

Thermoregulation

By

Dr. Nour A. Mohammed

MUTAH SCHOOL OF MEDICINE

Regulation of body temperature

Human body temperature: In young adult:

Oral temperature = 37.3 °C

Rectal temperature is higher by 0.5 °C

Axillary temperature is lower by 0.5°C

Skin temperature (shell temp.) is lower than the central (core) temperature.

Factors affecting body temperature:

1) Age:

In the premature baby, the temperature is lower than in mature one.

Old age have slight decrease in temperature due to:

- a) Sedentary life. b) Decrease in metabolic rate.
- c) Decrease tissue activity. d) Decrease muscle tone.

2) Sex:

- Basal temperature in females ↑ by 0.5°C in 2nd half of menstrual cycle.
- **Pregnancy** → ↑ body temperature (due to **P**rogesterone).

3) Diurnal variation:

- It is lowest during sleep and early morning.
- Slightly higher during awake state or afternoon (+ 0.5°C).

4) Diseases:

- Hyperthyroidism → ↑ body temperature.
- Febrile diseases → Fever.
- Peripheral circulatory disorder → cold skin.

5) Exercise → ↑ body temperature.

6) Emotions → ↑ body temperature (↑ muscle tone & hormones).

7) Environmental temperature: Its increase → ↑ body temperature.

8) Food intake → ↑ body temperature.

Heat balance

I. Heat production:

1. Basal Metabolic Rate: It is the rate of **energy expenditure** per unit time (**hour**) divided by **body surface area** under the following **basal** conditions:

- 1) Complete physical and mental rest but not sleeping.
- 2) Post absorptive state 12 hours after the last meal to avoid (**SDA**).
- 3) Comfortable external temperature 20 – 25°C.

to avoid sweating (heat loss) or shivering (heat gain).

Normal value of BMR: $BMR = 40 \text{ Kcal / hour / m}^2 \pm 15\%$.

BMR represents the **unavoidable cost of life**. i.e. metabolic activity of: Heart & liver & respiratory muscles & intestine & muscle tone.

2. Extra metabolic rate by:

1) *Muscular activity*: Shivering \Rightarrow heat production.

2) *Endocrinal activity*:

a) **Thyroxin**: \uparrow heat production **slowly** but for long time.

b) **Catecholamines**: \uparrow heat production **rapidly** but for short period.

3. **Fat (Brown fat)**: Present in children \Rightarrow high rate of metabolism.

4. **Food intake**: Especially proteins \Rightarrow \uparrow SDA & \uparrow heat production.

5. **Sun radiation**.

Specific dynamic action (SDA)

Definition of SDA: It is the power of **food** to stimulate the MR **above** the BMR.

SDA starts **1** hour after food intake, reach a maximum in **3-4** hours, and disappears after **12** hours.

Causes of SDA:

Due to metabolic processes taking place in the **liver**.

Evidence: SDA is **zero** in hepatectomized animals.

Not due to digestion & absorption of the ingested food.

Evidence: injection of a.a. produce the same effect as oral intake of a.a.

Fate of SDA:

It is lost as a **waste heat**.

However, it is useful in exposure to **cold** to **maintain** body temperature.

II. Heat loss:

1. Non-evaporative heat loss:

1) *Radiation*: (60% of heat loss).

- From hot to cold objects not in contact to each other.

2) *Conduction*: (5% of heat loss).

From hot objects to surrounding objects in direct contact. (limited).

3) *Convection*: (15% of heat loss).

