erection (Not important for human being)
  - iii. Increase in heat production by :
    - a. Shivering
    - b. Sympathetic excitation of heat production.
    - c. Thyroxine secretion.

(Ref. Guyton & Hall 11th edition)

**Behavioral control :** The obvious types of behavioral adjustment include-

- i. Selecting appropriate clothing
- ii. Moving the body to a different environment setting
- iii. Increasing in the delivery of heat or cold from appropriate heaters or air conditioner and so forth.

(Ref. Guyton & Hall 11th edition)

**Local skin reflex :** When a person places a foot under a hot lamp and leaves it there for a short time, local vasodilation and mild local sweating occur. Conversely, placing the foot in cold water causes vasoconstriction and cessation of sweating. These reaction are caused both by local effect of temperature change directly on the blood vessels and sweat glands.

(Ref. Guyton & Hall 11th edition)

## Maintenance of body temperature in cold weather

When a person is exposed to extreme cold, the cold receptors of skin send sensory signal to the cold sensitive area of hypothalamus which then stimulate the temperature increasing mechanism of the body. *These are-*

1. **Skin vasoconstriction throughout the body :** Stimulation of the hypothalamic sympathetic center causes vasoconstriction of the peripheral blood vessels reduced blood flow to the skin there by decreasing heat loss and increases body temperature.
2. **Increase in heat production by shivering :** Cold signal excited the center for shivering of posterior hypothalamus, which then discharge rhythmic signals to skeletal muscle and increase the muscle tone throughout the body and shivering begins- causes heat production.
3. **Sympathetic excitation of heat production :** Sympathetic excitation increases the rate of metabolism thereby increasing the body temperature.
4. **Thyroxine secretion :** Celling of hypothalamus increases the release of thyrotropin releasing hormone from hypothalamus which then acts on anterior pituitary causes secretion of TSH. This then stimulate the thyroid gland to secrete thyroxine. This thyroxine increases the rate of cellular metabolism thereby increasing body temperature.  
In this way body maintains its normal temperature during cold season.

(Ref. Guyton & Hall 11th edition)

## Mechanism of maintaining temperature in hot weather

In hot weather the body temperature become too great. The thermostatic system then employs three important mechanism to reduce body heat. *These are :*

1. **Vasodilatation :** In hot weather the skin blood vessel are intensely dilated due to inhibition of sympathetic centers in the posterior hypothalamus that cause vasoconstriction. This increases the blood flow to the skin and also increases heat loss thereby decreasing the body heat.
2. **Sweating :** Stimulation of the preoptic area in the anterior hypothalamus cause transmission of impulse through the autonomic pathway to the spinal cord and thence through sympathetic nerve fibre to the sweat gland which then increases sweating and the body heat lost along with sweat by the process of evaporation.
3. **Decrease in heat production :** Those mechanism that cause excess heat production such as shivering, chemical thermogenesis are strongly inhibited and decreases the body heat production.

In this way, body maintain its normal temperature in hot climate.

(Ref. Guyton & Hall 11th edition)



**Q. Why shivering follows on exposure to intense cold?**

Ans. When a person exposed to extreme cold, (temperature below 25°C) causes stimulation of cold receptors (Krause's end bulb). The impulse passes from the Krause's end bulb to the centre of shivering. It sends afferent impulses to the anterior horn cells via lateral column of spinal cord. This impulse increases the tone of skeletal muscles through out the body and there occurs reflex twitches (uncoordinated) at first of the muscles of the body which increase in intensity. Ultimately leading to rhythmic slow contraction and manifest shivering.

