Thermoregulation

Exercise in Hot and Cold Environments

Mgr. Tereza Brůžová

Learning objectives

- Why do we need to regulate body temperature?
- How do we regulate body temperature – mechanisms of heat transfer
- How our body gets rid of excess heat?
- How our body minimizes heat loss in cold environments?
- Do factors such as humidity, wind and cloud cover impact when exercising in hot environment?

Thermoregulation

- Humans are endothermic organisms
  - Keep their body temperature within certain range even if the temperature of the environment changes significantly
  - Metabolic processes as a heat source
  - Most heat in generated in the liver, brain, heart, and in skeletal muscles
  - We have systems that decrease or increase our body temperature as needed
- Ectothermic organisms use external energy sources to regulate body temperature

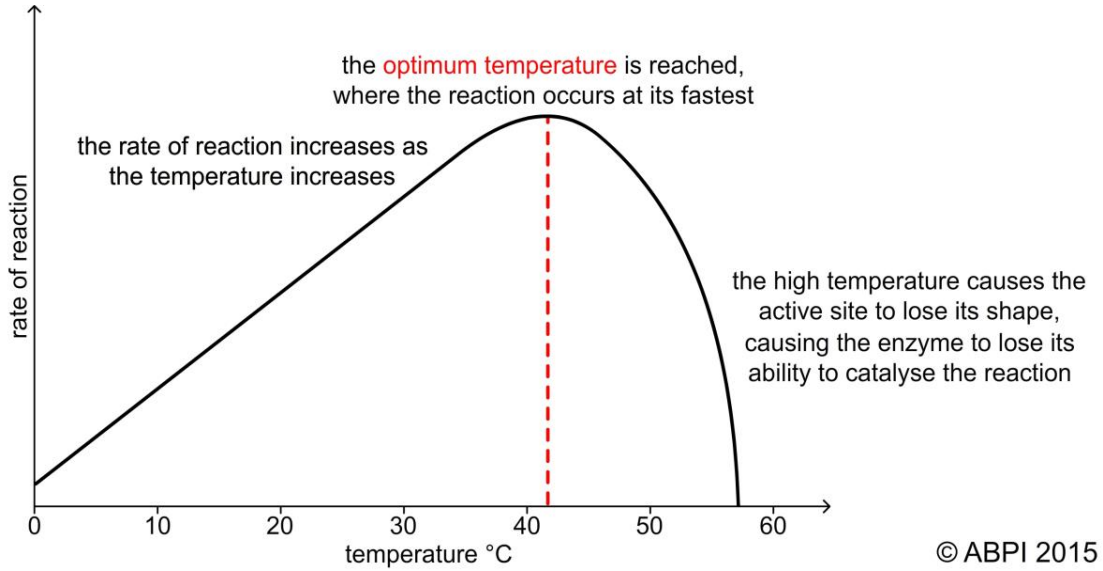
Thermoregulation

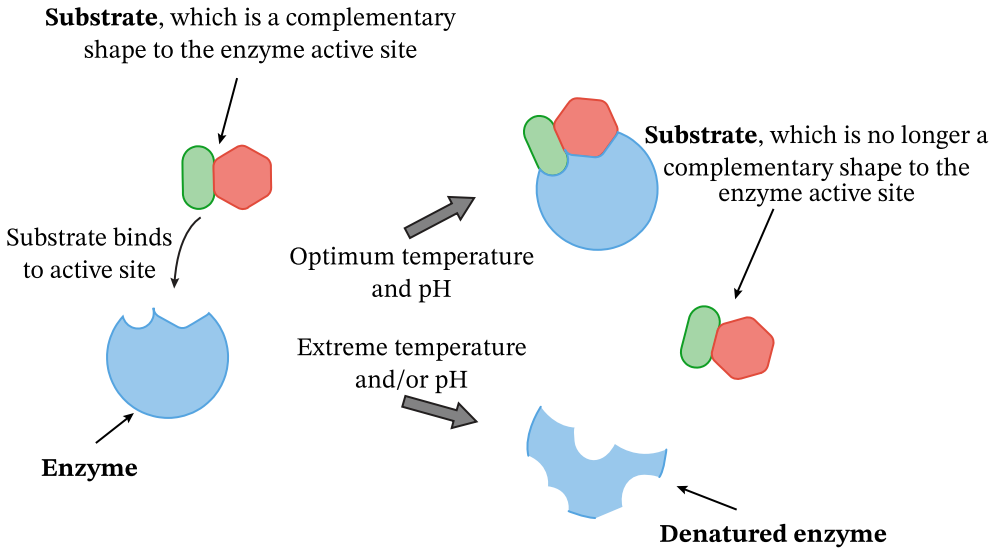
- Is the ability of an organism to control its body temperature

Why is it important?

Thermoregulation

- Is the ability of an organism to control its body temperature
- Temperature influences the speed of biochemical processes

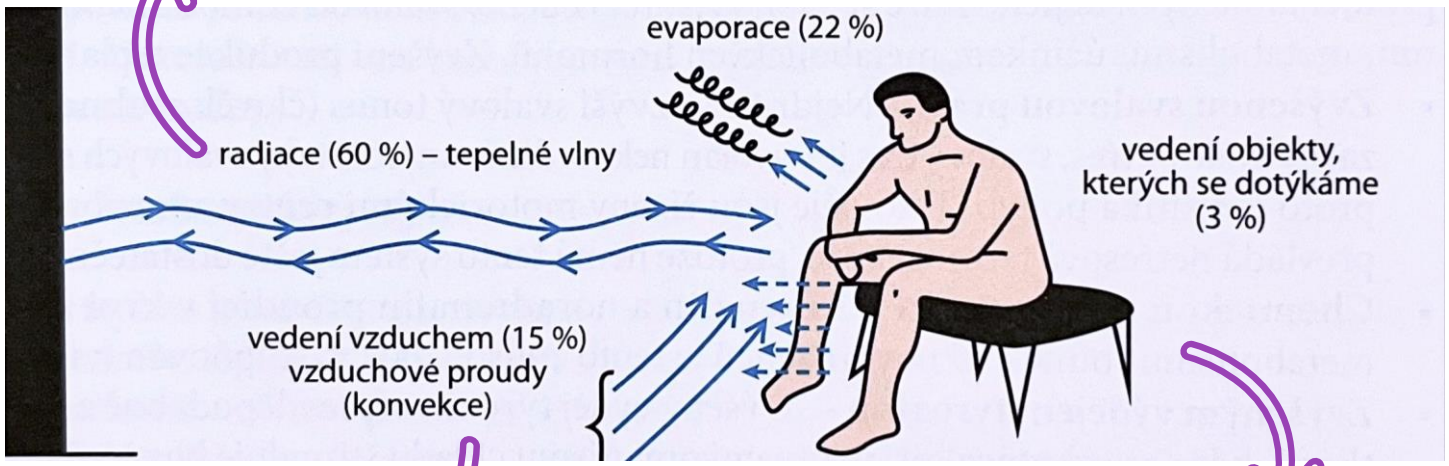




Heat Transfer

A. Radiation – Heat transfer through infrared rays which are emitted by all objects with temperature above absolute zero; approx. 60% of heat transfer (HT)

D. Evaporation – Crucial when temperature of the environment is higher than body temperature, its efficacy depends on humidity; at rest approx. 20%, during exercise up to 80% of HT; around 450-800 ml per day; 580 kcal/L



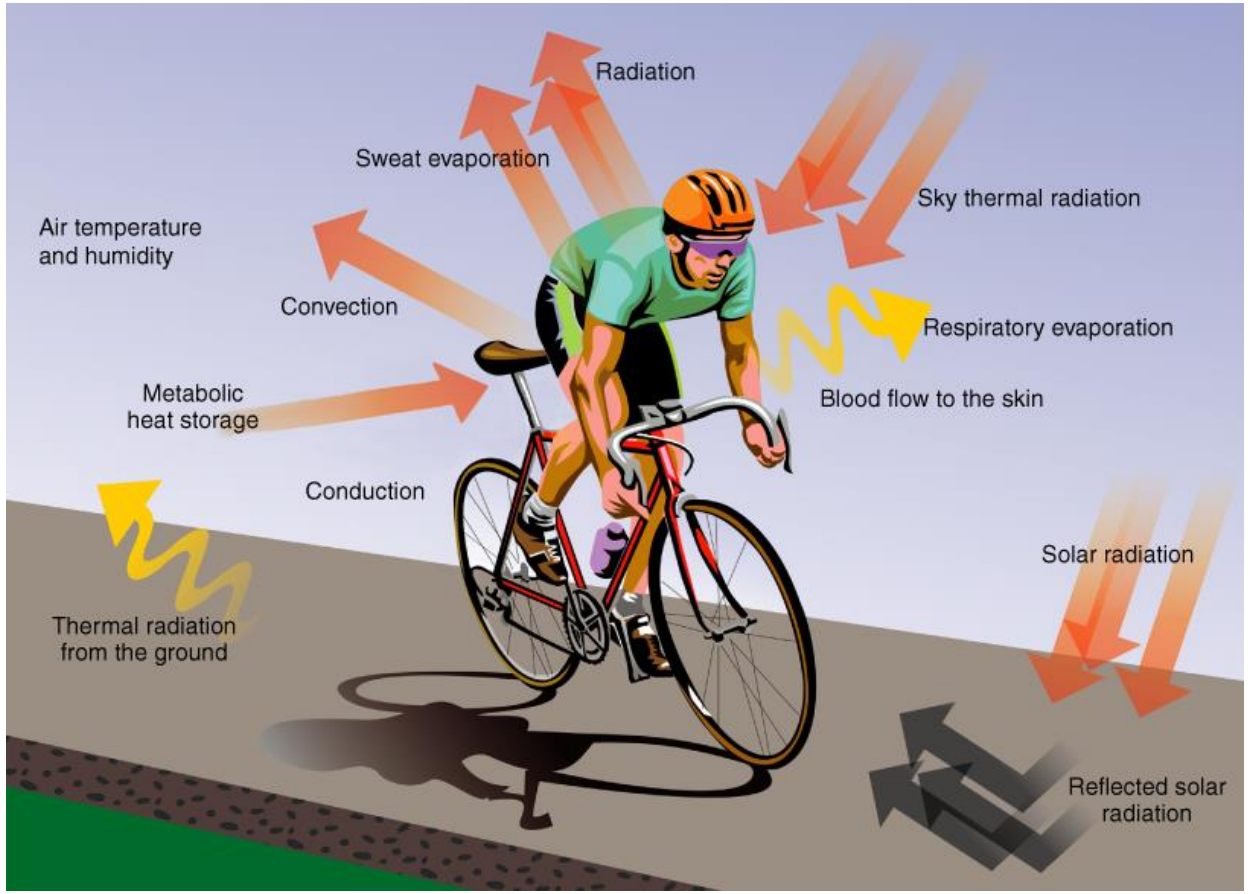
B. Convection – Heat transfer through air flow; approx. 15% of HT; quicker transfer in windy environments