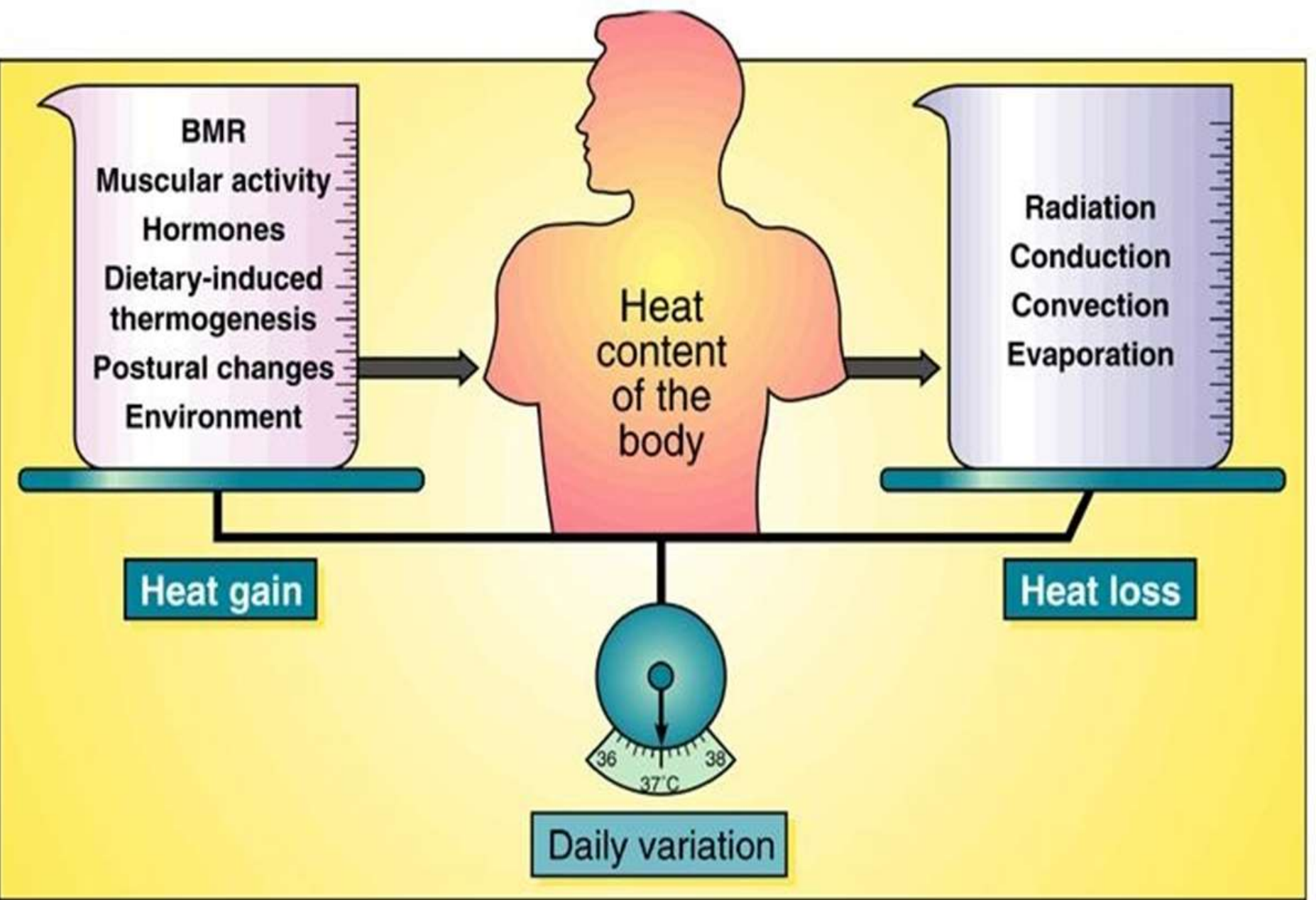
Heat must be conducted to air or water and then carried away by **convection current** as wind.

2. Evaporative heat loss: (20% of heat loss).

1) Insensible perspiration.

2) Sweat secretion: see later.

3. Heat loss via urine & stool: (less than 1% of heat loss).



Control of body temperature

The thermoregulatory system is composed of:

A. Thermoreceptors:

1. Peripheral thermoreceptors:

- **Skin** contains both cold & warm receptors with **more cold** receptors.

"Cold" sensation between 10° and 30c°.

"warm" sensation between 30° and 45c°.

Pathway: discharge impulses via the **lateral spinothalamic tract** to the **thalamus** and **somatosensory cortex** with **collateral** from the thalamus pass to activate **the heat regulatory center in hypothalamus.**

2. Central thermoreceptors:

- **The anterior hypothalamus** and the **preoptic area** contain large number of

heat sensitive neurons and cold sensitive neurons.

- These receptors are sensitive to **Core temperature** (brain & blood temp).

