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Thermoregulation

Physiology II lecture (aVLFY0422p)

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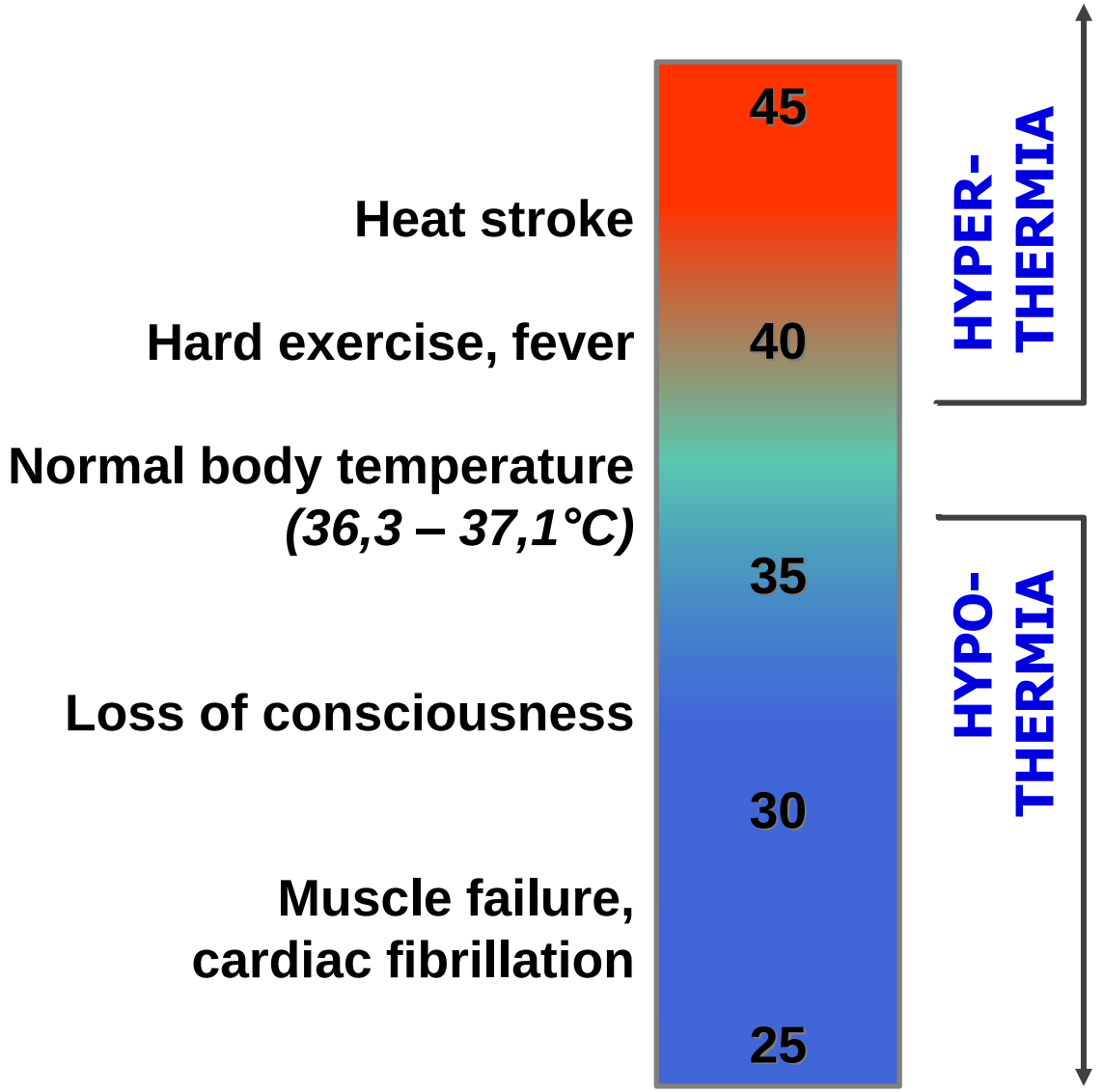
Body temperature – homeostatic parameter



