

# **FIRST PRESENTATION**

## **Heat; Humidity; Performance**

May 1<sup>st</sup> and 2<sup>nd</sup>  
Furman University

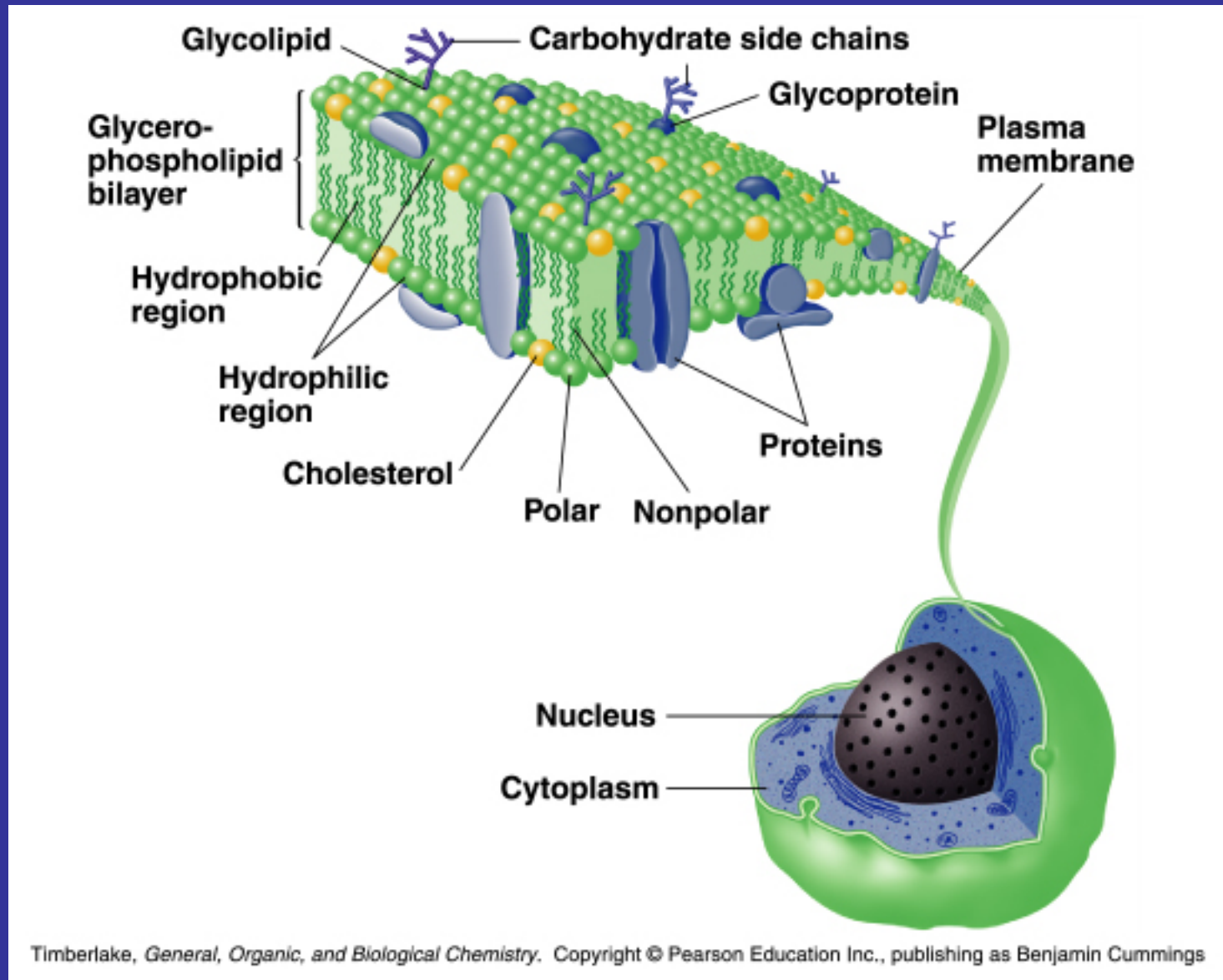
# Brain's Main Concerns

- pH: Blood's Acidity Level
- Osmolarity: Concentration of Particles in Blood
- Blood Glucose: Brain's Favorite Energy Source
- Surface Membrane Charge: Electrolyte Balance
- Core Temperature: Temperature of Vital Organs

# Heat and Humidity

- **Major Problems for Runners**
- **Excess body heat leads to heat disorders**
- **Performance decrement**

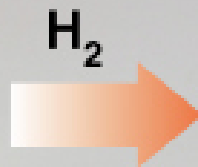
# Cells are Made of Bi-Lipid Layers



# Lipid Fluidity is Function of Temperature



**Vegetable oils  
(liquids)**



**Tub (soft)  
margarine**



**Shortening  
(solid)**

**Stick margarine  
(soft and solid)**

# Heat Illness

Training / competition stress exacerbated by heat  
high air temps or humidity:

↓  
skin & muscles compete for blood

↓  
progressive dehydration

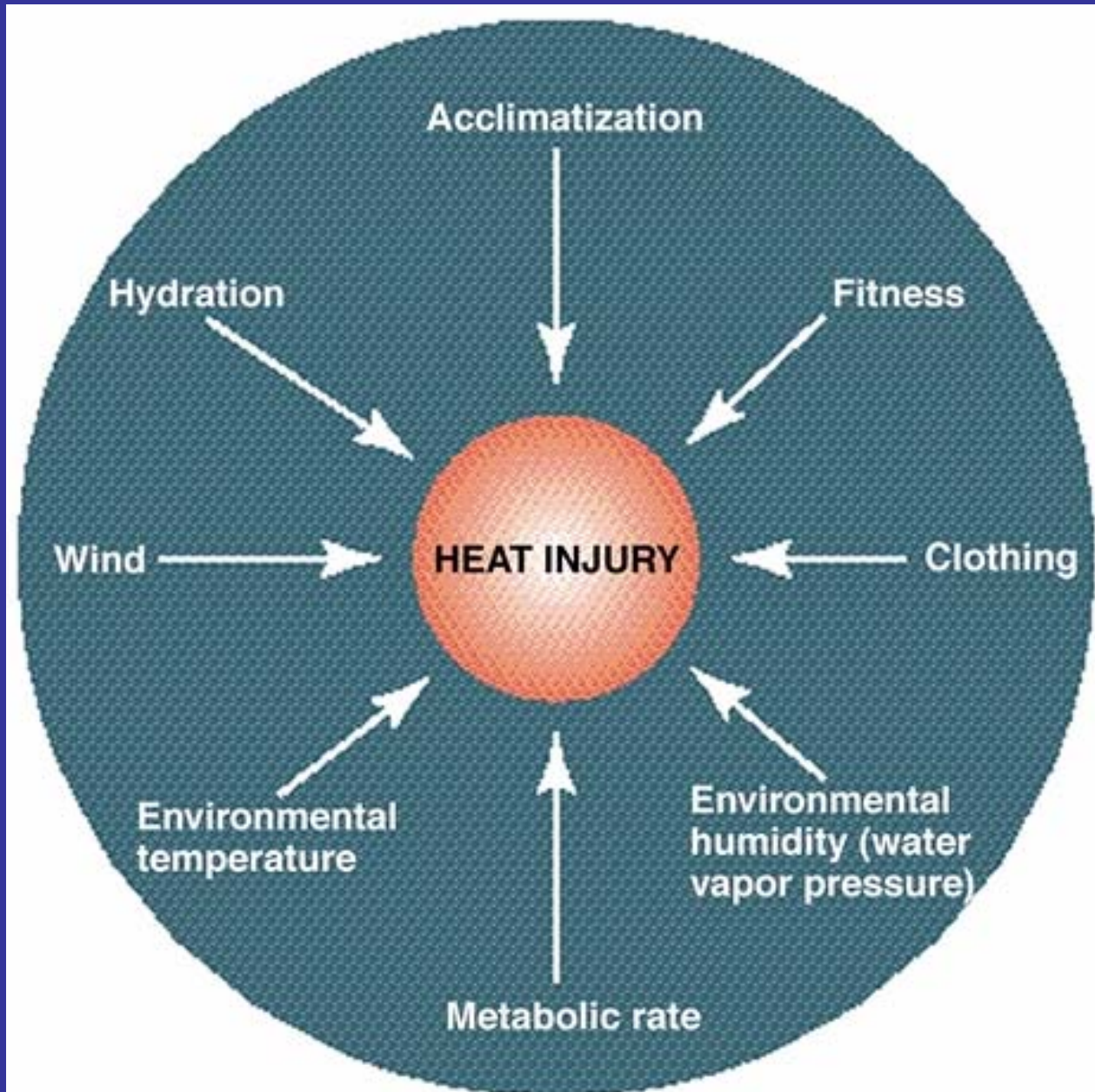
↓  
Hyperthermia

↓  
collapse

↓  
death



# Factors Affecting Heat Injury

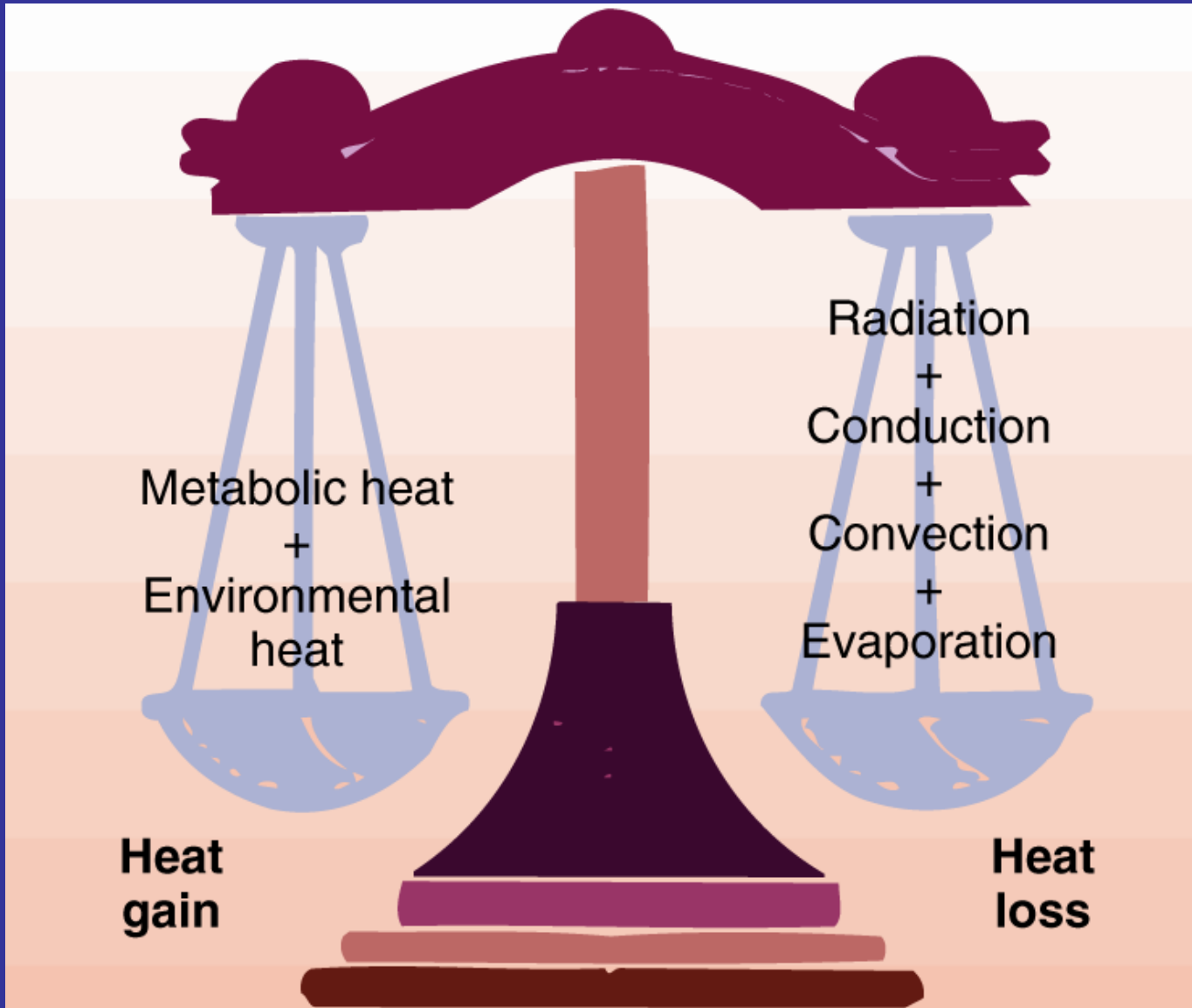


# Body Temperature

- Shell temperature:
  - Temperature closer to skin
  - Oral temperature
    - 36.6°-37.0°C (97.9°-98.6°F)
- Core temperature:
  - Most important temperature
  - Temperature of “core” (organs in cranial, thoracic and abdominal cavities)
  - Rectal temperature
    - 37.2°-37.6°C (99.0°-99.7°F)



# BODY HEAT GAINED AND LOST



# Heat Production

- Exergonic reactions:
  - Oxidation and ATP use.
- Most heat generated by brain, heart, liver and glands at rest.
- Skeletal muscles 20-30% at rest. Can increase 10-20 times during exercise.

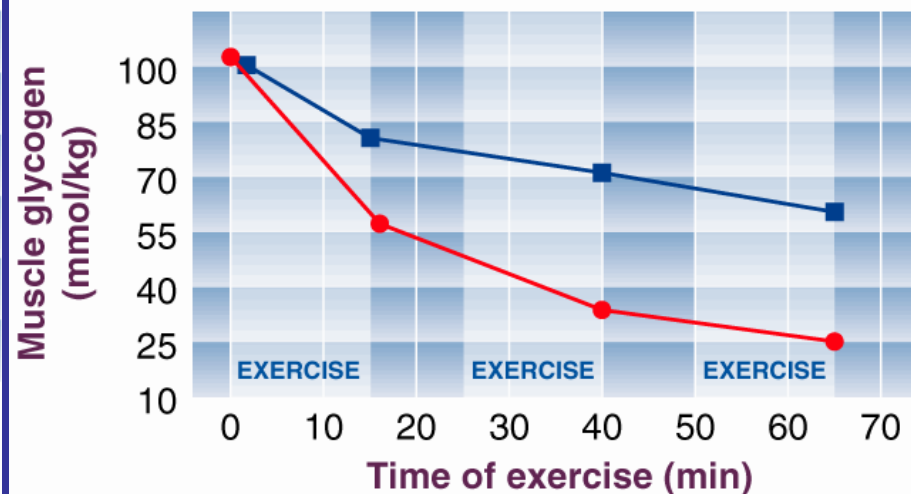
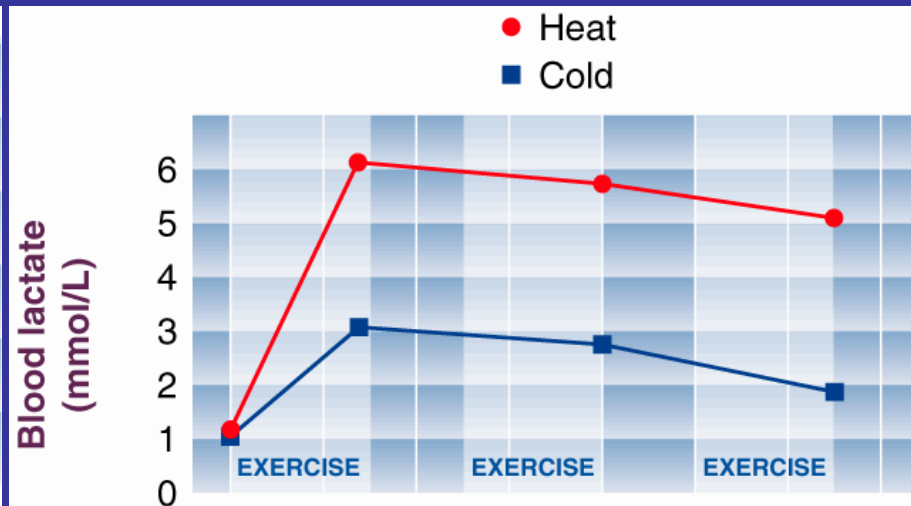
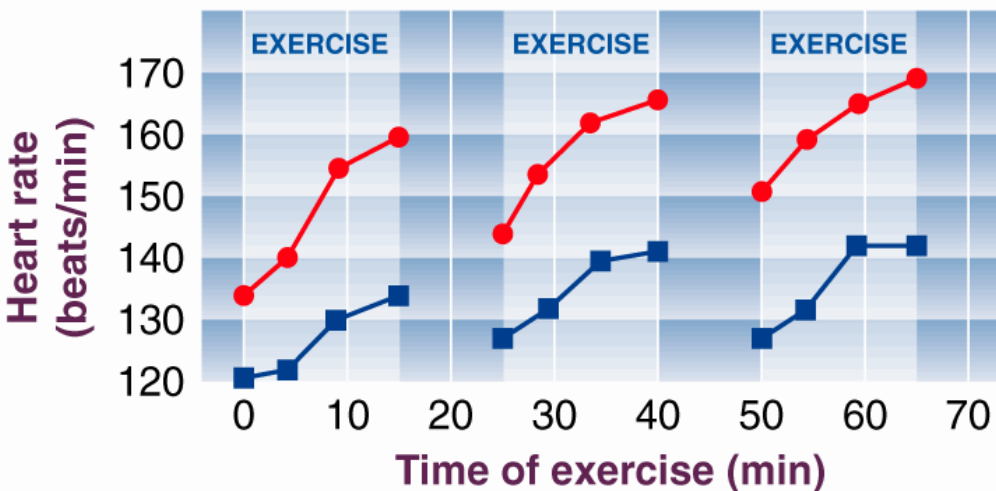
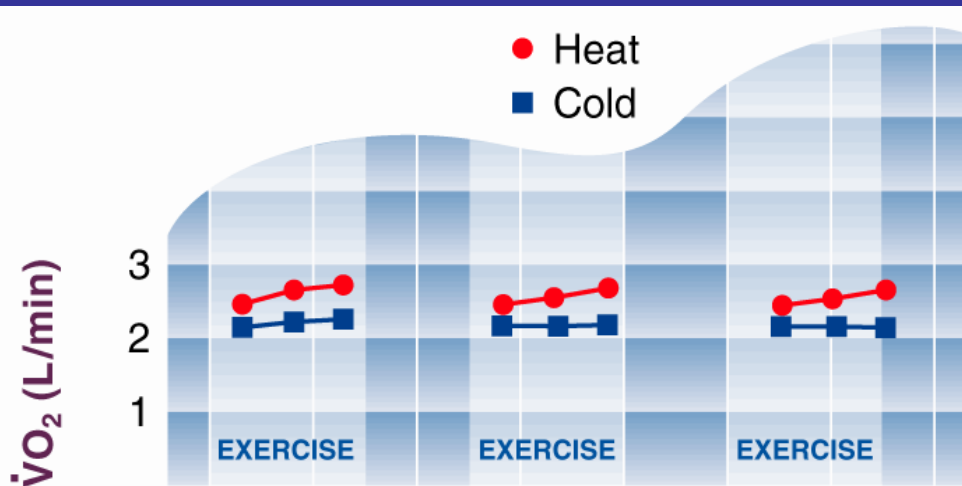
# Exercise

- Maximum exercise, heat production can be 10-20 times resting.
- Highest temperatures occur in the exercising muscles.
- Body temperature increases during exercise and levels off a few degrees above normal (except at extreme temperatures).
- Regulated response with heat loss = heat production at a stabilized core temperature.

