MSS MODULE
PHYSIOLOGY (LECTURE 4)
THERMOREGULATION II

BY

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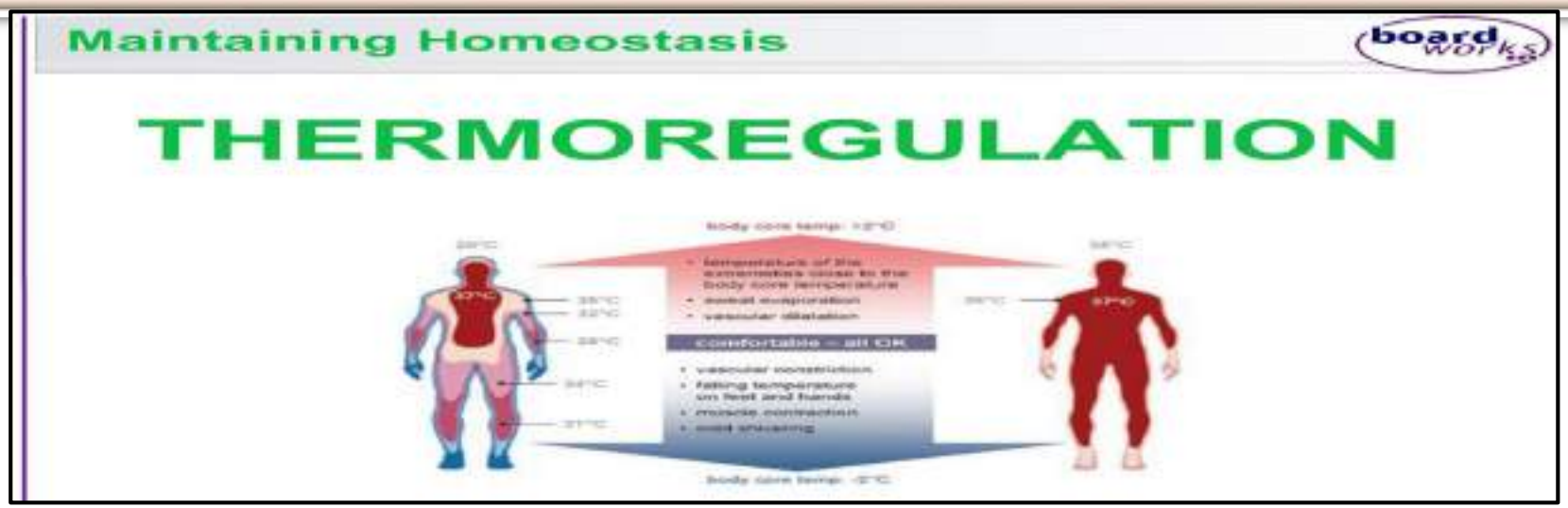
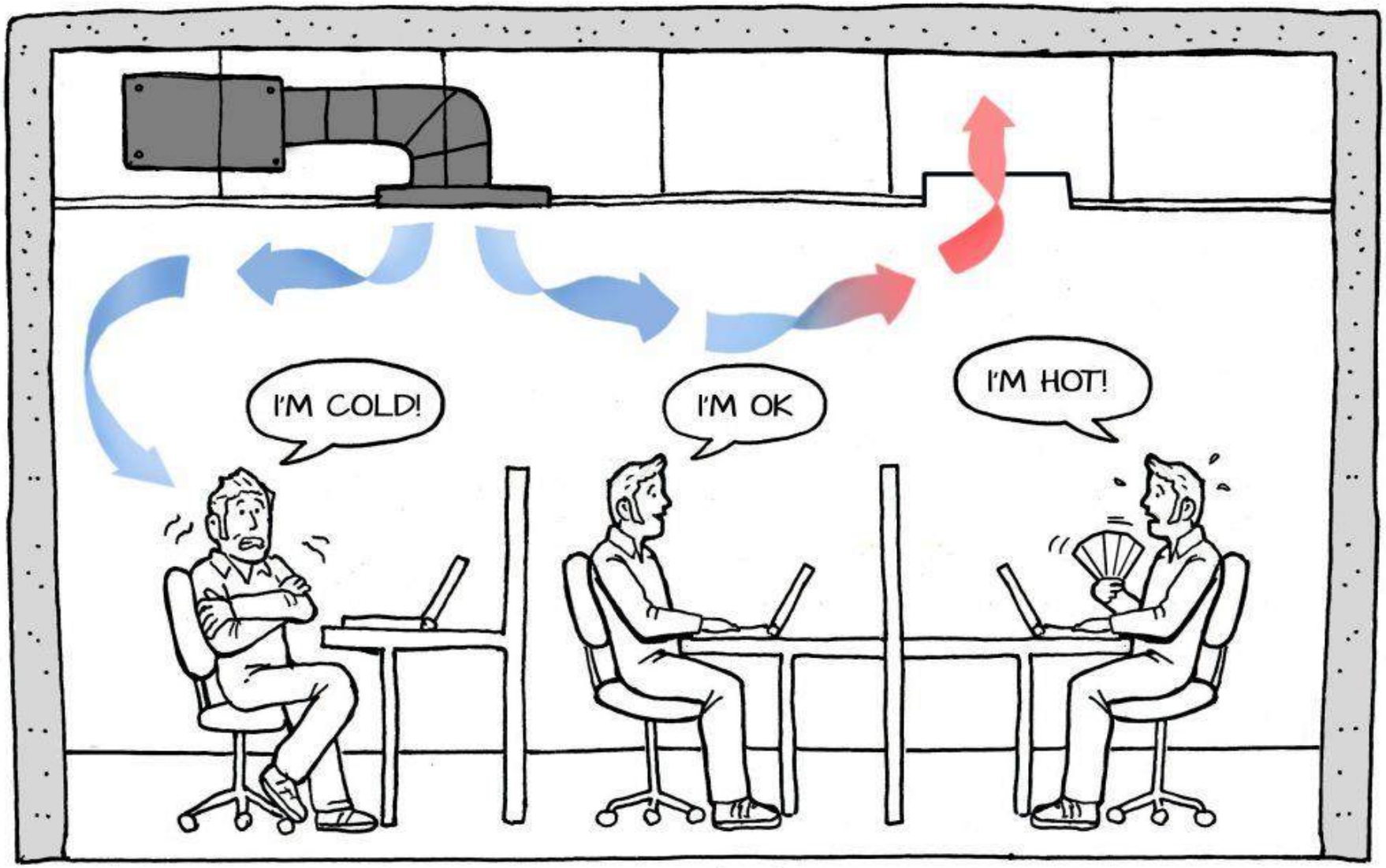
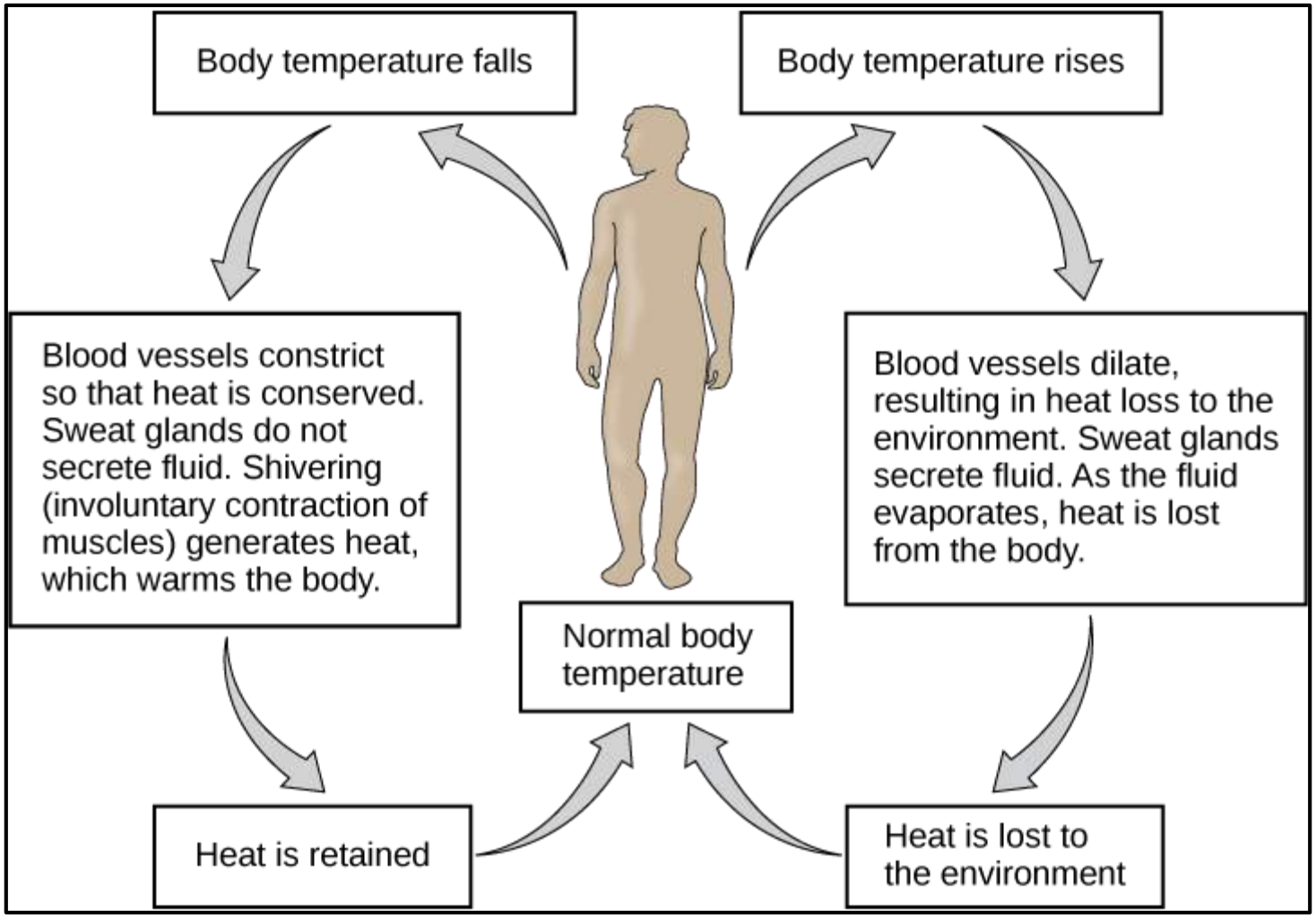