C. Conduction – Heat transfer through direct molecular contact with an object; approx. 3% of HT

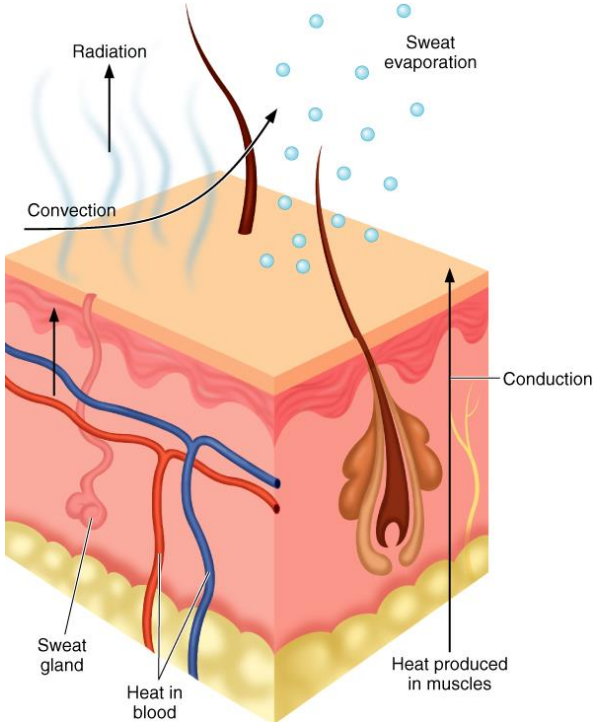
Heat Transfer

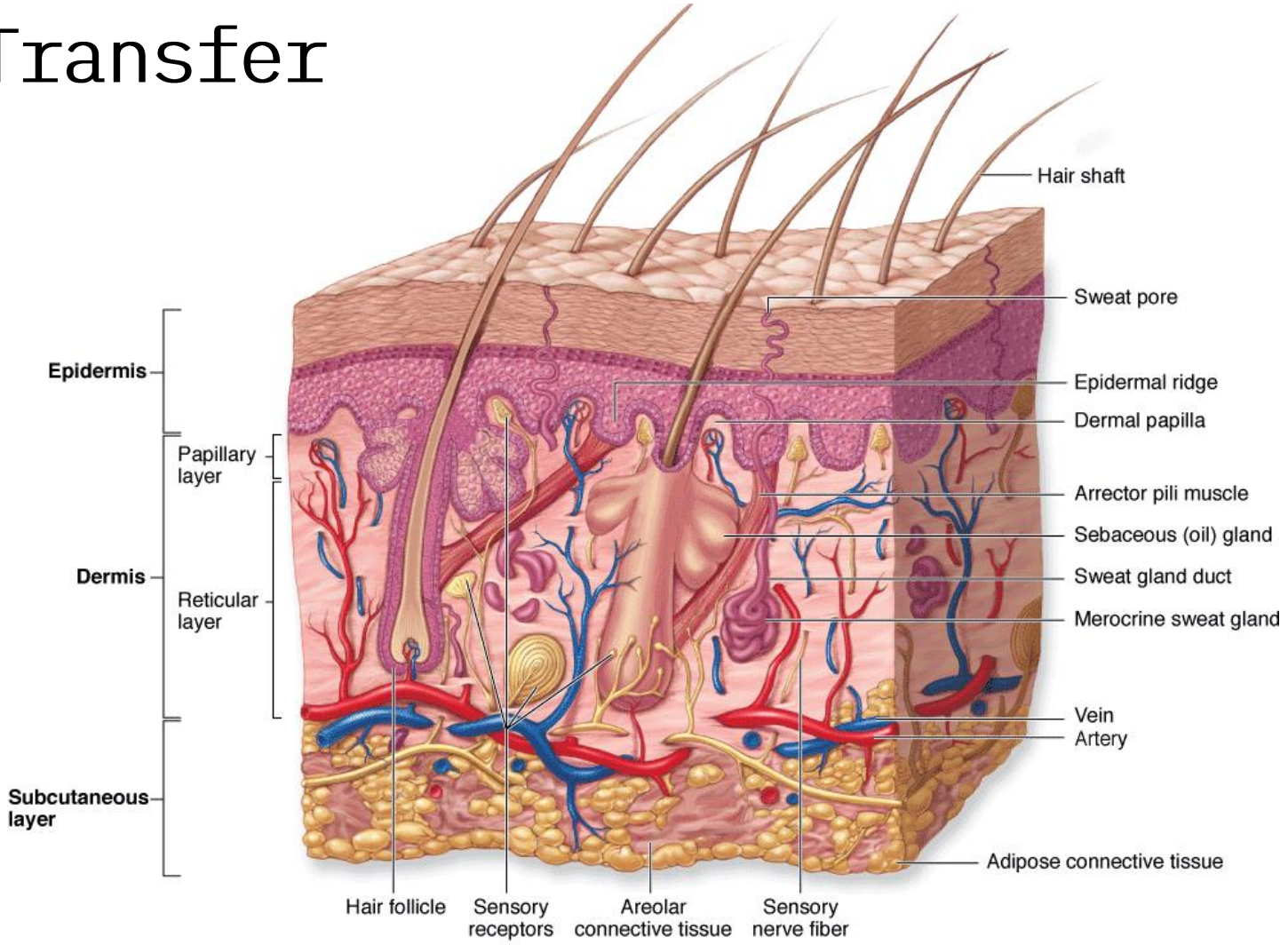
Mechanism of heat loss	Rest		Exercise	
	% total	kcal/min	% total	kcal/min
Conduction and convection	20	0.3	15	2.2
Radiation	60	0.9	5	0.8
Evaporation	20	0.3	80	12.0
Total	100	1.5	100	15.0

Heat Transfer



Skin and Heat Transfer



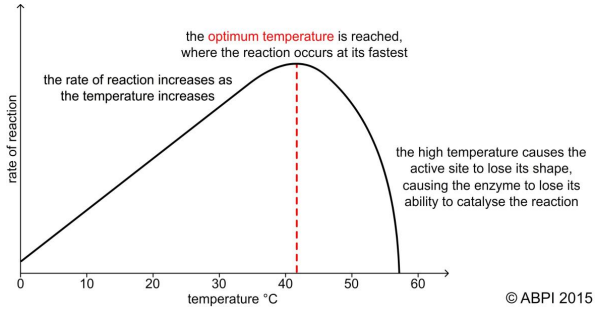


Source: Mescher AL: *Junqueira's Basic Histology: Text and Atlas, 12th Edition:* http://www.accessmedicine.com

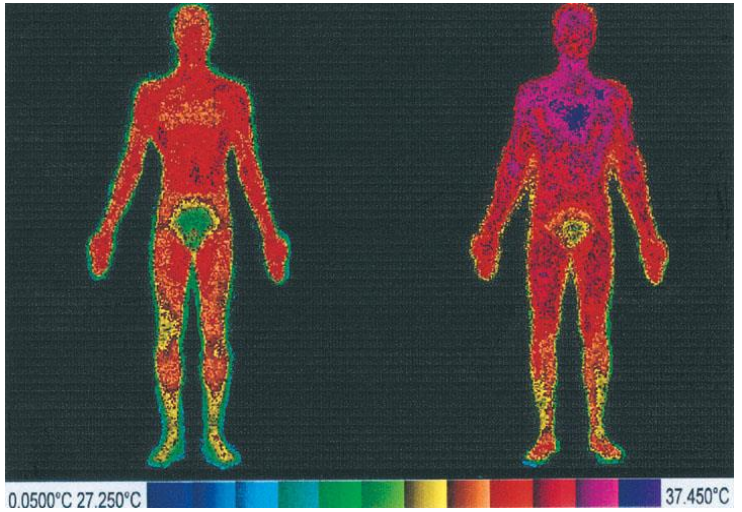
- Surface of 1.5-1.8 m^2
- Mass around 4.5 kg

