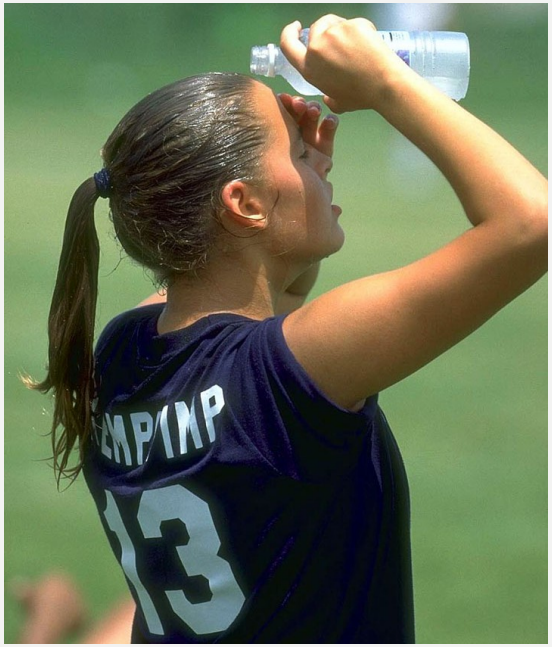
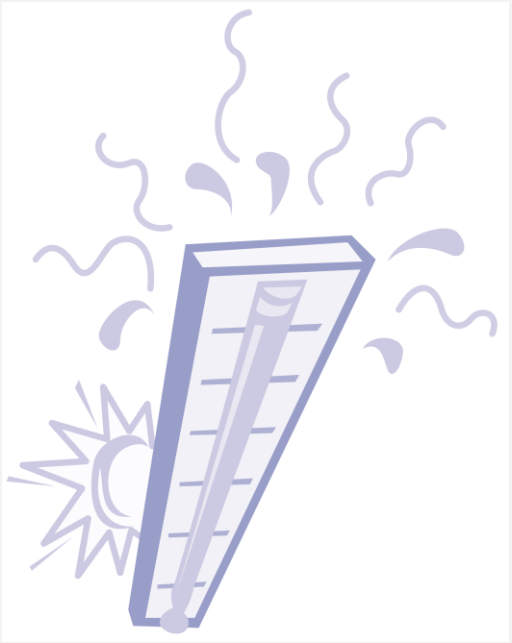
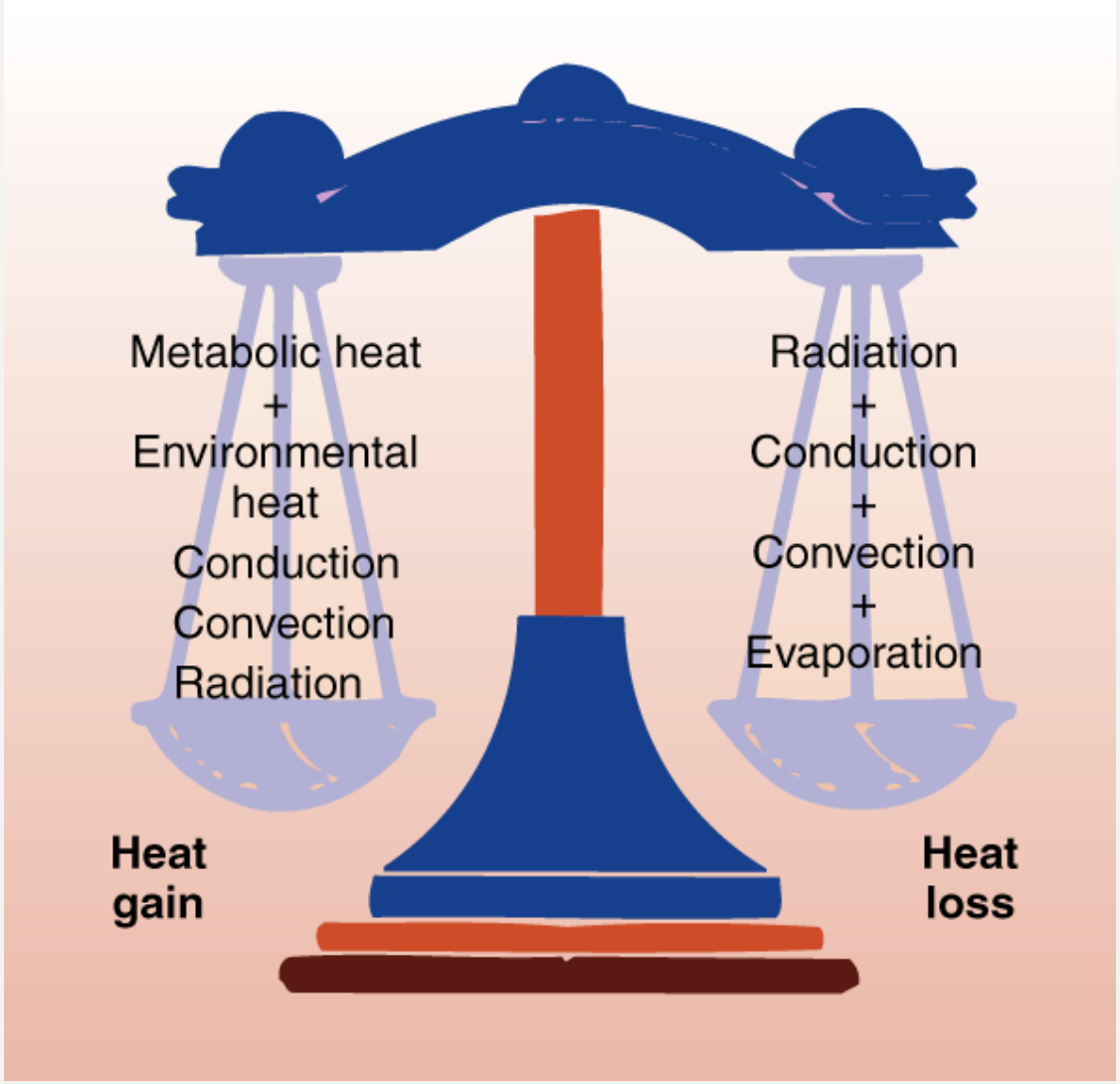
EXERCISE IN HOT AND COLD ENVIRONMENTS: THERMOREGULATION