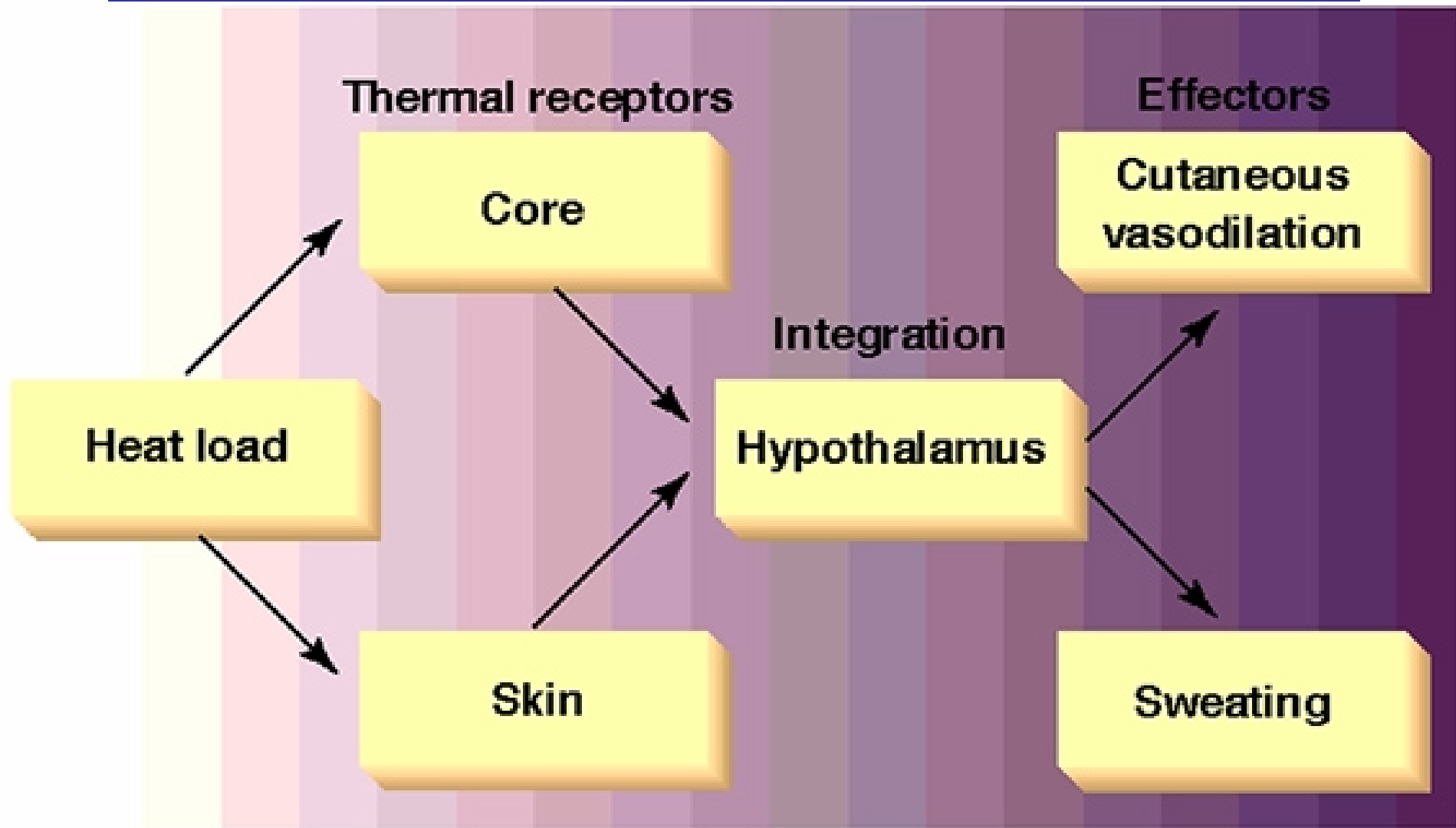
# Physiological Responses to Heat Accumulation

- Surface blood flow is increased at expense to other tissues
- ↓ Blood volume
- Cardiac efficiency ↓ (↓SV, ↑HR)
- Cardiovascular drift (↑ HR)
- ↑  $\text{VO}_2$ , ↑ glycogen use
- ↑ Fatigue

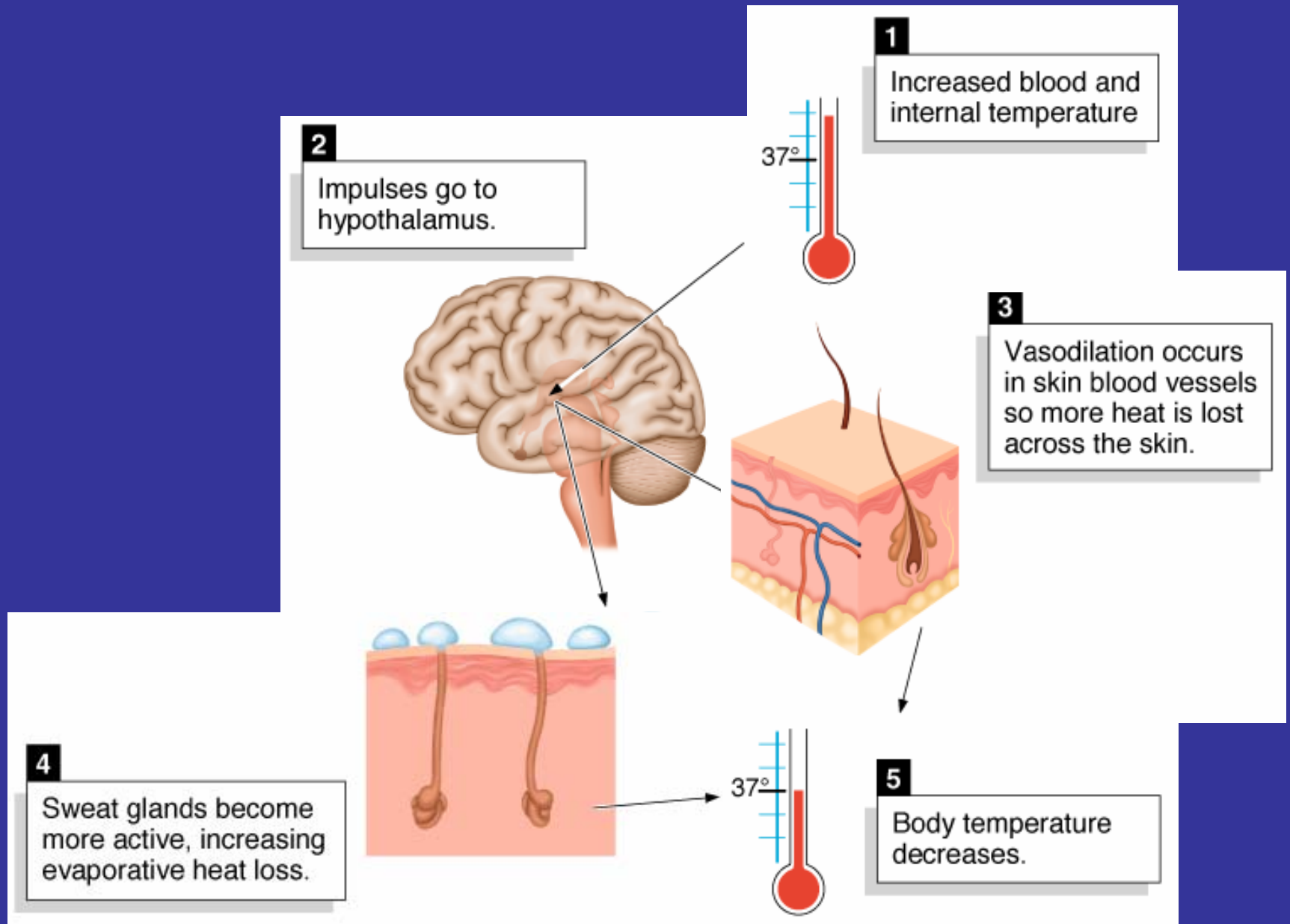
# Effects of Exercise in Heat



# Responses to Heat Stress



# THE HYPOTHALAMUS AND HYPERTHERMIA



# Primary Responses

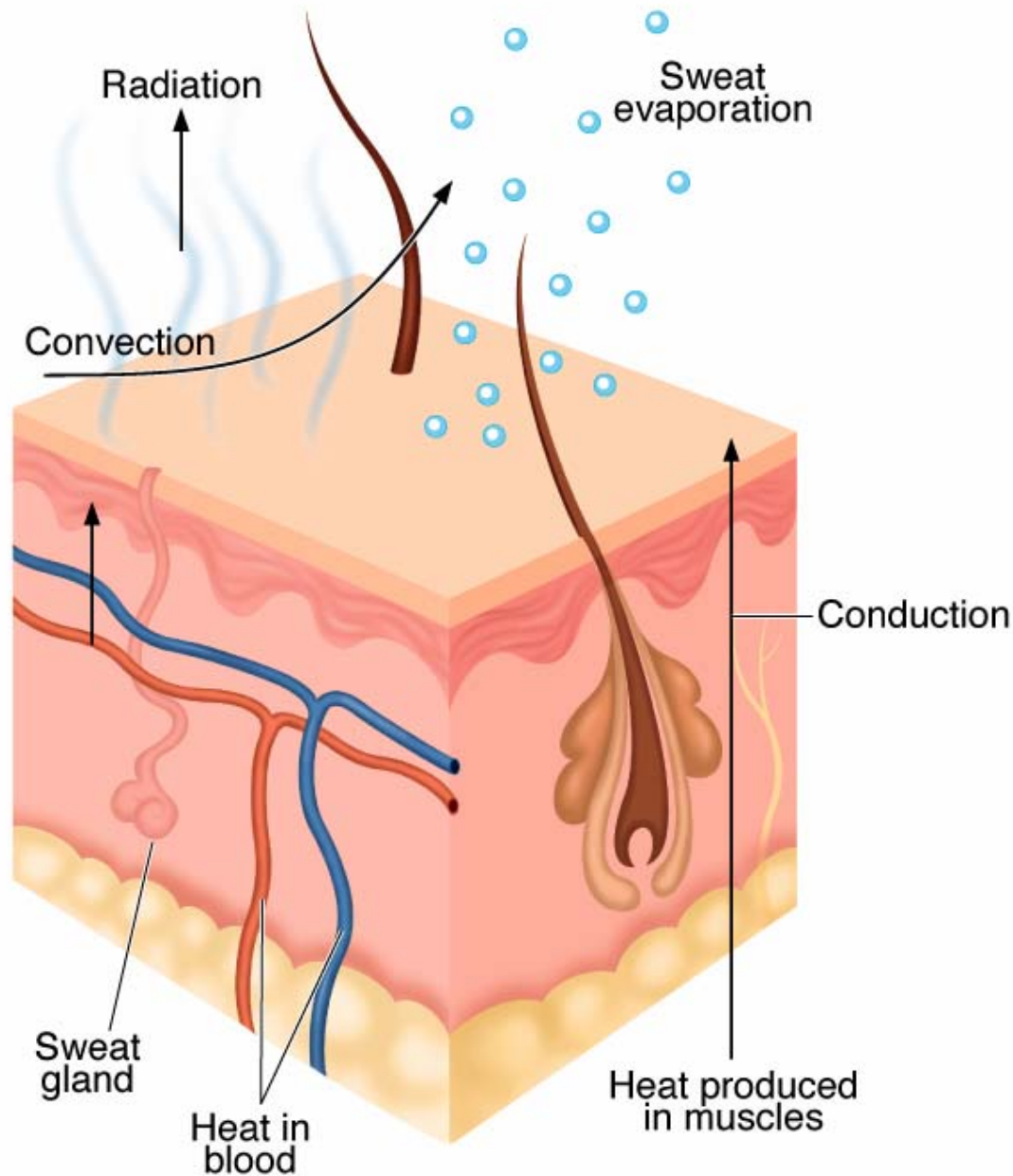
- Antidiuretic hormone (vasopressin)
  - Reduces urine loss and conserves body fluids and electrolytes.
- Release
  - Secreted from posterior pituitary in response to changes in plasma volume and osmolality
- Osmolality
  - The osmotic concentration of plasma. How many particles (ionic concentration) are present in plasma.