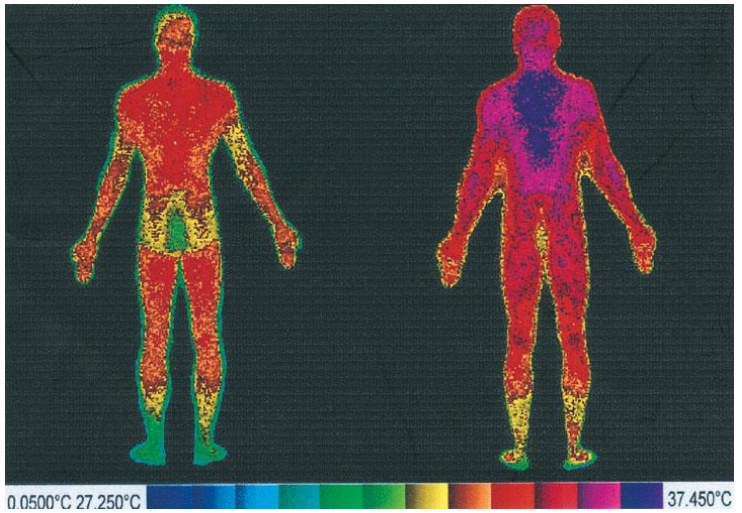
Body Temperature

- At rest, the temperature is kept around 37 °C
- When exercising it can exceed 40 °C (104 °F)
- Can raise up to 42 °C (107.6 °F) in active muscles
- Small increases can make their function more efficient
- Too high temperature can cause affect the nervous system, can cause enzyme denaturation



Before (left) and after (right) running outside at 30° C (75% humidity)





Body Temperature Assessment

- Is assessed from skin temperature (T_{skin}) and core temperature (T_r)
- $T_{body} = (0.4 \times T_{skin}) + (0.6 \times T_r)$

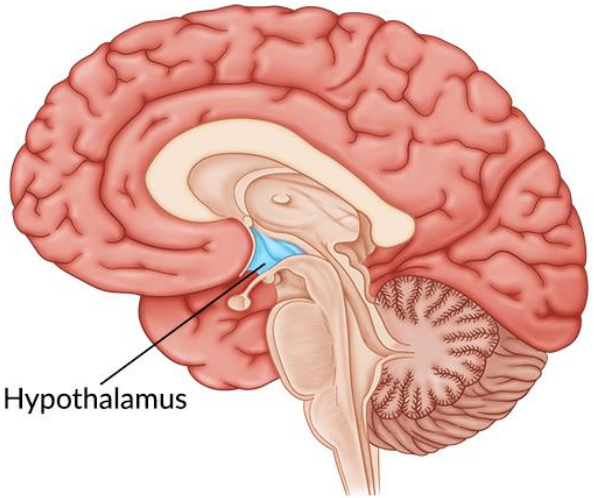
Heat Content

- Total calories of heat contained in body tissues
- Average specific heat of body tissues is 0.83 kcal x kg^{-1} x $°C^{-1}$
- Heat content = 0.83 (Body weight x T_{body})

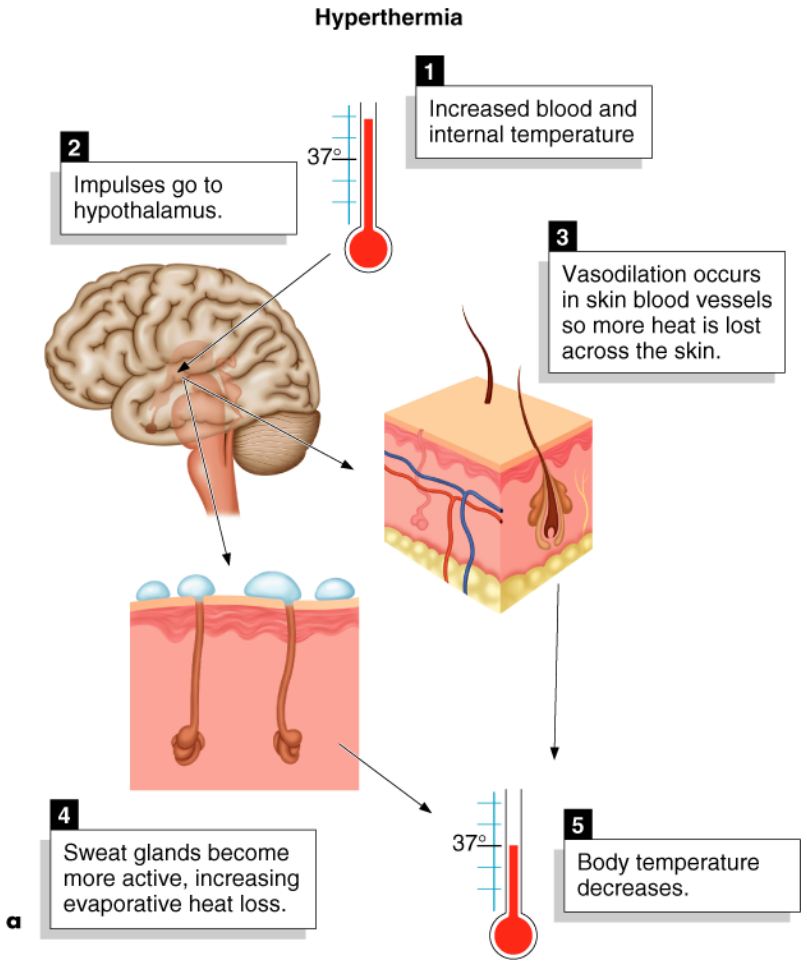
- Heat produced by average body at rest is 1.25 to 1.5 kcal per minute
- Heat produced during exercise can exceed 15 kcal per minute
- This heat must be dissipated by the body's thermoregulatory systems

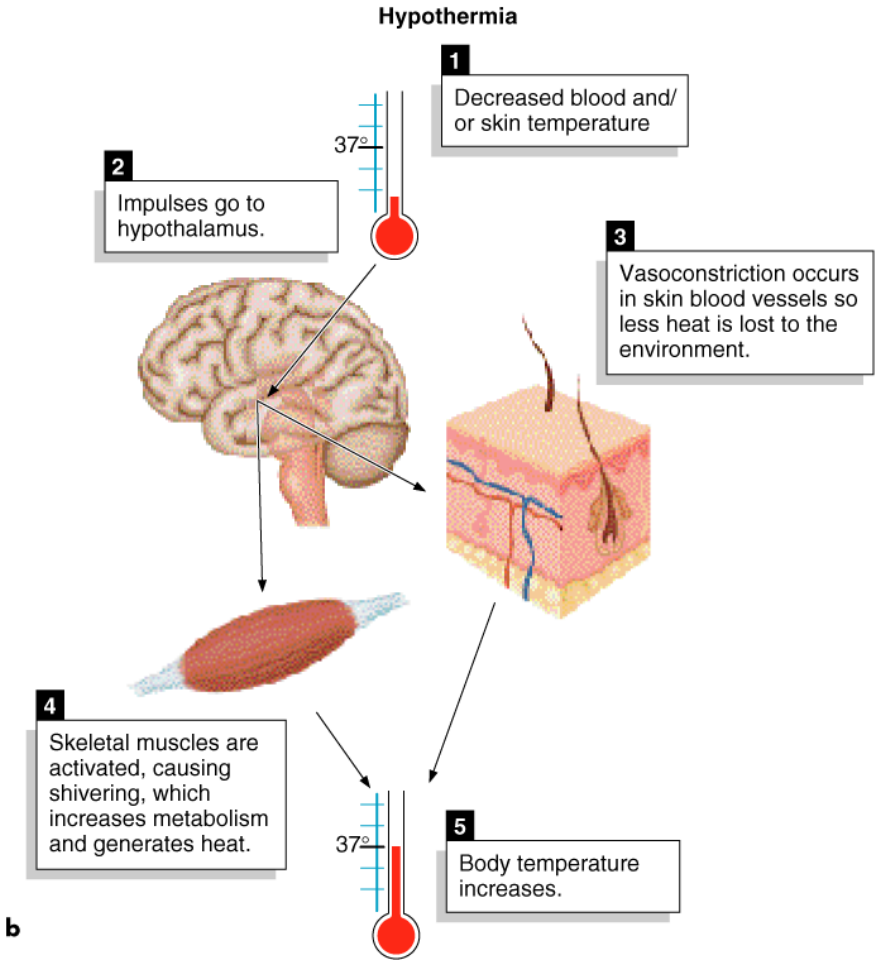
Thermoregulation Control

1. By preoptic area of the anterior hypothalamus = “thermostat’
2. Central and peripheral thermoreceptors
3. Effectors
    a) Sweat glands
    b) Smooth muscles around arterioles
    c) Skeletal muscle
    d) Endocrine glands



