Physiology - Topic 12 - Integrated Physiology

Integration of Physiological Systems

The Body as a Coordinated Whole

- **Integrated physiology** explains how several organ systems work together during a common challenge.
    - Temperature change, exercise, growth, ageing and acute illness all require coordinated responses.
    - A response that helps one variable can place a demand on another system.
    - For example, increased **skin blood flow** helps heat loss but also requires adequate cardiac output and circulating volume.
- Interpret a physiological response in relation to the person, the activity, the environment and the time course.
    - An immediate adjustment and a long-term adaptation are different processes.

Body Temperature and Heat Balance

Core Temperature and Heat Production

Temperature Distribution and Variation

Core and Skin Temperatures

- **Core temperature** reflects the temperature of deeper tissues, while skin temperature varies more widely with the environment.
- Temperature depends on the measurement site, time of day, activity and physiological state.

Measurement and Normal Variation

- A value near 37°C is a useful central reference, but normal **temperature** is not one fixed number.
- Oral, axillary, tympanic and rectal measurements are not directly interchangeable.
- **Temperature** is usually lower during the early morning and higher later in the day.
- Progesterone can produce a small rise in basal temperature after ovulation.

Metabolic Heat Production

Shivering and Non-Shivering Thermogenesis

- **Heat** is produced by metabolism, particularly in active muscle and metabolically active organs.
- Shivering increases skeletal-muscle activity, while non-shivering thermogenesis produces heat without visible shivering.

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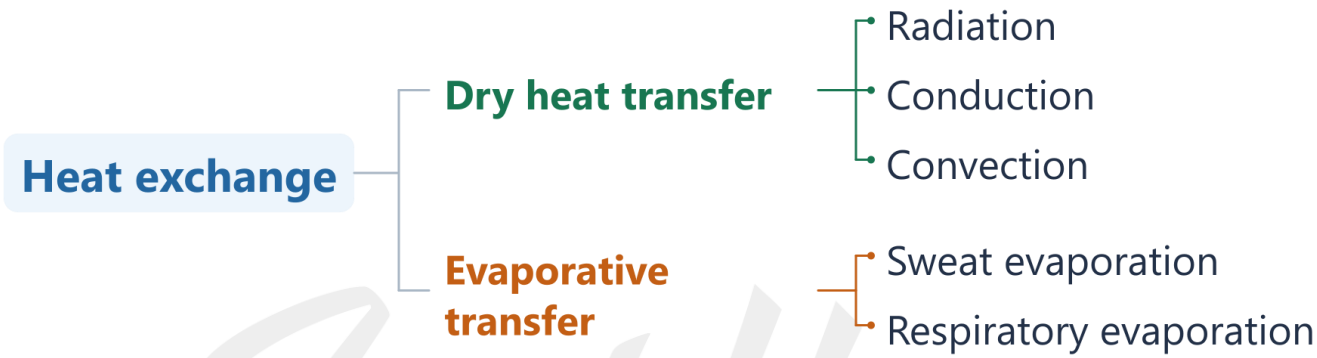
Brown Adipose Tissue

- **Brown adipose tissue** uses uncoupling protein 1 to release energy as heat.
- This mechanism is particularly important in newborns and can also be active to varying degrees in adults.

Heat-Balance Equation

- Body heat storage reflects **metabolic heat production minus external work and net heat loss**.
- At a steady core temperature, heat production and heat transfer to the environment are balanced.

Routes of Heat Exchange



1. Radiation

- **Radiation** transfers heat through electromagnetic energy without direct contact.
  - A warm person can lose heat to cooler surrounding surfaces even when the air is still.
  - Radiant **heat** from the sun or a hot surface can instead add heat to the body.
  - Therefore, air temperature alone does not describe the whole thermal environment.

2. Conduction

- **Conduction** transfers heat through direct contact.
  - Heat moves from the warmer material to the cooler material at the contact surface.
  - Water conducts **heat** away from the body much more effectively than still air.
  - Wet clothing and cold-water immersion can therefore accelerate cooling.