**Hormonal control of temperature**

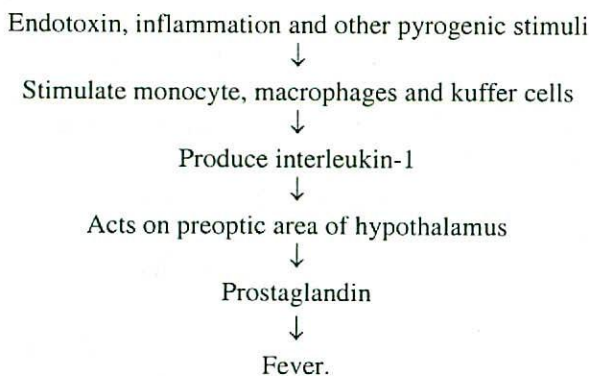
- i. **Catecholamine** : It causes increase metabolism and vasoconstriction.  
Effects : Increase heat production.
- ii. **Thyroid hormone** : It causes increase metabolism; synergistic action with catecholamines  
Effects : Increase heat production.
- iii. **Cortisol** : It potentiates the catecholamine.  
Effects : Antidrop response.
- iv. **Thyroid stimulating hormone-TSH and ACTH** : TSH causes thyroid hormone secretion and ACTH causes cortisole secretion.  
Effects : Antidrop response.

**Thermal counter-current system**

In excessive cold condition cutaneous vessels become more sensitive to catecholamines and so, arterioles and venules are constrict. This causes flow of blood from artery to deep vein without reaching the skin and carried back into the heart. This is called thermal counter current system.

**Fever**

- a. **Definition** : An elevation of the normal body temperature is called fever.
- b. **Pathogenesis** :



or Inflammation → Prostaglandin → Fever.

**c. Benefit of fever :**

1. Inhibit growth of microorganisms
2. Increase antibody production
3. Inhibit tumor growth.

However, a very high temperature is harmful

**d. Classification of fever :**

- i. **Continued fever** : When fever does not fluctuate more than 1°C during 24 hours and at no time touches the normal called continued fever.
- ii. **Remittent fever** : A fever, which fluctuates (daily 2°C) but does not return to normal temperature is called remittent fever.
- iii. **Intermittent fever** : Fever only for several hours during the day is called intermittent fever.
- iv. **Relapsing fever** : Periods of fever interspersed with periods of normal temperature is called relapsing fever.

(Ref. Guyton & Hall 11th edition & others)

**Hyper-pyrexia** : When the body temperature rises above 41.2°C or 106°F it is called hyperpyrexia. This is accompanied by increased heart rate, respiratory rate, great discomfort, weakness, prostration, headache, mental confusion and ultimately loss of consciousness occurs.

Rise of temperature above 43°C or 109°F and its persistence for a certain length of time results in death.

**Sweating**

1. **Sweat** : Sweat is the secretion from sweat glands.
2. **Sweating** : The process of secretion of sweat from the sweat gland is called sweating. Skin temperature at which sweating begins is about 34°C.
3. **Mental sweating** : Sweating which occurs due to emotion, anxiety is called mental sweating. It occurs in the palm of hand, sole of foot, forehead, neck etc.
4. **Thermal sweating** : Sweating which occurs due to rise of external or body temperature is the called thermal sweating. It is controlled by hypothalamus.

**Function of sweating :**

- i. It is concern with the regulation of temperature
- ii. It is concern with the maintenance of water, electrolytes and acid-base balance.
- iii. It performs some excretory function
- iv. It keeps the skin moist.

**Q. Why during evaporation body heat is lost?**

Ans. When water evaporates from the body surface; 0.58 calorie (kilocalorie) of heat is lost for each gram of water that evaporate. Even when a person is not sweating, water still



evaporate insensibly from the skin and lungs at a rate of about 600 milliliter per days. This cause continual heat loss at a rate of 12 to 16 calorie per hour. This is the way of heat loss during evaporation.

(Ref. Guyton & Hall 11th edition)

### ✓ Chills

i. *Definition* : An attacked of shivering accompanied by the sensation of coldness even the body temperature (set point 100°F) is above normal is called chills.

In this condition normal set point changed higher than normal value.

ii. *Effects* :

- a. Piloerection
- b. Vasoconstriction
- c. Epinephrine secretion
- d. Shivering.

### Heat stroke

i. *Definition* : A condition or derangement of the heat control centers due to exposure to very high temperature is called heat stroke.

Heat stroke is an acute life-threatening situation when body temperature is above 41°C.

ii. *Condition for heat stroke* : In hot, humid climates with little cooling wind, even without exercise.

iii. Body temperature (>41°C or 106°-108°F) → Hypothalamic heat regulating ability depressed → Sweating diminished. This condition is called heat stroke.

iv. *Symptoms and signs* :

- a. The patients suffer from headache, nausea, vomiting, and weakness.
- b. The skin is hot.
- c. Sweating is often absent.
- d. Neurological involvement leads to confusion, delirium eventually coma.

v. *Complications* :

- a. Dry burning skin (the hot dry man)
- b. Loss of consciousness
- c. Cerebral edema
- d. Renal and hepatic failure.