B. Thermoregulatory center (thermostat):

- It is present in the **hypothalamus**.
- It receives impulses from the thermo receptors and compares it with specific **standard** reference temperature (**set - point**) = **37.1°C** body core temperature.
- **If body temp < set point** \Rightarrow stimulation of **posterior** hypothalamus \Rightarrow \downarrow heat loss & \uparrow heat production.
- **If body temp > set point** \Rightarrow stimulation of **anterior** hypothalamus \Rightarrow \uparrow heat loss & \downarrow heat production.

C. The effectors organs:

- Skin (blood vessels & sweat gland) & Skeletal muscle & Endocrine glands.

Effects of exposure to cold environment

- If body temp < set point \Rightarrow stimulation of **posterior** hypothalamus \Rightarrow
 \downarrow heat loss & \uparrow heat production.

I. Decrease in heat loss:

1) VC of skin blood vessels:

- Posterior hypothalamus stimulates **VC center in medulla** \Rightarrow sympathetic adrenergic fibers \Rightarrow VC \Rightarrow skin becomes cold \Rightarrow \downarrow heat loss.
- Also, sympathetic stimulation \Rightarrow erection of hair (little effect in human).(goose bombs)

2) Counter-Current heat exchanger:

- VC of cutaneous blood vessels directs blood to deep veins which run parallel to the arteries.
- Heat is conducted from warm arterial blood to the cold venous blood.
- Warm venous blood return to the heart & cold arterial blood go to skin.

3) Behavioral responses: - Putting on heavy Clothes.

- Curling the body to decrease surface area.
- Erection of hair as an insulator for cold.



II. Increase in heat production (heat gain):

1) *Shivering:*

Definition: It is involuntary rhythmic contractions of the skeletal muscle to produce large amount of heat.

Its center: is present in **posterior hypothalamus** in area called the primary motor center for shivering (this area is normally inhibited by impulses from heat center in the anterior hypothalamic preoptic area).

This center stimulation \Rightarrow \uparrow muscle tone.

2) Secretion of hormones (Hormonal thermogenesis):

A. Adrenaline:

-Hypothalamus ⇒ stimulates the adrenaline secreting center in **medulla oblongata** ⇒ stimulate suprarenal medulla ⇒ ↑ adrenaline:

- Increase metabolic rate.
- Cutaneous VC.
- Stimulate glycogenolysis.
- Stimulate lipolysis (of depot fat)

B. Thyroxin:

- Hypothalamus ⇒ TRF ⇒ stimulate anterior pituitary ⇒ secrete TSH ⇒ stimulate thyroid gland ⇒ secrete thyroxin hormone:

- ↑ BMR slowly

C. Cortisol:

- Hypothalamus ⇒ CRF ⇒ stimulate anterior pituitary ⇒ secrete ACTH ⇒ stimulate adrenal cortex ⇒ secrete cortisol ➤ ↑ Blood glucose & metabolic rate.

3) Behavioral responses: - Increase appetite ⇒ increase **SDA**.

Effect of exposure to heat

If body temp > set point \Rightarrow stimulation of **anterior** hypothalamus \Rightarrow \uparrow heat loss & \downarrow heat production.

I. Decrease in heat production (heat gain):

By inhibition of mechanisms that cause heat production:

- 1) Decrease muscle tone.
- 2) Anorexia (decrease appetite).
- 3) Behavioral responses as apathy (decreased activity).

II. Increase in heat loss:

1) VD of skin blood vessels:

- It is caused by:

- a) Inhibition of the sympathetic centers.
- b) Direct effect of heat on skin.

2) Sweating:

- **Sweat is** hypotonic secretion of NaCl.
- **Its center:** is the **preoptic nuclei** in the anterior hypothalamus.



Types of sweat glands

Eccrine glands	Apocrine glands
All over the body.	In axilla & pubic (hairy skin).
Supplied by sympathetic cholinergic.	Supplied by sympathetic adrenergic.
For heat loss by sweating.	For sexual attraction.

Cooling effect of sweat:

- Each **1 ml** evaporated sweat **removes 0.6 K Cal.**
 - Sweat start at environmental **temp of 32°C.**
 - Sweat evaporation is **helped by dry atmosphere.**
 - **Dribbling** alone without evaporation leads to **no heat loss.**
- Cold sweat: is **emotional sweating** even with **cold and VC.**
- Sweat secretion is **an active process.**
- a) **Primary sweat:** in the acini is isotonic as plasma.
 - b) **Secondary sweat:** by the ducts under effect of aldosterone leads to **NaCl** reabsorption.