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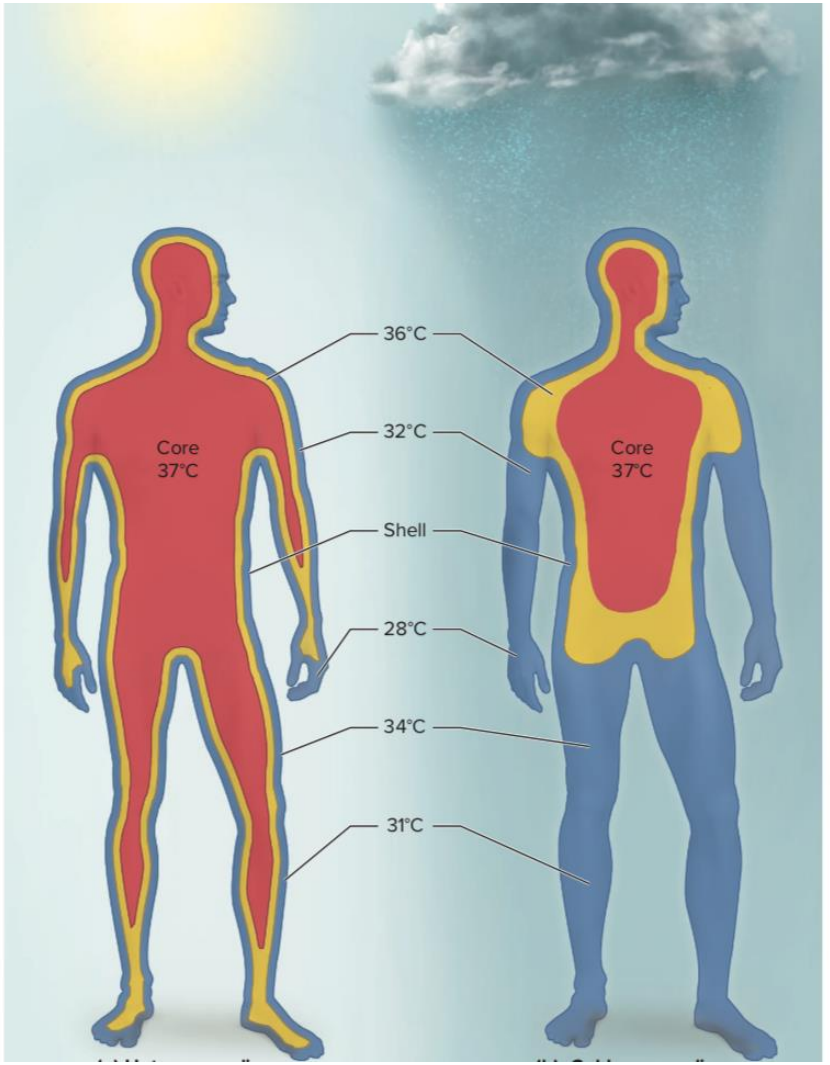
Body core vs. shell

- homeotherms vs. poikilotherms
- Body core temperature – regulated within certain (narrow) range
- Skin temperature (shell) – more variable (ambient t., core body t.)



Adopted from: K.S. Saladin, *Anatomy & Physiology—The Unity of Form and Function,* 8th ed. (McGraw-Hill, 2018)