### Heat exhaustion

i. *Definition* : This usually occurs in subjects who are not acclimatized and who undertake heavy exercise.

ii. *Cause* :

- a. Water depletion : Water loss can be as high as 5-6 liters per day.

- b. Salt and water depletion, due to sweating : Salt loss may be up to 20 gm.

iii. *Symptoms* :

- a. Giddiness
- b. Generalized fatigue
- c. Weakness
- d. Dehydration and delirium
- e. Syncope.

### Heat cramps

i. *Definition* : These are painful cramps in the muscles (usually of the legs) after exercise.

ii. *Cause* : They often occur in fit young people when they take vigorous exercise in hot weather.

iii. *Symptoms* : Symptoms are thought to be the result of low extracellular sodium caused by replenishment of water but not salt during prolonged sweating.

### ✓ Hypothermia

i. *Definition* : Decrease body temperature below normal (below 34°C) is called hypothermia.

Mild hypothermia (32-35°C) causes shivering and initially a feeling of intense cold.

Severe hypothermia occurs when core temperature becomes below 32°C.

Following emersion in cold water dangerous hypothermia can develop after several hours (immersion at temperature of 15-20°C). Below 12°C the patient's limbs become anaesthetized and paralyzed and take some hours to recover after the patient is rescued.

ii. *Causes* :

1. Accidentally occurs in babies
2. Exposed to low temperatures
3. Associated with certain diseases :  
Addison's disease  
Myxoedema  
Cerebrovascular accident  
Uraemia  
Muscular paralysis.

iii. *Symptoms and signs* :

- a. Patient becomes cold and pale
- b. Pulse rate and volume fall
- c. Systemic blood pressure falls
- d. Stiffness of muscle
- e. Unconsciousness (below 27°C)
- f. Tendon reflexes are depressed
- g. Pupillary and other brain-stem reflexes are lost
- h. Death follows usually from ventricular fibrillations.

### Frostbite

- i. **Definition** : The formation of the ice crystals in the skin and superficial tissues begins when the temperature falls to  $-3^{\circ}\text{C}$ ; ambient temperatures generally have to be below  $-6^{\circ}\text{C}$  for this to occur.
- ii. **Characteristics** :
  - a. **Frostbitten tissue** : is pale, grayish and initially doughy to the touch. Later it freezes hard, when it looks (and feels) like meat taken from a deep freeze.
  - b. **Hands and feet** : that have lost their feeling are an important feature when the temperature is below  $-5^{\circ}\text{C}$ , as frostbite may then develop insidiously.

**Q. 01. Which part of the temperature is more accurate?**

Ans. Core temperature is more accurate i.e rectal temperature.

**Q. 02. Why a person feels cold in a fever of rapid onset?**

Ans. The set point of the hypothalamus integrating center has risen to a high level, so the subject feels cold until his core temperature is raised to match the new set point.

**Q. 00. Describe the innervation of sweat gland.**

Ans. Sympathetic cholinergic fibres innervate sweat gland.

**Q. 00. What hormonal changes occurs in cold environment.**

Ans. In cold environment secretion of catecholamines and thyroid hormones secretion is increased.

**Q. 00. What is insensible heat loss?**

Ans. Loss of heat through respiratory system and skin is called insensible heat loss. Insensible loss occurs in all weather in any condition. 20-25% basal heat production loss in this way.

**Q. 00. What is set point?**

Ans. It is a level of the critical body core temperature (exactly  $37.1^{\circ}\text{C}$ ) that is always maintained by the temperature control mechanisms in any condition (excess heat or cold).



