# MSS MODULE
# PHYSIOLOGY LECTURE (3)
# THERMOREGULATION I


**BY**

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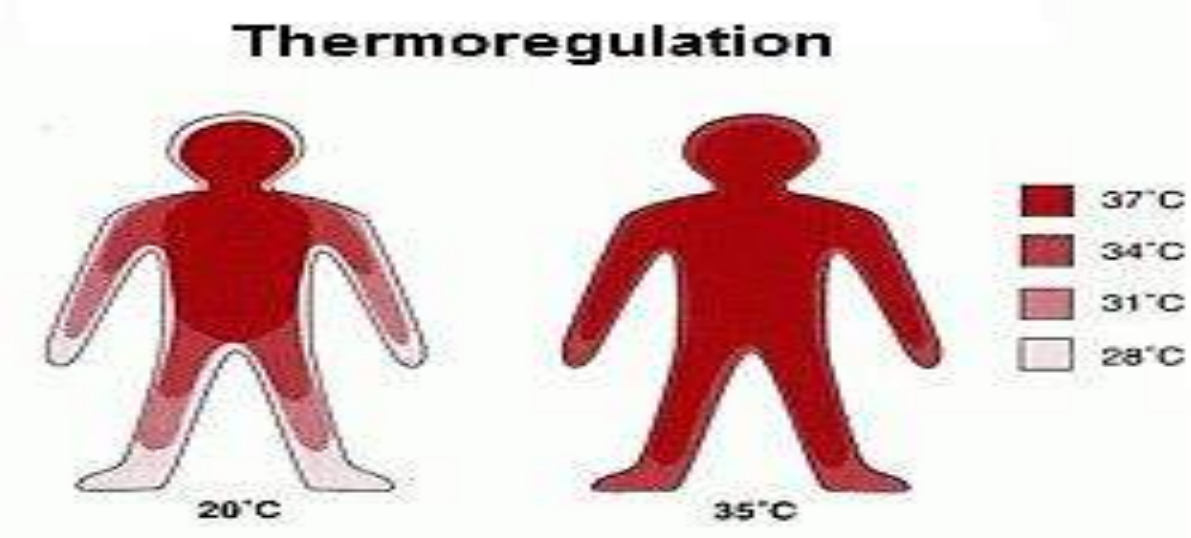


# BODY TEMPERATURE

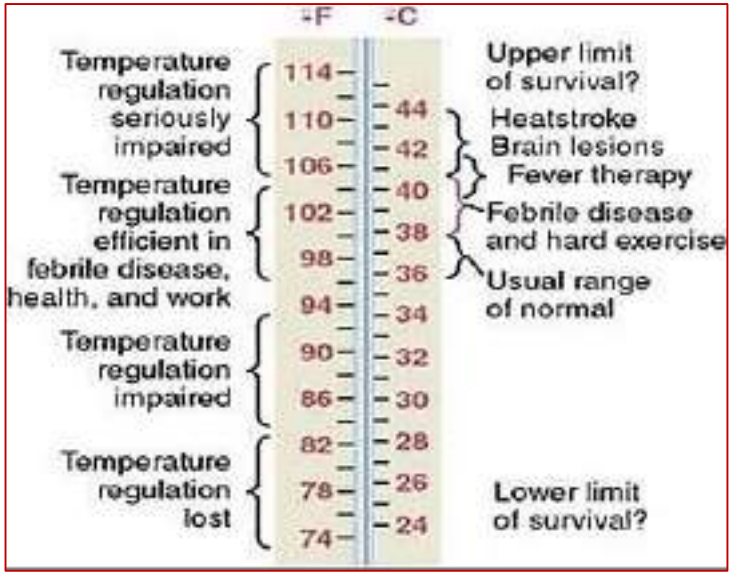
- ✓ **Humans are endotherms:** they generate their own internal body heat**.**
- ✓ **Humans are homeotherms:** they maintain their body temperatures within very narrow limits despite wide fluctuations in ambient temperature**.**
- ✓ **However, the maintenance of a warm body temperature (approximately 37$^{O}$C in healthy persons) requires regulatory mechanisms.**

# NORMAL BODY TEMPERATURE

Average body temperature in adults: 37 °C (36.5-37.3°C)

**Measured by:**

1. ***Oral root.***
2. ***Axillary root.***
3. ***Rectal root .***



**1. Rectal temperature (Core temperature):**

- It represents the **temperature of deep viscera** as brain, heart, lungs and abdominal organs.
- It is **relatively constant**.

