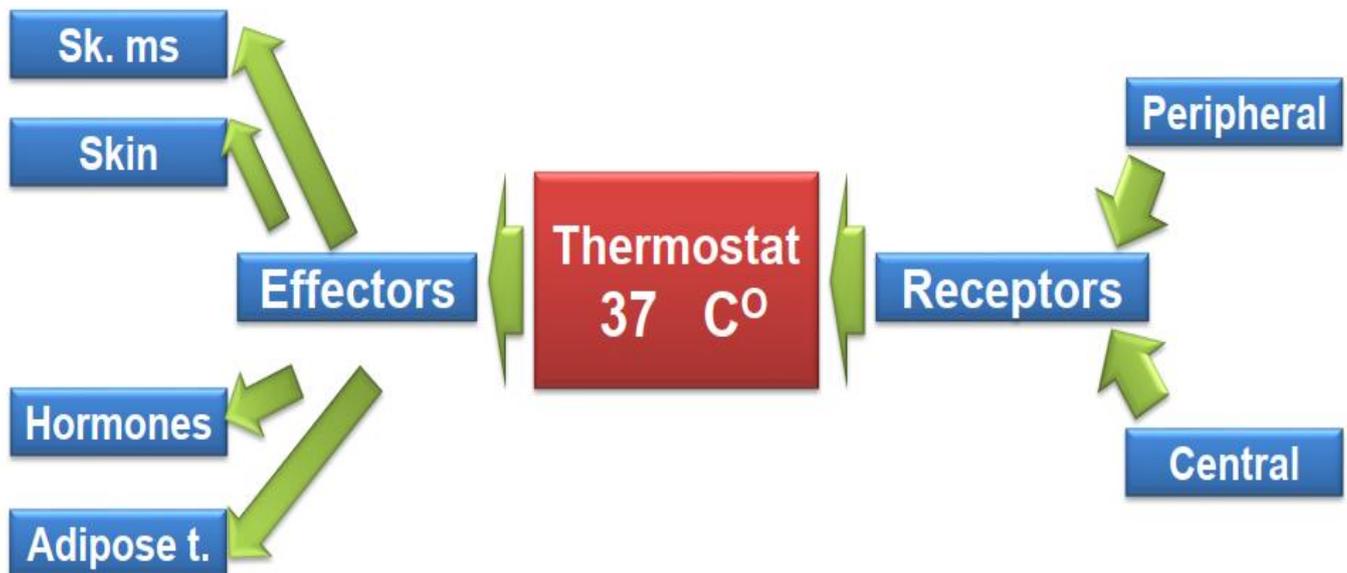


Physiological Thermoregulatory System

Def:	<ul style="list-style-type: none">It is a highly developed system that restores the body temperature back to its normal level when it is disturbed.
Consists of:	<p>a) Thermoreceptors.</p> <ol style="list-style-type: none">Central thermo-receptors.Peripheral thermo-receptors. <p>b) Temperature regulating center (hypothalamic thermostat).</p> <p>c) Effector organs: skin, skeletal muscles., hormones and adipose tissues.</p>



A) Thermoreceptors:

	1- Central thermo-receptors	2- Peripheral thermo-receptors
Site	<ul style="list-style-type: none"> • Preoptic area at the anterior hypothalamus. 	<ul style="list-style-type: none"> • Located in the skin. • Also found in spinal cord, abdominal viscera & around the great veins.
Include	<ul style="list-style-type: none"> • They include heat & cold sensitive neurons. 	<ul style="list-style-type: none"> • Warm or Cold receptors. • Cold receptors are 10 times as many as warm receptors in the skin.
Detect	<ul style="list-style-type: none"> • Heat sensitive neurons increase their firing rate when body temperature increases. • Cold sensitive neurons increase their firing rate when body temperature decreases. 	<ul style="list-style-type: none"> • Detect skin temperature.
Transition	<ul style="list-style-type: none"> • Information to central receptors is via blood supplying the internal organs. 	<ul style="list-style-type: none"> • Transmitted via C & Aδ afferent nerves to lateral spinothalamic tract to thalamus & hypothalamus.
Function:	<ul style="list-style-type: none"> • Prevent high body temperature. 	<ul style="list-style-type: none"> • Prevent low body temperature.