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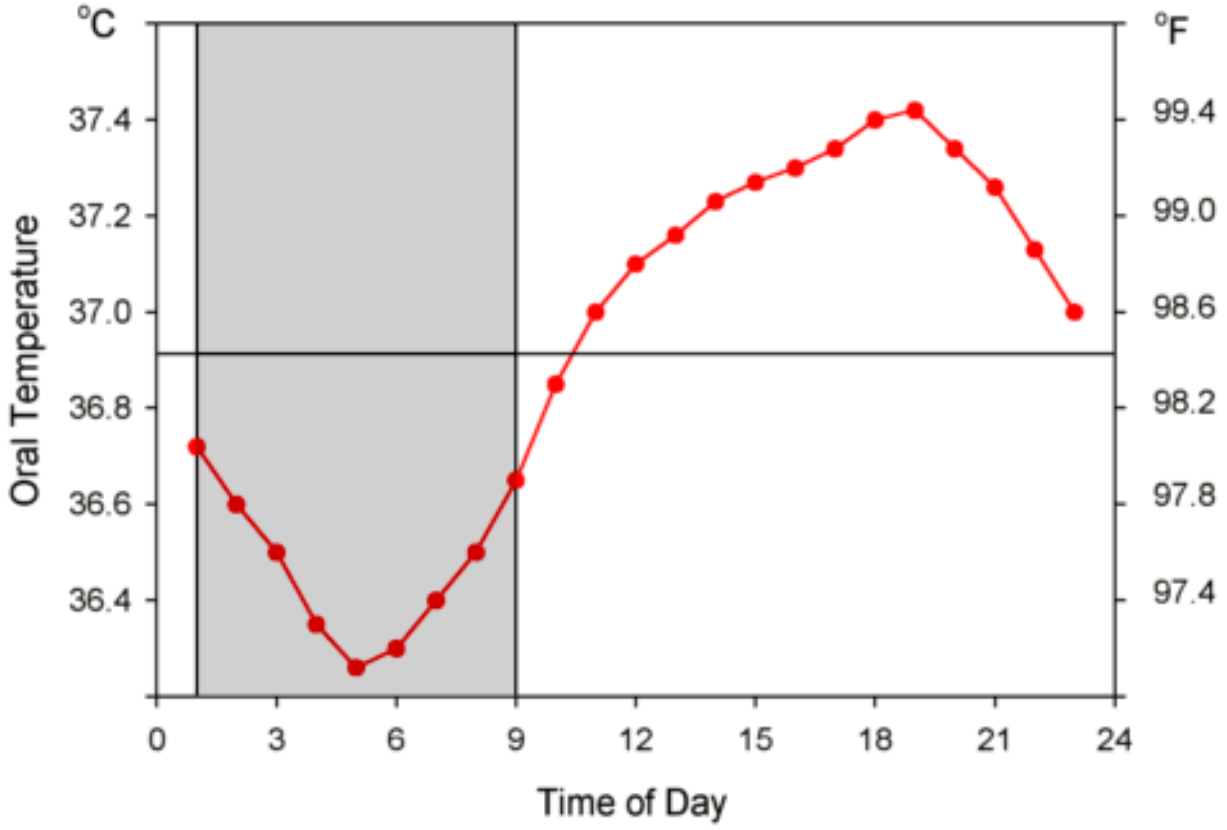
Variations of body core temperature

- Circadian rhythm
- Circamensal rhythm (women between puberty and menopause)
- Seasonal variations (circannul rhythm)
- Ageing