Temperature

15.7

- Q. 01. **For each 1° F rise of temperature, cerebral blood flow falls by**
- T a. 4%
  - F b. 1%
  - F c. 2%
  - F d. 7%
  - F e. 3%.
- Q. 02. **False about body temperature**
- T a. AM temperature > 98.4°F
  - F b. Mean temperature 98.2° (+/-) 0.7° F
  - F c. PM temperature > 99.9° F
  - F d. Rectal temperature 0.6° F > oral temp.
- Q. 03. **Physiologic changes in heat acclimatization are :**
- T a. increased aldosterone secretion
  - T b. decreased loss of salt in sweat
  - T c. increased sweating
  - F d. decreased plasma volume
  - F e. increased loss of salt in urine.
- Q. 04. **Normal body temperature is**
- T a. is increased during exercise
  - T b. about 98.6°C
  - T c. determined by the balance between heat production and loss
  - T d. lowest during sleep
  - F e. elevated in hypothyroidism.
- Q. 05. **Body heat is produced by**
- T a. hunger
  - T b. muscular activity
  - F c. respiration
  - F d. urination
  - F e. defecation.
- Q. 06. **Body heat is lost by**
- T a. anorexia
  - T b. increased respiration
  - T c. radiation
  - F d. horripilation
  - F e. hunger.
- Q. 07. **Temperature regulating mechanism activated by cold are**
- T a. increased secretion of epinephrine
  - T b. shivering
  - T c. curling up
  - F d. cutaneous vasodilatation
  - F e. apathy and inertia.
- Q. 08. **Temperature regulating mechanism is activated by warm are**
- T a. anorexia
  - T b. increased respiration
  - T c. sweating
  - F d. shivering
  - F e. increased muscular activity.
- Q. 09. **Heat is produced by**
- T a. epinephrine
  - T b. shivering
  - T c. thyroxine
  - F d. decreased metabolism
  - F e. insulin.
- Q. 10. **Response in hot environment are**
- T a. vasodilation
  - T b. sweating.
  - T c. increased heat loss
  - T d. decreased heat production
  - F e. vasoconstriction.
- Q. 11. **Response in cold environment are**
- T a. vasoconstriction
  - T b. pilo-erection.
  - T c. decreased heat loss
  - T d. increaser heat production
  - F e. vasodilatation.
- Q. 12. **When a healthy individual is exposed to cold, following changes occurs :**
- T a. increased catecholamines secretion
  - T b. surface temperature is decreases more than core temperature
  - F c. total peripheral vascular resistance decreases
  - F d. adjustments are controlled from centers in the medulla
  - F e. shivering decreases the body temperature
- Q. 13. **When a normal individual is exposed to a hot environment following changes occurs**
- T a. Excessive sweating
  - T b. Increased resting cardiac output

- T c. Decrease urine volume  
T d. Cutaneous vasodilatation  
F e. Reflex increase in ventilation is the major way of increase heat loss.
- Q. 14. **The core temperature of an individual is above normal**  
T a. As a result of administration of progesterone  
T b. As a result of administration of adrenaline  
T c. Exercising strenuously  
T d. As a result of administration of pyrogens  
F e. With deficiency of thyroid function.
- Q. 15. **When a normal adult human from a temperate climate adapts to a tropical climate, there is a decrease in**  
a. thyroxine production  
b. the vascular peripheral resistance  
c. the salt concentration of sweat  
d. the overall rate of heat loss from the body  
e. The basal metabolic rate.
- Q. 16. **In hypothermia**  
T c. Tendon reflexes are depressed  
T e. Death occur due to ventricular fibrillation  
F d. Muscle become flaccid  
F a. Temperature usually falls below 25°C  
F b. Pulse become rapid.
- Q. 17. **Following hormones are involved in temperature regulation :**  
T a. Thyroxine  
T b. Norepinephrine  
F c. Aldosterone  
F d. Somatostatin  
F e. Substance-P.
- Q. 18. **Regarding shivering**  
T a. It is mediated by somatic nerve  
T b. It is due to contraction of smooth muscle  
T c. Increases heat production  
T d. Center is located in the hypothalamus  
F e. Is only activated in febrile condition
- Q. 19. **Regarding body temperature**  
T a. A core temperature of 43°C signifies a danger to life  
T b. Newborn produces heat mainly by brown fat metabolism  
T c. Insensible heat loss occurs via evaporation  
T d. Temperature is distributed throughout the body via blood  
T e. Central thermoreceptor is located in the thalamus.