Acclimatization of sweating

Acute exposure to hot weather	After exposure to hot for 6 weeks
Sweat = 700 ml/h.	Sweat = 2000 ml/h.
Loss of 15-30 gm NaCl/day.	Loss of 3-5 gm NaCl/day. Due to \uparrow aldosterone secretion.

Disorders of temperature regulation

A. Fever (pyrexia):

➤ Definition:

- It is hyperthermia caused by resetting of the set-point of the hypothalamus to a higher level.

➤ Mechanism of fever:

- Toxins of bacteria + degenerated tissue ⇒ **exogenous pyrogens**.

⇒ act on the monocytes & macrophages ⇒ release **interleukin & tumor necrosis factor (endogenous pyrogens)**.

- Endogenous pyrogens (**IL-1**) ⇒ reach the hypothalamic thermo-sensitive neurons ⇒ formation of **prostaglandin E2 (PGE2)** ⇒ ↑ cAMP

⇒ activates **resetting** of the central thermostat (**ñ set-point**) ⇒ fever within ten minutes.

- Because body temperature is still **less than the set-point**, the person has **false**

feeling of cold and mechanisms of elevation of body temperature occur ⇒ VC

with cold skin and **shivers (CHILLS)** which continue till the body temperature is

The crisis (flush)

If the factor that causes fever is removed (treated), the set-point returns to the normal level and the body temperature is still more than the set-point ⇒ **true sensation of hotness** ⇒ ↑ mechanism of heat loss ⇒ VD (flushed skin) and intense sweating ⇒ return the body temperature to normal level.

Control of fever:

- 1) **PGE2** has a negative feed back on **interleukin I**
- 2) ↑ **Interleukin I** ⇒ down regulation of its receptors.
- 3) Glucocorticoids as cortisol ⇒ ↓ **interleukin I**
- 4) **Antipyretic** drugs as Aspirin: ⇒ ↓ synthesis of **PGE2** from arachidonic acid ⇒ ↓ set point level ⇒ ↑ heat loss by sweating.

N.B

Aspirin doesn't lower body temperature of a normal person because normal person doesn't have any interleukin- I.

B. Heat stroke



➤ *Cause:*

- Exposure to **Hot Humid** weather or to **High fever**.

➤ *Mechanism:*

- ↑ Body temp ⇒ excessive sweating ⇒ dehydration and salt loss
⇒ depression of heat regulating center ⇒ ↓ sweating & dry hot skin
⇒ ↑ body temp ⇒ irreversible denaturation of tissue protein
⇒ depression of the center (vicious circle) ⇒ death.

➤ *Clinical picture:*

- **Dizziness & Dehydration** (loss of fluids & sweat) may lead to **circulatory shock** & **Degeneration** of body tissue may occur.

➤ *Treatment:*

- 1) Immediate cooling of the body by immersion in ice cold water.
- 2) Sponge with alcohol.
- 3) Antipyretic drugs as aspirin.

C. Sun stroke: Beside sweating and dehydration damage of brain tissue by direct sun rays ⇒ severe fever.

- Treated as heat stroke + drinking saline or intravenous saline.

D. Hypothermia:

➤ **Definition:** It is a drop of body temperature to low level with slow metabolic and physiologic processes (↓ respiration & ↓ heart rate).

➤ **Causes:**

1) Exposure of the body to extreme cold water (ice water) for 20 minutes:

⇒ ↓ body temperature to 35°C ⇒ heart stop.

The ability of the hypothalamus to regulate body temperature is greatly impaired with sleepiness and even coma occurs.

2) Frost-bite: exposure of the body to extreme cold weather ⇒ freezing in lobes of ears and digits of hands & feet (frost - bite) may lead to gangrene and loss of these areas.

3) Artificial hypothermia: by strong sedative which depress heat regulating centers or cooling the patient with ice.

This is used to stop the heart artificially during cardiac surgery.

A vibrant sunset scene over a body of water. The sky is a mix of deep red, orange, and purple, with a large, dark cloud formation on the left. The sun is low on the horizon, creating a bright glow and reflecting on the water. The text 'THank you' is overlaid in a bold, blue, sans-serif font with a white outline. The 'T' is all caps, while 'Hank you' is in title case. The background image is framed by a white border.

THank you