BODY HEAT GAINED AND LOST



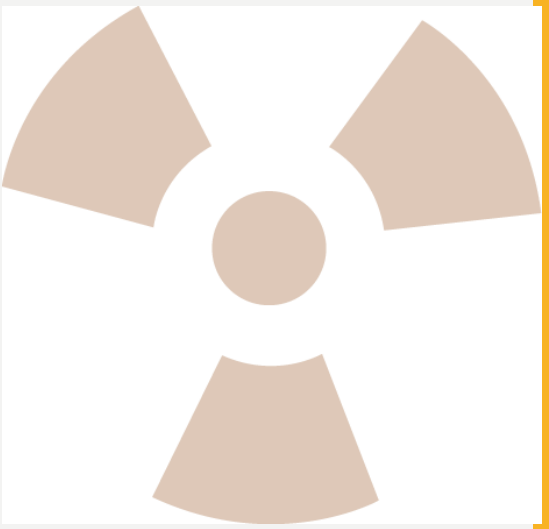
Modes of Heat Transfer

Conduction—direct molecular contact with an object

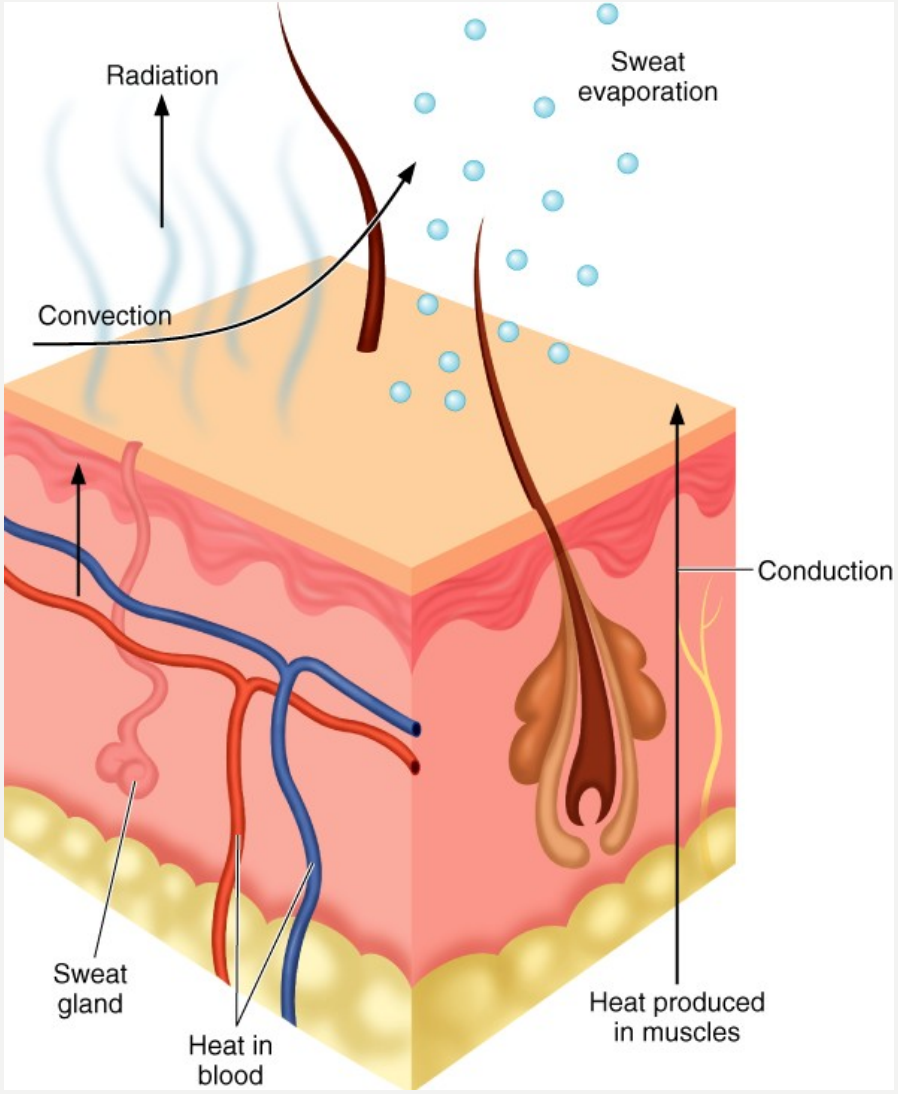
Convection—motion of gas or liquid across heated surface

Radiation—infrared rays

Evaporation—as fluid evaporates, heat is lost (580 kcal/L)



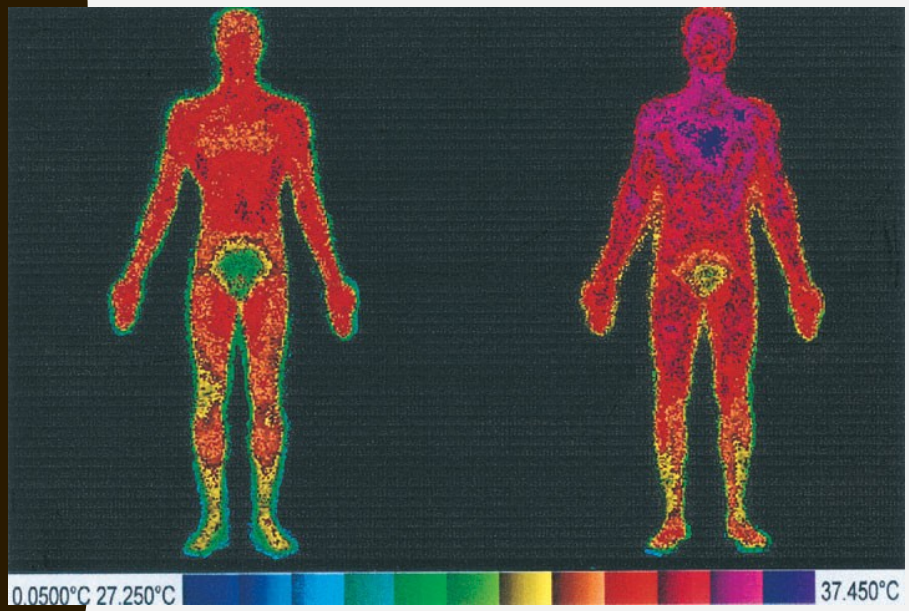
HEAT REMOVAL FROM THE SKIN



THERMOGRAMS

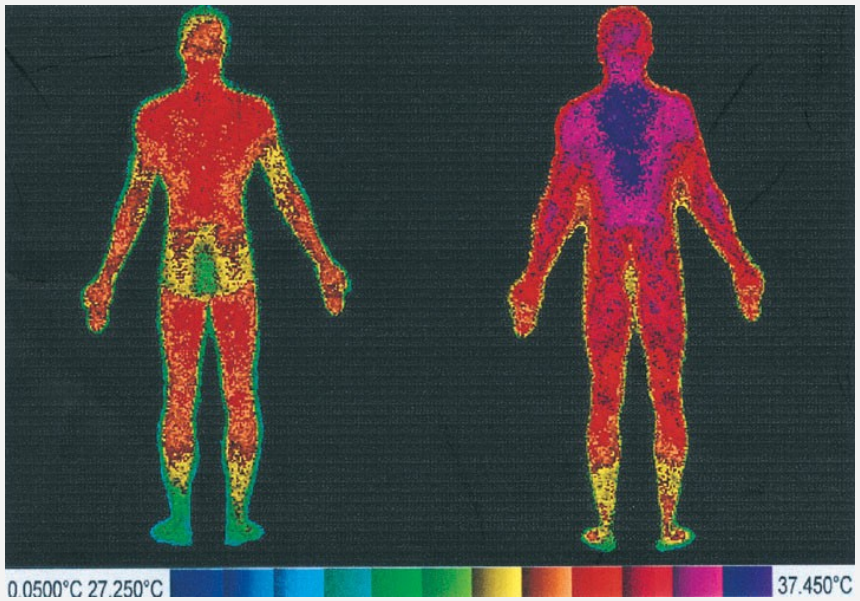
Front

Before After



Back

Before After



Before running outside at 30° C (75% humidity)

After running outside at 30° C (75% humidity)