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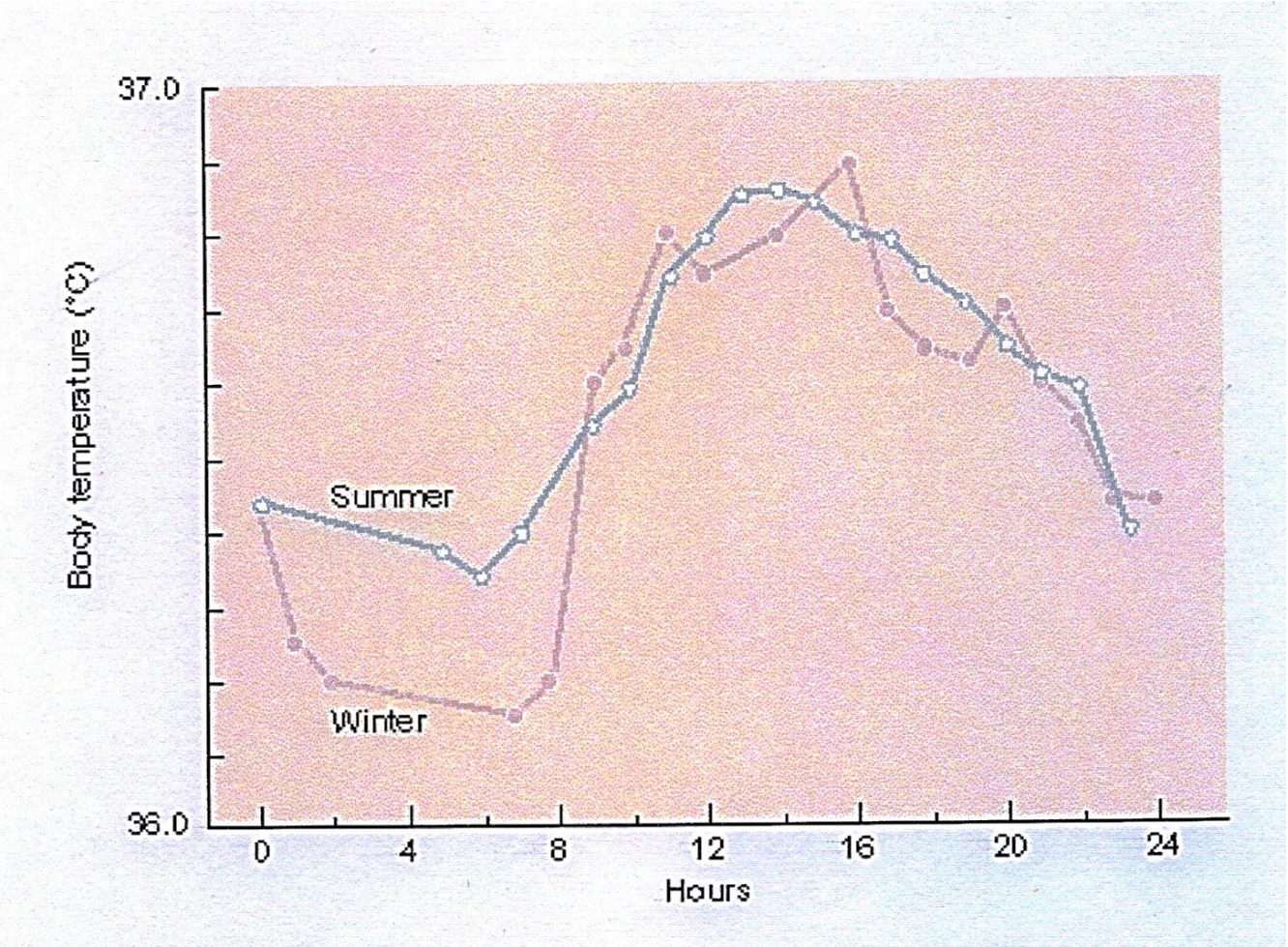
Variations of body core temperature



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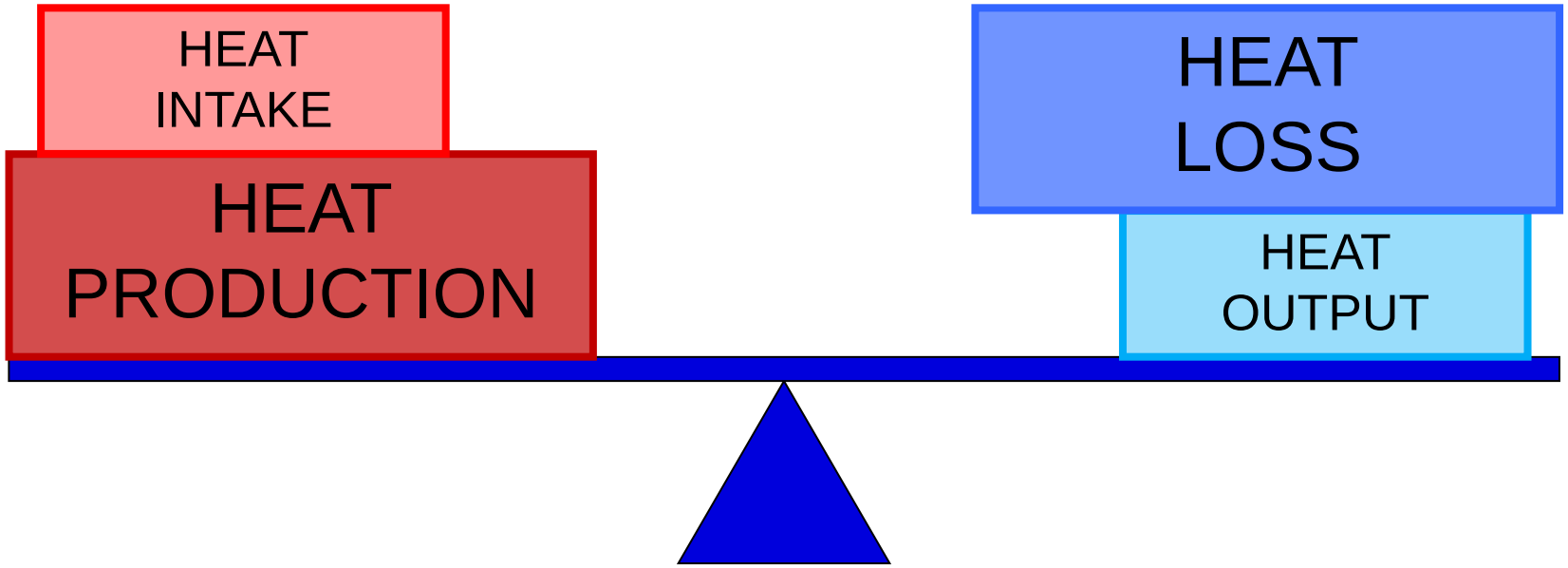
Heat vs. temperature