B) Temperature regulating center (hypothalamic thermostat):

Def:	<ul style="list-style-type: none">• It is the main regulator of body temperature• It is normally adjusted at a standard critical temperature called the set point.
Location:	<ul style="list-style-type: none">• The anterior hypothalamus (heat loss center).• The posterior hypothalamus (heat gain center).
Mechanism:	<ul style="list-style-type: none">• Detect any deviation of body temperature from the set point by comparing the temperature input information from the thermoreceptors with the set point and discharge output to the effector organs which modify the rates of heat production and heat loss to restore the body temperature back to the normal set point.

C) Effector organs:

- 1) **Skin** (blood vessels, sweat glands and piloerector muscles).
- 2) **Skeletal muscles**.
- 3) **Endocrine glands** (particularly adrenal medulla and thyroid gland).
- 4) **Brown fat thermogenesis** (in newborn).

Physiologic Regulation of Body Temperature

Include:

- 1) **On exposure to hot weather.**
- 2) **On exposure to cold weather.**

1) On exposure to hot weather:

A- Increase heat loss by:

1) VD of cutaneous blood vessels:

- **Mechanism:** inhibition of sympathetic center in posterior hypothalamus by impulses from heat loss center.

a) If environmental temp. > 37:

- Cutaneous vasodilatation → ↑ skin blood flow (due to shift of blood from deep veins to dilated cutaneous vessels) → heat transfer from deeper structures to body surface → ↑ skin temperature → ↓ **heat gain** by conduction, convection & irradiation.

b) If environmental temp. < 37:

- ↑ **Heat loss.**

2) Sweating Occurs in:

- **Exposure to hot weather** (environmental temp. 32 °C or more).
- **During muscular exercise**, even if environmental temp. is low (as heat production is more than heat loss).
- **Shock**

2) On exposure to cold weather:

A- Decrease heat loss by:

1) Cutaneous VC:

- Decrease skin temp → ↓ temperature gradient between skin & atmosphere → ↓ heat loss.

2) Countercurrent heat exchange mechanism:

- Heat is **transferred from hot arterial blood to the cold venous blood** as it returns to the heart, thus heat is returned back to the body core.

3) Curling up in a ball:

- ↓ surface area exposed to environment → ↓ heat loss.

4) Horripilation (erection of hair):

- Hold air in between → insulate skin from environment (important in animals).

5) Clothes:

- There are two air traps: one in meshes of the cloth and the other between the inner surface of cloth and the skin.
- Several layers of clothes produce several air traps.
- **Air is bad conductor of heat** → **insulate** against heat loss.

B- Decrease heat production by:

1) **Inhibition of muscle tone & shivering**

2) **Anorexia (lost appetite).**

3) **Inhibition of chemical thermogenesis** by inhibiting the secretion of thermogenic hormones as catecholamines and thyroid hormones.

B- Increased heat production:

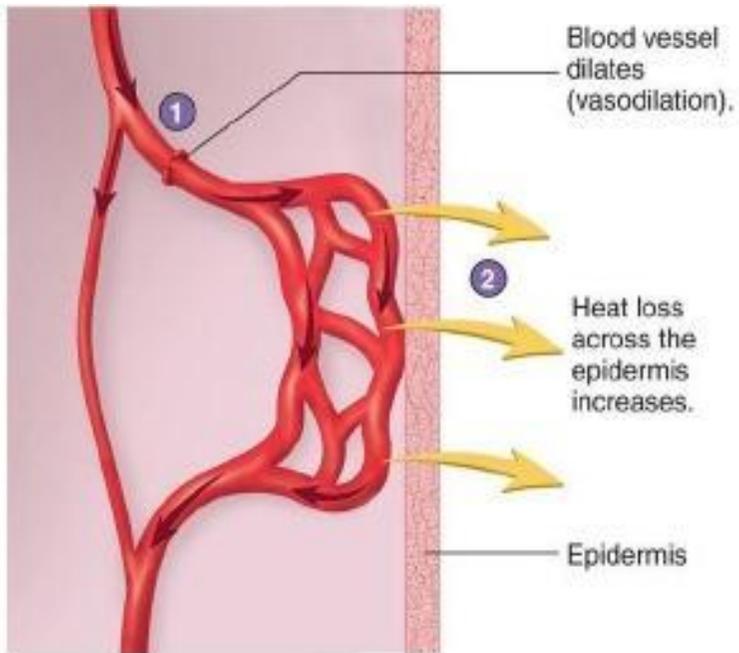
1) **Increase muscle tone & shivering:**