3. Convection

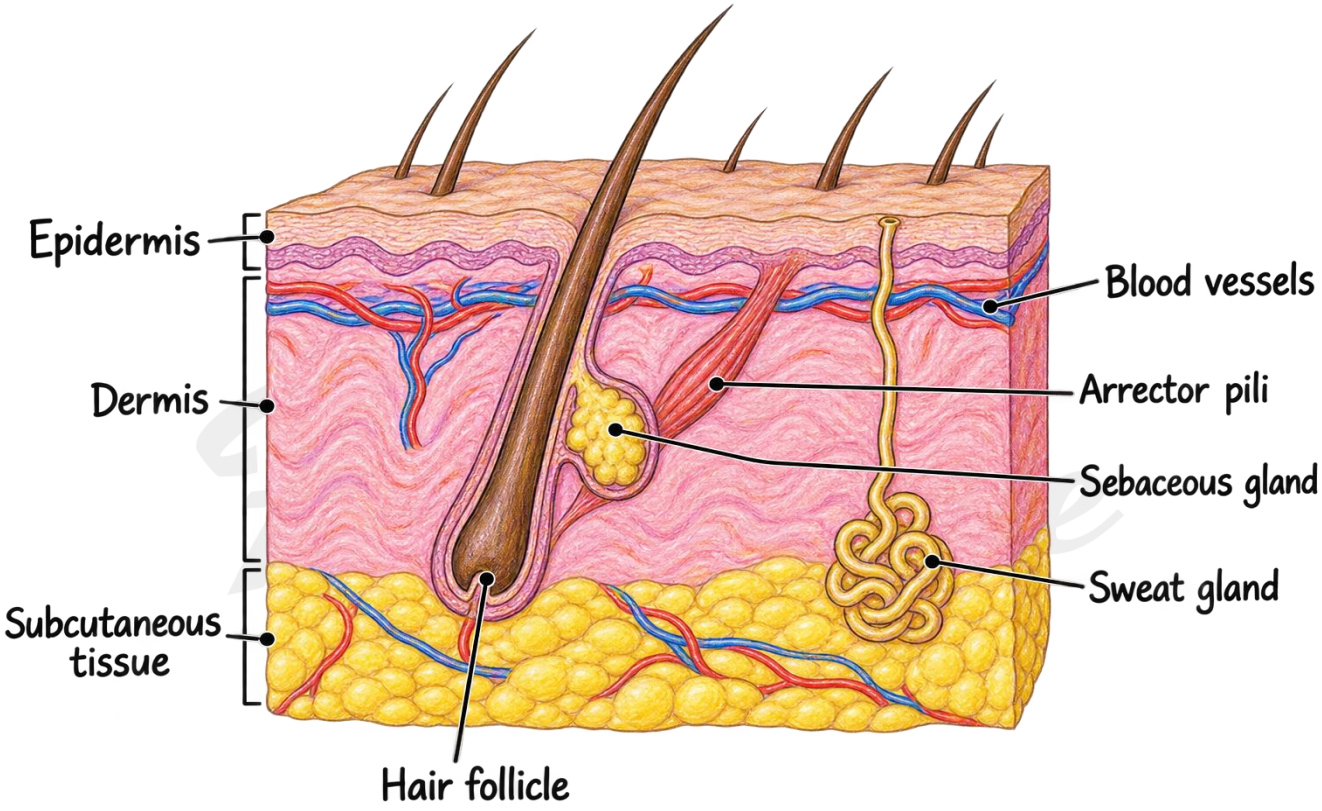
- **Convection** transfers heat as moving air or water carries warmed material away from the skin.
  - Wind can increase this heat loss when the surrounding medium is cooler than the skin.

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4. Evaporation

- **Evaporation** removes heat when water changes into vapour.
  - Sweating cools the body only when sweat evaporates; sweat that drips away contributes much less cooling.
  - High **humidity** limits evaporation because the surrounding air already contains substantial water vapour.
  - When the environment is hotter than the skin, evaporation becomes especially important because other routes may produce heat gain.

Thermoregulatory Control



Skin blood vessels and sweat glands contribute to temperature regulation

Sensors and Integrating Centres

Thermal Sensors

- **Temperature**-sensitive receptors in the skin and deeper tissues provide information about thermal conditions.
- Preoptic and other hypothalamic networks integrate this information with temperature-sensitive central activity.

Integrated Effector Responses

- The system coordinates autonomic, endocrine, somatic and behavioural responses.
- **Behaviour**, such as seeking shade or adding clothing, is often the first effective adjustment.

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Responses to Heat

Skin Blood Flow

- Increased skin blood flow transfers more core heat to the surface.

Sweat Formation

- Eccrine sweat glands receive sympathetic **cholinergic** stimulation, which is an important exception to the usual adrenergic pattern of sympathetic postganglionic transmission.
- **Sweat** is produced from a secretory fluid that is modified as it passes along the duct.
- Ductal salt reabsorption usually makes the final sweat hypotonic relative to plasma.
- At high **sweat** rates, there is less time for salt reabsorption, so sweat tends to contain more sodium.
- Heat acclimatisation improves salt conservation as well as sweating capacity.

Responses to Cold

Vasoconstriction and Thermogenesis

- **Cutaneous vasoconstriction** reduces blood flow near the surface and limits heat loss.
- Shivering and increased metabolic heat production help defend core temperature.

Behaviour and Insulation

- **Piloerection** has little insulating value in humans because body hair is sparse.
- Clothing, shelter and voluntary movement are much more effective behavioural responses.

Adaptation to Heat and Cold

Acclimatisation and Vulnerability

Responses to Repeated Environmental Exposure

A. Heat Acclimatisation

- **Heat acclimatisation** develops with repeated exposure over days to weeks.
- Sweating starts earlier, sweat production becomes more effective, plasma volume may expand and cardiovascular strain falls at a given workload.
- **Aldosterone** contributes to salt conservation.
- Adaptation is incomplete if the person cannot replace fluid losses, rest or use suitable environmental protection.

B. Cold Adaptation

- **Cold adaptation** varies with the pattern of exposure and may involve behavioural, vascular and metabolic changes.