I'M COLD!
I'M OK
I'M HOT!

Thermoregulatory Mechanisms During Thermoneutral Zone: Integration of Effector Mechanisms

- **Thermoneutral zone** is the range of environmental temperature at which the body temperature is kept constant through **skin vasomotor changes only** (which control heat transfer across the skin by R &CD).
- In **humans**, the **thermoneutral zone is approximately 24^{O}C to 32-34^{O}C for a nude (= unclothed) individual**.
- **At temperatures lower than this**, even **maximal vasoconstriction** of blood vessels in the skin (which occurs at **24^{O}C) cannot prevent heat loss from exceeding heat gain** and the **body must increase its heat production (as shivering) to maintain temperature**.
- At environmental temperatures above the thermoneutral zone, even **maximal vasodilation of cutaneous blood vessels** (which occurs at **32-34^{O}C)** cannot eliminate heat as fast as it is produced, and **another heat loss mechanism—sweating**—therefore comes strongly into play.
- **At environmental temperatures above that of the body, heat is actually added to the body by radiation and conduction**. Under such conditions, **evaporation is the sole mechanism for heat loss**. A person's ability to tolerate such temperatures is determined by **the humidity** and by his or her maximal sweating rate.


Body temperature falls
Body temperature rises
Blood vessels constrict so that heat is conserved. Sweat glands do not secrete fluid. Shivering (involuntary contraction of muscles) generates heat, which warms the body.
Blood vessels dilate, resulting in heat loss to the environment. Sweat glands secrete fluid. As the fluid evaporates, heat is lost from the body.
Normal body temperature
Heat is retained
Heat is lost to the environment

Thermoregulatory Mechanisms on Exposure to Cold

- Drop of the body temperature below the standard set point due to exposure to cold environment.
- **The heat gain center is stimulated**.
- Thermostasis is maintained by :

Anti-drop response:

(A) Increasing heat production.

(B) Decreasing heat loss.

(A) Increasing Heat Production Mechanisms:

Increasing the rate of heat production is the main thermoregulatory mechanism on exposure to cold.

(1) Increased muscle tone and shivering:

- ✓ Changes in muscle activity constitute the major control of heat production for temperature regulation.
- ✓ **The first muscle change in response to a decrease in core body temperature is a gradual and general increase in skeletal muscle contraction**.
- ✓ This may lead to **shivering, which consists of oscillating, rhythmic muscle contractions and relaxations occurring at a rapid rate**.
- ✓ During shivering, the efferent motor nerves to the skeletal muscles are influenced by descending pathways under the primary control of the hypothalamus.
- ✓ Because almost **no external work is performed by shivering**, most of the energy liberated by the metabolic machinery appears as **internal heat**, a process known as **shivering thermogenesis**.
- ✓ People also use their muscles for **voluntary heat producing activities such as foot stamping and hand rubbing**.

(2) Increasing secretion of thermogenic hormones (chemical or non-shivering thermogenesis):

Stimulation of **heat gain center** leads to secretion of the following hormones which increase the cellular metabolism leading to more heat production.

a) Catecholamines:

The **heat gain center** discharges impulses to the spinal cord which stimulate the **sympathetic preganglionic cholinergic fibers** that supply **the adrenal medullae** leading to secretion of **catecholamines (mainly adrenaline; epinephrine)**. These hormones increase the cellular metabolism and leads to oxidation of various food stuffs (which releases energy in the form of heat; **calorigenic effect**).

b) Thyroxine and glucocorticoids:

Excitation of **heat gain center** leads to secretion of both thyrotropin and corticotropin releasing hormones from the hypothalamus → stimulation of secretion of anterior pituitary tropic hormones:

- **Thyrotropin releasing hormone (TRH)** → ↑ thyroid stimulating hormone **(TSH)** → ↑ **thyroxine** → ↑ heat production.
- **Corticotropin releasing hormone(CRH)** → ↑ adrenocorticotropic hormone **(ACTH)** → ↑ **glucocorticoids** → stimulation of organic metabolism → ↑ heat production .

(3) Increased sensations of appetite and food Intake:

Mechanism:

Impulses discharged from the **heat gain center** → increased appetite → increased food intake→ increases heat production by its **SDA**. **Protein is the preferable food in cold climates due to its high SDA**.

(4) Brown Fat:

- It is a special type of fat present between and around the scapulae.
- It is a source of a considerable heat production, particularly in **infants** (absent in human adults).
- It has a high rate of metabolism→ increase heat production (thus **infants tolerate cold better than adults**).
- It is similar to **electric blanket** as it is **richly supplied by sympathetic nerve fibers**.
- It is also important for **acclimatization to cold**.

(B) Decreasing Heat loss Mechanisms :

Decreasing heat loss occurs by non-evaporative mechanisms.

The body tries to decrease non-evaporative heat loss by :

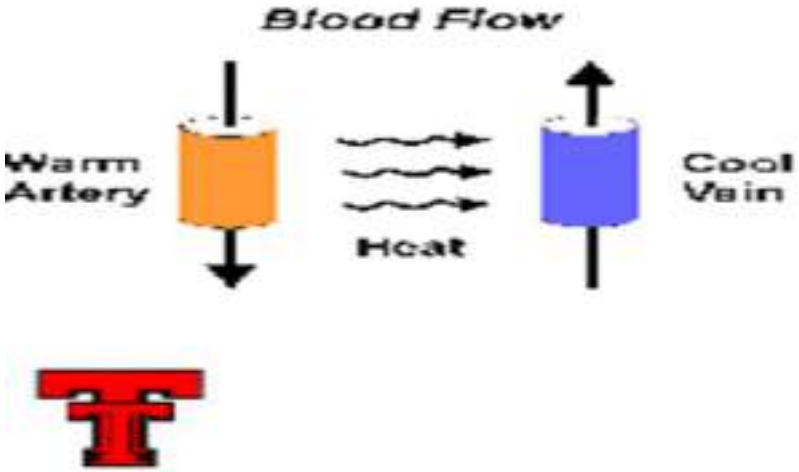
1)Vasoconstriction (V.C.) of skin blood vessels: this occurs as a result of **stimulation of sympathetic centers in posterior hypothalamus** → **decrease skin blood flow** → **decrease skin temperature** → decrease temperature gradient between skin and environment → **decrease heat loss**. **Maximal V.C. occurs at 24°C**.