**2. Skin temperature (Shell temperature):**

- It normally varies with the environmental temperature (follow it).
- In comfortable environmental temperature, it **averages 33°C**.
- Higher in skin covering organs of high resting **heat as head, chest, abdomen (34 °C).**
- Lower in extremities as hands and feet **(28 °C).**

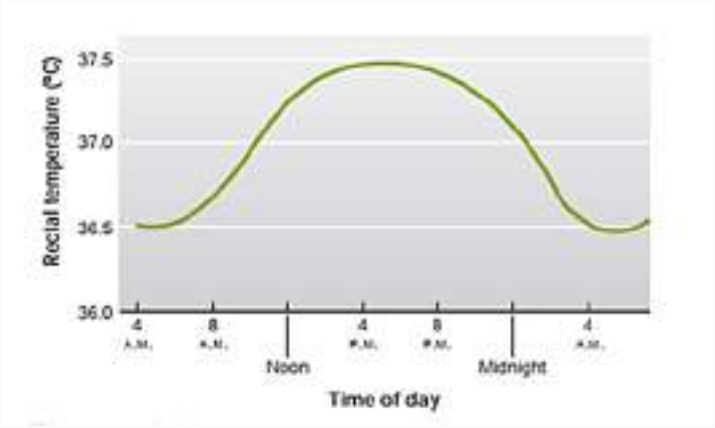
# FACTORS AFFECTING BODY (CORE)TEMPERATURE

## *1) Diurnal rhythm:*

- Normally, the human core temperature shows regular cyclic changes during the 24 hours (= **circadian fluctuation**).
- The body temperature is lowest in the early morning (at 6 am) and gradually ↑ to a maximum in late afternoon & evening **(difference is around 0.5-0.7 °C)**.

## *2) Age:*

- The body temperature is **higher in young children than in adults**. In young children, temperature regulation is less fine than in adults and they may have a temperature of **about 0.5°C** above that of normal adults.
- Premature babies have immature thermoregulatory systems, hence their temperature varies with that of the environment. They must therefore be put in incubators.



## 3) Sex:

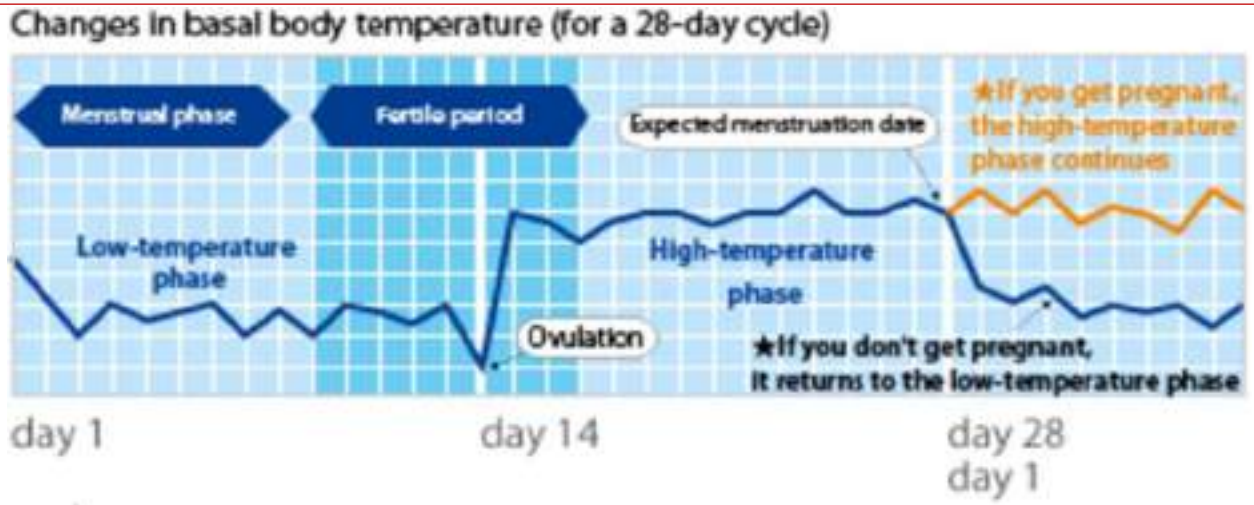
- In adult **females**, body temperature varies with the **menstrual cycle**:

A)The temperature rises about **0.5 $^{O}$C** at the time of **ovulation** (14$^{th}$ day of the cycle),and is maintained at that level till the end of the cycle due to the **thermogenic effect of progesterone**.

B) Body temperature decreases before menstruation (**premenstrual drop**) till ovulation of the next cycle.

