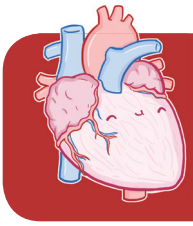

NOTES
THERMOREGULATION

CARDIOVASCULAR TEMPERATURE HOMEOSTASIS

osms.it/cardiovascular-temperature-homeostasis

NORMAL BODY TEMPERATURE

- 37 ± 0.5 °C (98.6 ± 0.9 °F)
- Hypothalamic thermoregulatory center acts as a thermostat
  - Sets temperature set-point
- Thermoreceptors
  - Peripheral (in skin) → sense surface temperature
  - Central (in the body core—e.g. hypothalamus itself) → sense core temperature
- Temperature variations activate thermoreceptors → thermoreceptors inform hypothalamus → hypothalamus activates heat regulation mechanisms → temperature returns to baseline
- Body region variations
  - *Core:* higher temperature, more stable
  - *Skin:* lower temperature, more variable
- Core temperature varies with throughout the day
  - Lower during sleep
  - Higher when awake

BODY TEMPERATURE MAINTENANCE

- Body temperature maintained by balancing heat-generation, heat loss

Heat generation

- Activation of sympathetic nervous system
  - Vasoconstriction of skin arterioles → blood bypasses skin → ↓ heat loss
  - Adrenal glands release catecholamines (epinephrine, norepinephrine) → increased metabolic rate → ↑ heat production
  - Piloerection (goosebumps) → heat trapping
- Thyroid hormones released from hypothalamus → ↑ metabolic rate → ↑ heat production
- Non-shivering thermogenesis using brown adipose tissue
  - Activation of primary motor center for shivering in the posterior hypothalamus → skeletal muscle contraction → shivering → ↑ heat production
  - Behavioral changes (adding garments, tightening the arms across the chest, moving around)

Heat dissipation

- Inhibition of sympathetic activity in skin blood vessels → blood goes to skin → ↑ heat loss
- Activation of sympathetic cholinergic fibers innervating sweat glands → ↑ sweating → ↑ heat loss
- Behavioral changes (removing garments, reducing movements, fanning air over body)

Fever

- Body temperature elevation due to change in hypothalamic set-point
- Pyrogens act on hypothalamus → hypothalamus releases prostaglandins → hypothalamic set-point temperature increases → heat-generating mechanisms kicks in → body temperature rises and

reaches new baseline temperature
    - Aspirin reduces fever by inhibiting prostaglandins production
- Benefits of fever
    - Inhibit bacterial growth by making growing conditions less favorable
    - Increase efficiency of immune cells

HYPERTHERMIA

- Elevation of body temperature without change in hypothalamic set-point
- Normal mechanisms of thermoregulation are overwhelmed by various factors
    - Excessive environmental temperature
    - Impaired ability to dissipate heat
    - Excessive heat production

Heat exhaustion

- Excessive sweating → significant water and electrolyte loss → ↓ blood volume → ↓ arterial pressure

Heat stroke

- Hyperthermia > 40°C/105.1°F
- Potentially fatal
- Causes
    - High environmental temperature
    - Periods of intense physical activity
- Risk factors
    - *Susceptible individuals:* infants, children (higher metabolic rate; ineffective sweating; physical, psychological limitations); elderly (pre-existing conditions; physical, psychological limitations)
    - *Medications:* ones that inhibit heat-dissipating mechanisms (beta blockers, diuretics)

Malignant hyperthermia

- Genetic alteration of ryanodine receptor 1 (*RYR1*) in the muscle cells
- *Normally*: cell depolarization → *RYR1* activation → calcium release from sarcoplasmic reticulum into cytoplasm → muscle contraction
- *In malignant hyperthermia:* cell depolarization → *RYR1* hyperactivation → excessive calcium release → inappropriate muscle contraction, ↑↑ metabolic rate → excessive heat production
- Triggered by drugs
    - *Anesthetic gas:* Alothane, Sevoflurane, Desflurane
    - *Depolarizing muscle relaxants:* Succinylcholine, Decamethonium
- Potentially fatal
- Treatment
    - Dantrolene (skeletal muscle relaxant)

HYPOTHERMIA

- Abnormally low temperature
    - *Diagnosis:* core temperature < 35°C/95°F
- Compensatory mechanisms responding to cold stress are overwhelmed
- ↓ core body temperature → ↓↓ metabolic rate → myocardial irritability, cold diuresis (↓ renal blood flow, water resorption)
    - Progressive oliguria as ↓ core temperature → ↓ intravascular volume, ↑ hematocrit, central nervous system depression

Risk factors

- Prolonged cold exposure
    - E.g. inadequate clothing/shelter, cold water immersion
- Impaired thermoregulation
    - E.g. hypothalamic dysfunction, metabolic derangement
- ↑ heat loss
    - Multisystem trauma, shock, spinal cord transection
- Iatrogenic
    - Cold IV fluid administration, inadequate operating room warming
- ↑ risk populations
    - Older adults (↓ physiologic reserve, ↓ sensory perception, chronic medical conditions)
    - Children (↑ body surface area to body mass ratio, ↓ glycogen stores, young infants unable to use shivering thermogenesis)

Complications

- Cardiac arrhythmias, myocardial infarction, pulmonary edema, pulmonary embolism, lactic acidosis, disseminated intravascular coagulation (DIC), coma, death

Signs & symptoms

- Mild hypothermia
  - Core temperature 32–35°C/90–95°F
  - Shivering, tachypnea, tachycardia, confusion
- Moderate hypothermia
  - Core temperature 28–32°C/82–90°F
  - ↓ shivering and muscle rigidity, hypoventilation, bradycardia, ↓ cardiac output, lethargy, arrhythmias, loss of pupillary reflexes
- Severe hypothermia
  - Core temperature < 28°C/82°F
  - Apnea, ↓ cardiac activity → ventricular arrhythmias → asystole, coma, loss of ocular reflexes, ↓↓ metabolic rate

Rewarming treatment

- Warmed blankets/forced warm-air system; heated, humidified oxygen; warmed crystalloid IV fluid; pleural, peritoneal lavage using warm saline solution; vasopressors
- Extracorporeal blood rewarming
  - Venovenous rewarming, hemodialysis, continuous arteriovenous rewarming (CAVR), cardiopulmonary bypass (CPB), extracorporeal membrane oxygenation (ECMO)