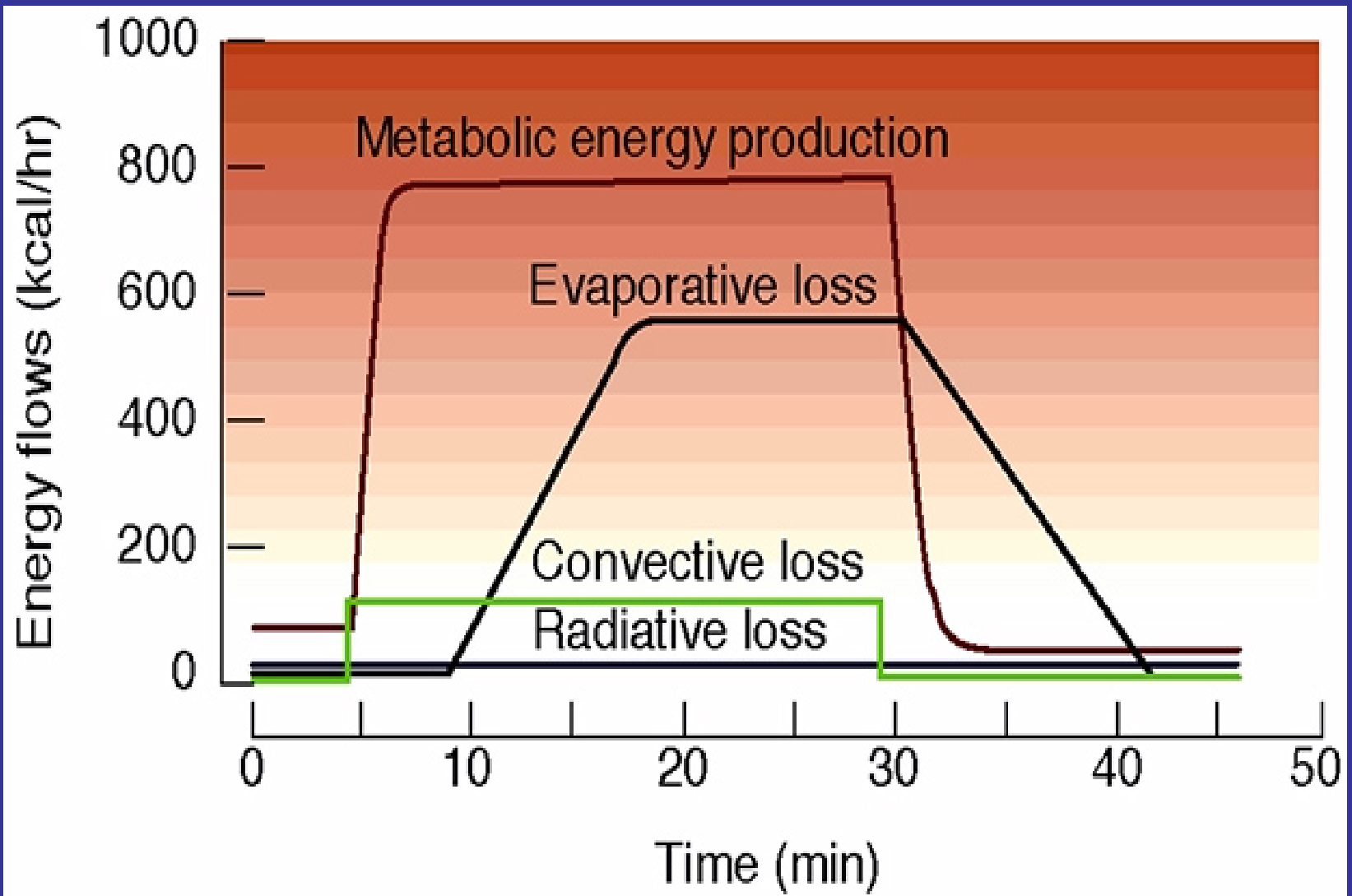
# Mechanisms of Heat Transfer

- Radiation:
  - Infrared radiation.
- Conduction:
  - Direct transfer of energy through physical contact.
- Convection:
  - Heat loss to air around the human body.
- Evaporation:
  - Energy change in water molecule from liquid to vapor.