- Exposure to cold → ↑ muscle tone then shivering.
- These are initiated by a center located in the posterior hypothalamus called **primary motor center for shivering**.
- This center discharge nonrhythmic stimulating signals downward through **reticulospinal tracts** to AHCs → ↑ of skeletal muscle tone throughout the body → ↑ heat production.
- Increase tone above certain critical level → feedback oscillation of muscle spindle stretch reflex → shivering.
- Shivering ↑ heat production rapidly (**400-500%**) → maintain body temperature on exposure to cold.

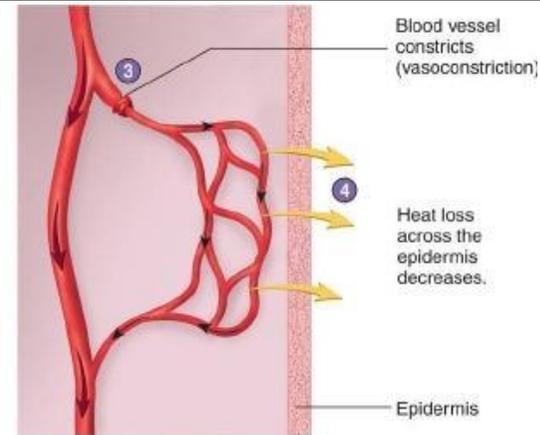
2) **Increase secretion of thermogenic hormones:**

- Exposure to cold → stimulation of post hypothalamus → ↑ **secretion of T4, adrenaline, NA & steroid hormones** → ↑ cellular metabolism → ↑ heat release.

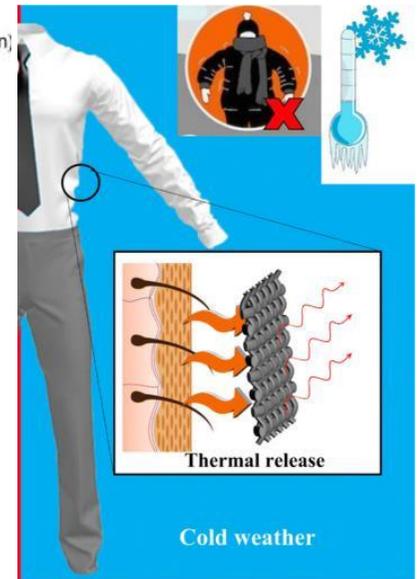
3) **Increased sensation of hunger and appetite.**



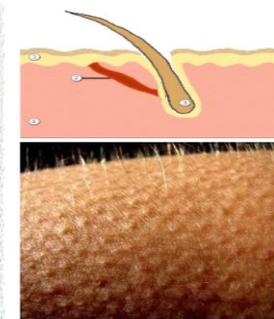
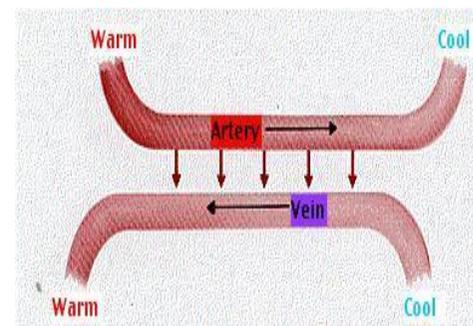
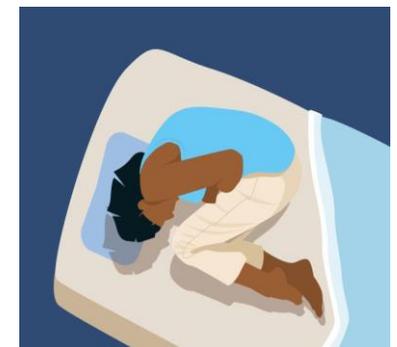
1. Blood vessel dilation results in increased blood flow toward the surface of the skin.
2. Increased blood flow beneath the epidermis results in increased heat loss (gold arrows).