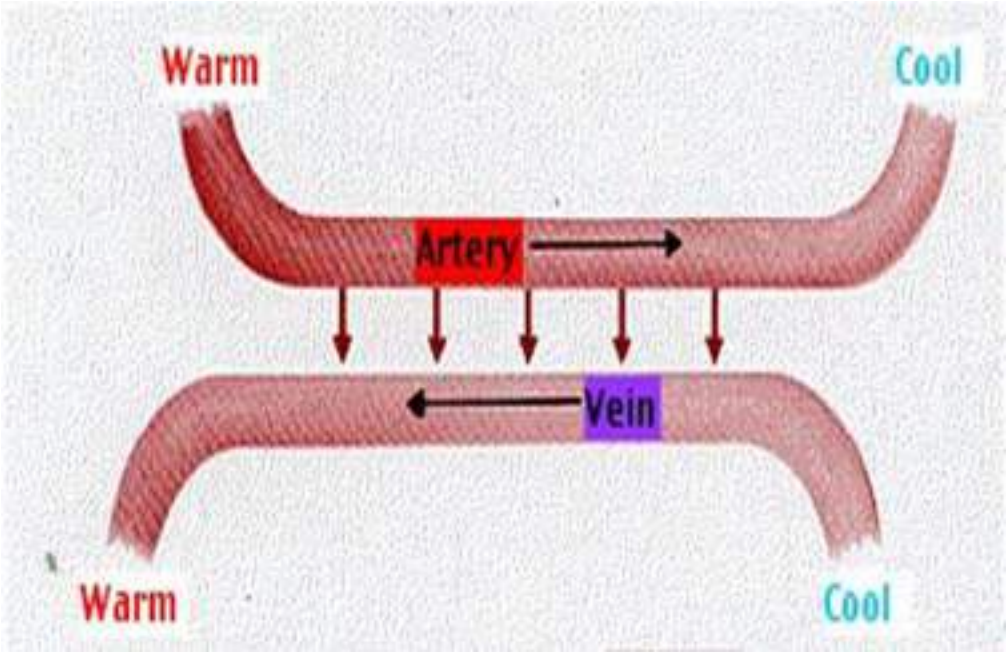
2) Countercurrent heat exchange mechanism: Heat is transferred from the warm arterial blood to the cold venous blood as it returns to the heart, thus **heat is returned back to the body core**.

Accordingly, the body core temperature will be kept constant although the skin temperature is decreased.

3) Behavioral responses to reduce the heat loss occur as **putting on heavy clothes and curling up** to decrease body surface area exposed to the environment.

4) Horripilation: Erection of skin hair in animals as a result of contraction of piloerector muscles as a result of increased sympathetic discharge from the heat gain center. In humans, it only produce goose pimples (because the skin hair is poor and thin). So in cold weather people usually supplement this layer of hair by wearing clothes.





N.B.

Maximal vasoconstriction occurs at 24ºC.

When the environmental temperature is <24 ºC, the main physiological mechanism of body temperature regulation is through increasing heat production.

Acclimatization to cold

- This occurs on **prolonged exposure to cold**.
- It is produced mainly through increasing the **hormonal (chemical) thermogenesis particularly by increased secretion of thyroxine** (this may explain the much higher incidence of toxic goiter in persons living in cold climates).
- **Thyroxine** plays a **minor role as an immediate mechanism** of increased heat production.
- The presence of **brown fat** also helps **acclimatization to cold in infants** due to its high rate of metabolism.

Thermoregulatory Mechanisms on Exposure to Heat

- Rise of the body temperature above the standard set point due to exposure to hot environment (**>32-34 ºC).**
- **Heat loss center is stimulated**.
- Thermostasis is maintained by:

Anti-rise response:

(a) Decreasing heat production.
(b) Increasing heat loss.

(A) Mechanisms of decreasing heat production:

- ❑ Anorexia (= loss of appetite).
- ❑ Apathy and inertia.
- ❑ Inhibition of chemical thermogenesis: by inhibiting secretion of the thermogenic hormones (catecholamines & thyroid hormones).

(B) Mechanisms of increasing heat loss:

Increasing heat loss is the main thermoregulatory mechanism during exposure to heat, and is produced through the following **3 effects**:

(1) Cutaneous V.D.:

This occurs as a result of **inhibition of sympathetic centers in posterior hypothalamus** by impulses discharged from the **heat loss center→ increase skin blood flow → increase skin temperature → increase heat loss by R and CD** (so the skin is called the radiator system of the body). Accordingly, the body core (rectal) temperature will be kept constant although the skin temperature is increased.

Such mechanism is sufficient to maintain the core body temperature constant only till the environmental temperature rises to 32-34 °C.

