Ministry of Higher Education and Scientific Research
Al-Mustaqbal University
College of Medicine

Medical Physics

Energy, Work, and power of the body

First stage

Lecture 5

2024-2025

Dr. Mohammed Abdullah Jassim

Energy, Work, and power of the body

All activities of the body including thinking, involve energy changes.

The conversion of the energy into work occurs continuously in the body. Under resting conditions the body energy is being used as follows.

1. *27 % by the liver and spleen.*
2. *25% by the skeletal muscles.*
3. *19% by the brain.*
4. *10 % by the kidney*

The body's basic energy (fuel) source is food; the food must be chemically changed by the body molecules that can combine with oxygen in the body.

The body uses the food energy to :-

1. Operate its various organs.
2. Maintain a constant body temperature.
3. Do external work e.g. lifting.

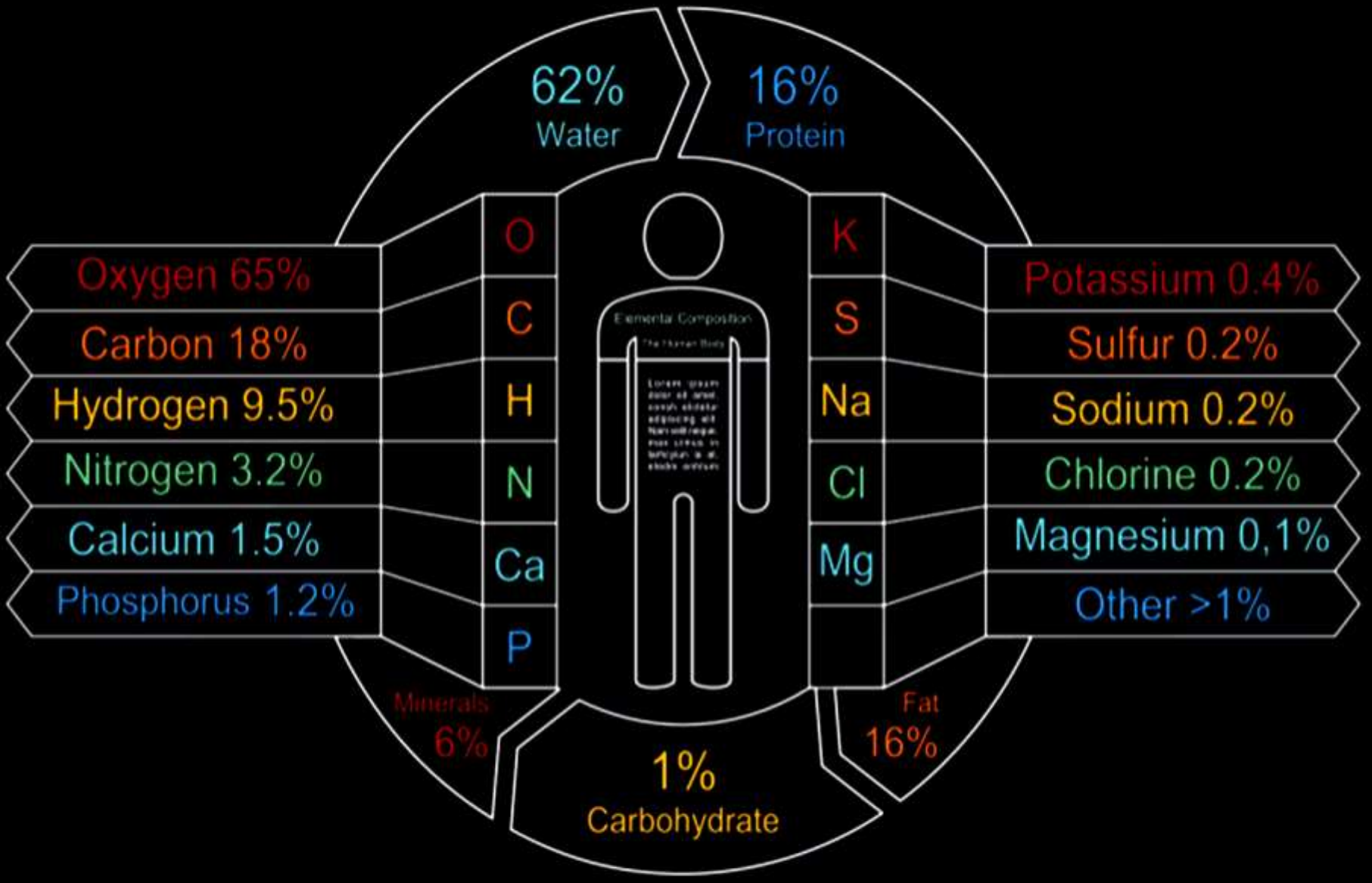
The oxidation equation for 1 mole of glucose is:-

$$\underset{1\ \text{mole}}{C_6H_{12}O_6} + \underset{6\ \text{mole}}{6O_2} \rightarrow \underset{6\ \text{mole}}{6H_2O} + \underset{6\ \text{mole}}{6CO_2} + \underset{\text{releasing (heat energy)}}{686\ \text{Kcal}}$$