- **Heat [J]** – energy transfered to or from the system; measure of the internal energy state

- **Temperature [K, °C, °F]** – a measure of heat content; mean kinetic energy of the particles (molecules, ions)

A fine balance of body core temperature



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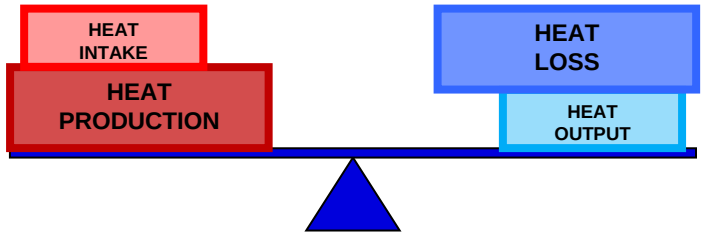
Heat production



- Metabolism: metabolic rate ≈ heat production
- Physical activity (active muscle contraction) – rest vs. exercise
- Postprandial thermogenesis (food intake)
- Shivering thermogenesis
- Non-shivering thermogenesis (brown adipose tissue)

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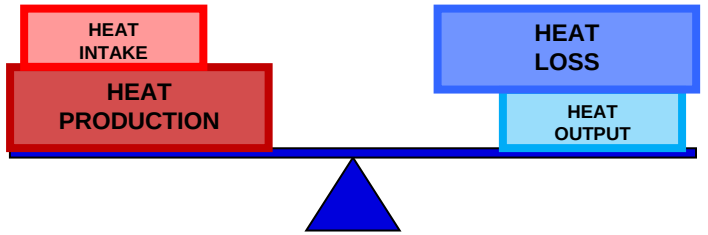
Transfer of heat within the body

- primarily by **CONVECTION**
- medium = blood

- minor amount by **CONDUCTION**
- direct contact of organs/tissues

Heat intake and loss



- passive processes

- RADIATION
- CONVECTION
- CONDUCTION

- skin-environment temperature gradient

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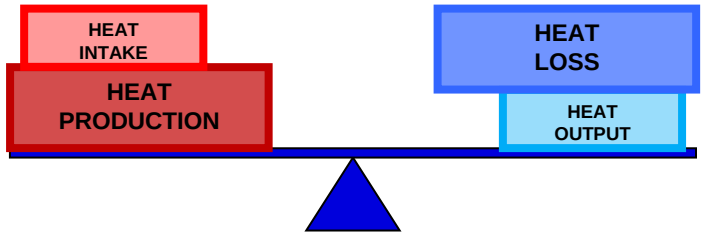
Heat output (active loss)



- EVAPORATION
- sensible perspiration = sweat production (*1 L of evaporated s. = 2 428 kJ*)
- insensible perspiration = diffusion of water through skin and mucosae

- from the skin to the environment
- (RADIATION)
- (CONDUCTION)
- (CONVECTION)