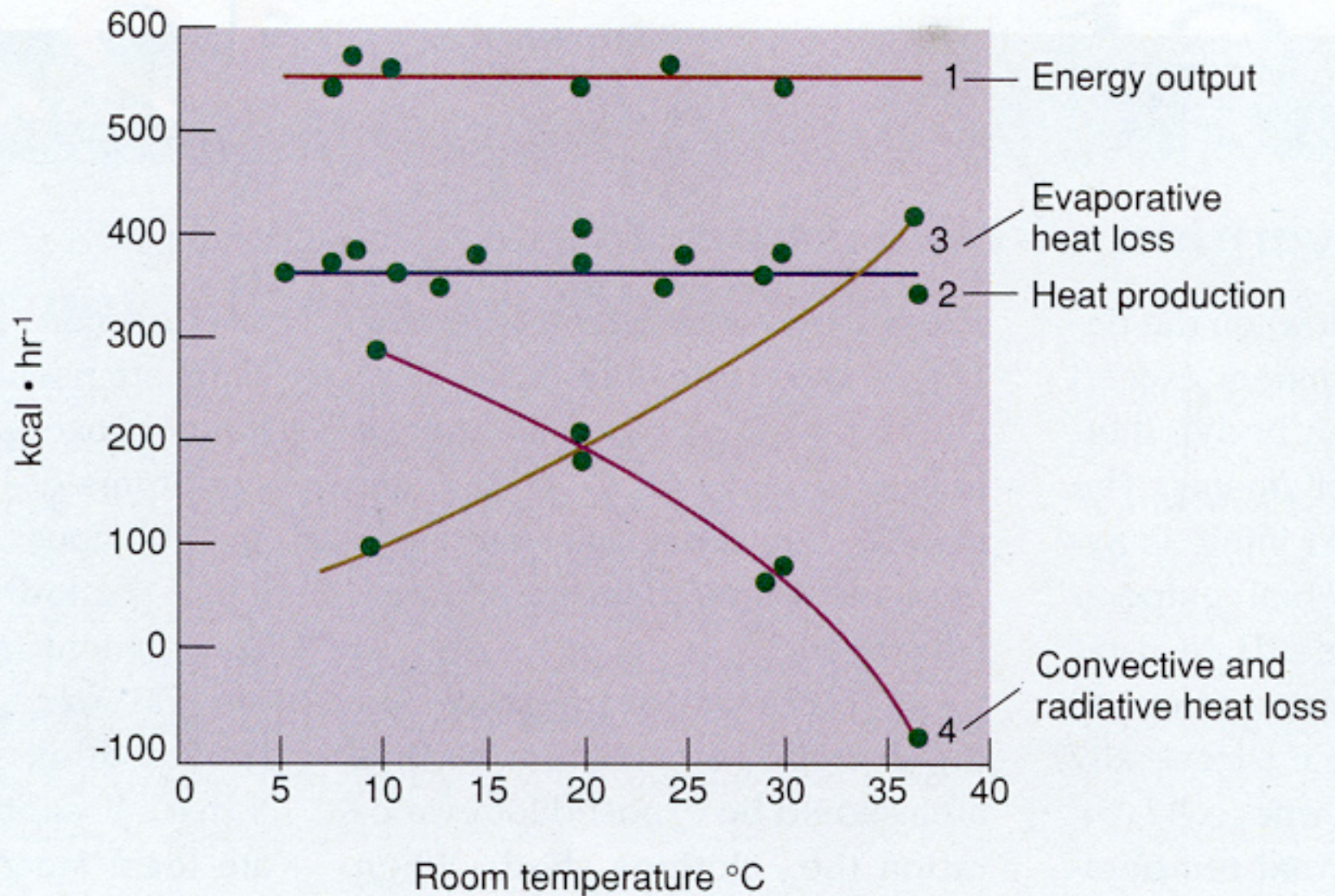
# HEAT REMOVAL FROM THE SKIN



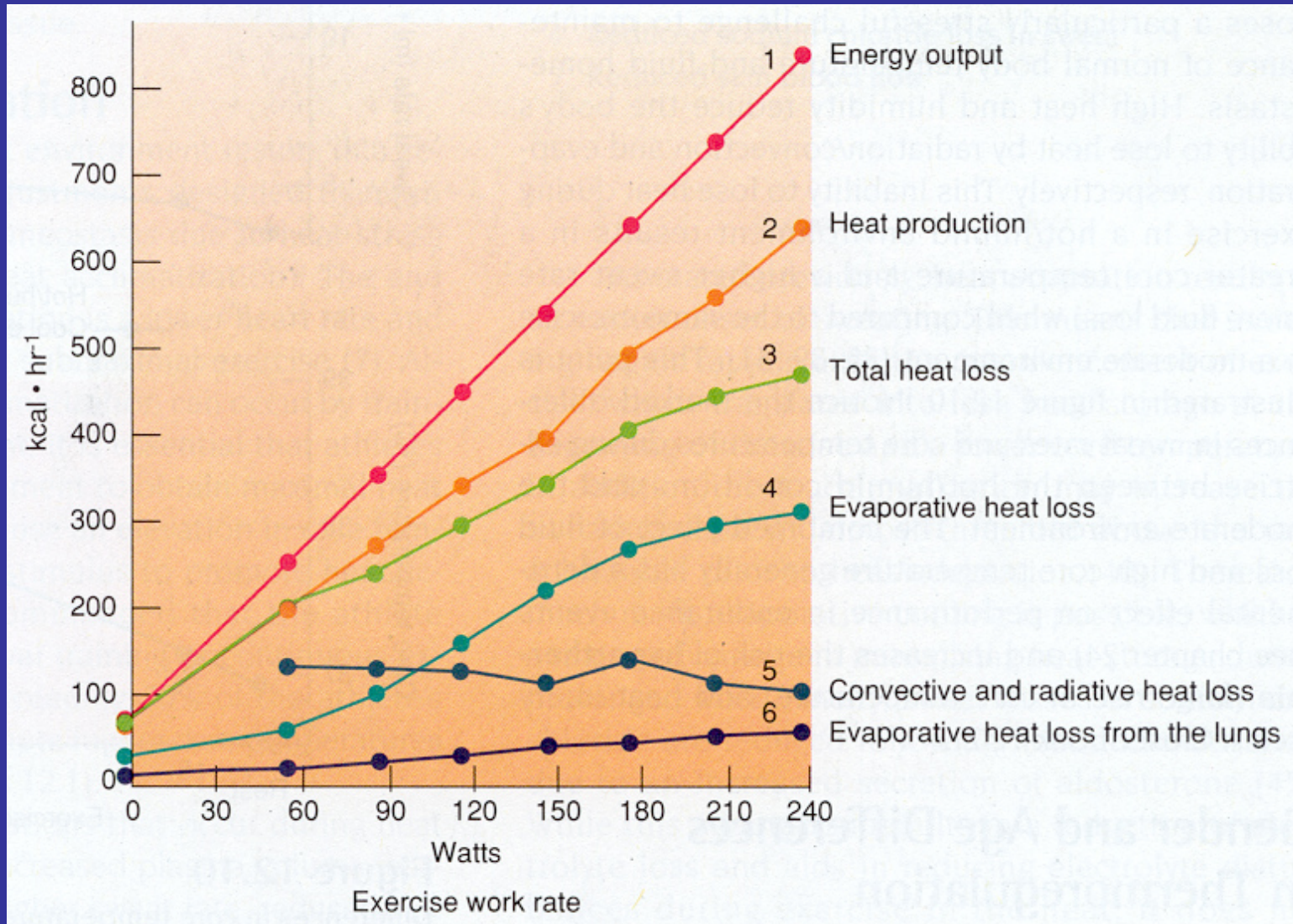
# Heat Exchange During Exercise



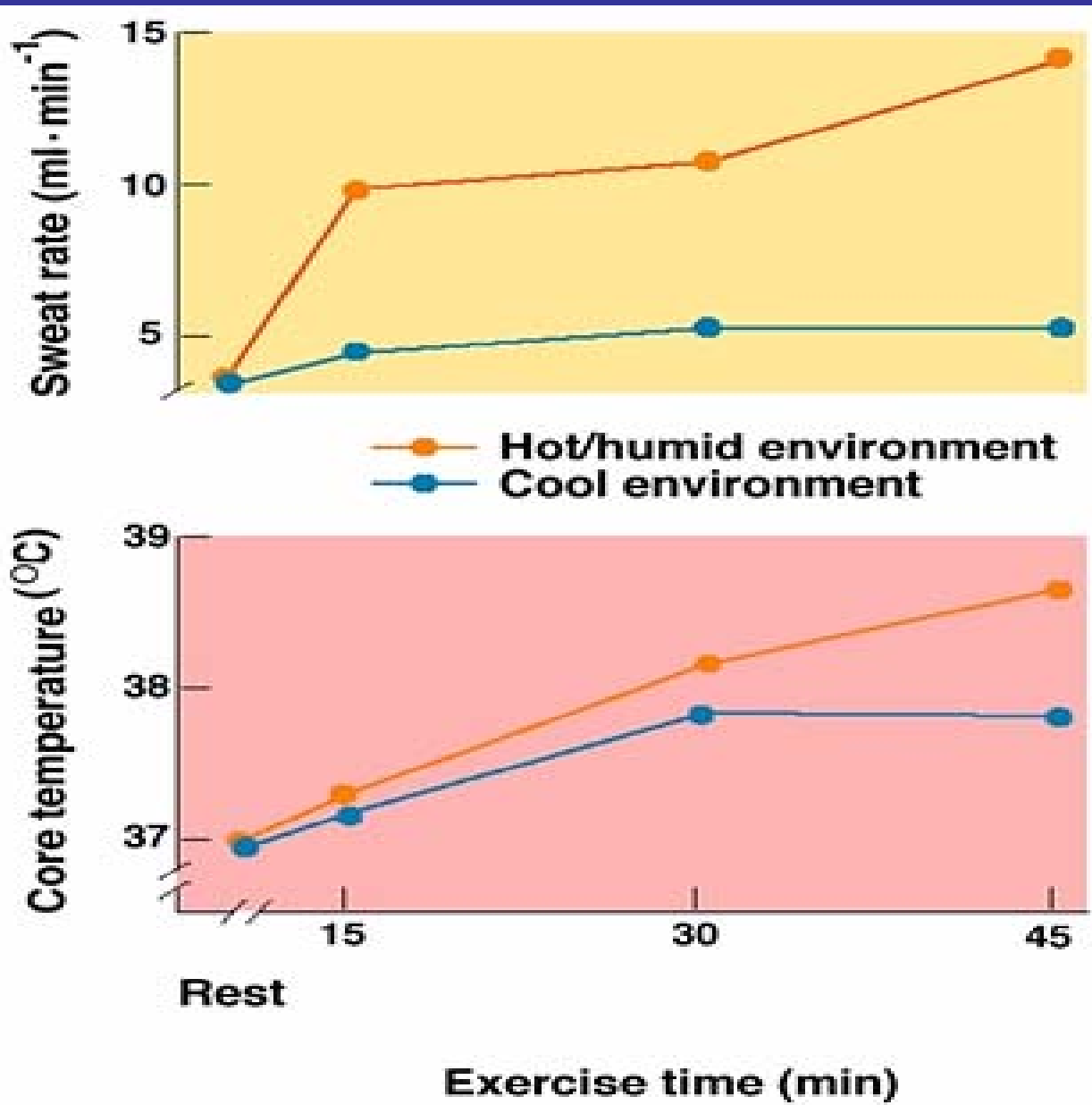
# Heat Exchange During Exercise: Effect of Ambient Temperature



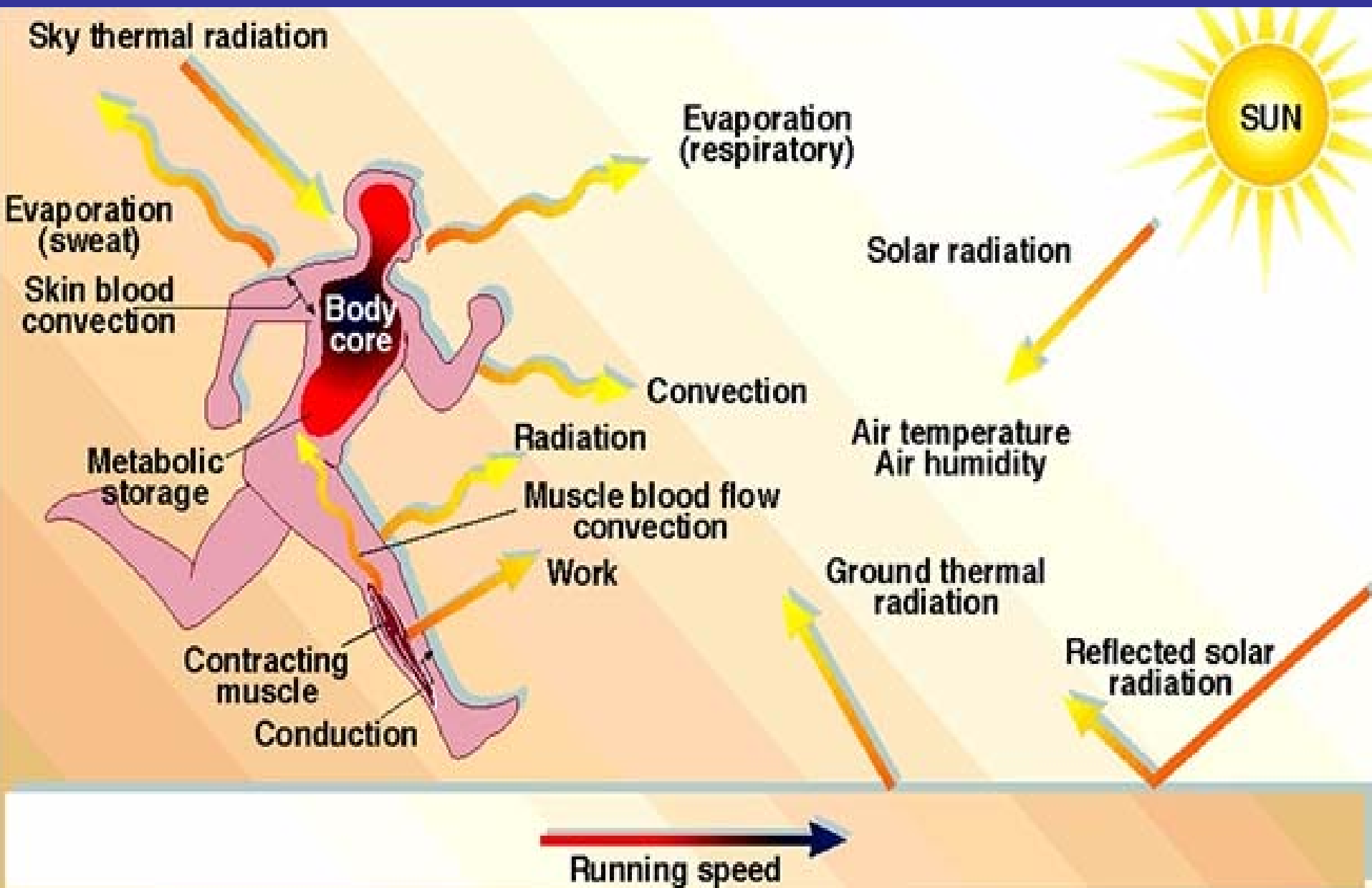
# Heat Exchange During Exercise: Effect of Exercise Intensity