This table for typical energy relationships for some foods

Food or fuel	energy released per liter Of O_2 used (Kcal/liter)	Caloric value (Kcal/g)
Carbohydrates	5.3	4.1
Proteins	4.3	4.1
Fats	4.7	9.3
Typical diet	4.8-5.0	—
Gasoline	—	11.4
Coal	—	8.0
Wood (pine)	–	4.5

THE HUMAN BODY



ELEMENTAL COMPOSITION

Conservation of energy in the body-:

There are continuous energy changes in the body both, when it is doing work and when it is not. We can write the first law of thermodynamics as:

$\Delta U = \Delta Q - \Delta W$.....(1)

Where:

ΔU : is the **change** in **stored energy**.

ΔQ : is the heat **lost** or **gained**.

ΔW: is the work done by the body.

If a body no work (**$\Delta W = 0$**) and at constant temperature continues to lose heat to its surrounding , and **ΔQ** is **negative**. Therefore, **ΔU** is also is **negative**, indication a decrease in stored energy.

The rate of change of energy is given by:

$\Delta U/\Delta t = \Delta Q / \Delta t - \Delta W / \Delta t$……(2)

Where:

$\Delta U / \Delta t$: Rate of change of stored energy.

$\Delta Q / \Delta t$: Rate of heat loss or gain.

$\Delta W/\Delta t$: Rate of doing work.

Equation (2) tells us that energy is conserved in all processes, but it does not tell us whether or not a process can occur.

Work and Energy:-

Chemical energy stored in the body is converted into external mechanical work as well as into life preserving functions.

The Internal work: is the force (F) moved through a displacement Δx.

Δ w= F Δx----------(3)

The force and the motion Δx must be in the same direction.

Power: is the rate of work done.

P= Δ w / Δ t = F Δ x/Δ t = F v (v =velocity)--------(4)

External work is done when a person is climbing hill or walking up stairs. We can **calculate** the work by: multiplying the person weight :

(**mg**) by the vertical distance (**h**) moved.

W = (mg) Δ h----------(5)

To study the human body as a machine for doing external work, we can measure the external work is done and power supplied by a subject riding on an ergo meter on a fixed bicycle.
We can also measure the oxygen consumed during any activity:
The total food consumed can be calculated since 4.8 kcal are produced ***for each 1 liter of oxygen consumed***.
The **efficiency** of the human body as machine can be obtained from the following:

ŋ = work done / energy consumed----------(6)

P=E/t---------- (7)

****Energy unit is joule***

1 J = 10^7 ergs

1Kcal =4184 j

****Power is given in joule per second or watts (W)***

Example 1:

3000 J of heat is added to a system and 2500 J of work is done by the system. What is the change in internal energy of the system?

Solution:

$\Delta U = 3000\text{-}2500$

$\Delta U = 500$ Joule

Internal energy increases by 500 Joule.

Example 2

How much work is required to lift a 40Kg crate 20M high?

Solution:

$W = mg\Delta h$

$W = (40Kg)\ (9.8M/s^2)\ (20M)$

$= 7840J$

Example 3:

How far must a 5N force pull a 50g toy car if 30J of energy are transferred?

Solution:

$WD = F \times d$

Rearrange to get:

$$d = \frac{WD}{F} =$$

$$= \frac{30}{5}$$

So $d = 6m$

Example 4:

A man exerts a force of 200 N on a boulder but fails to move it. Calculate the work done.

Solution:

By Using:

WD = F x d

Note that: d = 0 because the boulder doesn't move

= 2000 x 0

So WD = 0

*If an object does not move when the force is applied then no work is done. Work is only done if the object moves.

Example 5:

A person of mass 70kg runs up a flight of stairs with a vertical height of 5m. If the trip takes 7s to complete, calculate the person's power.

Solution:

$WD = mgh$

$= 70 \times 10 \times 5$

$= 3500\ J$

$$\text{Power} = \frac{\text{work done}}{\text{time}}$$

$$= \frac{3500}{7}$$

So Power = 500 W

Questions

1 - We can write the first law of thermodynamics as:----------

A- $\Delta U=\Delta Q \times \Delta W$ **B**- $\Delta U=\Delta Q / \Delta W$ **C**- $\Delta U=\Delta Q + \Delta W$ **D** - $\Delta U=\Delta Q - \Delta W$

E- $\Delta U= \Delta W / \Delta Q$

2 -We can calculate the work using the relationship----------

A- W= τgh **B**- W=mgτ **C**- W=mg/ h **D** - W=m/ g h **E**- W=mg **Δ** h

Temperature of the Body

Normal body Temperatures

Body temperature or Core temperature is the average temperature of structures present in deeper part of the body; it is always more than oral or rectal temperature. It is about 37 C ° (100°F) and it's usually remains very constant, within ±1°F (±0.6 C°),except when a person has a febrile illness.