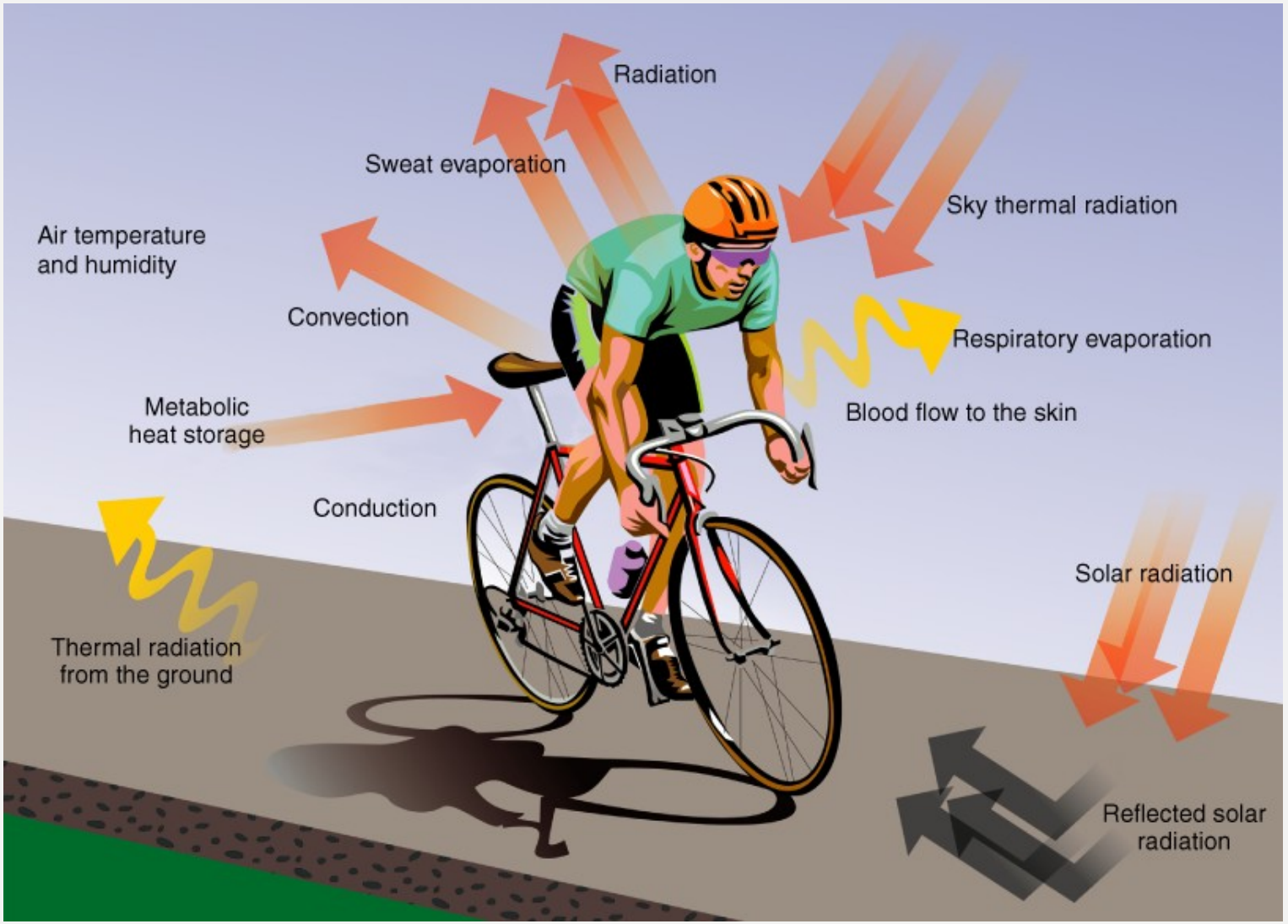
Evaporation

- As body temperature rises, sweat production increases.
- Sweat reaches the skin and evaporates.
- Evaporation accounts for 80% of heat lost during exercise, but only for about 20% at rest.
- Insensible water loss removes about 10% of heat.
- Dehydration is a potential problem with sweating.

Estimated Caloric Heat Loss at Rest and During Prolonged Exercise

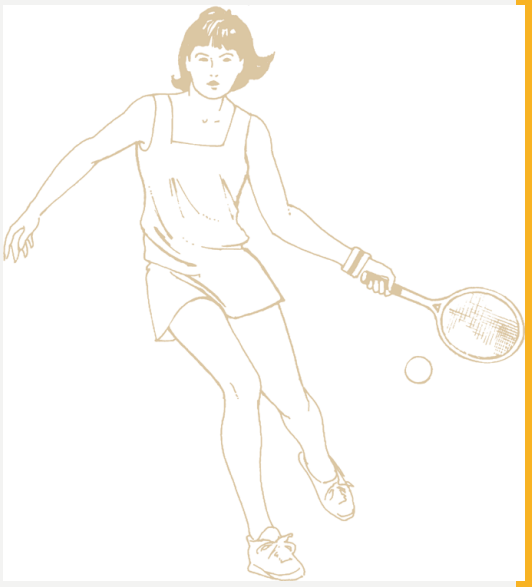
	Rest		Exercise	
Mechanism of heat loss	**% total**	**kcal/min**	**% total**	**kcal/min**
Conduction and convection	20	0.3	15	2.2
Radiation	60	0.9	5	0.8
Evaporation	20	0.3	80	12.0
Total	100	1.5	100	15.0

MECHANISMS FOR HEAT BALANCE



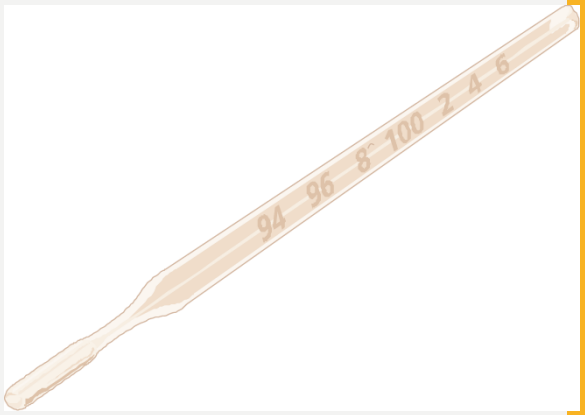
Humidity

- Plays a major role in heat loss
- Affects our perception of thermal stress
- When high (regardless of temperature), limits evaporation of sweat



Internal Body Temperature

- Can exceed 40 °C during exercise
- May be 42 °C in active muscles
- Small increases can make muscles' energy systems more efficient
- Above 40 °C can affect the nervous system and reduce the ability to unload excess heat