# Core Temperature and Sweat Rate During Exercise in Heat/Humidity



# Heat Exchange During Exercise

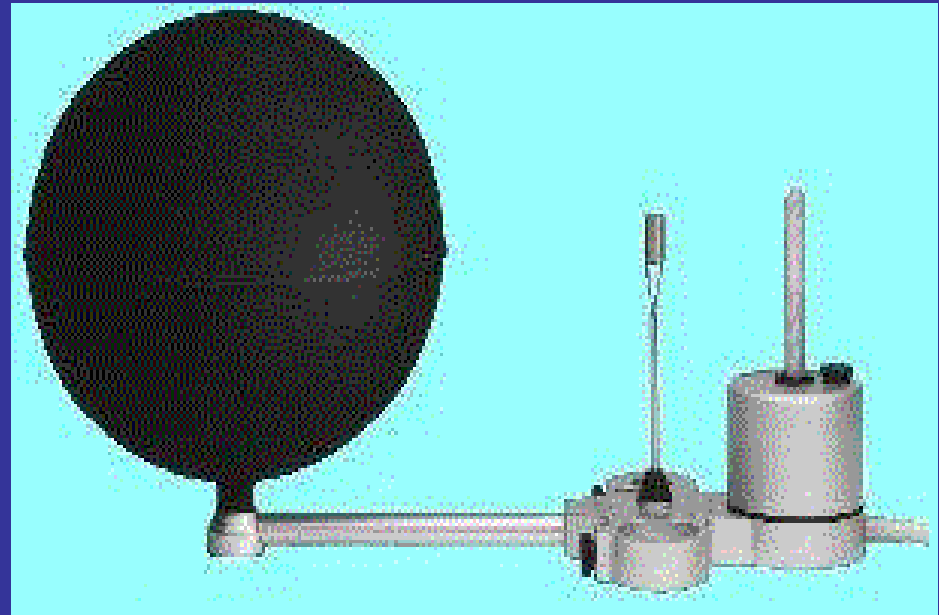


- The black globe absorbs infrared heat

## WBGT

- Dry bulb is typical thermometer

- Wet bulb is a thermometer with a wetted wick on the end. Air is blown across to evaporate water. As water evaporates, it cools the thermometer





# WBGT Calculation

$WBGT = 0.1$  (dry bulb) +  $0.7$  (wet bulb) +  $0.2$  (black globe)

Low Risk = < 65 F

Moderate = 66 - 73

High risk = 74 - 82

Very High = > 82 F

Rule of Thumb: If sum of temperature and humidity is over 150, be careful.

# Heat Stress Index

## Heat Stress Index

Air temperature (°F)

70° 75° 80° 85° 90° 95° 100° 105° 110° 115° 120°  
Heat sensation

0%	64°	69°	73°	78°	83°	87°	91°	95°	99°	103°	107°
10%	65°	70°	75°	80°	85°	90°	95°	100°	105°	111°	116°
20%	66°	72°	77°	82°	87°	93°	99°	105°	112°	120°	130°
30%	67°	73°	78°	84°	90°	96°	104°	113°	123°	135°	148°
40%	68°	74°	79°	86°	93°	101°	110°	123°	137°	151°	
50%	69°	75°	81°	88°	96°	107°	120°	135°	150°		
60%	70°	76°	82°	90°	100°	114°	132°	149°			
70%	70°	77°	85°	93°	106°	124°	144°				
80%	71°	78°	86°	97°	113°	136°					
90%	71°	79°	88°	102°	122°						
100%	72°	80°	91°	108°							

Heat sensation	Risk of heat injury
90°–105°	Possibility of heat cramps
105°–130°	Heat cramps or heat exhaustion likely Heat stroke possible
130°+	Heat stroke a definite risk

What is the Primary Aim  
of Fluid Replacement?

**To maintain plasma volume  
so that circulation and  
sweating progress at  
optimal levels**

# Functions of Body Water

- Serves as body's transport system
- Gas transport and gas exchange takes place across moist surfaces
- Nutrients and gases are transported in aqueous solution
- Waste products exit via urine and feces
- Water has heat stabilizing qualities (absorbs large amounts of heat with minimal changes in Temp)
- Fluids lubricate joints; prevents bone grinding
- Gives turgor to body tissues because water is noncompressible

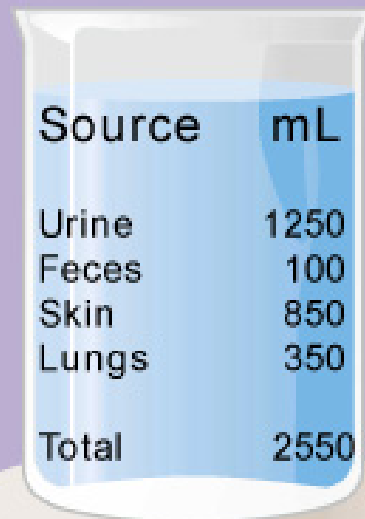
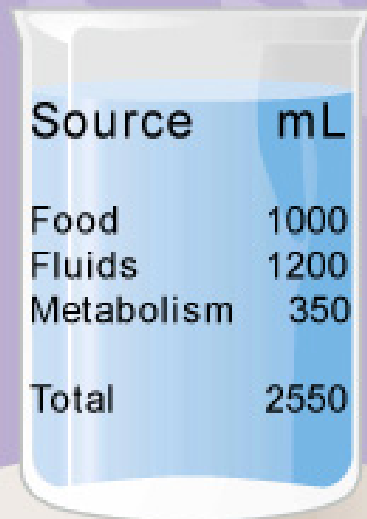
# Hydration Terminology

- Euhydration
  - Normal daily water variation
- Hyperhydration
  - Increased water content
- Hypohydration
  - Decreased water content
- Dehydration
  - Losing water
- Rehydration
  - Gaining water

## Normal Temperature (little or no exercise)

Daily water input

Daily water output



# Water Balance - No Exercise

## Hot Weather (heavy exercise)

Daily water input

Source	mL
Food	1000
Fluids	1200
Metabolism	350
<b>Total</b>	<b>2550</b>

Daily water output

Source	mL
Urine	500
Feces	100
Skin	5000
Lungs	700
<b>Total</b>	<b>6300</b>

# Water Balance in Exercise



# Fluid Balance

- Dehydration impairs endurance performance, minimal effect on power and speed events
- ↓ Blood volume will ↓ skin blood flow and heat dissipation
- Electrolyte loss accompanies dehydration
- Thirst mechanism doesn't keep up with dehydration
- Need for water replacement > than electrolyte replacement in most instances