C) If **pregnancy** occurred, **no drop** of body temperature occurs due to the thermogenic effect of progesterone.

D) In **an-ovulatory cycles**, the basal body temperature is **monophasic** with no drop around the 14$^{th}$ day of the cycle.



## *4) Site of measurement:*

The rectal temperature is higher than oral temperature by about 0.5 $^{o}$C. While, the axillary is lower than oral temperature by about 0.5 $^{o}$C.

## *5) Emotions:*

The body temperature rises during emotional excitement due to increase in both the muscle tone and sympathetic activity.

## *6) Activity:*

The body temperature markedly increases during muscular exercise (1-3 $^{o}$C); core temperature may reach 40 $^{o}$C.

## *7) Environmental (atmospheric) temperature:*

The body temperature tends to increase at excessively high environmental temperature and to decrease at excessively low environmental temperature.

## *8) Endocrinal factors:*

The body temperature is elevated in hyperthyroidism and lowered in hypothyroidism (0.5 $^{o}$C).

## *9) Individual variations:*

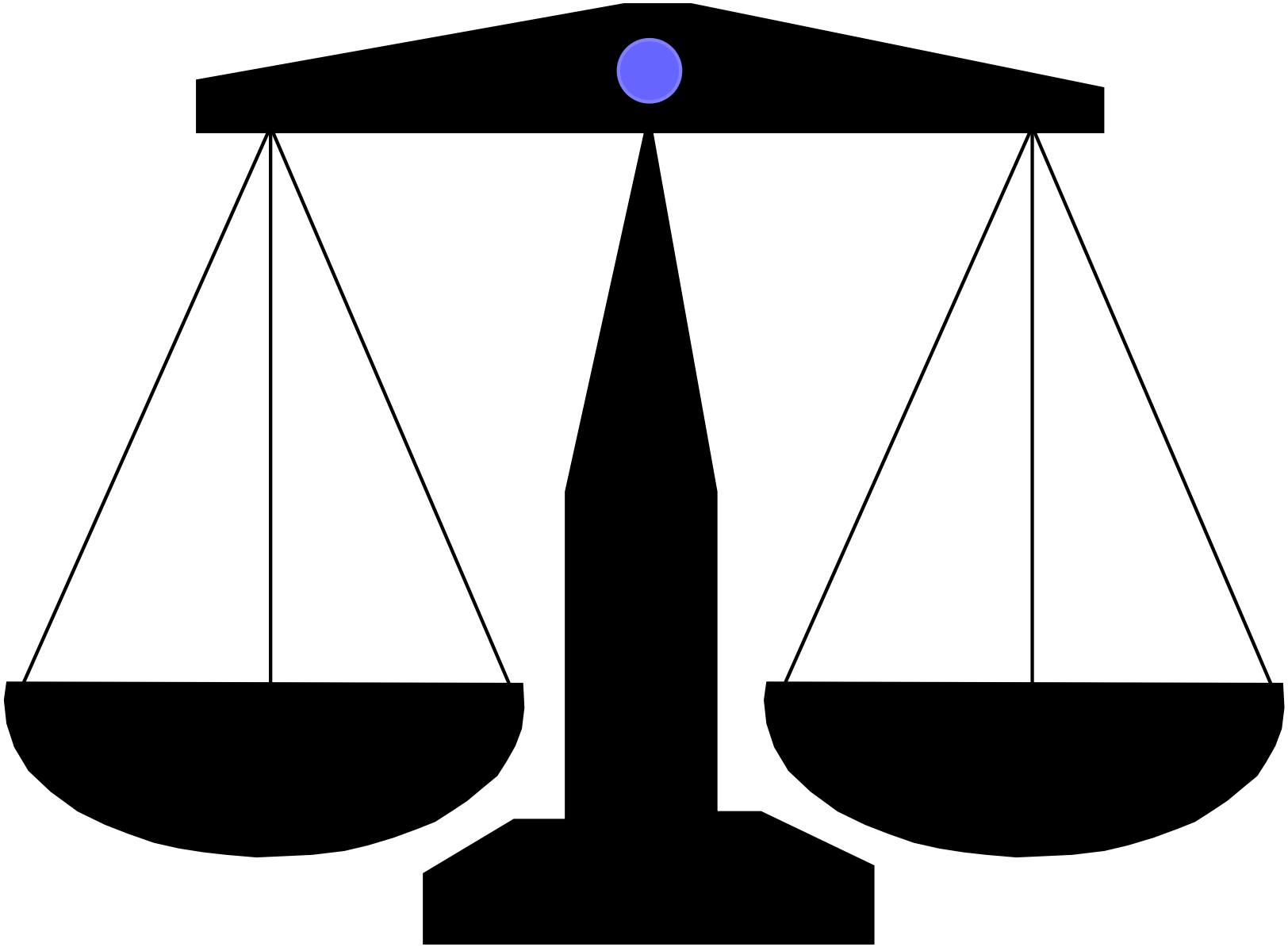
Some normal adult persons have an average body temperature that is higher than the normal range without obvious causes (= **constitutional hyperthermia**).