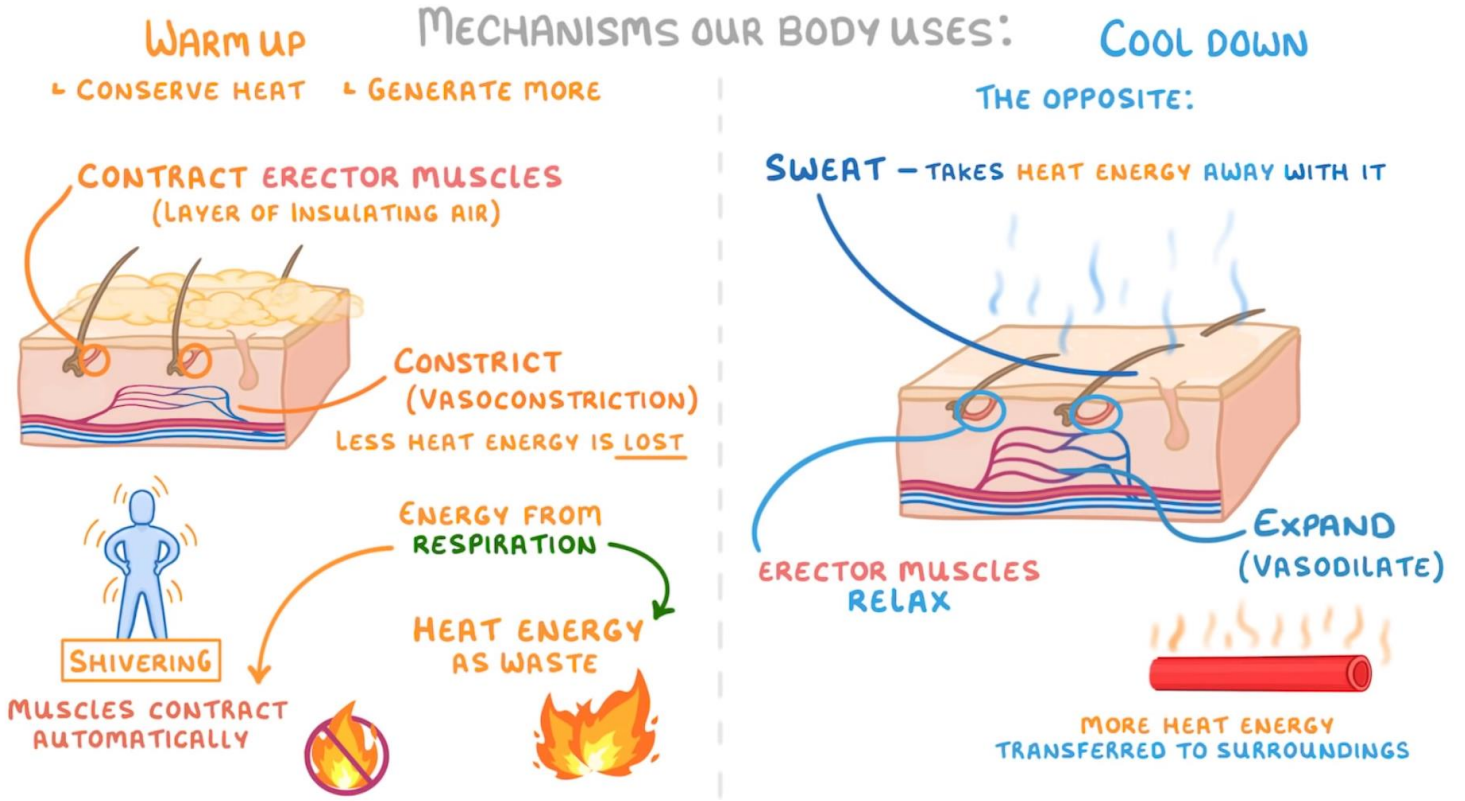
1. Hypothalamus Control





3. Effectors

- Sweat production
- Vasodilation, Vasoconstriction
- Shivering
- Goosebumps



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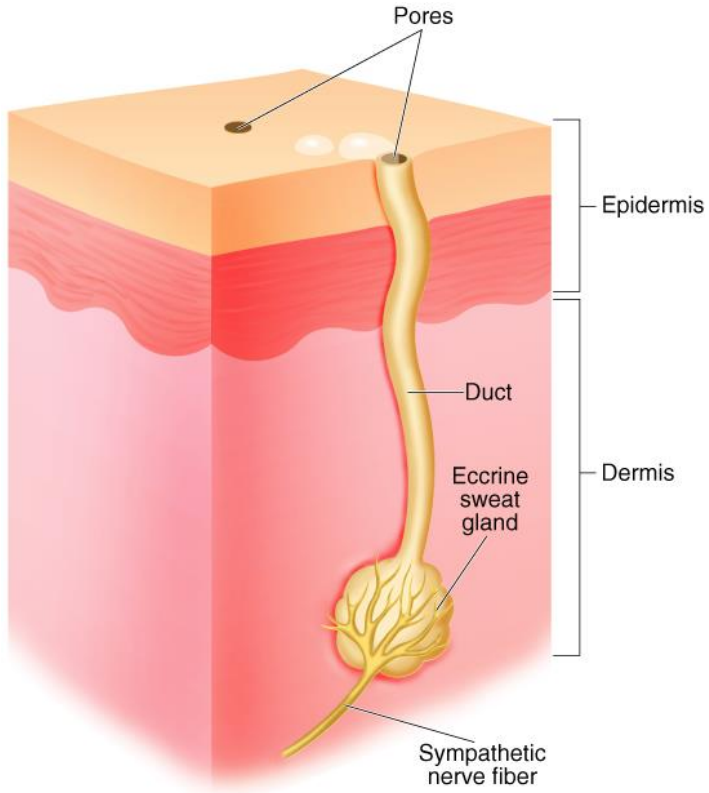
- As body temperature rises the production of sweat increases
- Sweat evaporates when it reaches skin
- Accounts for up to 80% of heat loss during exercise



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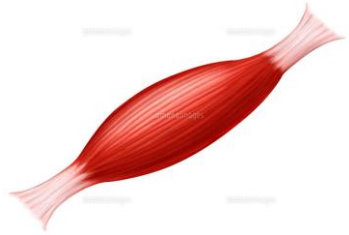

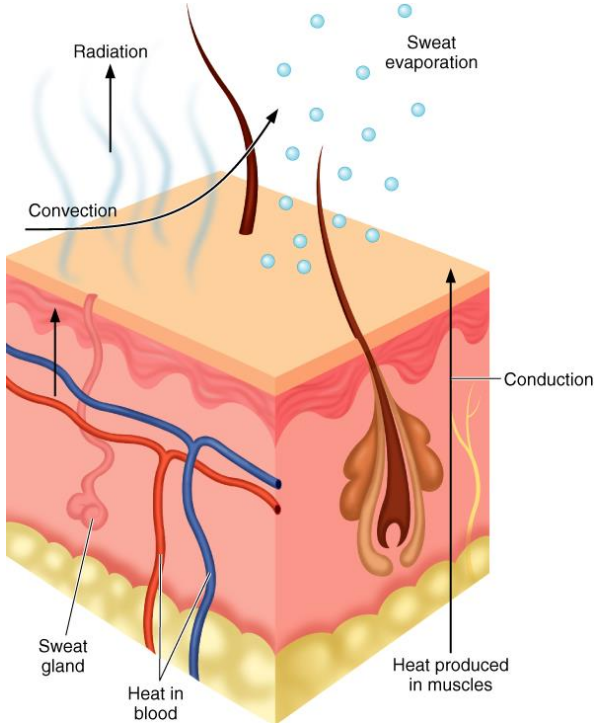

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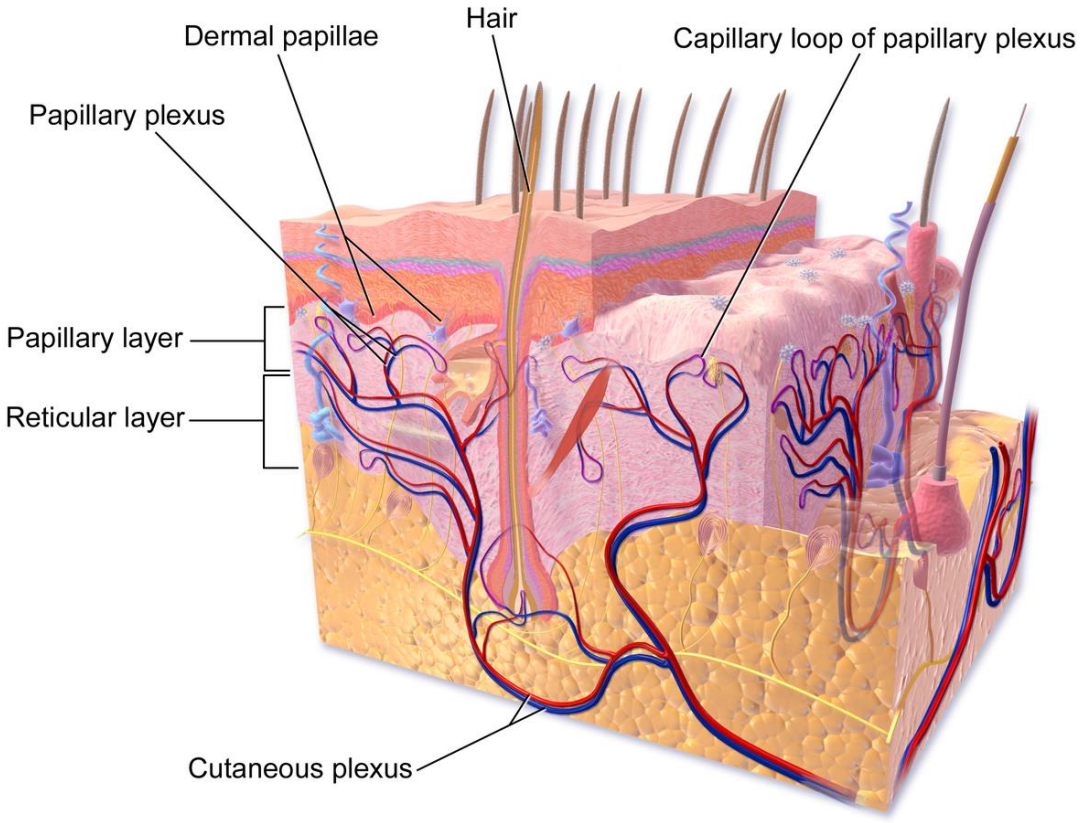
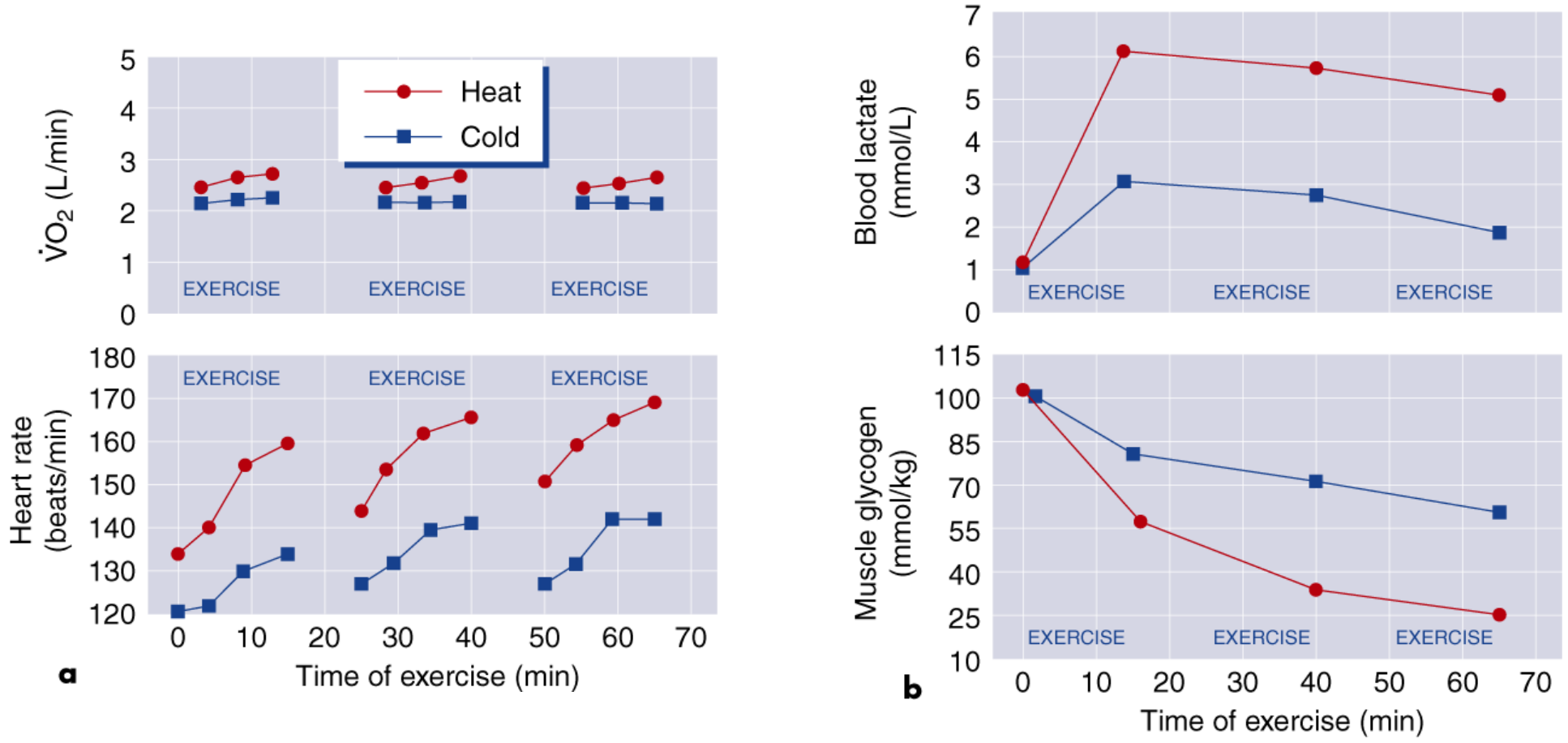