# Physical performance

% maximal performance

100  
95  
90  
85  
80  
75  
70

0.0

0.5

1.0

1.5

2.0

2.5

3.0

3.5

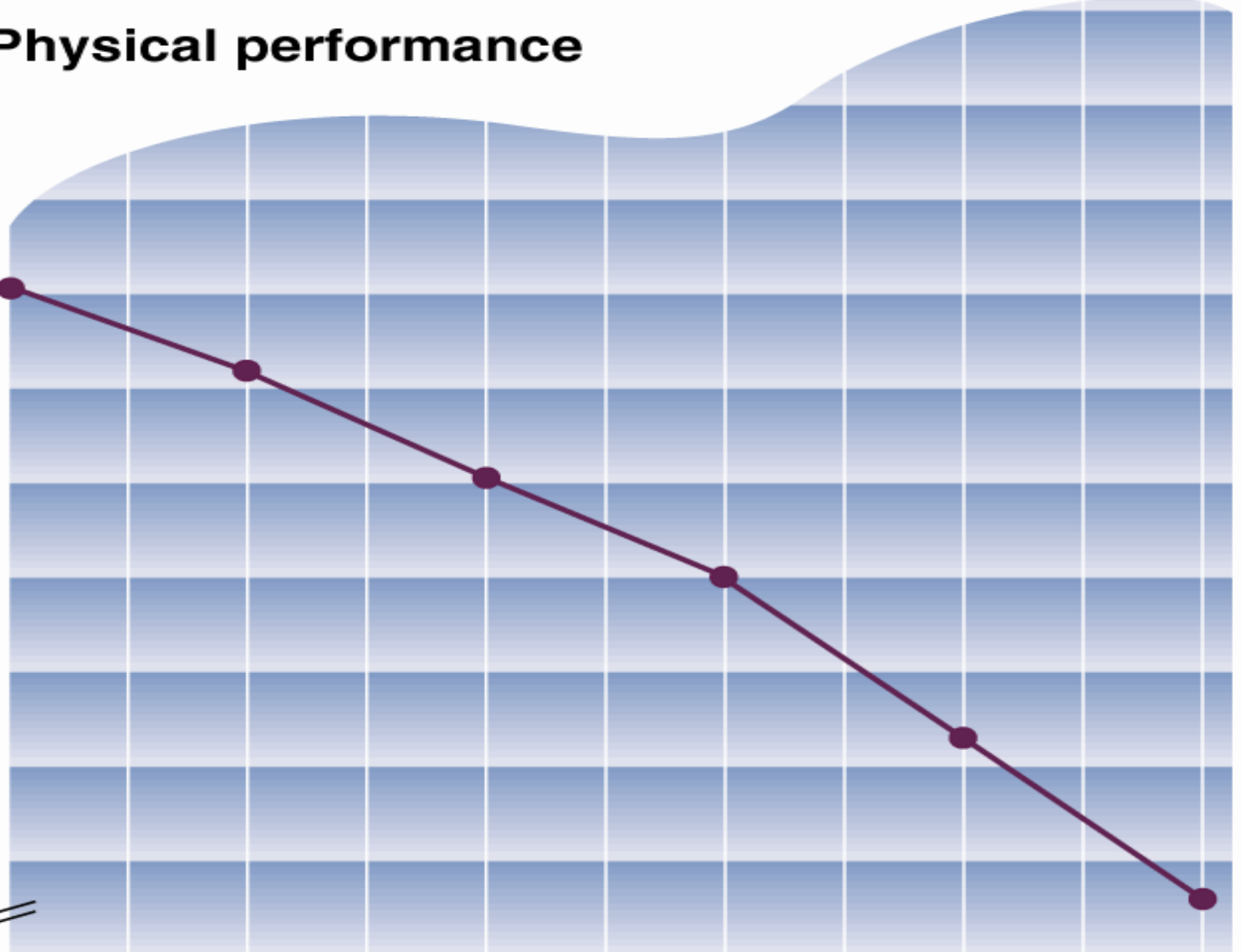
4.0

4.5

5.0

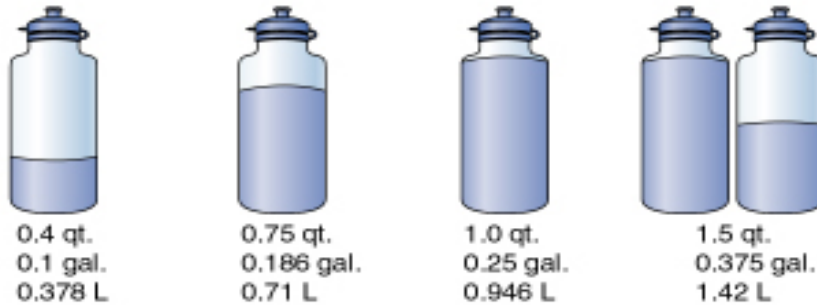
% dehydration

//

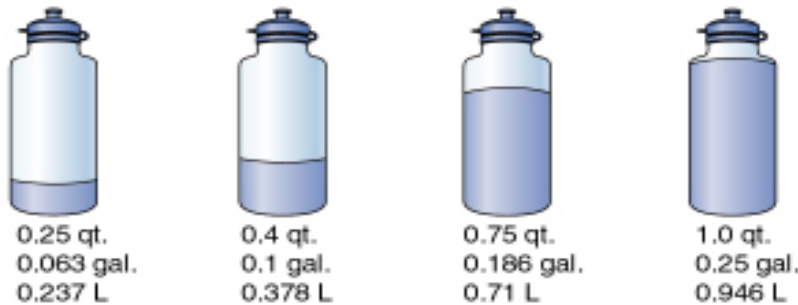


## Water Loss Per Hour

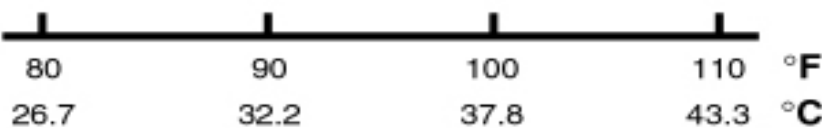
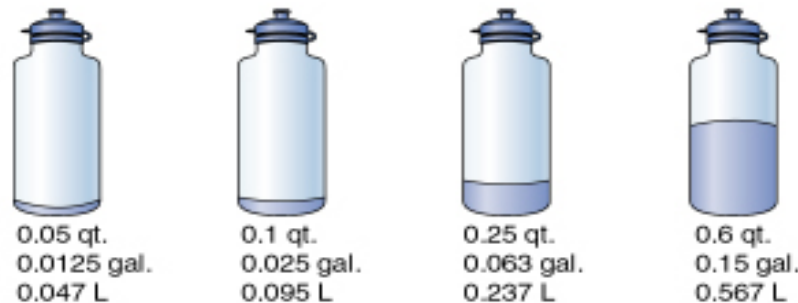
Moderate Activity



Light Activity



Rest



Air Temperature

# Water Loss and Temperature

# Drink By The Clock; Not Thirst

- Inadequate fluid intake is the primary obstacle to fluid replacement. Thirst is not an adequate guide, since athletes only replace about 50% of their fluid losses during exercise.
- Athletes can dehydrate by 2% to 10% of their body weight during exercise in the heat despite the availability of fluids. Thus, fluid intake must be regulated by drinking according to a schedule, rather than by the perception of thirst.



# Maintaining Fluid Balance

Fluid intake during exercise will:

- minimize dehydration

- minimize rise in body temperature

- reduce CV stress

Cold fluids enhance body cooling and empty faster from stomach

[CHO] > 6-8% slows absorption from gut

**TRAIN TO HYDRATE**

# Water Loss And Performance

<b>% Body Weight Lost as Sweat</b>	<b>Physiological Effect</b>
<b>2%</b>	<b>Impaired performance</b>
<b>4%</b>	<b>Capacity for muscular work declines</b>
<b>5%</b>	<b>Heat exhaustion</b>
<b>7%</b>	<b>Hallucinations</b>
<b>10%</b>	<b>Circulatory collapse and heat stroke</b>

# ACSM Position Stand: Exercise and Fluid Replacement

1. Primary objective for replacing body fluid loss during exercise is to maintain normal hydration.
2. Important to consume adequate fluids during the 24-h period before an event and drink about 500 ml (about 17 oz) of fluid about 2 h before exercise to promote adequate hydration and allow time for excretion of excess ingested water.

3. To minimize risk of thermal injury and impairment of exercise performance during exercise, fluid replacement should attempt to equal fluid loss.
4. At equal exercise intensity, the requirement for fluid replacement becomes greater with increased sweating during environmental thermal stress.
5. During exercise lasting longer than 1 h, it is important to do the following:
  - a. **add CHO to the fluid replacement solution to maintain blood glucose concentration and delay the onset of fatigue**



- b. electrolytes (primarily NaCl; ) should be added to the fluid replacement solution to enhance palatability and reduce the probability for development of *hyponatremia*.**
- c. During exercise fluid and CHO requirements can be met simultaneously by ingesting 600-1200 ml/hr of solutions containing 4% to 8% CHO.**
- d. During exercise greater than 1 h, approximately 0.5 to 0.7 g of sodium per liter of water would be appropriate to replace that lost from sweating.**

# Good Taste

- In order to encourage more fluid consumption, just the right amount of flavoring must be added. A light blend of sweetness (carbohydrate) and flavor with a touch of salt (sodium) seems to be the most effective combination. The sports drink should have a taste that is appealing when you are hot and thirsty or you won't drink it.

# Gastric Emptying

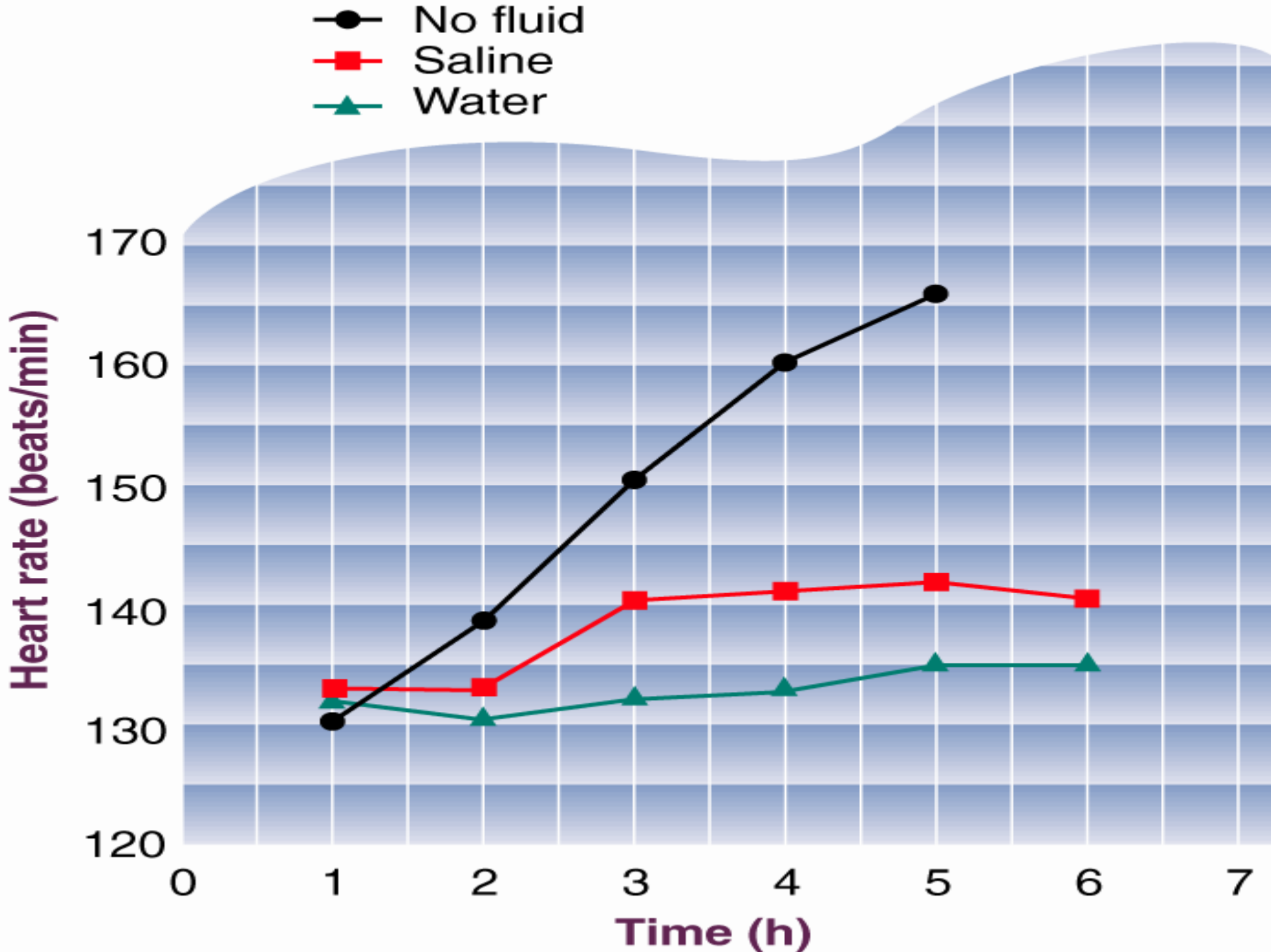
- Fluids must be emptied from the stomach before absorption in the small intestine.
- Three factors influence gastric emptying:
  - *Fluid temperature*; cold water empties fastest (41 degrees F)
  - *Fluid volume*; 8.5 oz every 15 min. Too much slows gastric emptying
  - *Fluid osmolarity*; gastric emptying slowed when fluid is concentrated >10%. Sugary solutions (4 - 8% should be goal for CHO concentration for exercise longer than 60 min)

# Glucose Polymers

- What is a glucose polymer? (link of 10-15 glucose molecules)
- Sports drinks are popular because:
  - low osmolarity (maltodextrins). Polymerized glucose solutions provide water and CHO at a faster rate than a drink of similar CHO content consisting of monosaccharides and disaccharides.