***10)*** The body temperature is increased in febrile (= fever-producing) diseases.

# REGULATION OF BODY TEMPERATURE

# HEAT BALANCE

- This is the balance between **heat production (gain)** and **heat loss in order to keep body temperature constant.**
- The body temperature is determined by the heat concentration in the body and both are determined by this balance.
- When heat production exceeds heat loss, the heat concentration in the body ↑↑ and body temperature rises.
- When heat loss exceeds heat production, the heat concentration in body ↓↓and body temperature drops.



**HEAT PRODUCTION** **37°C** **HEAT LOSS**

# Mechanisms of Heat Production (Gain)

**Heat production in body takes place by:**

1. **The basal metabolic activities (BMR)** of vital organs as the brain, heart, lungs, kidneys…etc. (which produce heat all the time).
2. **Muscular activity**.
3. **Food intake** (which produces heat by the specific dynamic action **(SDA), particularly proteins**).
4. The metabolic effects of **hormones** (especially **catecholamines and thyroid hormones**).They stimulate the metabolic processes in the body leading to heat production.
5. **Brown fat:**

- This is a special type of fat present between and around the scapula.
- It has a high rate of metabolism
- It is found in **infants** but **not in adults**.
- Its cells contain large numbers of **special mitochondria** (**uncoupling of oxidative phosphorylation**) and are richly supplied by **sympathetic nerve fibers**.

# MECHANISMS OF HEAT LOSS

- The **skin and subcutaneous tissues** (specially its fat content) constitute an **insulator system** that insulates the deep parts of the body from the skin surface. However, **heat can still be transferred** from deep tissues to the skin by the **blood**.
- The **blood carries the internal heat of the body areas to the surface of the body** and this can be **varied by changing the cutaneous blood flow** (VD ↑↑heat transfer to skin and vice versa).
- **Heat exchange between the skin and surrounding environment occurs by:**

**A. Non-evaporative Mechanisms:**

1. Radiation.
2. Conduction.
3. Convection.

**N.B. Heat loss from body by these mechanisms occurs ONLY when skin temperature is higher than that of the environment.**