Dermal Circulation

Exercising in Hot and Cold Environments



HOT environments

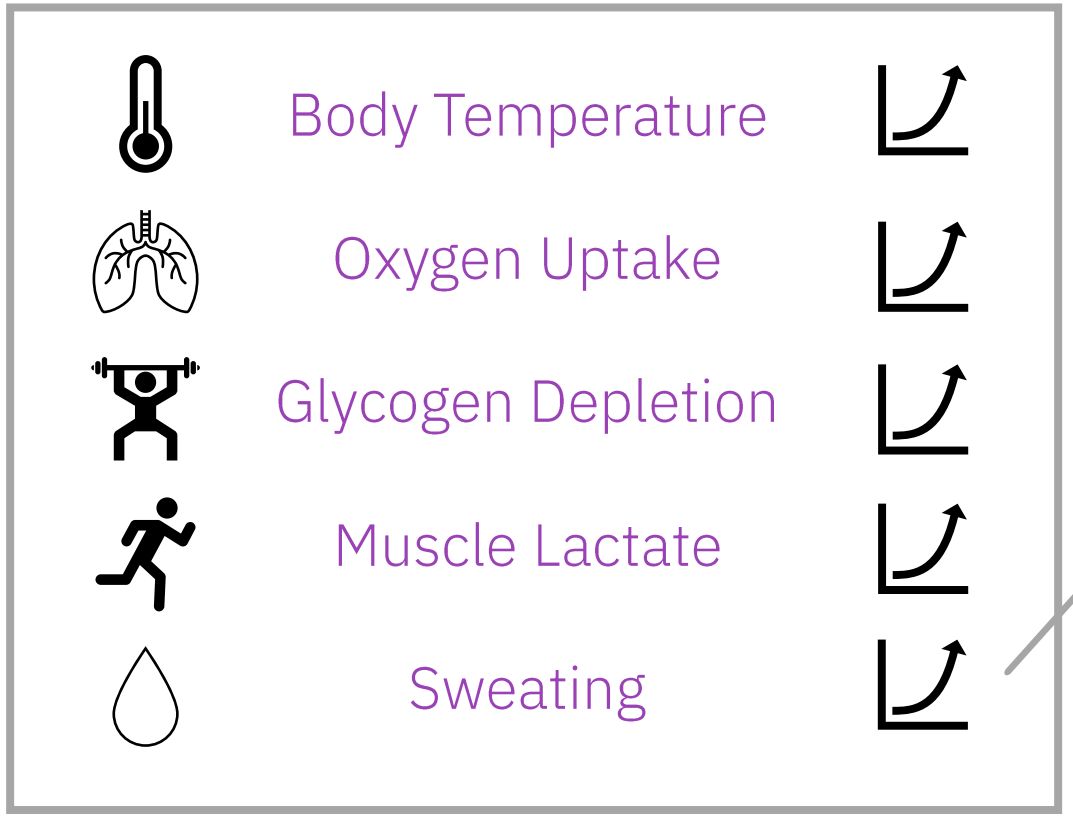
Exercising in Hot Environment

Cardiovascular response:

- Active muscles and skin compete for blood supply
- Stroke volume decreases
- Heart rate gradually increases to compensate for lower SV (cardiovascular drift)

Exercising in Hot Environment

Metabolic Response:



- High volumes of sweat cause:
  - Decreased blood volume
  - Loss of minerals and electrolytes
  - Release of aldosterone and ADH and water reabsorption in kidneys

Loss of ions through sweat during exercise

Subjects	Sweat Na^+ (mmol/L)	Sweat Cl^- (mmol/L)	Sweat K^+ (mmol/L)
Untrained males	90	60	4
Trained males	35	30	4
Untrained females	105	98	4
Trained females	62	47	4

Data from the Human Performance Laboratory, Ball State University

Variables Affecting Environmental Heat Load

Air Temperature

Humidity

Air Flow Velocity

Thermal Radiation

Temperature control in hot environment

- When temperature of the environment is higher than your body temperature

$$T_{environment} > T_{body}$$

- You gain heat from radiation, convection, and conduction. EVAPORATION becomes the only way of heat loss
- The efficacy of evaporation is limited by HUMIDITY – The higher the humidity the slower the evaporation
- Excessive sweating may lead to dehydration, reduced plasma volume and increased T_{body} Excessive sweating
- Reduced blood amounts hinder heat loss through capillaries
- Fluid intake is especially important when exercising in hot environment