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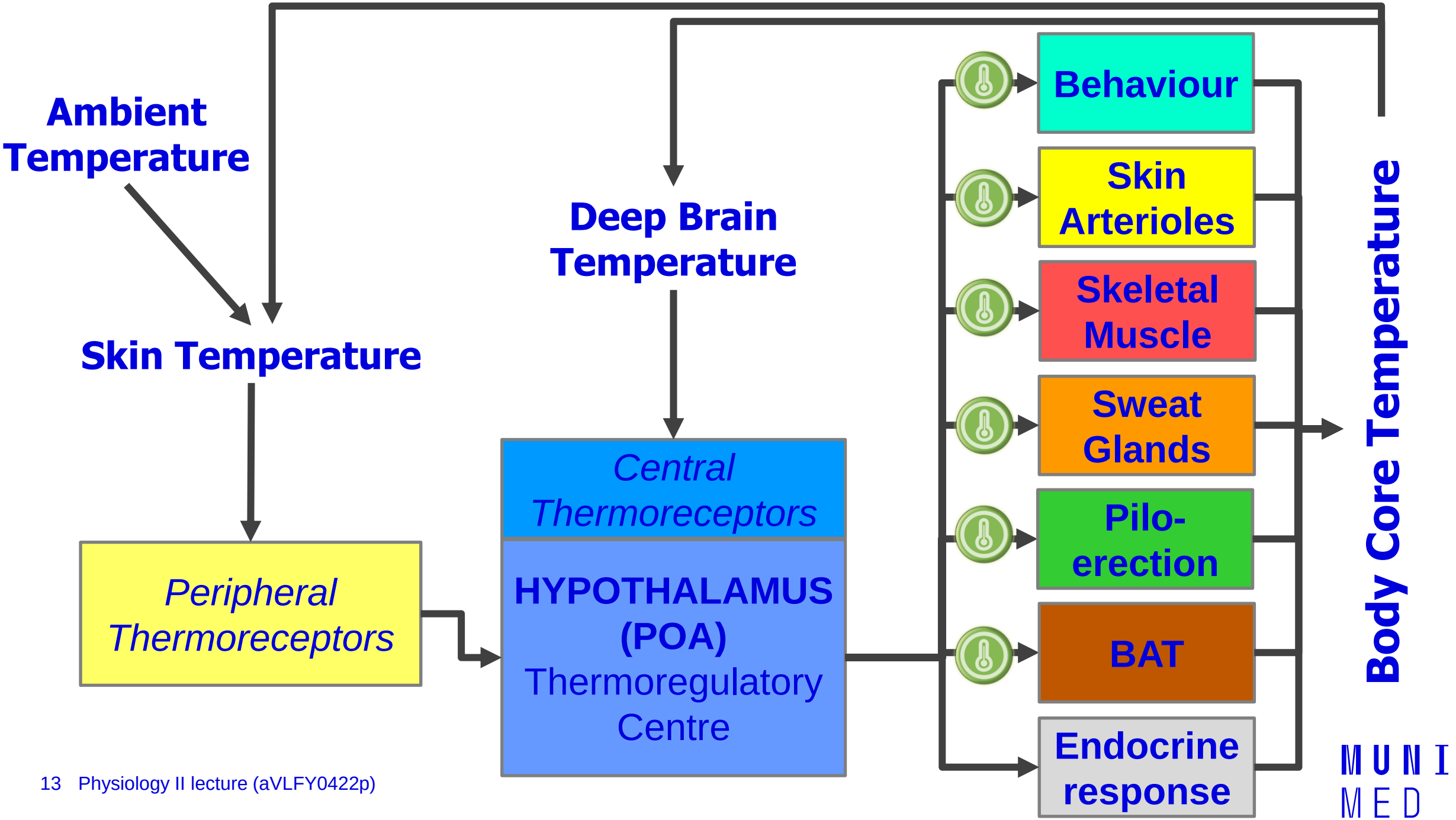
Thermoregulation

- All processes involved in keeping the body core temperature within the range
- Thermoregulatory behaviour
- Social thermoregulation