**B. Evaporative Mechanisms:**

1. Insensible perspiration.
2. Sweating.

# A. Non-evaporative Heat Loss Mechanisms

## 1. Radiation (R):

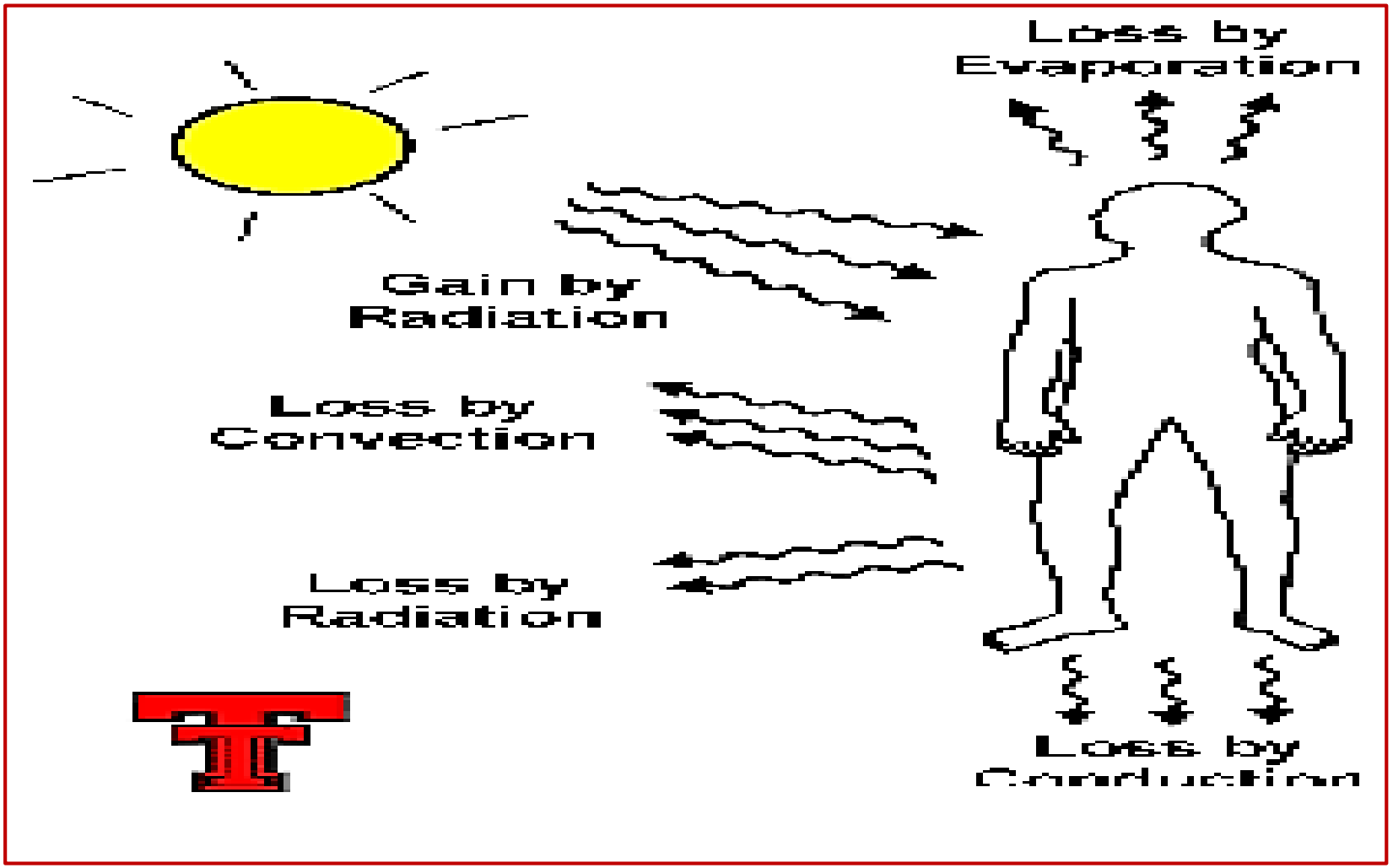
- This is the **heat transfer between objects that are not in contact with each other**.
- Heat is radiated **from warm objects to cooler ones** (the sun warms the earth by heat transferred by radiation).
- **The greater the thermal gradient** (the difference between the temperature of the objects), the more will be the amount of radiation and vice versa.
- **It is the main method of heat loss (about 60 %-70 %) at low environmental temperature**.

## 2. Conduction (CD):

- This is the **heat transfer between objects that are in direct contact with each other**.
- Its amount is also proportionate to the **thermal gradient** between objects.
- Normally, heat conduction from the **body to objects (e.g. a chair or bed) is little (about 3 %)**. However, **heat conduction to air is greater specially in presence of air currents and far greater to water** (**Water is a better conductor of heat than air**).
- It is less important as method of heat loss , but we can use it in immersing a feverish subject in cold water for reduction of body temperature in fever.

## 3. Convection (CV):

- It is removal of heat from body by **convection air currents**.
- It **only helps heat loss by conduction** (since heat must be first conducted to air then carried away by convection currents).
- When external temperature is less than that of the body , air in contact with the skin gets warmed and rises up transferring heat from the body. Cooler air from the environment replaces the warmed air and the process is repeated leading to increased heat loss from the body.
- **Forced convection** occurs if there are **air currents** as by using **fans**→→ more heat loss.




**N.B. ALL NON-EVAPORATIVE MECHANISMS OF HEAT LOSS DEPEND ON THE TEMPERATURE GRADIENT BETWEEN THE BODY SURFACE AND THE SURROUNDING ENVIRONMENT.**

# B. Evaporative Heat Loss Mechanisms

**There are 2 mechanisms for heat loss by evaporation:**

**1. Insensible Perspiration (Insensible water loss):**

- Means **water evaporation from the respiratory passages and from the skin surfaces other than sweating**.
- At rest about **25-50 ml** of **water are evaporated per hour** (= about **600-1200 ml /day**) through this mechanism→→→removing about **15-30 C/hour** →→→since **vaporization of I ml of water causes loss of 0.6 C**.
- It is important in panting animals having no sweat glands as dogs and cats.