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.

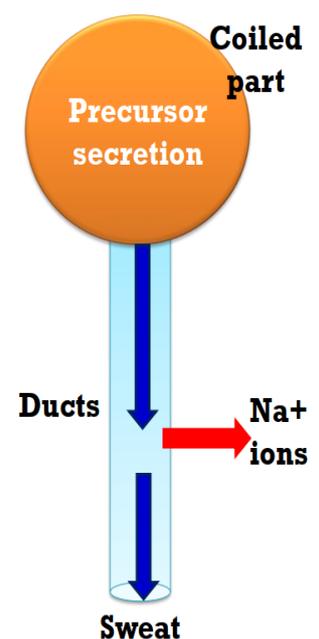
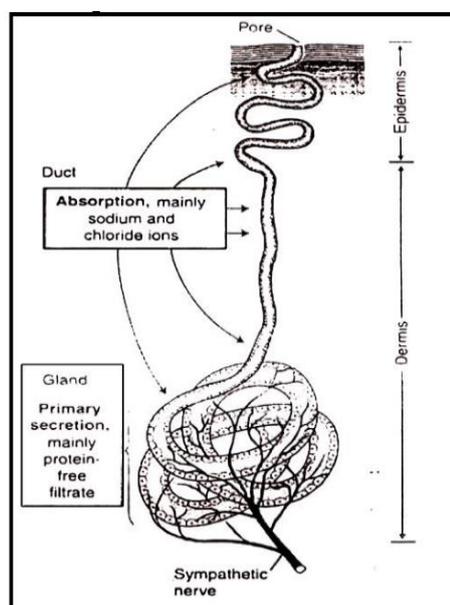
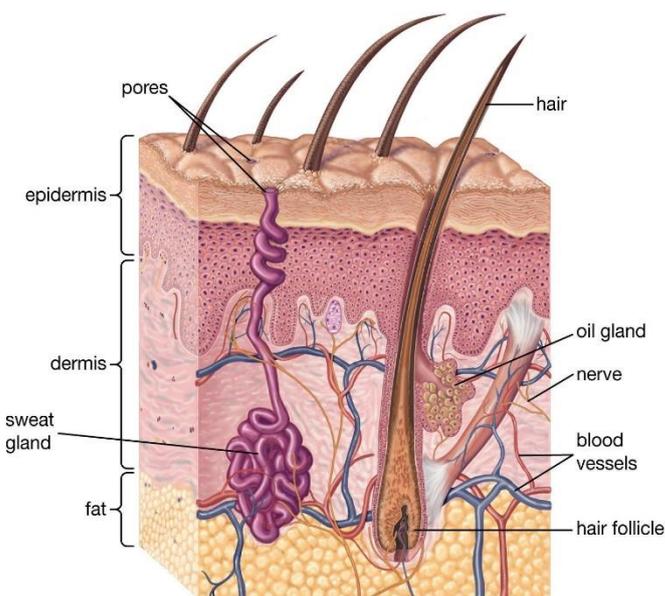


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Sweat glands

<p>Number:</p>	<ul style="list-style-type: none"> • Number of sweat glands in body 2.5 millions.
<p>Composed of:</p>	<ol style="list-style-type: none"> 1) Deep coiled portion → secrete sweat (precursor secretion). 2) Duct portion → pass outward to surface of skin
<p>Alteration of sweat constituents as it flows through ducts:</p>	<ul style="list-style-type: none"> • Precursor secretion is secreted from the secretory portion, then the constituents of this fluid are altered as it flows through the duct: <ol style="list-style-type: none"> 1) Low rate of sweat secretion: <ul style="list-style-type: none"> ➤ NaCl are absorbed from the precursor → ↓ NaCl in the ducts to 5 meq/L. 2) Increased rate of sweat secretion: <ul style="list-style-type: none"> ➤ NaCl are not absorbed from precursor → ↑ NaCl in the ducts to 60 meq/L.
<p>Rate of sweating:</p>	<ul style="list-style-type: none"> • In cold weather: Zero • In very hot weather: Maximum rate increase from 0.7 to 1.5 or 2 L/h in well acclimatized person to heat