Ambient Temperature
Skin Temperature
Deep Brain Temperature
Peripheral Thermoreceptors
Central Thermoreceptors
HYPOTHALAMUS (POA)
Thermoregulatory Centre
Behaviour
Skin Arterioles
Skeletal Muscle
Sweat Glands
Pilo-erection
BAT
Endocrine response
Body Core Temperature

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Afferentation - thermoreceptor

- Central thermoreceptors – deep brain temperature
  - temperature-sensitive neurons in anterior preoptic hypothalamus

- Peripheral thermoreceptors
  - Skin thermoreceptor - skin temperature

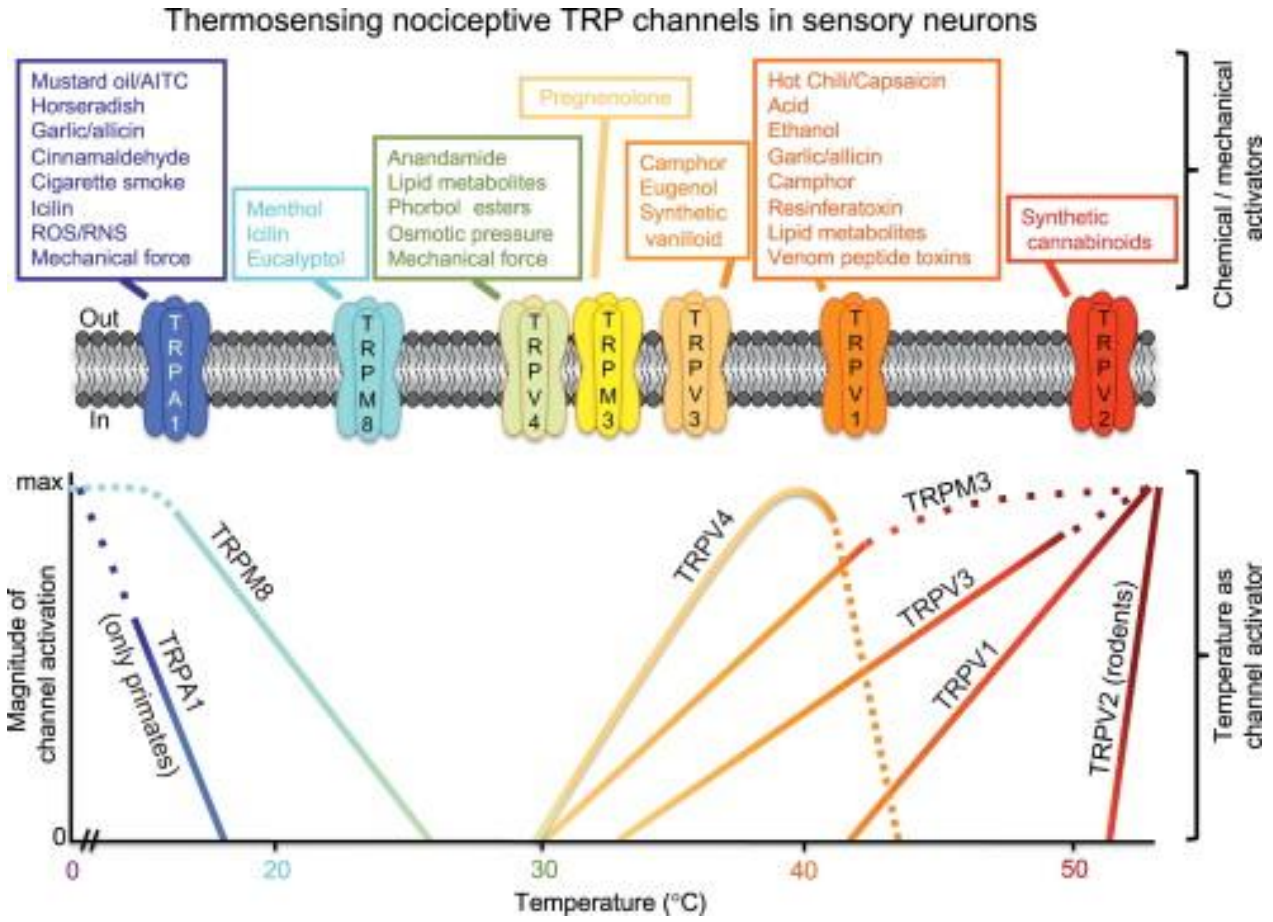
  - Thermoreceptors in GIT
  - Thermoreceptors in liver and other organs
  - Thermoreceptors in skeletal muscles