## 2. Sweating:

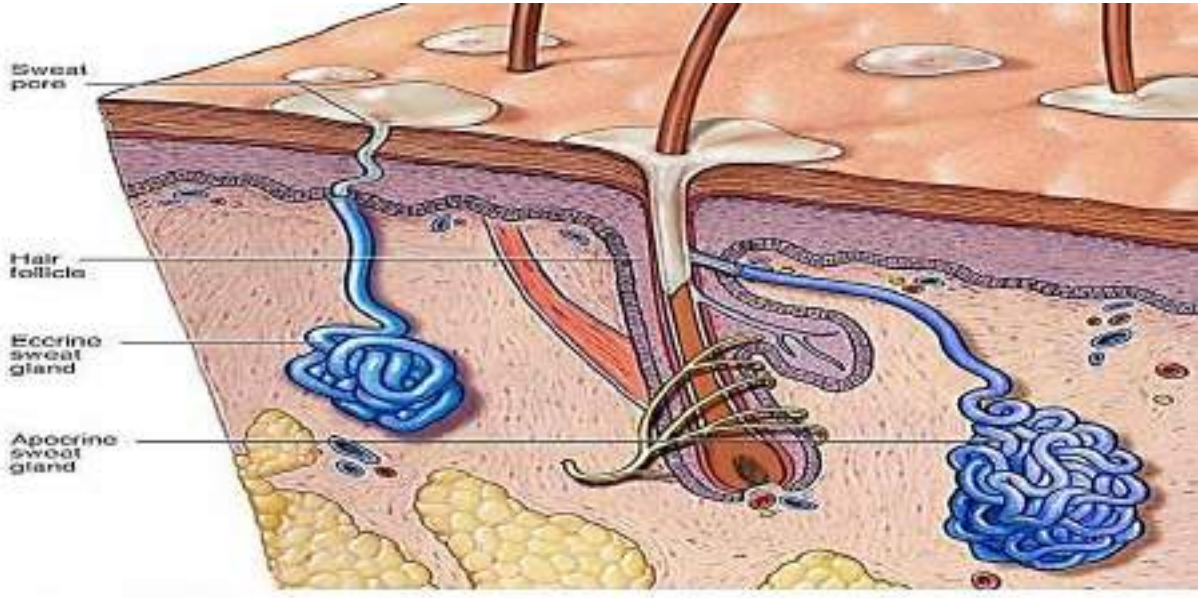
- The **cooling effect of sweat depends on its evaporation** which occurs only in **dry climates**.
- The **rate of sweat evaporation** is **inversely proportional to the humidity** of the atmosphere (The greater the humidity, the less will be sweat evaporation and vice versa).Therefore the **most annoying weather is the hot and humid**.
- In **humid climates, sweat only drips from the body** but is not evaporated (so a general sensation of hotness is felt on humid days).
- Sweat secretion **starts** at temperature between **32-34°C**.
- If the **environmental temperature** is **>34°C the only way of heat loss from the body is through sweat evaporation**.
- During muscular exercise in a hot environment, sweat secretion may reach 1600 ml/hour (or more) which leads to a heat loss of more than 900 C/hour (1600x 0.6).

# Sweat Glands

**There are two types of sweat glands:**

- Eccrine sweat glands
- Apocrine sweat glands

**Sweating** is a function of **eccrine sweat glands**, which are present in the skin and widely distributed on body surface.



# Sweat

**Composition:**

It is isotonic with blood plasma when first secreted. Then, it becomes hypotonic as it passes through the gland ducts due to reabsorption of NaCl and water as controlled by aldosterone.

**Center:**

Sweat secretion center is located in the anterior part of the hypothalamus.

**Control:**

Sweating is stimulated by sympathetic cholinergic fibers.

**Amount:**

Up to 700 ml/hour in normal person. May reach up to 2 L/hour in acclimatization (when exposed to a hot weather for 1-6 weeks).