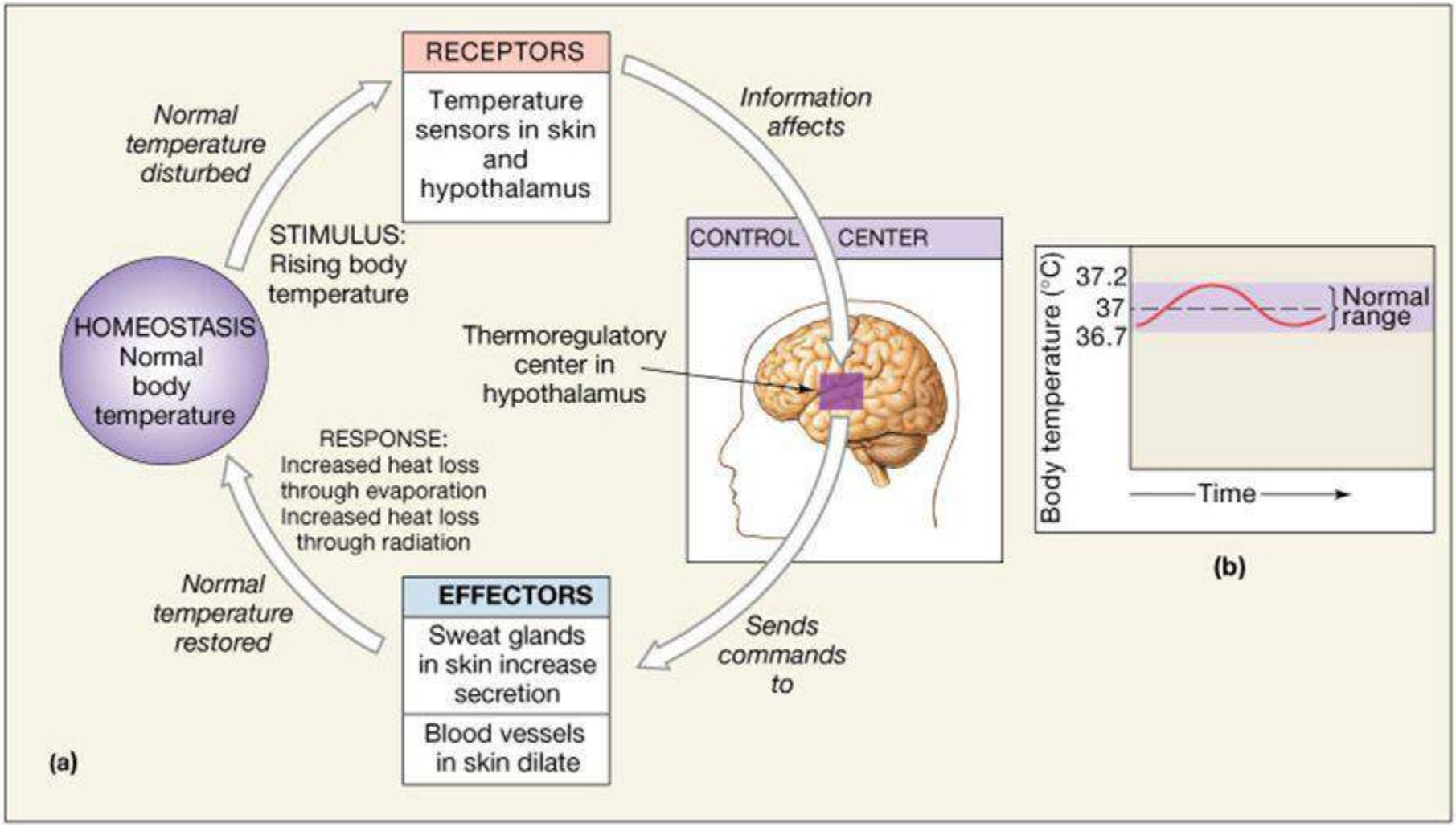
(2) Sweat secretion:

- This occurs whenever the **non-evaporative heat loss mechanisms fail to maintain the body temperature constant**.
- **If the environmental temperature is > that of the body, the body gains heat through non-evaporative methods** and so, **the evaporative methods becomes the only way for heat loss**.
- Therefore, **it starts when the environmental temperature exceeds 32-34 °C** .
- The **cooling effects of sweating is dependent on its evaporation which is inversely proportionate to humidity**.

(3) Panting:

- This is **shallow rapid breathing** that occurs in animals having **no sweat glands** (e.g. dogs) on exposure to hot environment.
- It occurs by impulses discharged from the **heat loss center** to a special **panting center** that is closely related to the pneumotaxic respiratory center in **pons**.
- It causes **heat loss through ↑ evaporation** from the **respiratory passages as well as evaporation of saliva**.

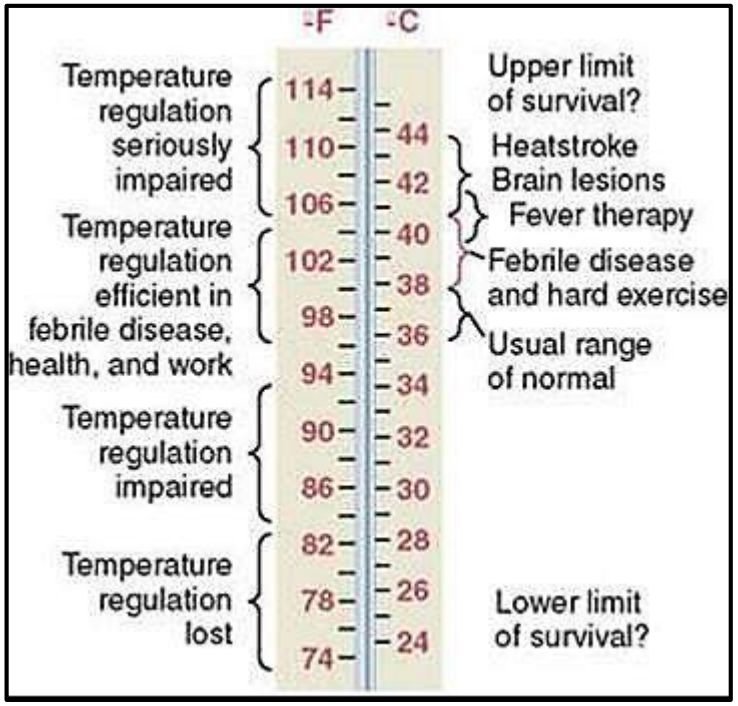
Negative Feedback: The Control of Body Temperature



Acclimatization to Heat

- Changes in the onset, volume, and composition of sweat determine the ability to adapt to chronic high temperatures.
- In a hot environment; body temperature increases, and severe weakness may occur.
- After several days, there is much less increase in body temperature, and the person is said to have acclimatized to the heat.
- Body temperature does not increase as much because sweating begins sooner and the volume of sweat produced is greater.
- There is also an important change in the composition of the sweat, namely, a **significant reduction in its salt concentration**.
- **This adaptation, which minimizes the loss of sodium ions from the body via sweat, is due to increased secretion of the adrenal cortex hormone aldosterone**.