▪ Types of sweat glands:

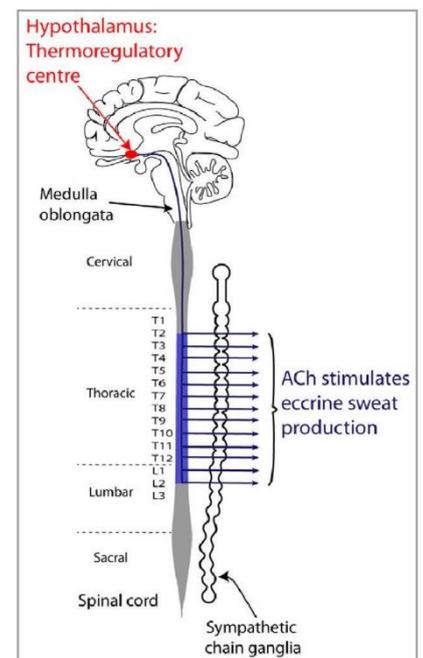
	1- Eccrine glands	2- Apocrine glands
Distribution	<ul style="list-style-type: none"> Widely distributed all over the body 	<ul style="list-style-type: none"> Fluid in axilla, groin, peri anal region & mammary areola.
Nerve supply	<ul style="list-style-type: none"> Cholinergic postganglionic sympathetic fibers 	<ul style="list-style-type: none"> Adrenergic sympathetic fibers
Mode of secretion	<ul style="list-style-type: none"> Merocrine i.e. cells are not destroyed during secretion. 	<ul style="list-style-type: none"> Apocrine i.e. their tips are destroyed during secretion.
Importance	<ul style="list-style-type: none"> Their secretion is correlated to regulation of body temperature They secrete on exposure to hot or when body temperature increases. 	<ul style="list-style-type: none"> Their secretion is not related to regulation of body temperature, but to sexual attraction in some animals.

▪ Mechanism of sweat secretion:

➤ ↑ body temperature → stimulation Ant hypoth. nuclei (preoptic area) → **reticular formation** → **reticulospinal tract** → stimulation of LHCs in Thoraco-lumber region of spinal cord → **sympathetic outflow to sweat glands (cholinergic fibers)**.

➤ Mechanism of accompanied V.D:

- 1- Direct effect of heat on blood vessels.
- 2- Reflex from heat receptors.
- 3- ↑ blood temperature at hypothalamus inhibits VCC.
- 4- Bradykinin secreted as a result of sweat gland activity.



Abnormal body temperature

1) Hyperthermia.

▪ Definition:

- Increase in body temperature **without change in the set point** of hypothalamic thermostat.

▪ Causes:

- 1- **Excessive heat production** (prolonged severe exercise).
- 2- **Impaired heat loss** (increase environmental humidity).
- 3- **Excessive environmental heat** (infants in closed car in hot weather).

▪ Includes:

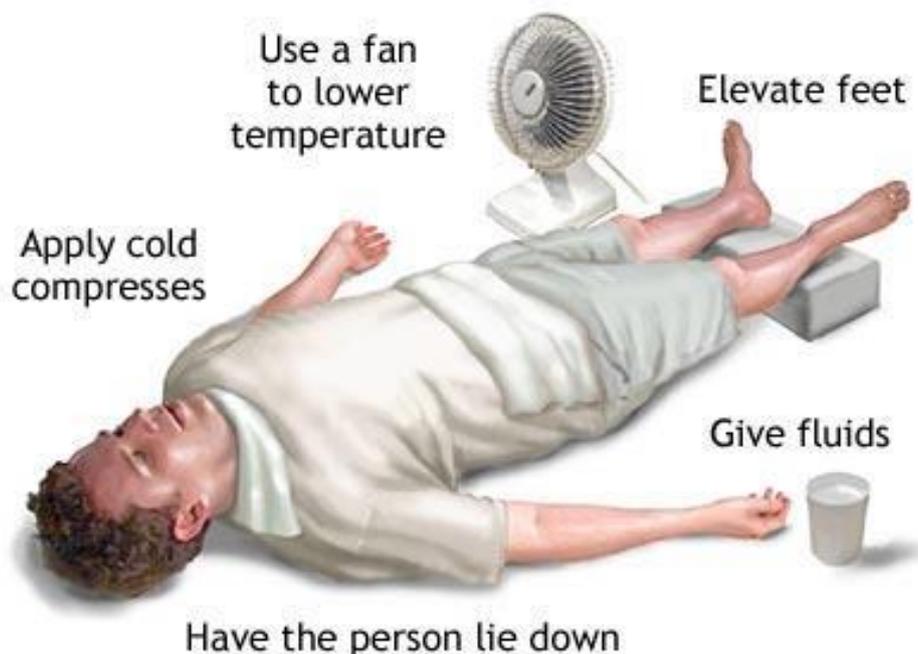
<p>a) Heat cramp:</p>	<ul style="list-style-type: none">• Slow painful skeletal muscle cramps & spasms.• Appear in most heavily used muscle.• Last for 1 – 3 min.• Cause: Salt depletion (due to replacement of fluid loss from heavy sweating by water alone).• Body temperature → normal or slightly elevated.
<p>b) Heat exhaustion:</p>	<ul style="list-style-type: none">• <u>Cause:</u><ul style="list-style-type: none">➤ Over activity in hot environment → marked increase in heat production → ↑ body temperature → stimulation of excessive heat loss mechanisms.• <u>State of collapse:</u><ul style="list-style-type: none">➤ in the form of fainting due to hypotension, that is caused by:<ol style="list-style-type: none">1- Depletion of plasma volume, 2ry to sweating.2- Extreme vasodilatation of skin blood vessels.• Body temperature → not elevated markedly (due to excessive sweating)

c) Heat stroke:

- Represent a **complete failure** of heat regulating system → ↑ body temperature more & more.
- **Extremely dangerous.**
- **Causes:**
 - 1- Overactivity in hot humid environment.
 - 2- End stage of prolonged untreated heat exhaustion → dehydration → impaired cerebral circulation.
- **Characters:**
 - **Body temperature** → elevated markedly.
 - Collapse.
 - Convulsions.
 - Failure to sweat.
 - Prolonged unconsciousness.

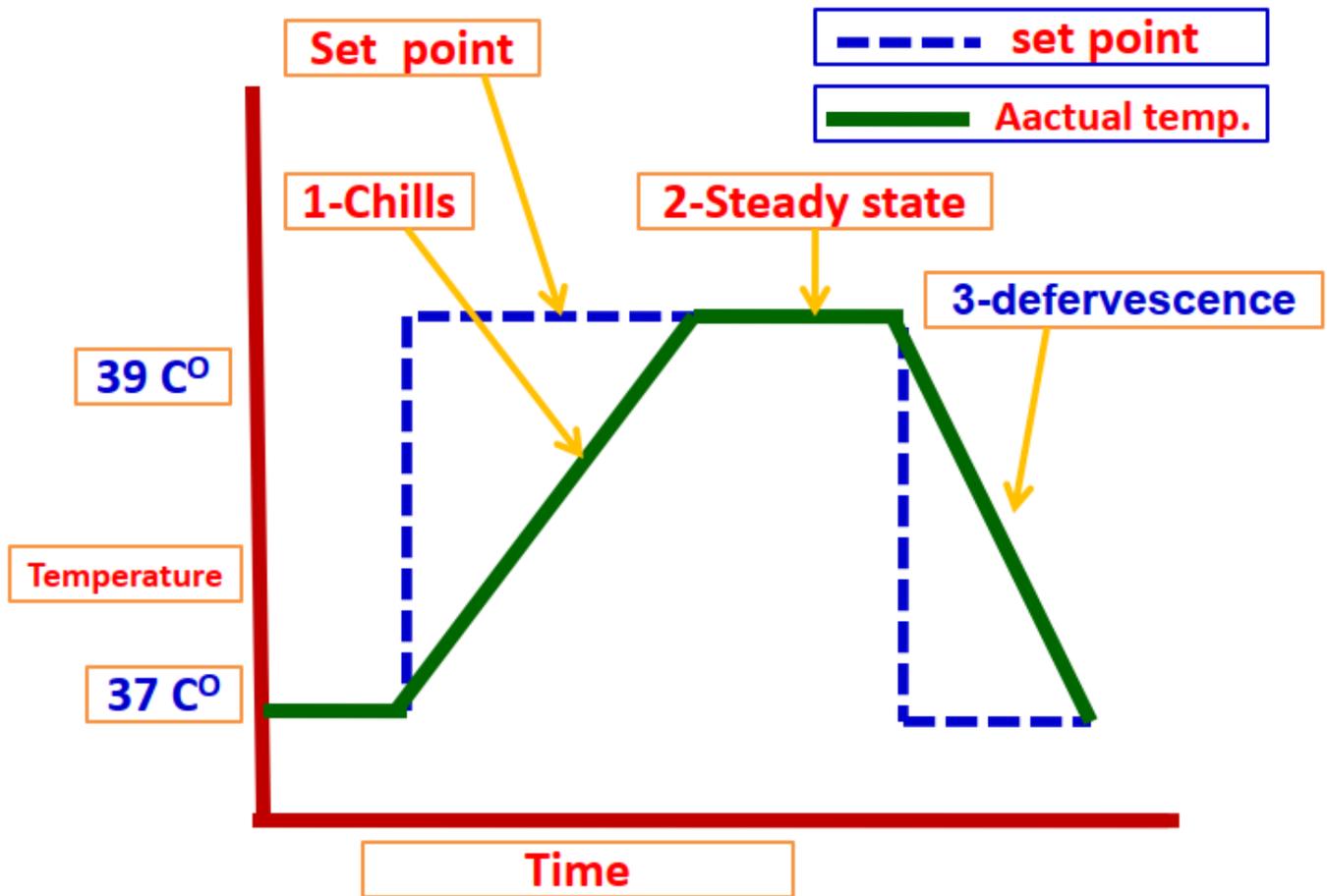
▪ Treatment of heat exhaustion & stroke:

- 1- External cooling.
- 2- Fluid replacement.
- 3- Cessation of activity.



2) Fever (Pyrexia):

Definition:	<ul style="list-style-type: none"> Elevation of body temperature due to resetting of hypo thalamic thermostat. A person with fever still regulates body temperature in response to heat or cold but at a higher set point.
Causes:	<ul style="list-style-type: none"> Infection. Physical trauma. Stress.
Patho-physiology:	<ul style="list-style-type: none"> Chemical messengers called endogenous pyrogens (group of peptides or chemical mediators called interleukins as IL1, 6, TNF) released from macrophages in presence of infection → circulate in blood → reach the brain → act on hypothalamic thermo receptors → alter their input to integrating center → Local synthesis & release of PG within the hypothalamus → reset thermostat at a new higher level.
Stages of fever:	<p>1- <u>Stage of chill:</u></p> <ul style="list-style-type: none"> ➤ Resetting of hypothalamic thermostat to a new level above 37 → Thermostat feel cold (hypothermia) → Stimulation heat gain mechanisms → ↓ heat loss (cut. VC) & ↑ heat production (shivering) → pale skin, cold feeling, put on more clothes. <p>2- <u>Steady stage of fever:</u></p> <ul style="list-style-type: none"> ➤ When body temperature reaches the new set point → shivering stop & sensation of warmth develop & cutaneous VD occurs → warm flushed skin. <p>3- <u>Stage of defervescence:</u></p> <ul style="list-style-type: none"> ➤ Removal of causative factor or treatment → set point drop back to normal to normal → Thermostat evoke mechanisms which ↓ body temperature (cutaneous VD & sweating).



3) Hypothermia:

<p>Causes:</p>	<p>1- Prolonged exposure to cold weather. 2- Immersion in cold water. 3- Anesthesia due to muscle relaxation.</p>
<p>Characters:</p>	<p>1- Depression of physiological systems especially CNS. 2- Decrease HR, ABP, Respiration. 3- Depression of renal tubules by cold → impair Na reabsorb → dehydration.</p>
<p>Cause of death:</p>	<ul style="list-style-type: none"> • Stop of respiration. • Heart failure.

NB:

- **Induced Hypothermia:** Used in **surgery** especially brain surgery & open-heart surgery (Bleeding is minimal) and **neonatal asphyxia** to minimize neuronal damage.