Regulators of Heat Exchange

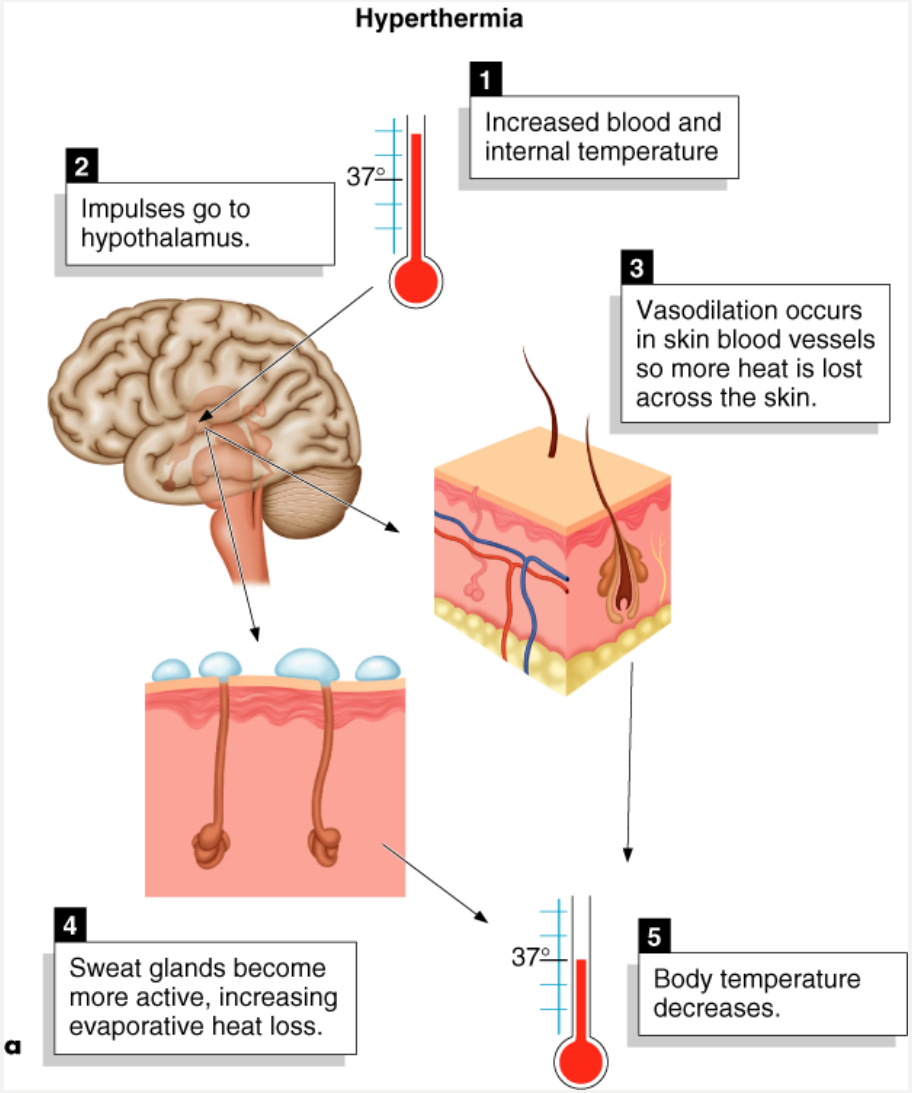
Hypothalamus

Central and peripheral thermoreceptors

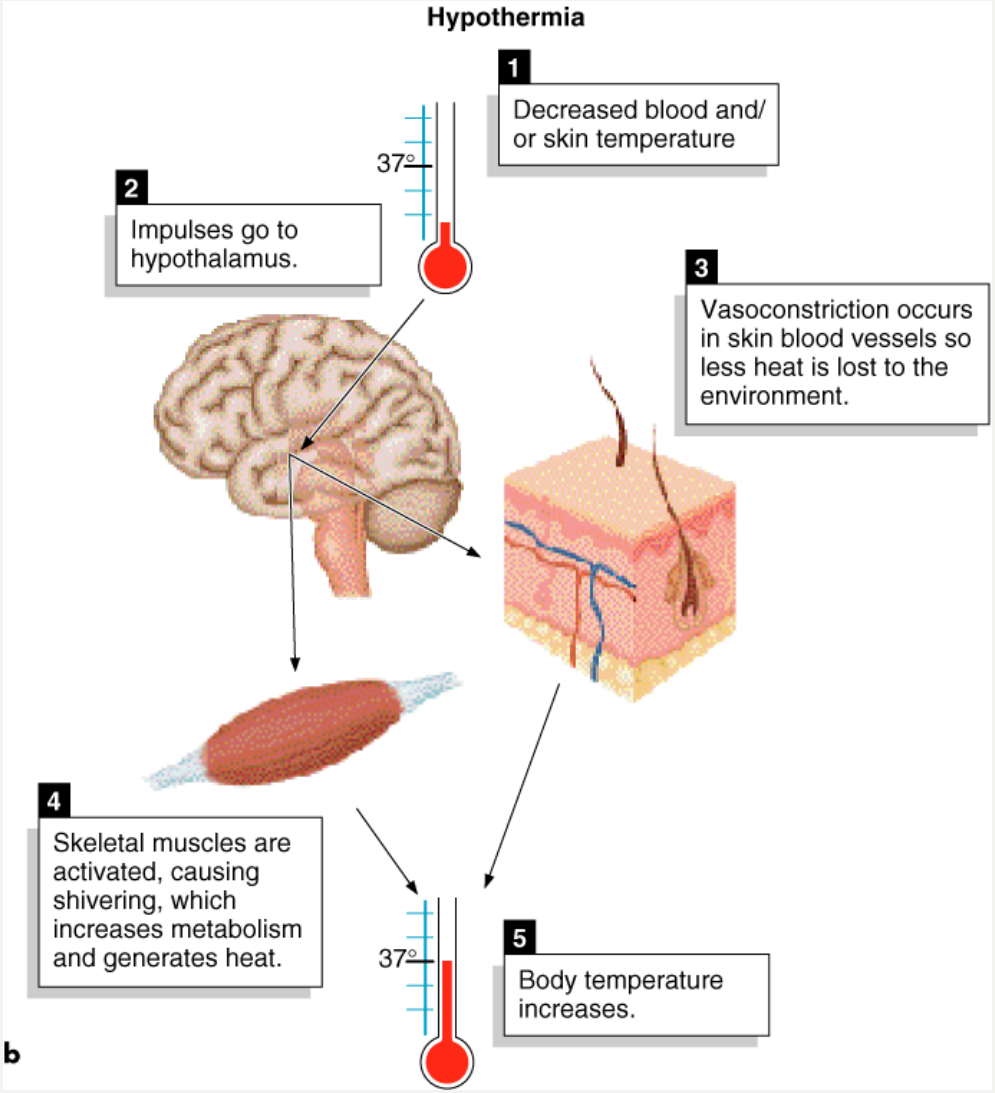
Effectors

- Sweat glands
- Smooth muscle around arterioles
- Skeletal muscles
- Endocrine glands

HYPOTHALAMUS AND HYPERTHERMIA



HYPOTHALAMUS AND HYPOTHERMIA

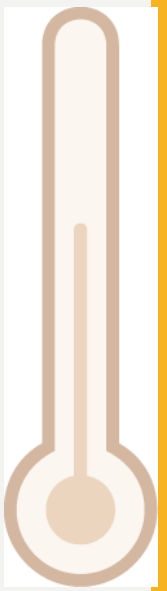


Body Temperature Assessments

Mean body temperature (T_{body}) is the weighted average of

- Skin temperature (T_{skin})
- Core temperature (T_r)

$$T_{body} = (0.4 \times T_{skin}) + (0.6 \times T_r)$$



Rate of Heat Exchange

- 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.