ABNORMALITIES OF THERMOREGULATION



Fever (Pyrexia)

- ✓ An increase of body temperature due to the **resetting** of the **hypothalamic thermostat set point (37.1 °C)** to a **higher level**.
- ✓ The most common cause of fever is infection.

What is the basis for the thermostat resetting?

Pathogenesis:

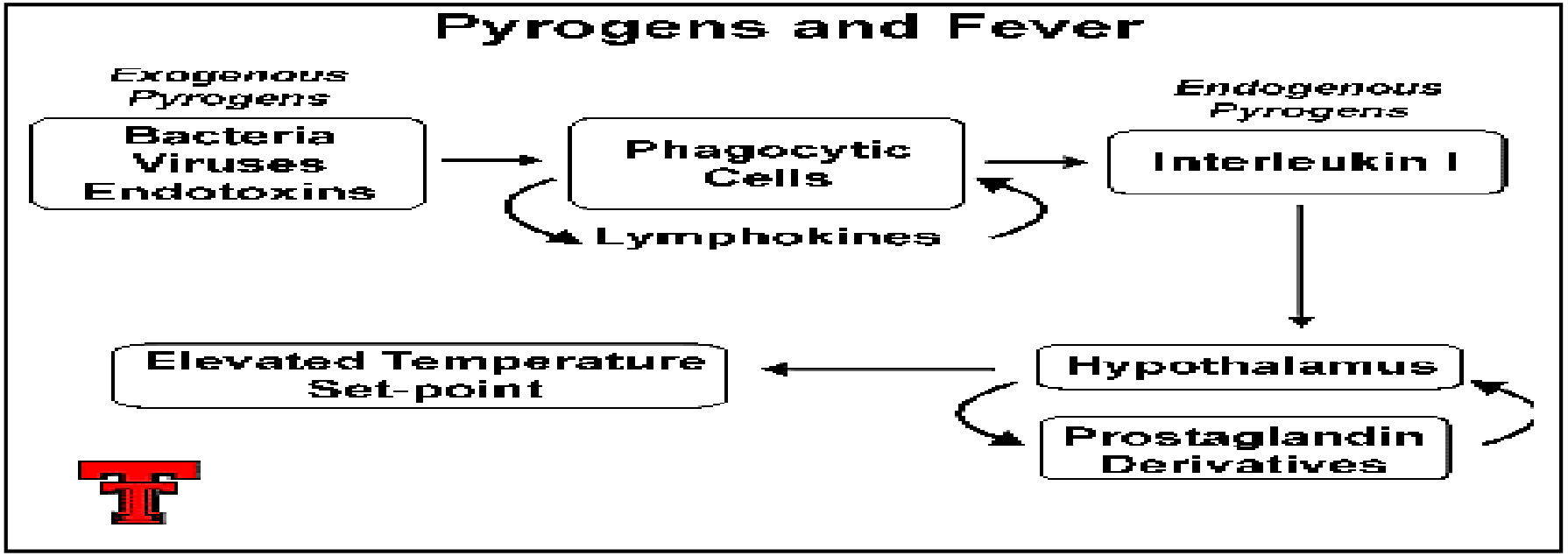
Febrile conditions:

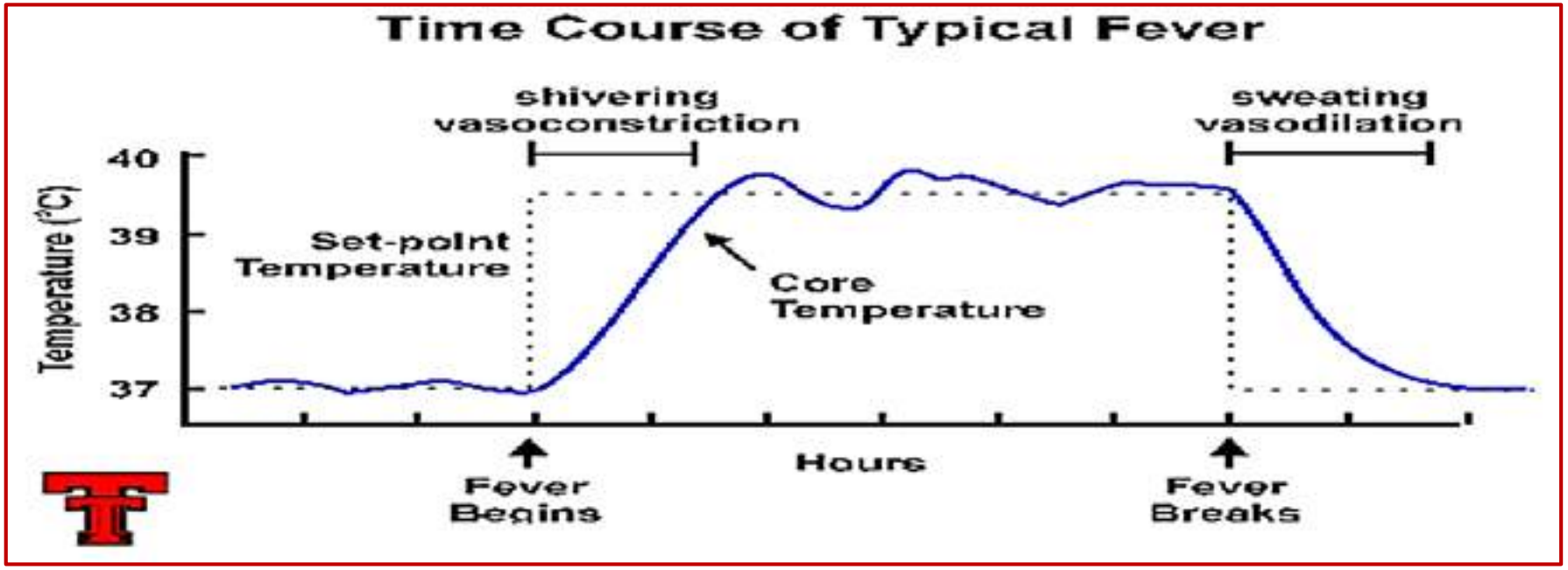
- **Substances that cause** the **set-point of the hypothalamic thermostat to rise (resetting)** are called **pyrogens**.
- When **bacteria or breakdown products of bacteria** are present in the tissues or in the blood, they are **phagocytized by the blood leukocytes and by tissue macrophages**. All these cells digest the bacterial products and then release substance called **endogenous pyrogen (EP)**—into the body fluids. **Endogenous pyrogen** on reaching the hypothalamus, immediately activates the processes to **produce fever**.
- At least three peptides, interleukin 1-beta (IL-1b), interleukin 6 (IL-6), and tumor necrosis factor-alpha (TNF-a), are now known to function as EPs.
- Several experiments have suggested that EP causes fever by first inducing the formation of **prostaglandins (PGs)** which act in the hypothalamus to elicit the fever reaction. This may be the explanation for the manner in which **aspirin reduces fever**, because aspirin inhibits the formation of prostaglandins. **Drugs such as aspirin that reduce fever are called antipyretics**.

- The **set-point** of the hypothalamic temperature-regulating center becomes **higher than normal** while the thermoreceptors signal that the actual body temperature is below the new set point.
- Accordingly, all the mechanisms for raising the body temperature are brought into play, including heat conservation and increased heat production **(anti-drop effect)**.
- **Decreased heat loss: Vasoconstriction of skin blood vessels** and contraction of piloerector muscle → goose skin → **decrease non-evaporative heat loss + curling up in bed and covering the body with blankets**.
- **Increased heat gain:** By **shivering**.

This produces a chilly (cold) sensation.

- Within a few hours after the set-point has been increased, the body temperature also approaches this level. So, the net effect is a rise in the body temperature to a new set point which is maintained so long as the pyrogen exists.
- **When recovery occurs:** The pyrogen disappears and the set point returns to its normal level. The **patient feels hot** and **anti-rise measures** occurs → **sweating and vasodilatation of skin blood vessels (Crisis or flush)**→ increase evaporative and non- evaporative heat loss mechanisms → drop of body temperature to normal.


Pyrogens and Fever
Exogenous Pyrogens
Bacteria
Viruses
Endotoxins
Phagocytic Cells
Lymphokines
Endogenous Pyrogens
Interleukin I
Hypothalamus
Prostaglandin Derivatives
Elevated Temperature Set-point


Time Course of Typical Fever
shivering vasoconstriction
sweating vasodilation
40
39
38
37
Temperature (°C)
Set-point Temperature
Core Temperature
Hours
Fever Begins
Fever Breaks

Hyperthermia

- **Elevation of body temperature beyond the normal range without a change in the temperature set point**.
- The most common cause of hyperthermia in a typical person is **exercise**. **The increase in body temperature above set point is due to the internal heat generated by the exercising muscles**.
- Heat production increases immediately during the initial stage of exercise and exceeds heat loss, causing heat storage in the body and an increase in the core temperature.
- This increase in core temperature triggers reflexes that cause increased heat loss.
- In some situations, hyperthermia may lead to life-threatening consequences.

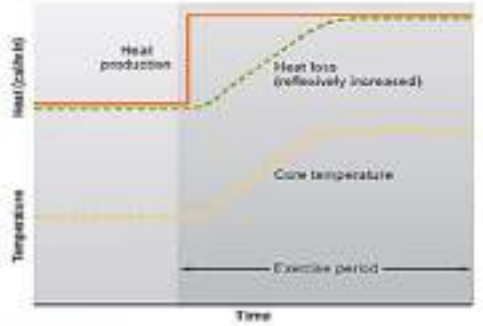


Figure 16.20 Thermal changes during exercise. Heat loss is reflexively increased. When heat loss once again equals heat production, core temperature stabilizes.

HEAT STROKE

- ✓ Heat stroke is the most severe form of heat exhaustion and is a life-threatening emergency.
- ✓ It is a condition that develops rapidly and requires immediate medical treatment.
- ✓ It occurs when the **rate of heat production exceeds that of heat loss**.
- ✓ Heat strokes occurs in **hot humid** atmosphere.
- ✓ **All mechanisms of heat loss** are **not functioning**.
- ✓ There is excessive sweating but **sweat doesn't evaporate** (only drips from the body).
- ✓ The body temperature is increased with dehydration and salt loss and may be circulatory shock (due to excessive sweating).
- ✓ Depression of thermoregulatory center may also occurs. It leads to more increase in body temperature →→ more depression of thermoregulatory center and a vicious circle develops leading to serious increase in body temperature, **(positive feedback mechanism)**.
- ✓ **If body temperature exceeds 43°C**, it is **fatal** due to denaturation of cellular proteins and permanent damage of the CNS (degeneration of cells allover the body especially in brain).