Variations of body temperature

Physiological Variations

(0.5° to 1 C°)

1. Age

2. Sex

3. Diurnal variation

4. After meals

5. sport

6. Sleep: During sleep, the body temperature decreases by **0.5 C°**

7. Emotion

8. Menstrual cycle

Heat loss occurs by the following methods

1. Conduction

Only minute quantities of heat, about **3%**, are normally lost from the body by direct conduct from the surface of the body to solid

2. Radiation:

60% of heat is lost by means of radiation, transfer of heat by infrared ray
(electromagnetic ray) radiation from body to other objects through the surrounding air.
The human body radiates heat rays in all directions. Heat rays are also being radiated from the walls of rooms and other objects toward the body. If the temperature of the body is greater than the temperature

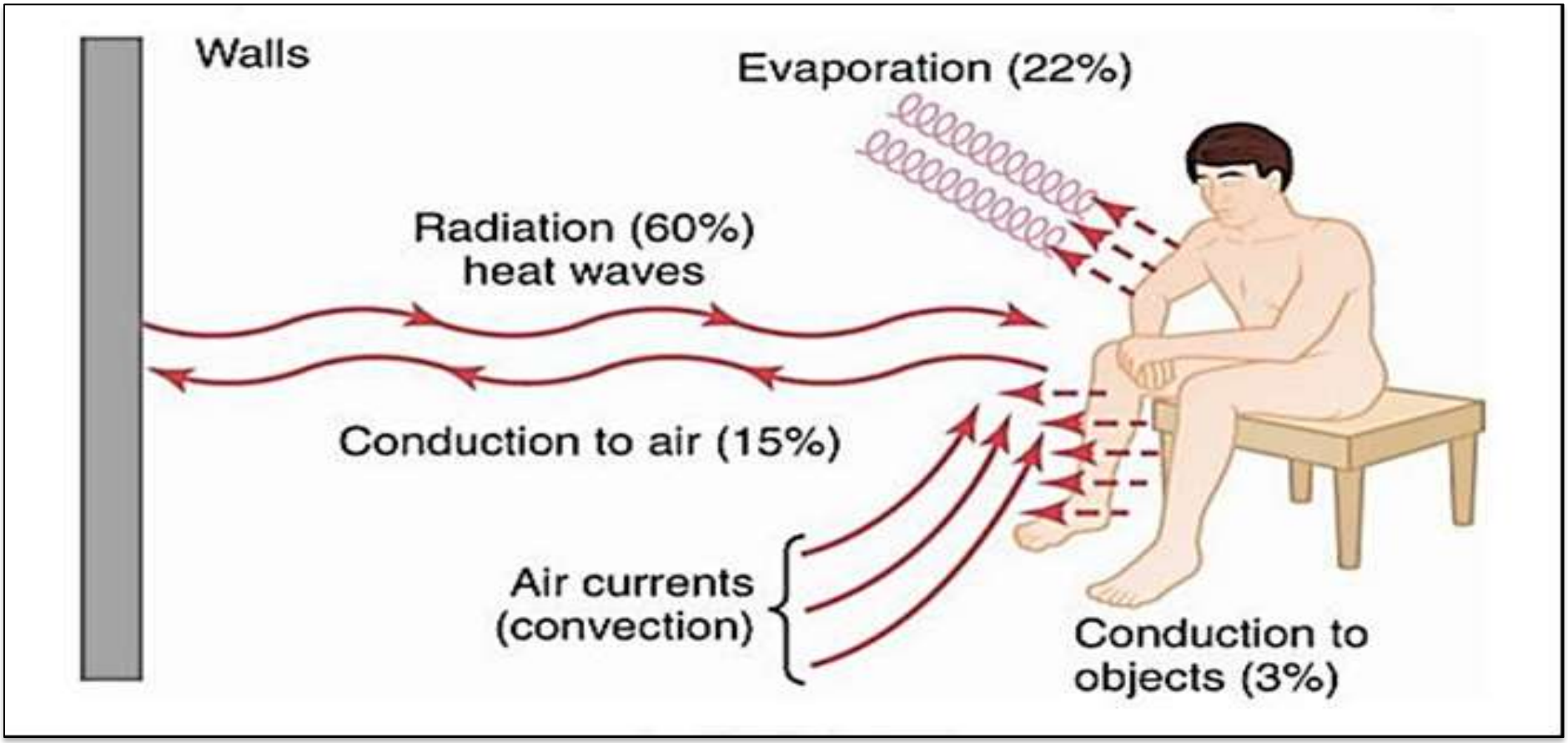
3. Convection

A small amount of heat convection almost always occurs around the body, about 15% of total heat loss occurs by conduction to the air and

om the

4. Evaporation – Insensible Perspiration

Normally, a small quantity of water is continuously evaporated from skin and lungs (22%).