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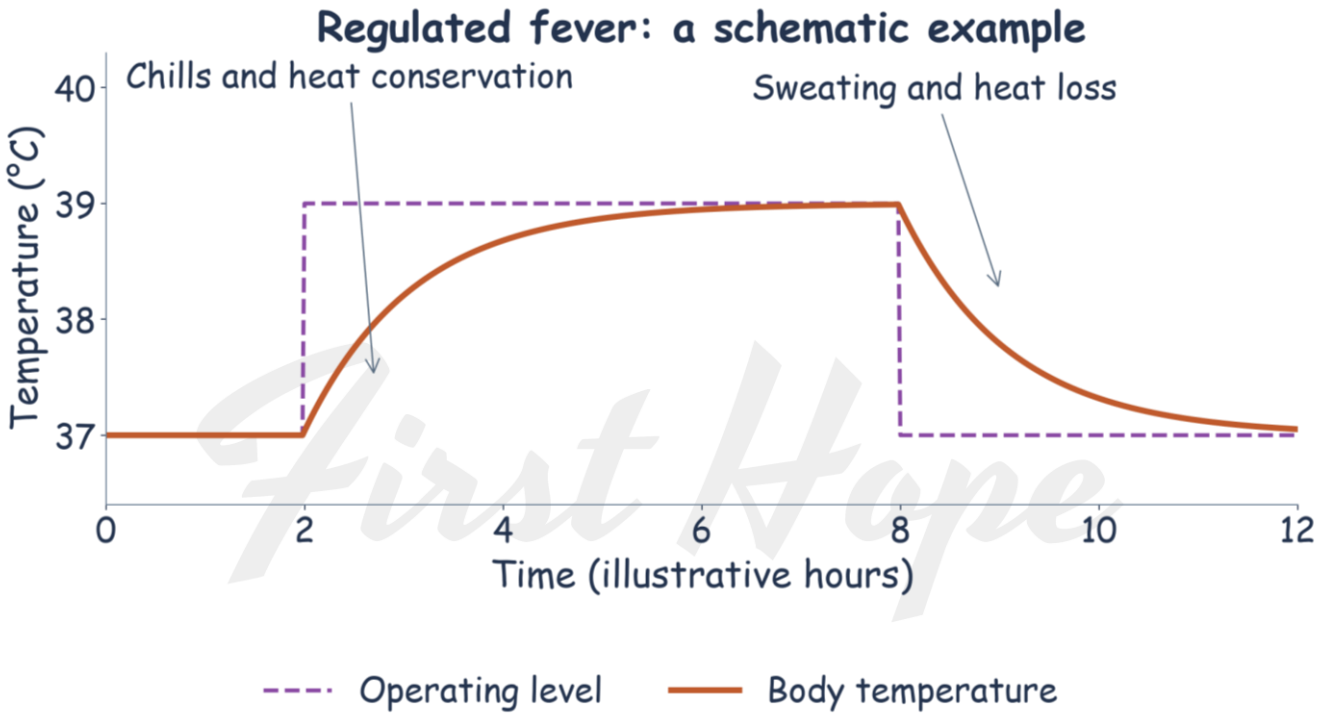
- It does not make a person immune to hypothermia or local cold injury.

Groups with Reduced Thermal Reserve

- Infants, older adults and people with impaired mobility or illness may have less effective thermal defence.
  - Medicines, **dehydration** and alcohol can also alter responses to heat or cold.

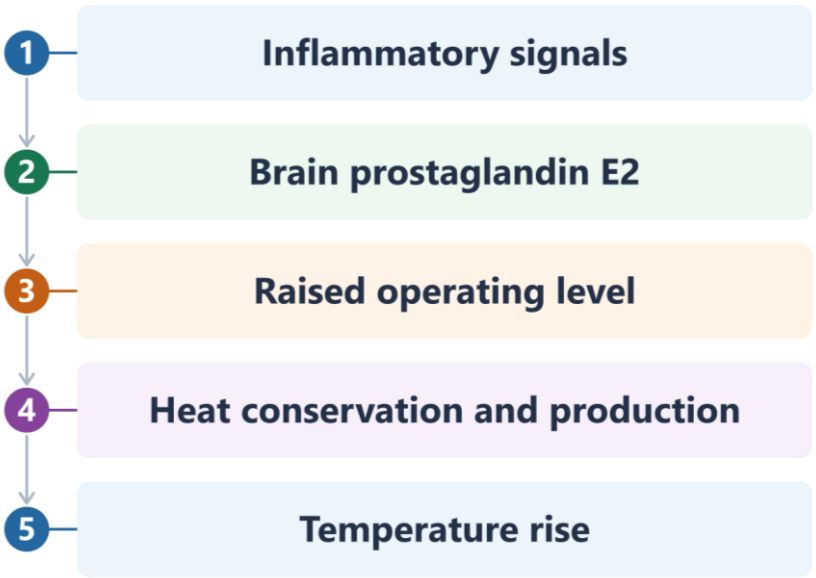
Fever

Mechanism, Phases and Consequences



A schematic fever response showing the changing operating level and body temperature

Raised Thermoregulatory Set Point



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