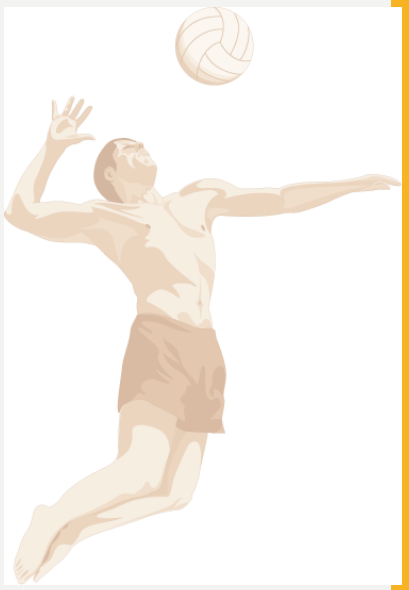
- 1 kcal = 4.185 kJ

Cardiovascular Response to Exercise in the Heat

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

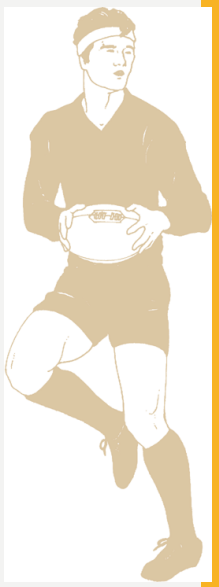
Metabolic Responses to Exercise in the Heat

- Body temperature increases.
- Metabolism speeds up.
- Oxygen uptake increases.
- Glycogen depletion is hastened.
- Muscle lactate levels increase.

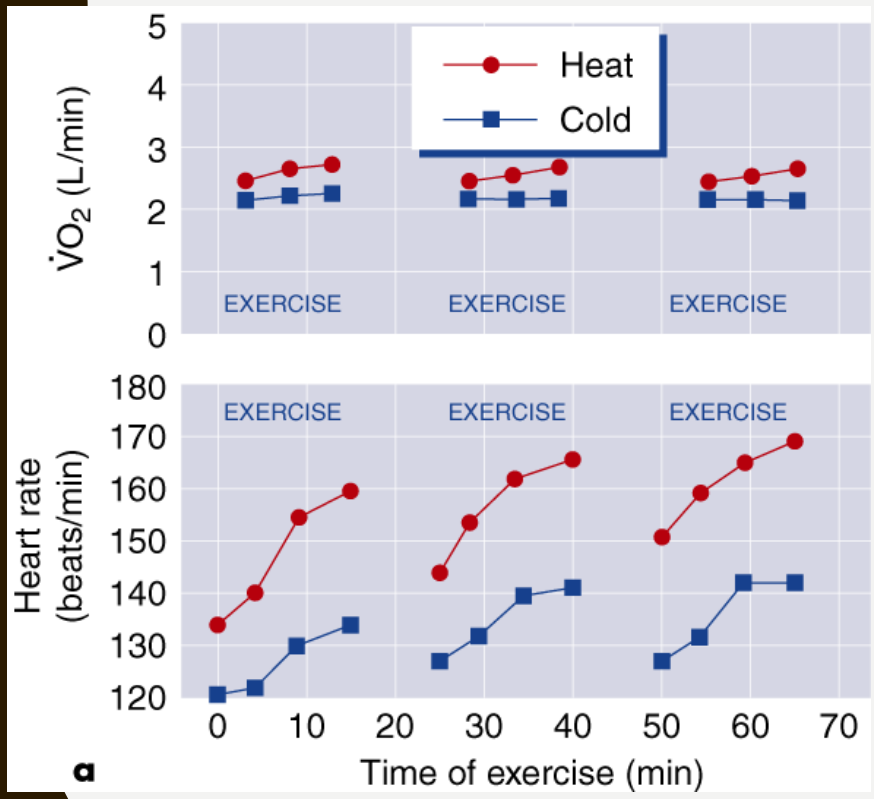


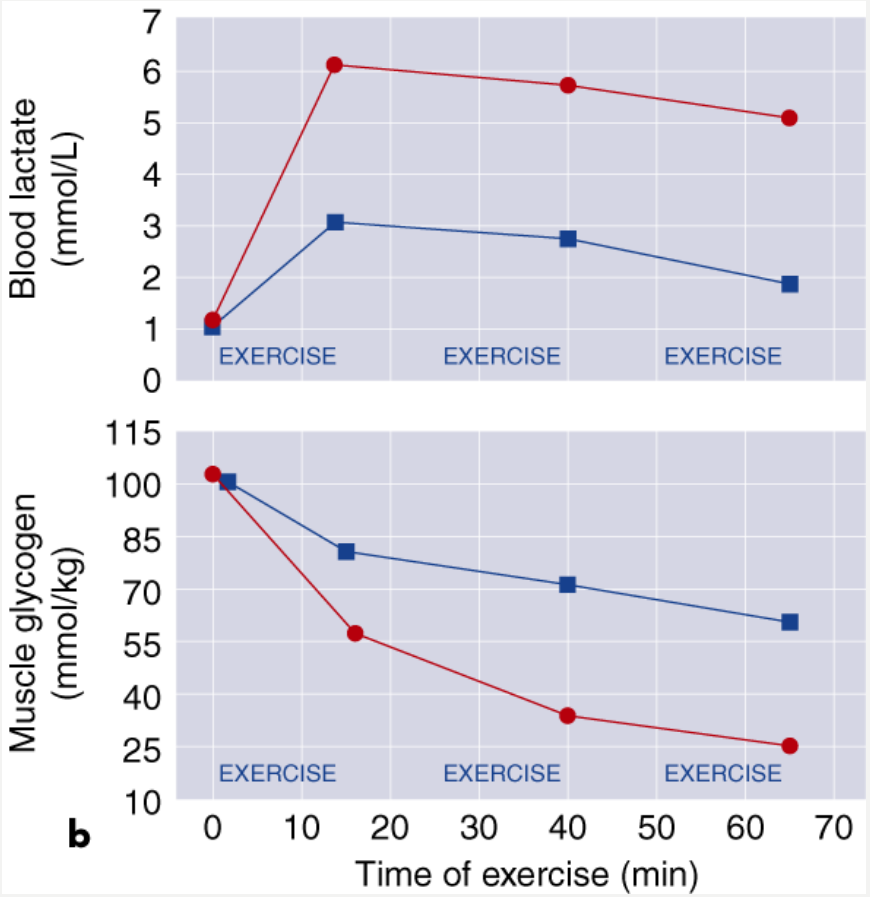
Body Fluid and Exercise in the Heat

- Sweating increases.
- High volumes of sweat cause
  - Blood volume to decrease,
  - Loss of minerals and electrolytes, and
  - Release of aldosterone and ADH and water reabsorption in kidneys.