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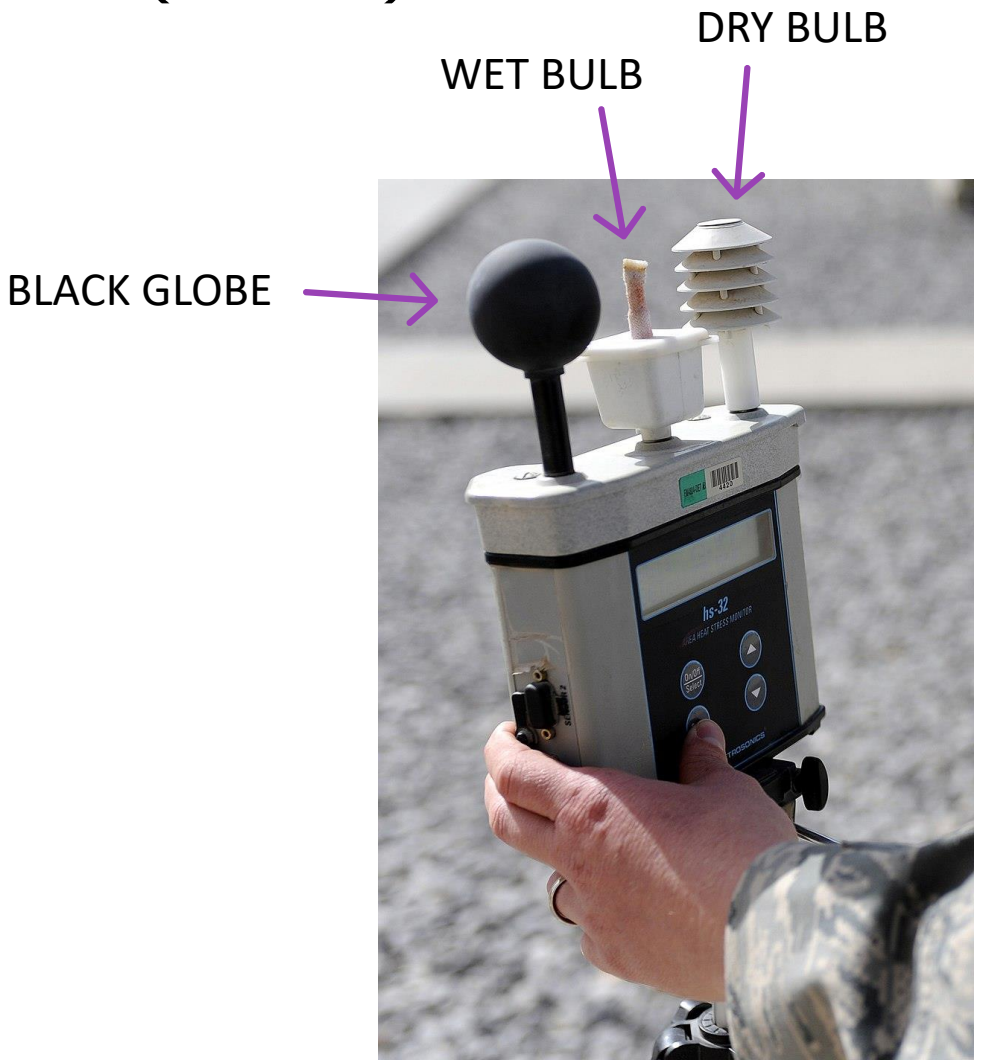
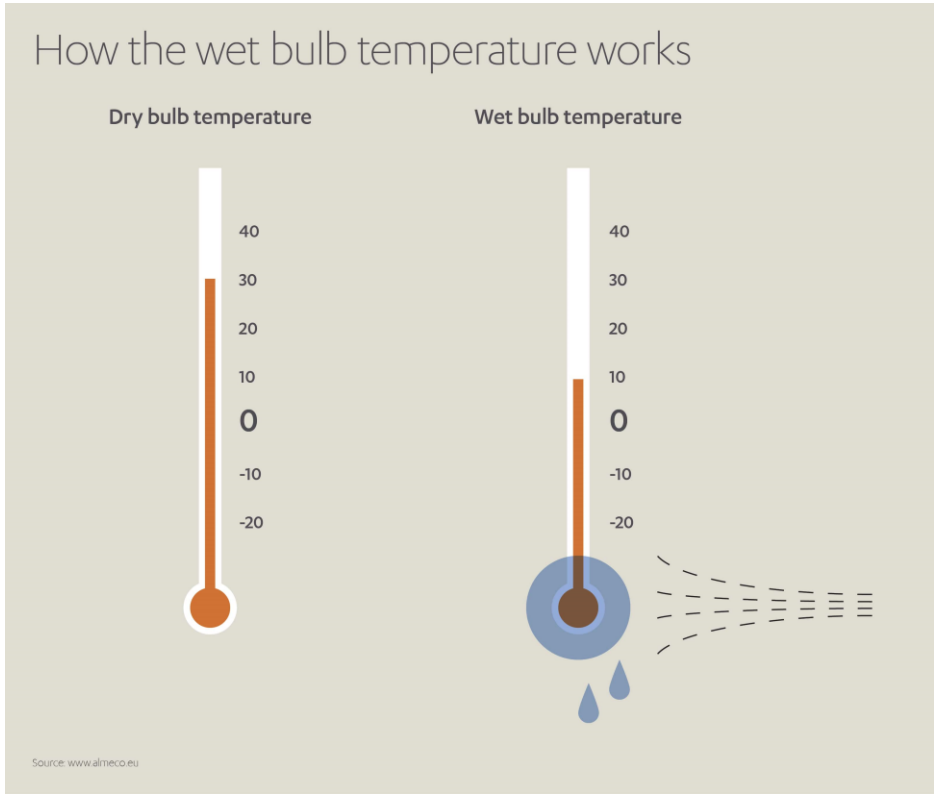
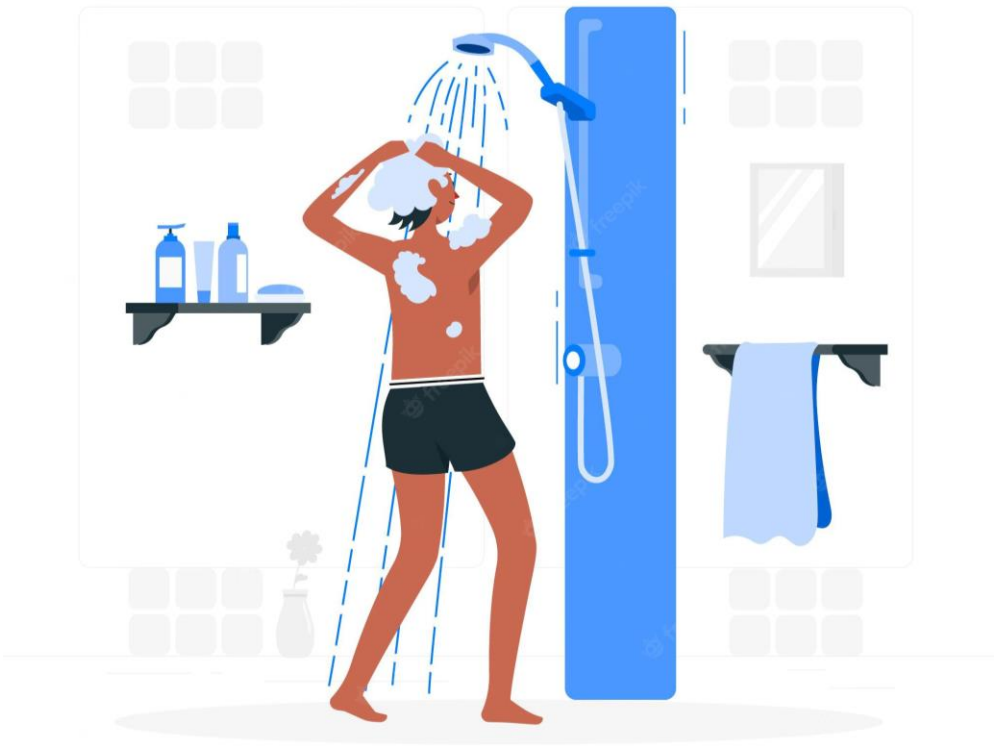
Wet Bulb Globe Temperature (WBGT)

- Measures the heat stress in direct sunlight
- Considers temperature, humidity, wind speed, sun angle and solar radiation (cloud cover)



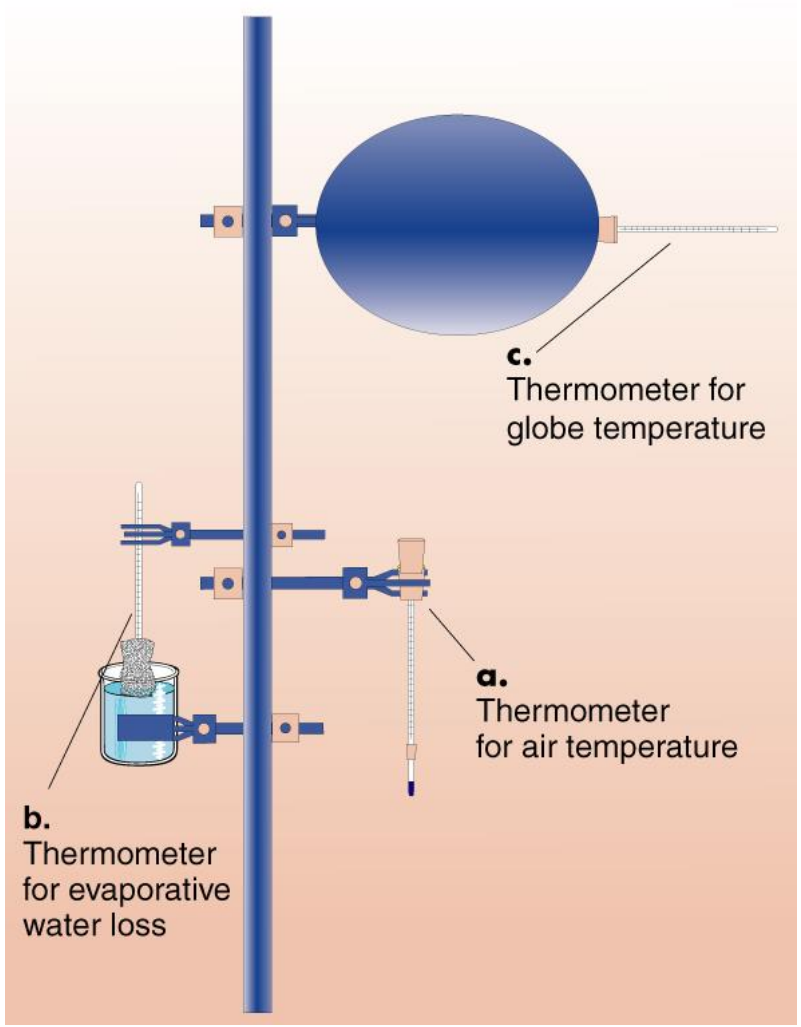
Wet Bulb


How the wet bulb temperature works
Dry bulb temperature
Wet bulb temperature
40
30
20
10
0
-10
-20
40
30
20
10
0
-10
-20
Source: www.almeco.eu