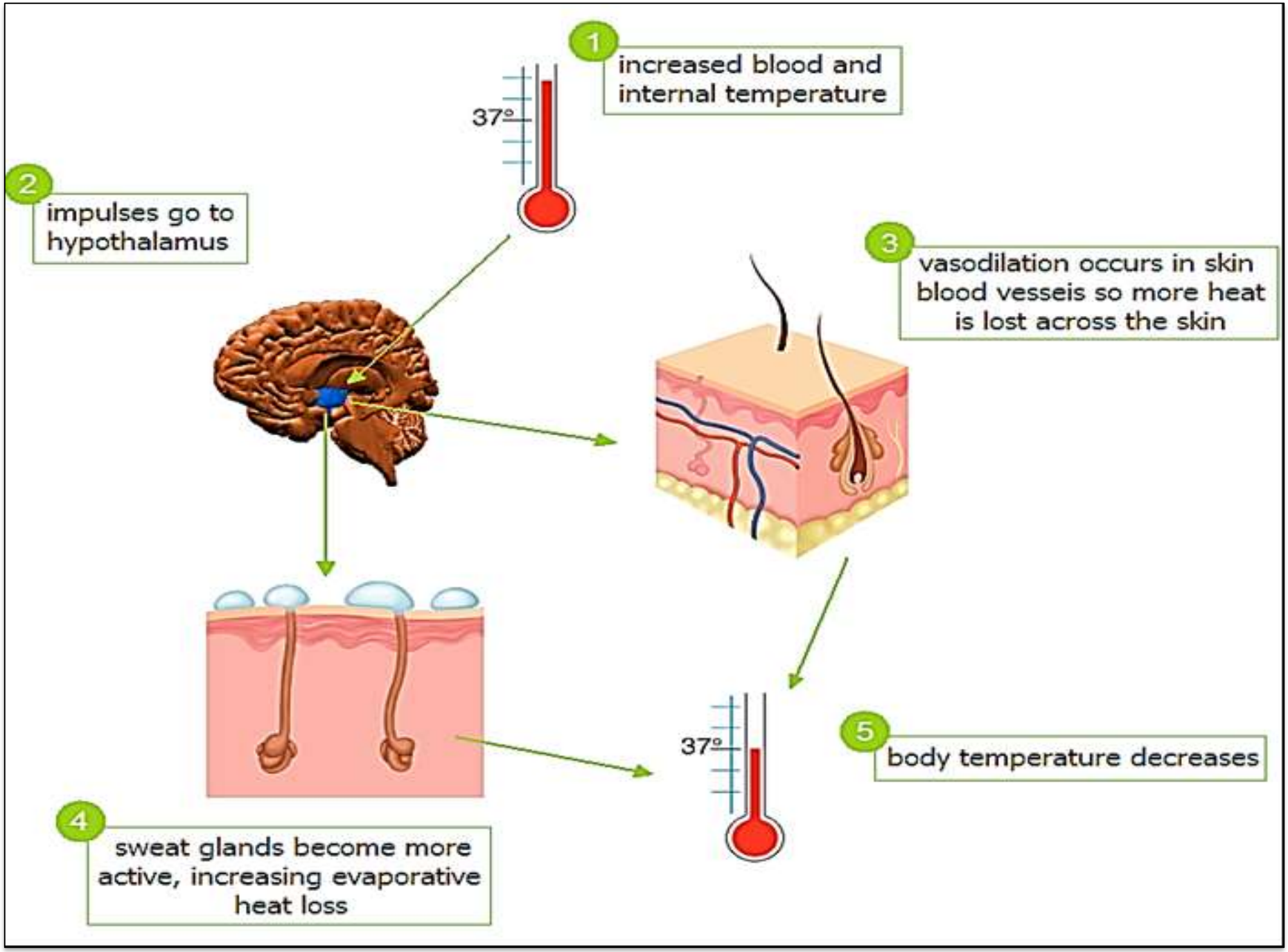


Regulation of body temperature

1- Role of sympathetic nervous system

Heat conduction to the skin by the blood

2- Role of Hypothalamus in regulation of body temperature


1
increased blood and internal temperature
37°
2
impulses go to hypothalamus
3
vasodilation occurs in skin blood vesseis so more heat is lost across the skin
37°
5
body temperature decreases
4
sweat glands become more active, increasing evaporative heat loss