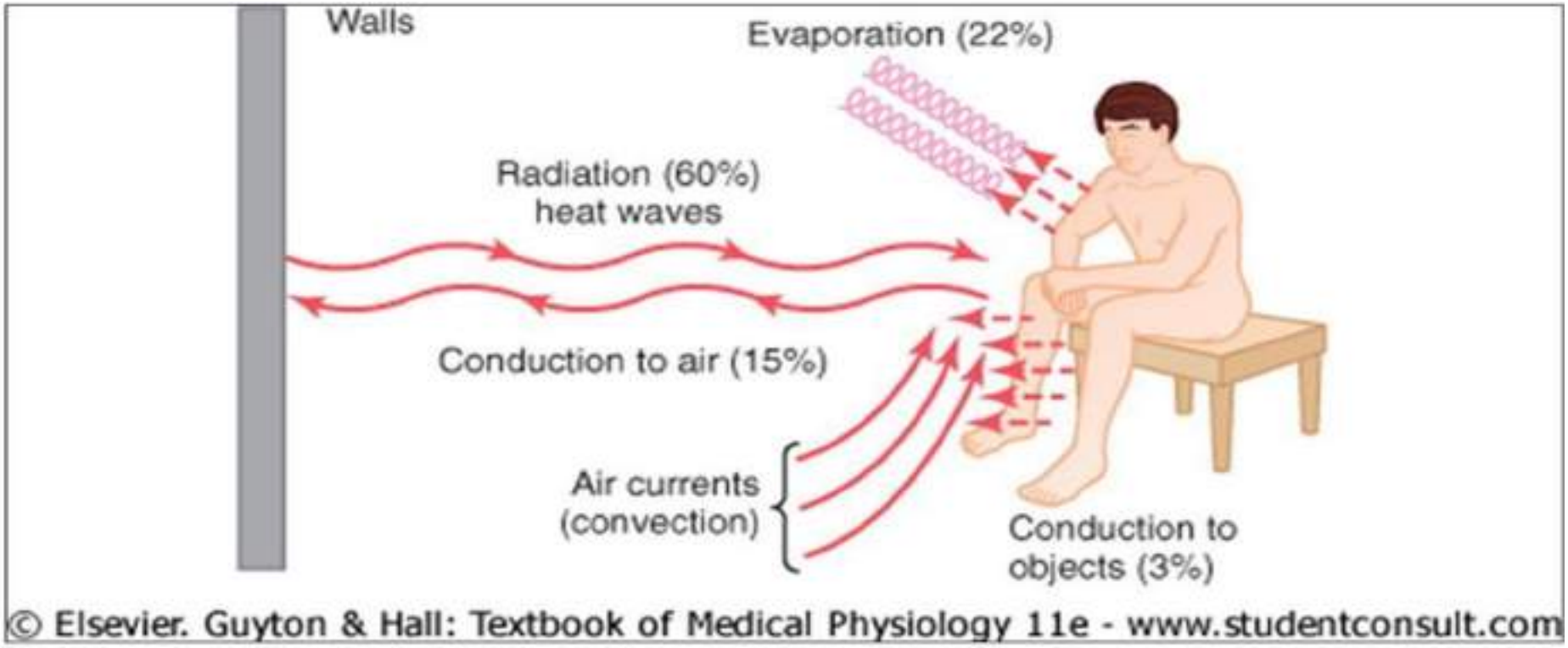
**Function:**

- Sweat is produced as a thermoregulatory response to heat either from:

a) Rise in environmental temperature ,or

b) Arise in body temperature as during exercise.

- The cooling effect of sweat depends on its evaporation which is inversely proportional to the humidity of the atmosphere.






# Mechanisms of heat loss from the body.

# Temperature Regulating Reflexes

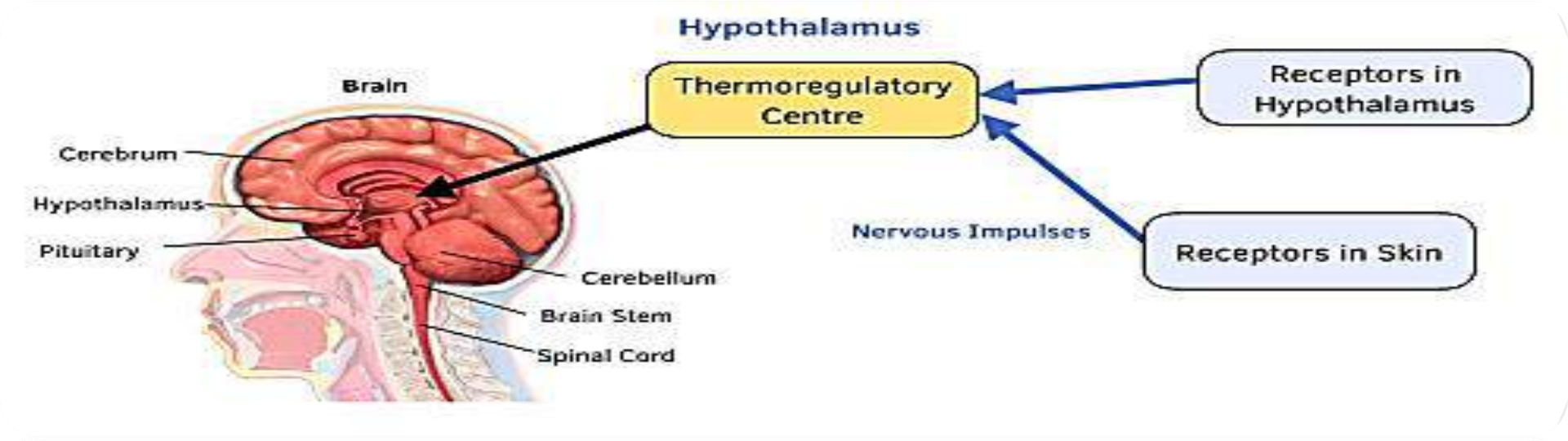
- **Temperature regulation offers a classic example of a homeostatic control system**.
- The balance between heat production (gain) and heat loss is continuously being disturbed, either by changes in metabolic rate (exercise being the most powerful influence) or by changes in the external environment such as air temperature.
- The resulting changes in body temperature are detected by thermoreceptors. These receptors initiate reflexes that change the output of various effectors so that heat production and/or loss are modified and body temperature is restored toward normal.