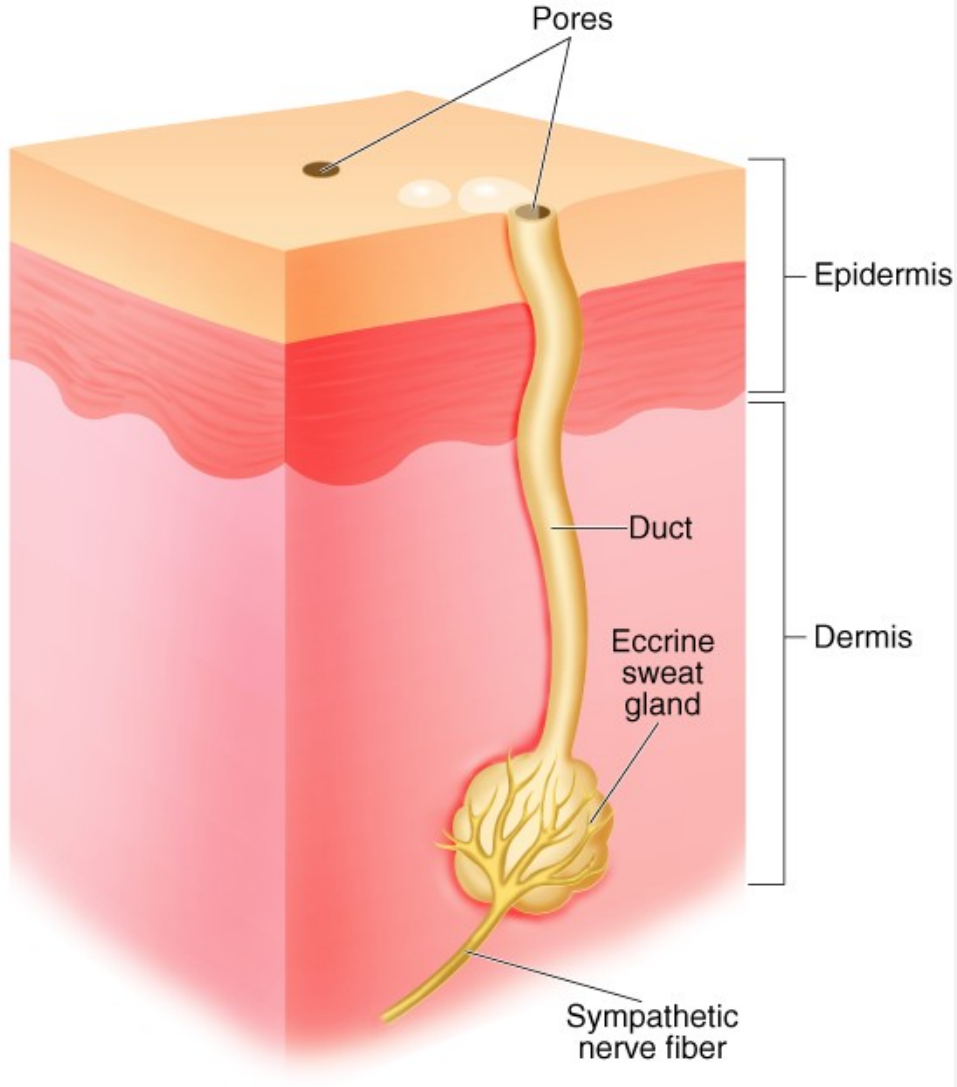


EXERCISE IN HEAT AND COLD





ECCRINE SWEAT GLAND



Body Temperature Control

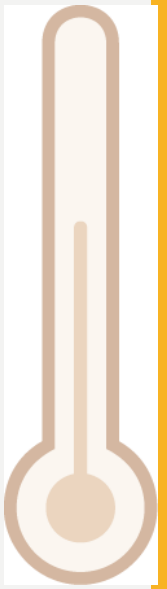
When $T_{environment} > T_{skin}$ you start gaining heat from

- Radiation (e.g., sun, pavement)
- Convection (e.g., air)
- Conduction (e.g., pavement)

Evaporation then becomes the only avenue of heat loss. Thus when you are in an environment with high humidity, evaporation is limited.

Evaporation requires sweating, and excessive sweating leads to dehydration, reduced plasma volume, and increased T_{body} .

You need more blood volume in skin to lose heat, but there is insufficient blood to do everything.



Sodium, Chloride, and Potassium Concentrations in the Sweat of Trained and Untrained Subjects During Exercise

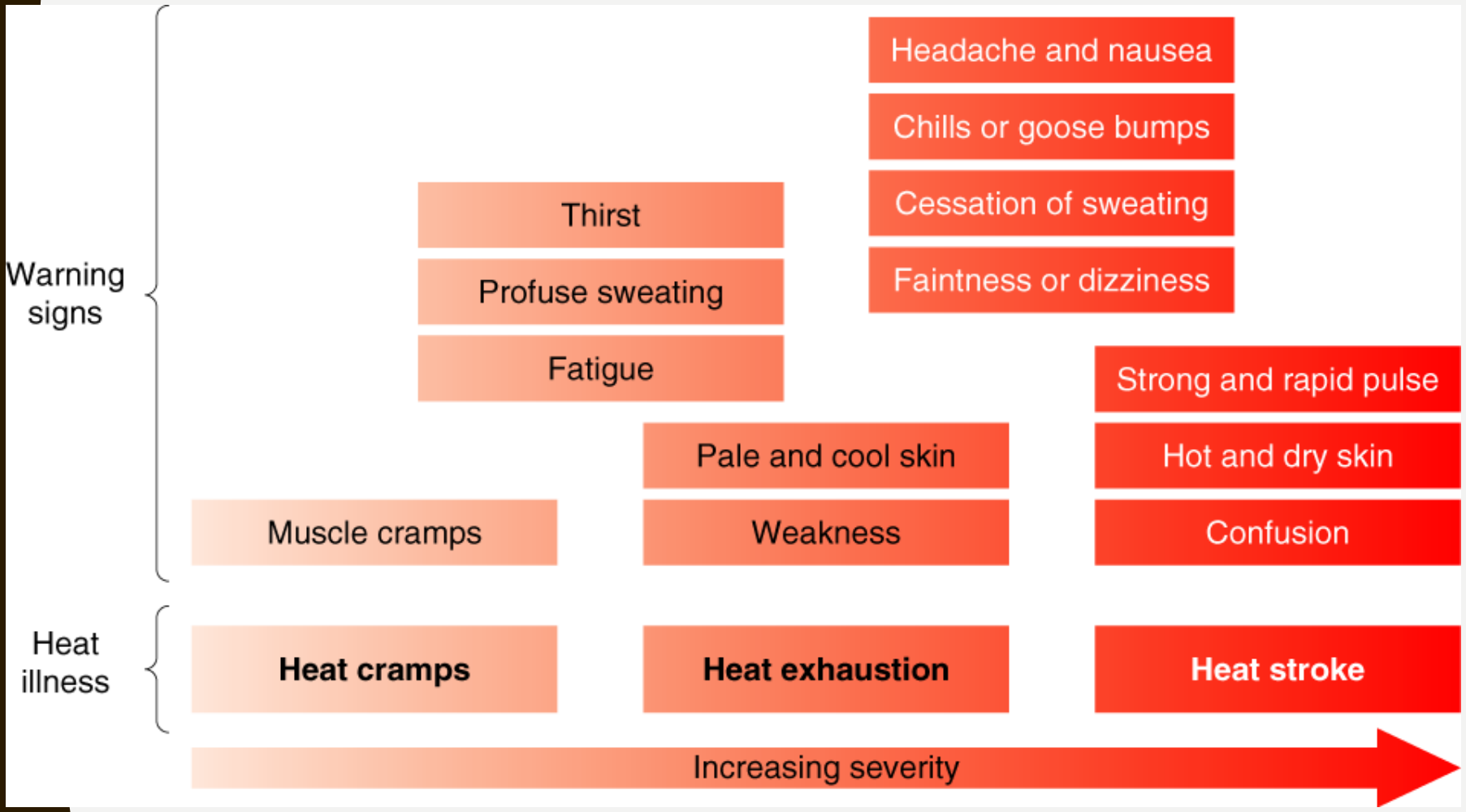
Subjects	Sweat Na^+ (mmol/L)	Sweat Cl^- (mmol/L)	Sweat K^+ (mmol/L)
Untrained males	90	60	4
Trained males	35	30	4
Untrained females	105	98	4
Trained females	62	47	4