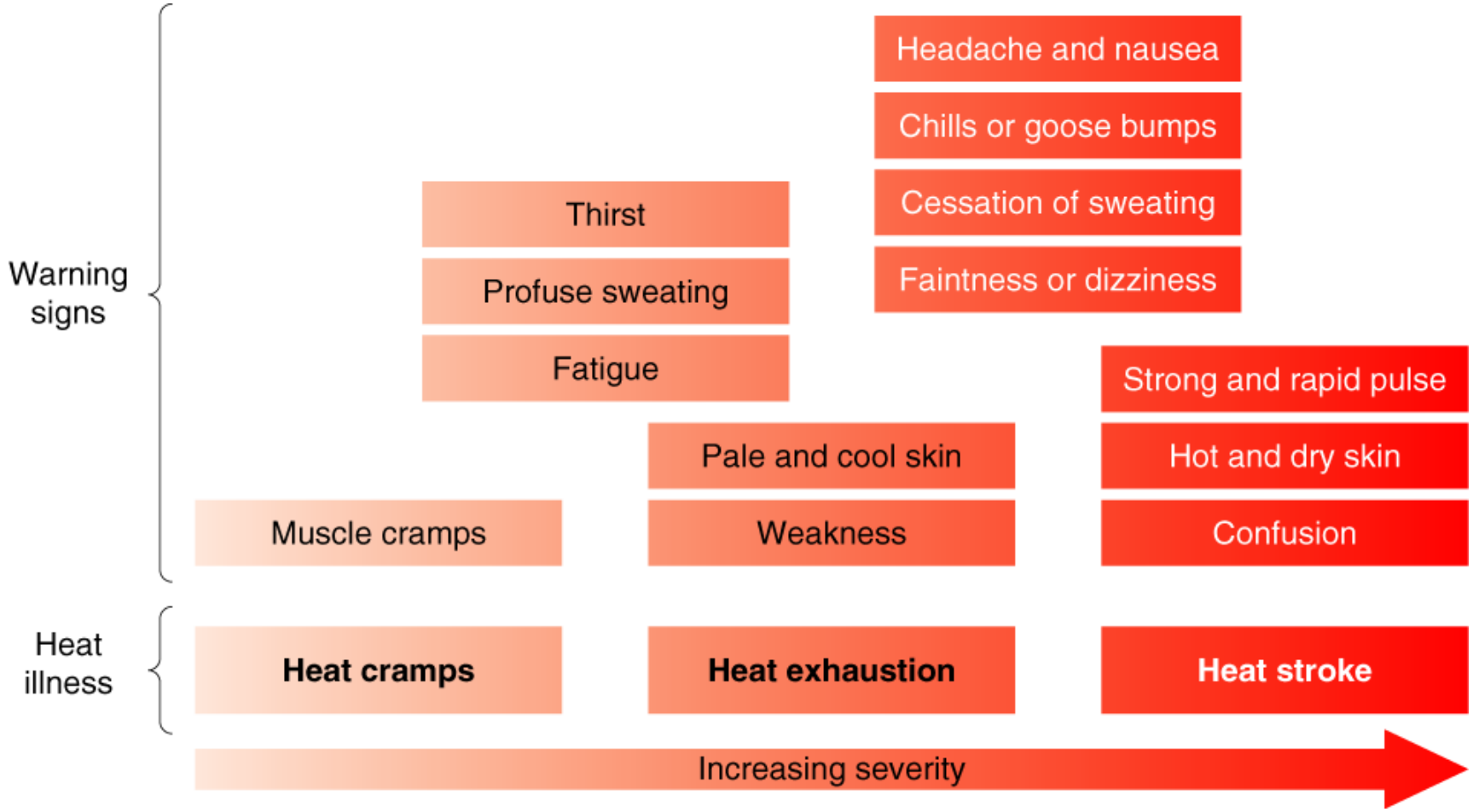


Wet Bulb Globe Temperature

- **Dry bulb** measures air temperature (T_{DB})
- **Wet bulb** measures temperature as water evaporates from it (T_{WB})
- **Black globe** absorbs radiated heat (T_G)
- $WBGT = 0.1T_{DB} + 0.7T_{WB} + 0.2T_G$



Warning Signs of Heat Disorders



Treatment of Heat Disorders

= Hyperthermia

A group of illnesses caused by prolonged exposure to hot temperatures, restricted fluid intake, or failure of the body's ability to regulate its temperature

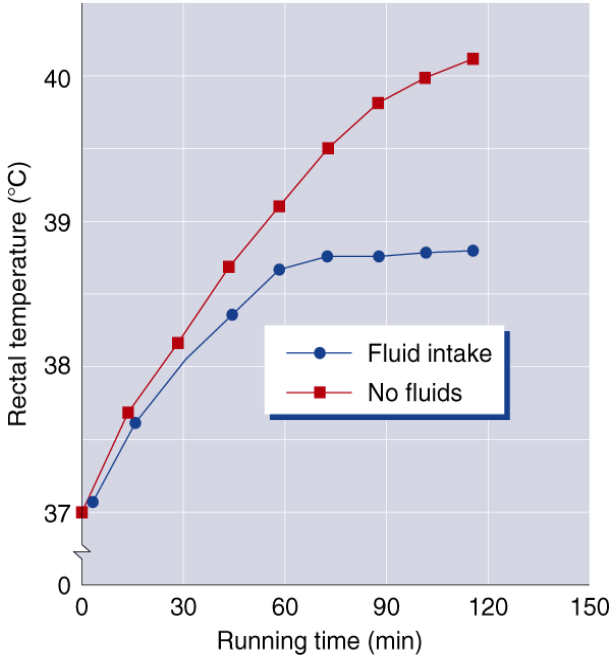
- Heat cramps
  - the least severe; warning sign that more serious problems may develop
  - move to cooler location and administer fluids or saline solution
- Heat exhaustion
  - move to cooler environment, elevate feet; give saline if conscious or intravenous saline if unconscious (liquid with electrolytes)
  - Results from the cardiovascular system being unable to meet the needs of muscles and skin due to lower blood volume (from sweating)
- Heat stroke
  - Immediate medical treatment vitally important !!!
  - Failure of the thermoregulatory system
  - rapidly cool body in cold water, ice bath or with wet towels

Subjective Symptoms Associated with Overheating

Rectal temperature	Symptoms
40-40.5° C (104-105° F)	Cold sensation over stomach and back with piloerection (goose bumps)
40.5-41.1° C (105-106° F)	Muscular weakness, disorientation, and loss of postural equilibrium
41.1-41.7° C (106-107° F)	Diminished sweating, loss of consciousness and hypothalamic control
>42.2° C (> 108° F)	Death

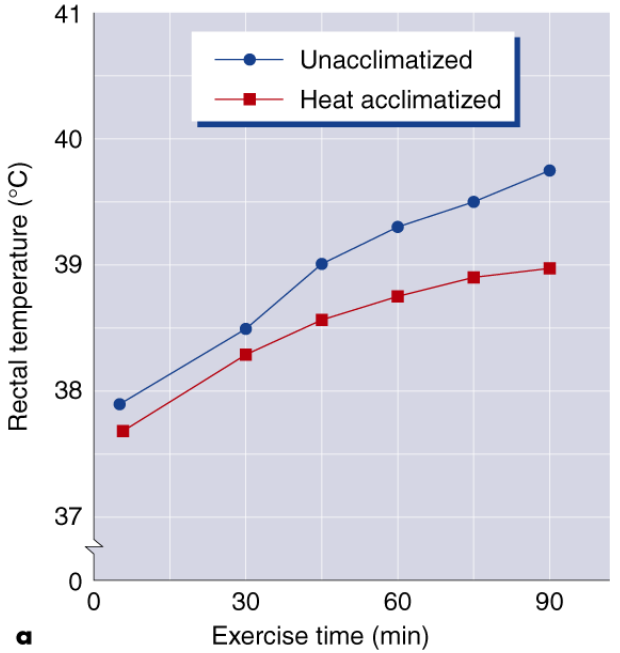
Preventing Hyperthermia

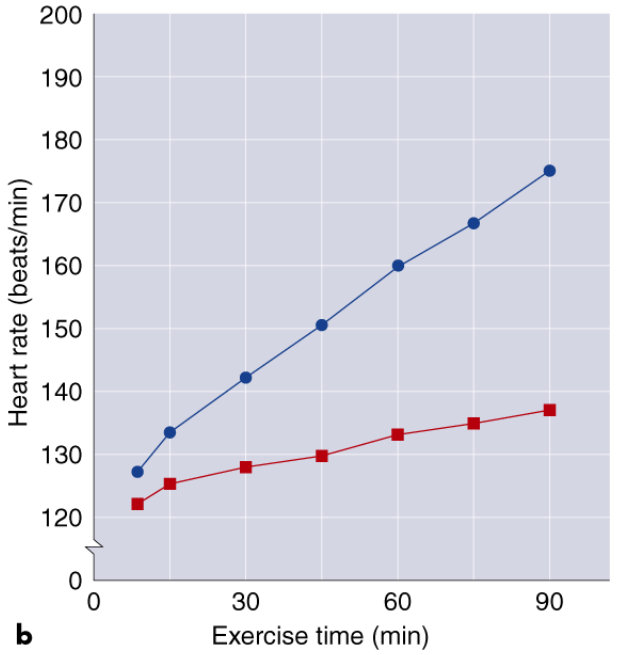
- Avoid exercising in hot and humid conditions above a WBGT index of 28° C (82.4° F)
- Schedule practices or events in early morning or at night
- Wear light-weight, light-colored, loosely-woven clothing
- Drink plenty fluids
- Know the symptoms of heat stress