Adopted from:: https://doi.org/10.1016/bs.pmbts.2015.01.002

Principle of thermorecetion: TRP channels

- Protein superfamily
- Mixed cation channels
- Activation leads to membrane depolarization

- Polymodal
- **Thermosensitive**



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Thermoregulatory centre

- anterior preoptic HYPOTHALAMUS

- integration of afferent information
- modifying the efferent pathways (vegetative, somatic) to the thermal effectors

- „set-point“ vs. threshold temperature for the effector(s)

Thermal effectors

- Behaviour
- Cutaneous circulation
- Sweat glands
- Skeletal muscles (voluntary movements, shivering)
- Horripilation
- Brown adipose tissue (nonshivering thermogenesis)

- Role of sympathetic nervous system (*see VLFY0422s demonstration*)

Endocrine reaction in thermoregulation

- **Epinephrin and norepinephrin**
  - Thermogenic effect
  - A part of sympathoadrenal reaction in „cold stress“ (extreme and/or prolonged exposure to cold)

- **Thyroid hormones** (T3 and T4)
  - Thermogenic effect – increase in BMR
  - Subacute / chronic effect
  - Long-term hyper-/hypo-production is involved in adaptation to cold / warm environment

- Indirect relationship with **ADH** and **aldosterone**

Cold-induced thermoregulatory mechanisms

- Decrease of heat loss
  - Behaviour: Decrease of body surface, taking warm clothes
  - Vasoconstriction in the skin. Horripilation
  - Inhibition of sweating
- Increase of heat production
  - Skeletal muscles: Intentional movements (behaviour). Shivering
  - Nonshivering thermogenesis (brown adipose tissue, NA, β3R, UCP1)
  - Hunger (increas of food intake)

Warm-induced thermoregulatory mechanisms

- Increase of heat loss/output
  - Skin vasodilatation
  - Increase of sweating (evaporation)
  - Increase of ventilation
- Decrease of heat production/intake
  - Behaviour: Moving out of the sun, taking light clothes. Inactiveness (decrease of intentional movements), apathy
  - Loss of appetite

Thermoregulation in high humidity

- High humidity decreses rate of evaporation
- Sweating becomes uneffective and leads to water loss
- To dry the skin regularly can increase the effectivity of evaporation (clothing, wiping with towel)

- High risk of overheating and dehydration
- The risk is increased by physical activity!
  - T 35°C and RH >60% is not safe for any phys. activity in non-adapted person

Thermoregulation in physical activity

- Physical activity = increase in heat production
- Physical activity = decrease in the effective volume of circulating fluids
  - Shift of the fluid to interstitial space
  - Loss of fluids by sweating
- **Maintaining the effective volume of circulating fluids (blood pressure) is always preferred over increasing active heat loss (thermoregulation)**
- Body core temperature increases
- Ambient temperature play a crucial role
- Role of sympathetic nervous system (*see VLFY0422s demonstration*)

Thermoregulation in children

- Shifted ration between body surface and overal body mass

- Newborns and children <3 years – uneffective central thermoregulatory mechanisms

- **Higher risk of hyper- and hypo-thermia**
- **Higher risk of dehydration in heat stress**

Thermoregulation in old people

- Decreased skin sensitivity to cold and warm
- Reduced ability to actively release heat
  - Decreasein number and activity of sweat glands
  - Reduced cardiac reserve
- Reduced ability to produce heat
  - Decrease in metabolic rate
  - Reduced muscle mass (sarcopaenia)

- **In old age, reduced ability to thermoregulate leads to greater fluctuations in core temperature**

Thermoregulation and body art

- Body art (tattoos, scarification, subdermal implants) can damage the sweat glands
- If body art covers large areas of skin, it can reduce the body's ability to cool itself
- The organism can thus be at risk of overheating, especially with greater heat stress (exposure to heat, physical activity)
- For elite athletes, body art on large areas of skin can limit performance