Data from the Human Performance Laboratory, Ball State University

Variables Affecting Environment Heat Load

- Air temperature
- Humidity—desert versus tropics
- Air velocity—still air versus moving air
- Amount of thermal radiation—e.g., cloud cover, ground

WARNING SIGNS OF HEAT DISORDERS



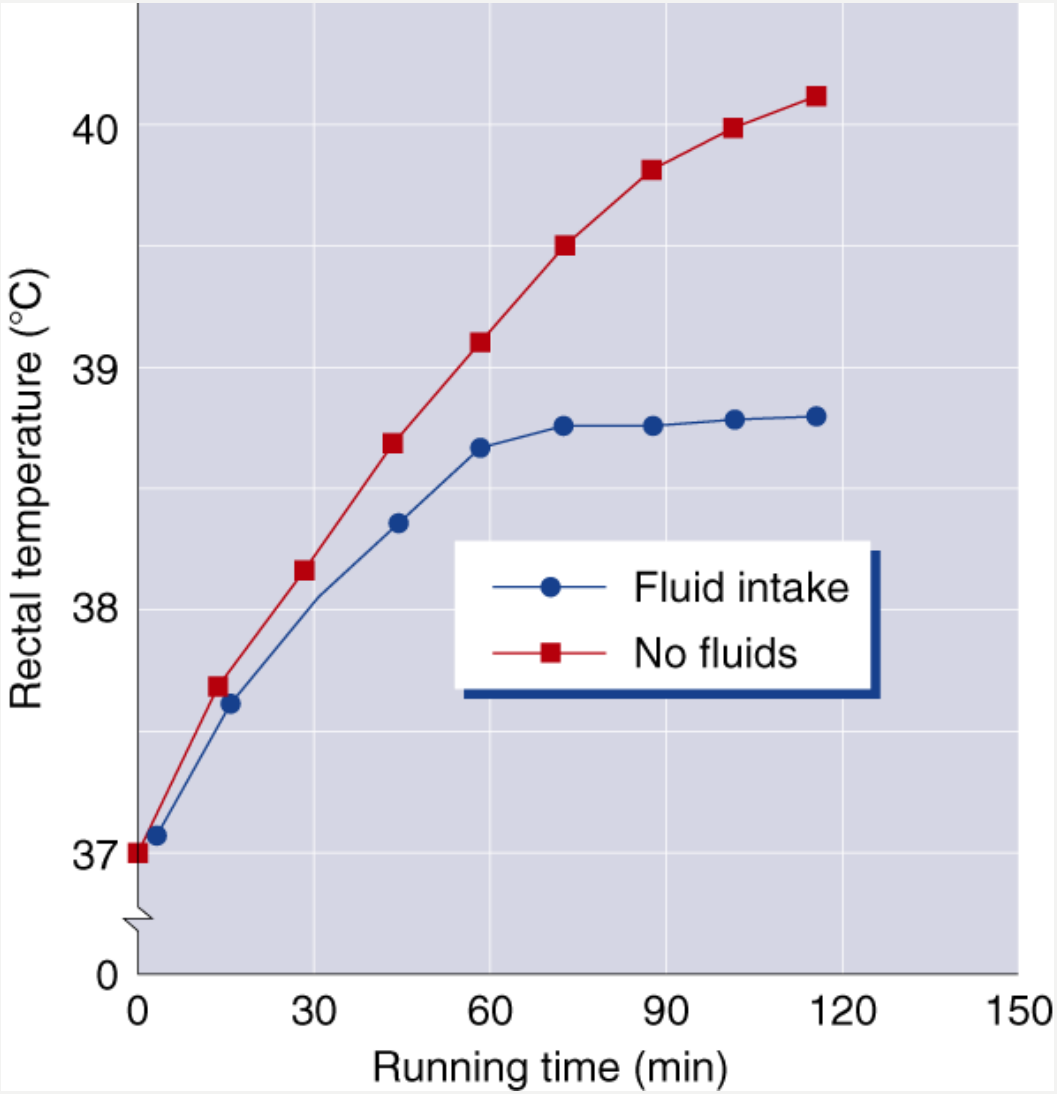
Treatment of Heat Disorders

Heat cramps—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

Heat stroke—rapidly cool body in cold water, ice bath or with wet towels; immediately seek medical attention