Heat Acclimatization

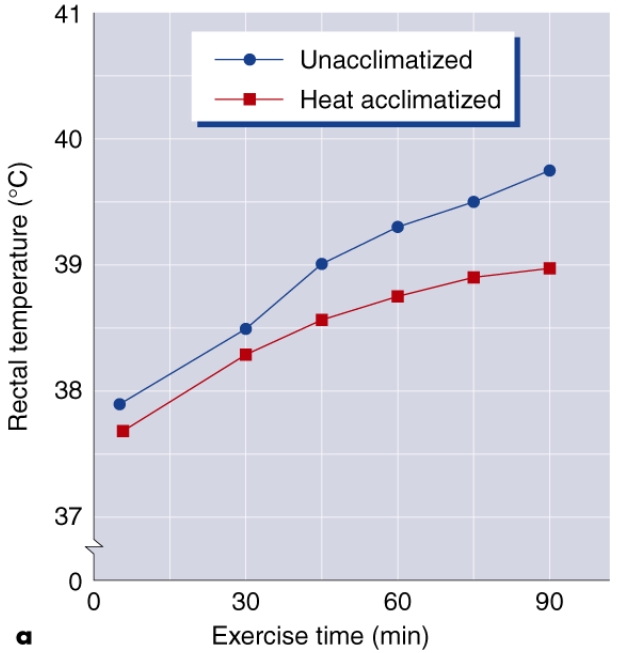
- With exercise the ability to get rid of excess heat improves
- Sweat sooner, sweat glands produce a greater volume of sweat, and the sweat is more dilute (less concentrated)
- Reduced blood flow to skin; more available to muscle
- Blood volume increases
- Heart rate increases more slowly
- Stroke volume increases
- Muscle glycogen usage decreases

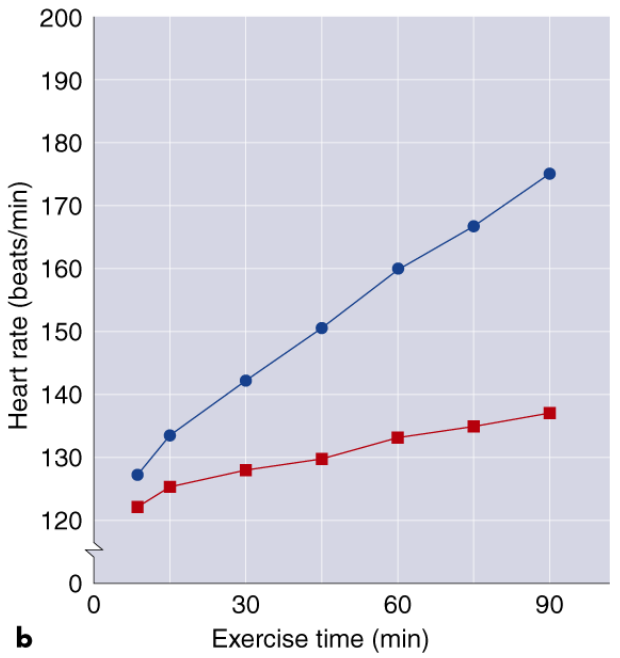




Heat Acclimatization

You can achieve heat acclimatization by exercising in the heat for 1 hour or more each day for 5 to 10 days. Cardiovascular adaptations occur within the first 3 to 5 days while changes in sweating mechanisms may take up to 10 days. Reduce exercise intensity to 60% to 70% the first few days before resuming more intense workouts.



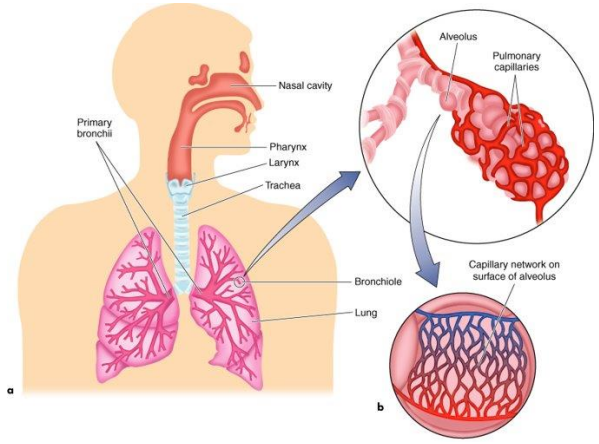


COLD environments

How does the Body Conserve Heat?

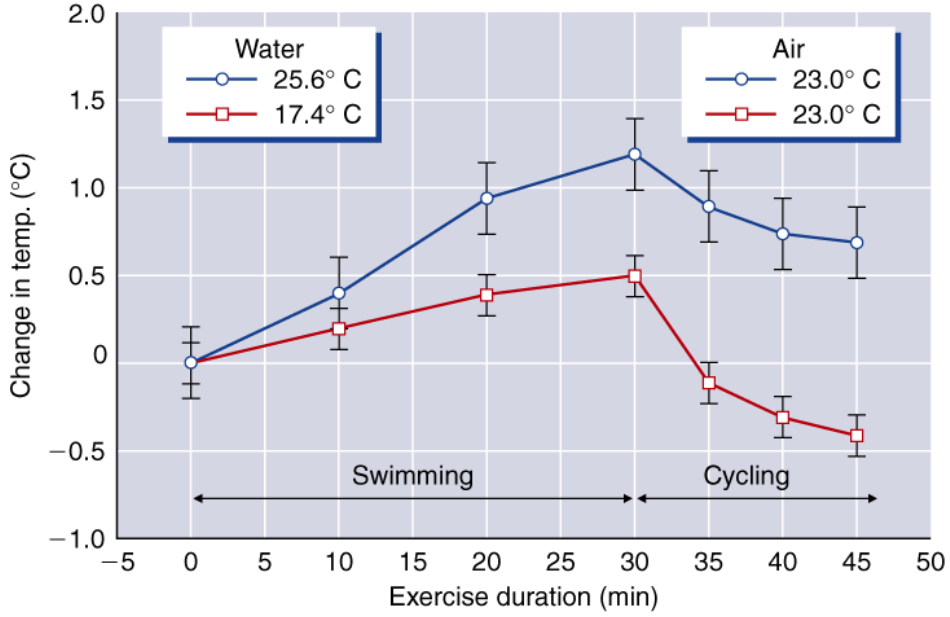
- SHIVERING – rapid involuntary cycle of contraction and relaxation of muscles
- NONSHIVERING THERMOGENESIS – stimulation of metabolism to produce heat (BAT – brown adipose tissue)
- PERIPHERAL VASOCONSTRICTION – to reduce blood flow close to skin thus minimizing heat exchange with the environment

- Warming of inspired air – paranasal sinuses



What Affects Body Heat Loss?

- Body size
- Air temperature
- Wind chill
- Water immersion

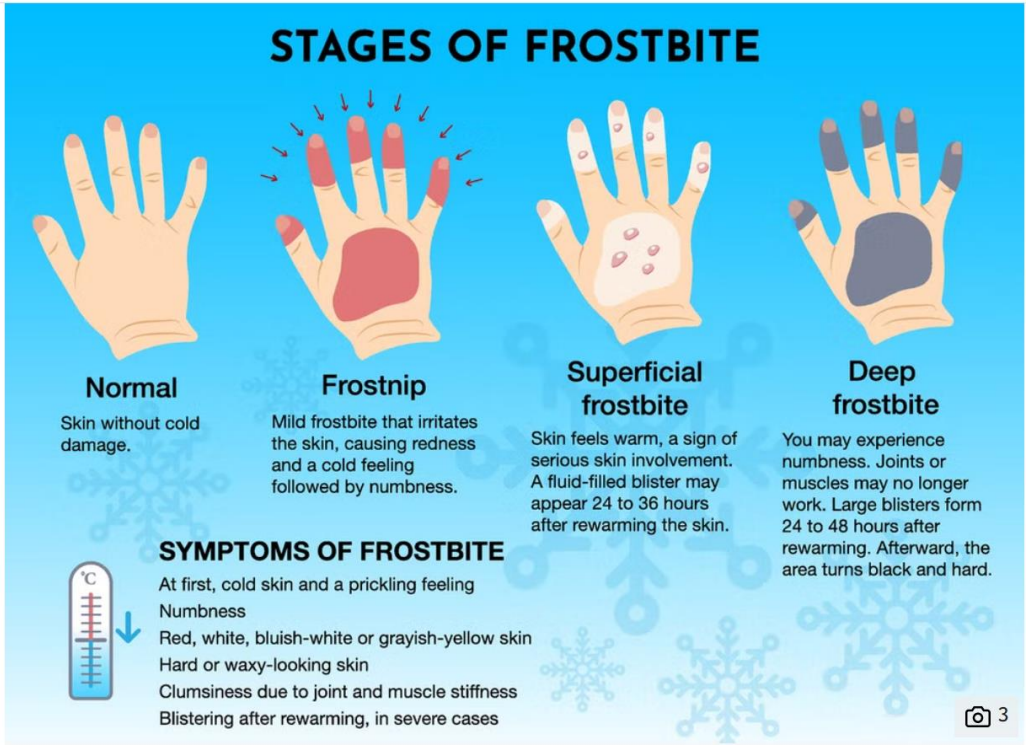


Responses to Exercise in the Cold

- Muscle weakens and fatigue occurs more rapidly
- Susceptibility to hypothermia increases
- Exercise-induced FFA mobilization is impaired due to vasoconstriction of subcutaneous blood vessels

Health Risks of Exercise in the Cold

- Ability to regulate body temperature is lost if T_{body} drops below 34.5° C (94.1° F)
- Hypothermia causes heart rate to drop, which reduces cardiac output
- Vasoconstriction in the skin reduces blood flow to skin, eventually causing frostbite



KEY POINTS

- Body temperature is regulated for all biochemical processes to run at an optimal speed – low temperature means slower processes, too high temperature can cause damage (denaturation of enzymes)
- Means of heat transfer – Conduction, convection, radiation, evaporation
- Body temperature is kept around 37 °C at rest
- Hypothalamus is the center of thermoregulation
- Mechanisms such as sweat production, vasoconstriction and vasodilation, shivering and goosebumps for heat loss and heat conservation

KEY POINTS

- Humidity – affects sweating
- HOT environment – evaporation is the main mechanism of heat loss, mechanisms of heat loss – vasoconstriction and vasodilation
- Heat stress, WBGT
- Dry and wet bulb temperature, black globe temperature
- Heat disorders – heat cramps, heat exhaustion, heat stroke
- Acclimatization to hot environment
- COLD environment – mechanisms of conserving heat

Thank you