# THE THERMOREGULATORY SYSTEM

- **The thermoregulatory system is a highly-developed system that restores the body temperature back to its normal level whenever it is disturbed.**
- **The core body temperature is kept constant** while the skin temperature varies markedly with variation of environmental temperature.

**Thermoregulatory Control System consists of:**

- ✓ **Thermoreceptors** (sensory receptors).
- ✓ Afferent neurons to the CNS.
- ✓ **Control center** for regulation in **hypothalamus**.
- ✓ Efferent neurons from the CNS.
- ✓ **Effector organs** to **adjust heat production and loss**.



## (1) The Thermoreceptors:

- ✓ These receptors detect changes in temperature then discharge to the hypothalamic control center.
- ✓ They include :

**Peripheral thermoreceptors:**

- They are located in the **skin** and record its temperature.
- They include :

1. Warm receptors.
2. Cold receptors.

- They discharge their impulses via the **lateral spinothalamic tract** to the thalamus and to the hypothalamus through a collateral branch.

**Central thermoreceptors:**

- They are present in the thermoreceptive neurons of **hypothalamus**.
- They are sensitive to **core** temperature.
- Because it is the core body temperature—not the skin temperature—that is maintained in a narrow homeostatic range, the central thermoreceptors provide the essential negative feedback component of the reflexes.

## (2) The central (Hypothalamic) Integrator:

- The **heat regulating center (thermostat)** is present in the **hypothalamus**.
- It is **adjusted** at a standard reference temperature or **set point (37.1 °C),** which is usually the normal body temperature.
- Its main function is to detect deviations of the body temperature from the set point.
- It receives **information** from the **peripheral and central thermoreceptors**.
- It compares the information arriving with the **set point**.
- It sends **output information** to **effector systems** controlling heat production and heat loss, thus regulating body temperature around the **set point** value.
- It contains **2 major subdivisions**:

1) **A heat loss center:** This is located in **the anterior part of hypothalamus**. It is **activated when the body temperature rises above the standard set point. Its stimulation increases the heat loss and decreases the heat production ( *anti-rise effects)***.
2) **A heat gain center:** This is located in the **posterior part of hypothalamus**. It is activated when the **body temperature drops** below the standard **set point. Its stimulation increases the heat production and decreases the heat loss ( *anti-drop effects )***.

## (3) Effector organs involved in temperature regulation:

**1. Skin**; all skin structures sharing in temperature regulation are controlled by sympathetic nerve fibers, they include;

**a) Cutaneous blood vessels:** receive **sympathetic noradrenergic nerve fibers**.

- ↑ Sympathetic Stimulation → VC.
- ↓ Sympathetic Stimulation → VD.

Through such **vasomotor effects**, the skin temperature can be changed and this largely determines the amounts of heat loss or gain by (R, CD & CV).

**b) Sweat glands:** receive **sympathetic cholinergic nerve fibers**.

Sweat evaporation markedly decreases body temperature.

**c) Piloerector muscles:** receive **sympathetic noradrenergic nerve fibers**. They contract in cold weather leading to erection of skin hairs. The air trapped between hairs constitute an insulating layer around the body which prevents heat loss.

**2. Skeletal muscles;**

They are supplied by **somatic nerves**, and their contraction greatly **↑heat production**.

**3. Endocrine glands;** especially **adrenal medulla and thyroid gland**; their hormones markedly stimulate metabolic processes leading to ↑heat production. Therefore, the secretion of catecholamines and thyroid hormones increases in cold climates and decreases on exposure to heat.


THANK YOU