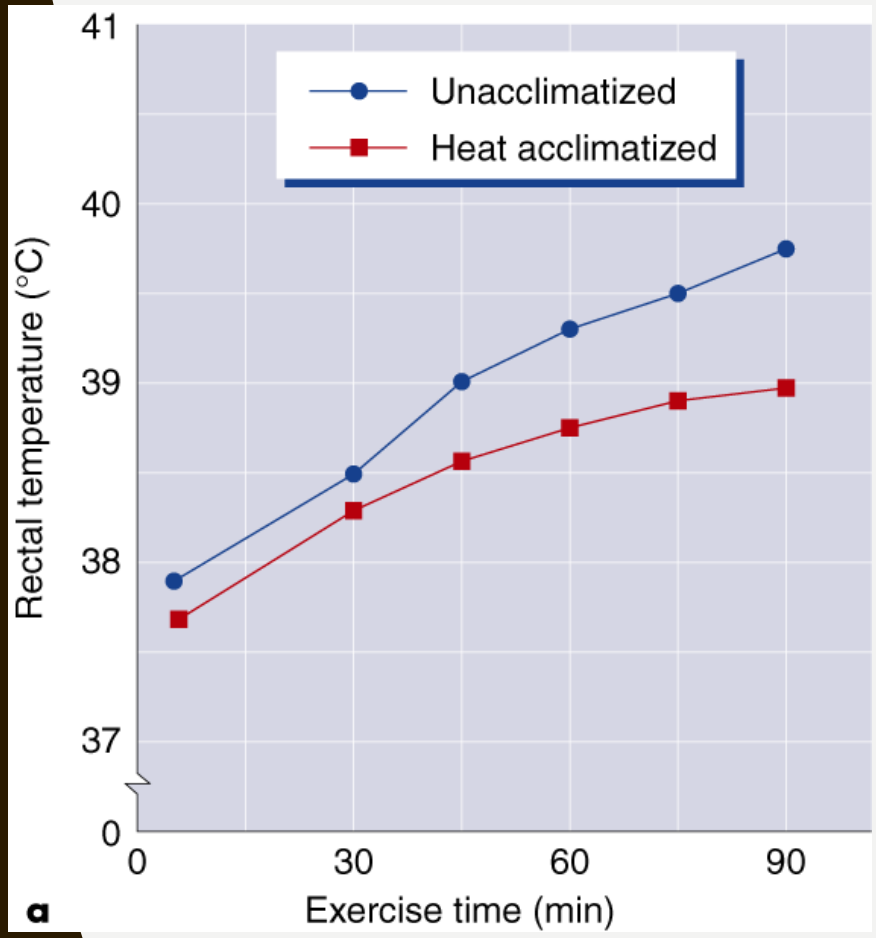
FLUID INTAKE AND EXERCISING IN THE HEAT

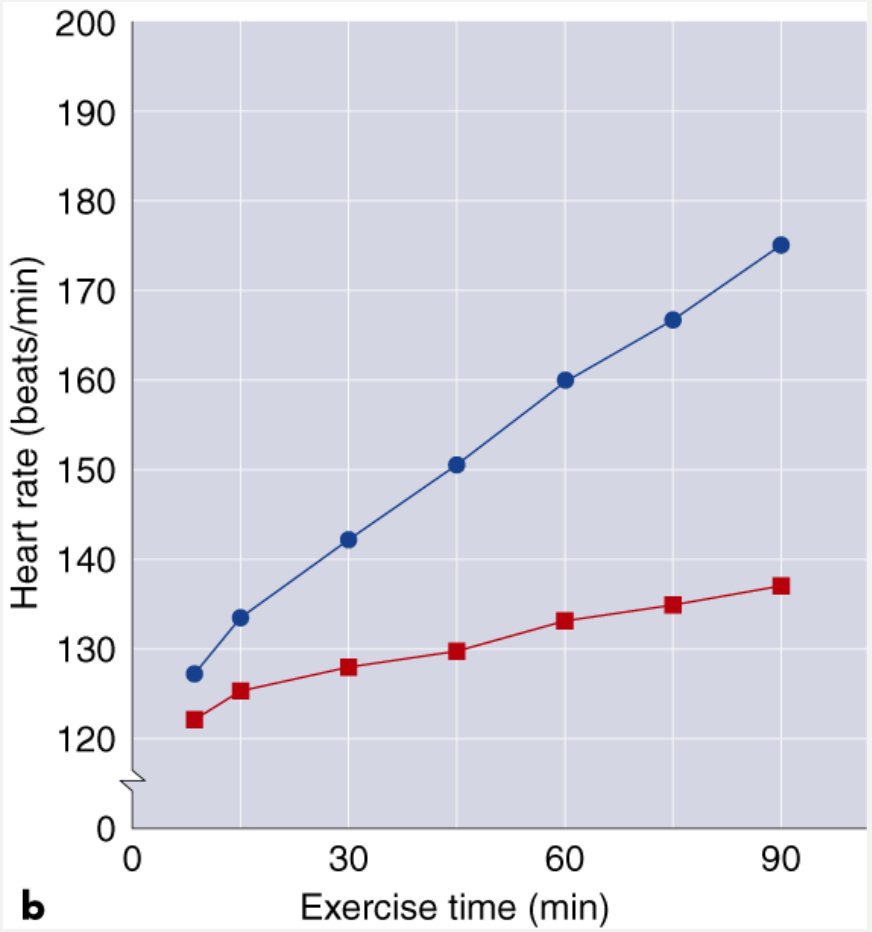


Heat Acclimatization

- 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 increase is less (than nonacclimatized)
- Stroke volume increases
- Muscle glycogen usage decreases

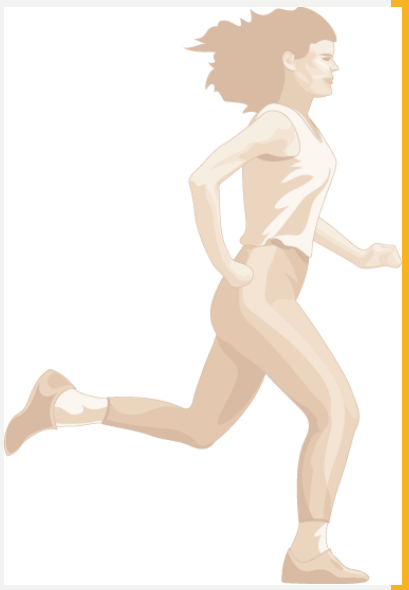
HEAT ACCLIMATIZATION





Did You Know…?

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.



How Does the Body Conserve Heat?

Shivering—rapid involuntary cycle of contraction and relaxation of muscles

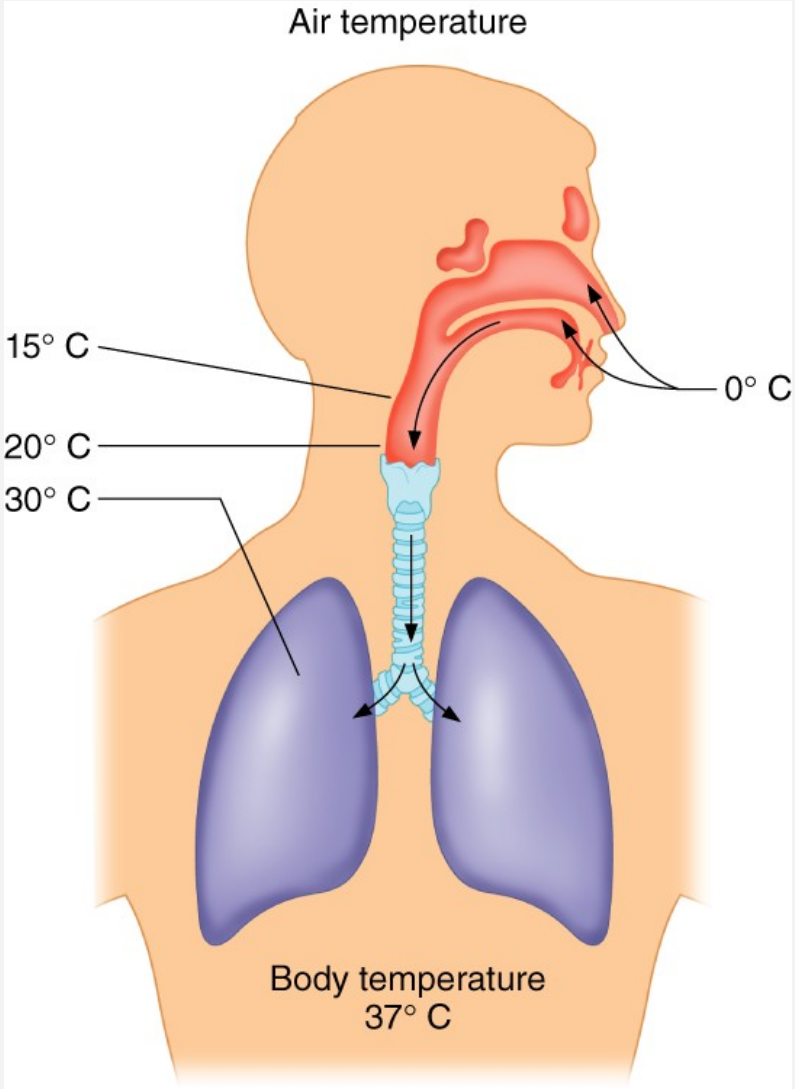
Nonshivering thermogenesis—stimulation of metabolism

Peripheral vasoconstriction—reduces blood flow to skin

Factors That Affect Body Heat Loss

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

WARMING OF INSPIRED AIR



Responses to Exercise in the Cold

- Muscles weaken and fatigue occurs more rapidly
- Susceptibility to hypothermia increases
- Exercise-induced free fatty acids 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.
- Hypothermia causes heart rate to drop, which reduces cardiac output.
- Vasoconstriction in the skin reduces blood flow to skin, eventually causing frostbite.