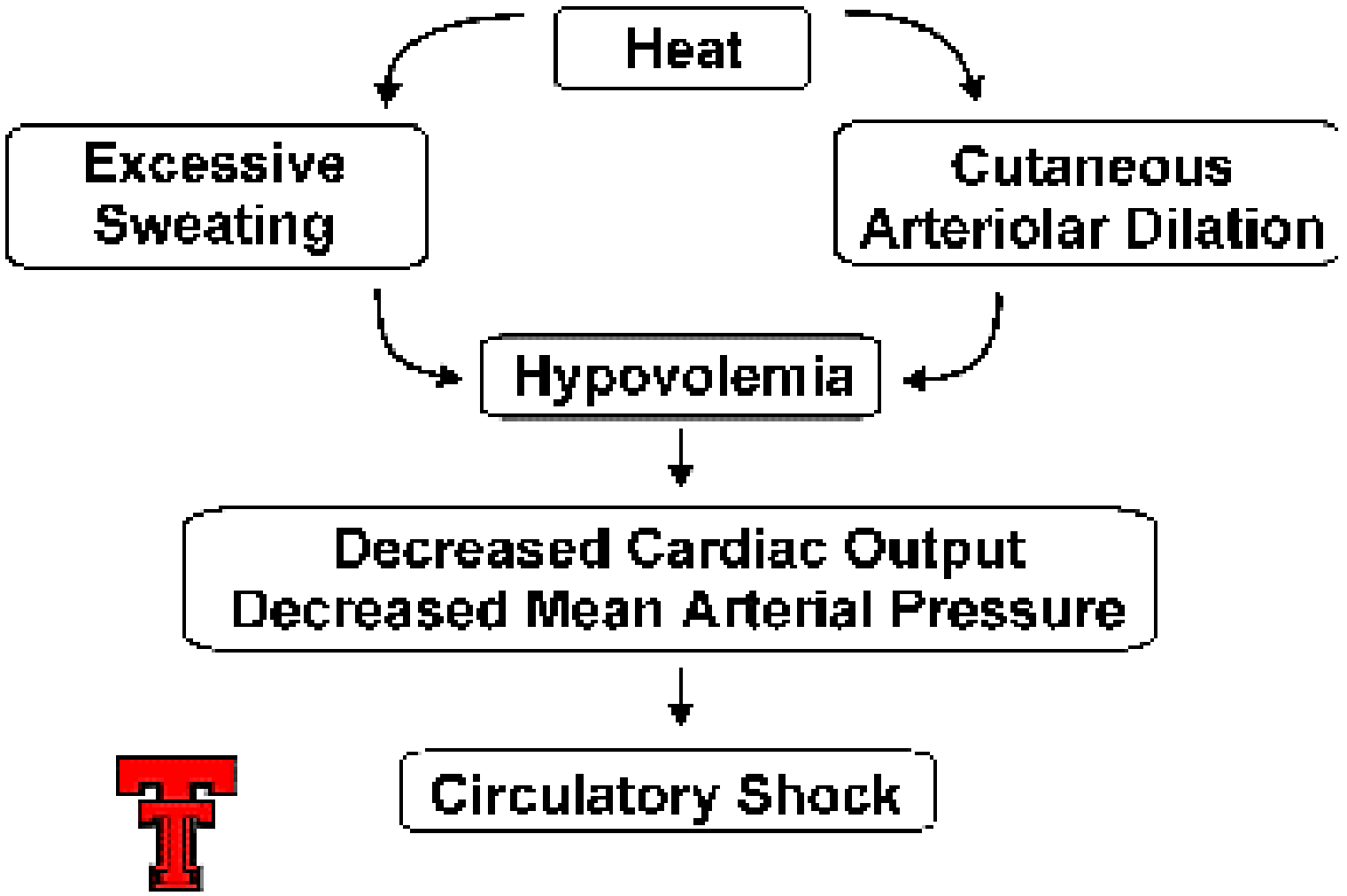
What are the symptoms of heat stroke?

The following are the most common symptoms of heat stroke. However, each individual may experience symptoms differently.

Symptoms may include:

- A high body temperature.
- Headache.
- Blurring of vision.
- Disorientation or confusion.
- Hot flushed skin.
- Rapid heartbeat.
- Hallucinations.
- Dehydration and salt loss →circulatory shock.
- Loss of consciousness.

Development of Heat Exhaustion



Treatment :

There are some immediate first-aid measures including the following:

- **External Cooling:**

Rapid cooling of the body by placing the person in a cold water bath OR Sponging with alcohol (which rapidly evaporates).

- **Fluid replacement:**

Intravenous (IV) fluids are often necessary to compensate for fluid or electrolyte loss.

- **Cessation of activity.**

Sunstroke

- It is similar to heat stroke but it is produced by prolonged direct exposure to sun rays.
- In addition to the manifestations of the heat stroke, the falling sun rays on the back of the neck and skull have a damaging effects on the brain and spinal cord by the local heating effect they produce.

Hypothermia

✓ **Definition:**

Hypothermia is a decrease in body temperature below 35°C.

✓ **Causes:**

Conditions in which heat loss is greater than heat gain:

- Prolonged exposure to cold.
- Alcohol intoxication.

✓ **Effects:**

- Most tissues tolerate hypothermia and ↓ their rate of metabolism and physiological processes slow down (↓HR, RR and ABP).
- It usually produces no ill effects and the person returns to normal condition if re-warmed within a certain period with external heat.
- However, the **thermoregulatory center is depressed in severe cases→ more hypothermia (positive feedback mechanism)** → sleepiness, coma and death.


Thank
you