Generalized Summary:

Drink Cool Solutions, Drink Often, Choose the Brand Wisely



# Water Intoxication (Hyponatremia)

- Water intoxication refers to excessive water intake of more than 10 quarts a day
- Causes significant dilution of the body's normal sodium concentration
- Symptoms include head-ache, blurred vision, excessive sweating, and vomiting. In severe cases, there is cerebral edema, convulsions, comatose, and death
- Consume 400-600 ml (13 to 20 oz) about 10-20 minutes before performance

# Heat Disorders

## HEAT CRAMPS

Cause: Prolonged exer in heat; negative Na

Symptom: Tightening, cramps, low Na

Prevent: Salt, acclimatization

## HEAT EXHAUSTION

Cause: Cumulative negative water loss

Symptom: Exhaustion, hypohydration, flushed skin

Prevent: Hydration before, during exercise

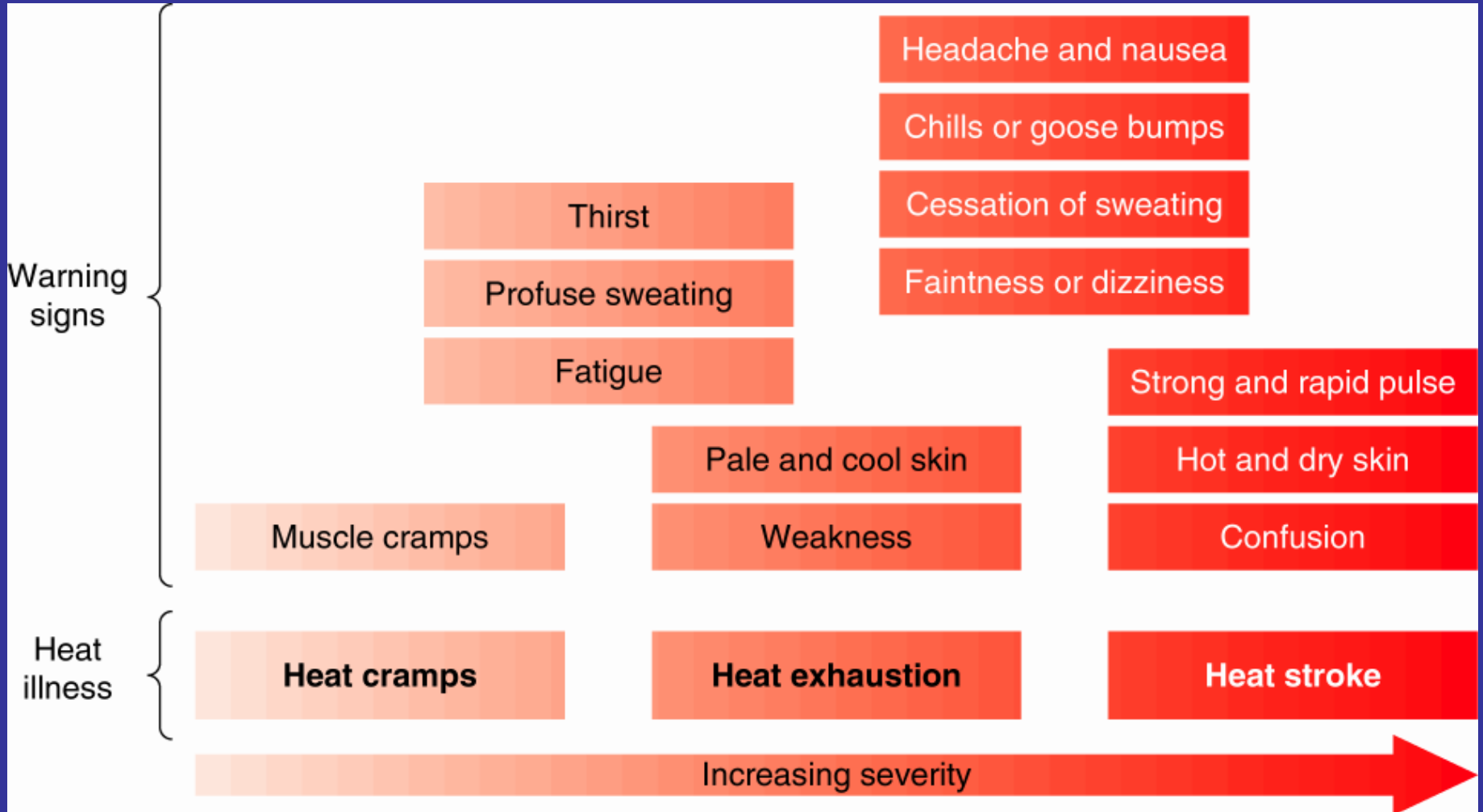
## HEAT STROKE

Cause: extreme hyperthermia, circulation failure

Symptom: hyperpyrexia, lack of sweat, neurologic failure

Prevent: Acclimatization, water, minerals, no exercise

# WARNING SIGNS OF HEAT DISORDERS





# Treatment of Heat Disorders

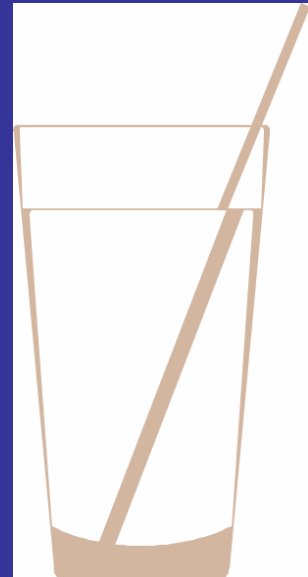
**Heat cramps**— move to cooler location and administer fluids or saline solution

**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; seek medical attention immediately

# Preventing Hyperthermia

- ◆ Avoid exercising in 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 of fluids.
- ◆ Know the symptoms of heat stress.



# Acclimatization to Exercise in Heat

- ↑ body fluids/blood volume (w/in 3-5 d)
- ↑ skin blood flow
- ↑ rate of sweating (may take up to 10 d)
- ↓ electrolyte loss
- ↑ heat tolerance

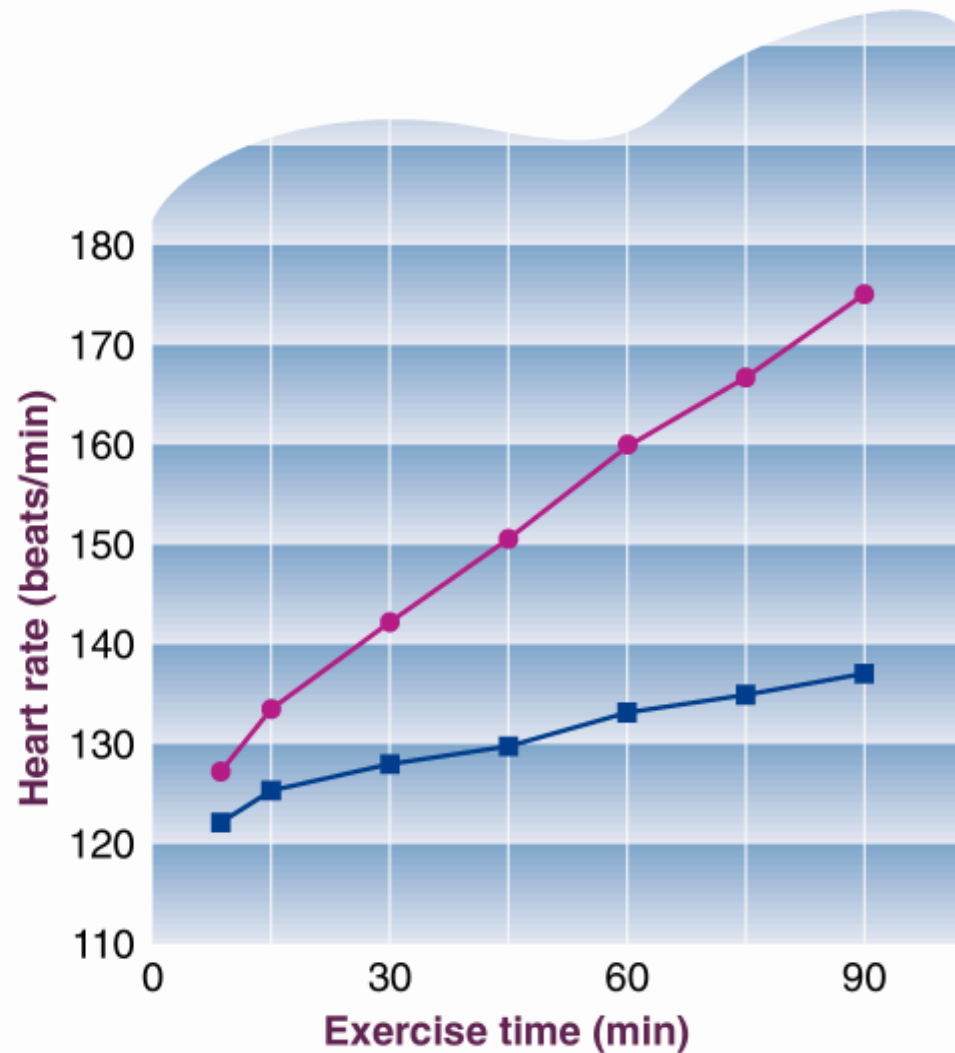
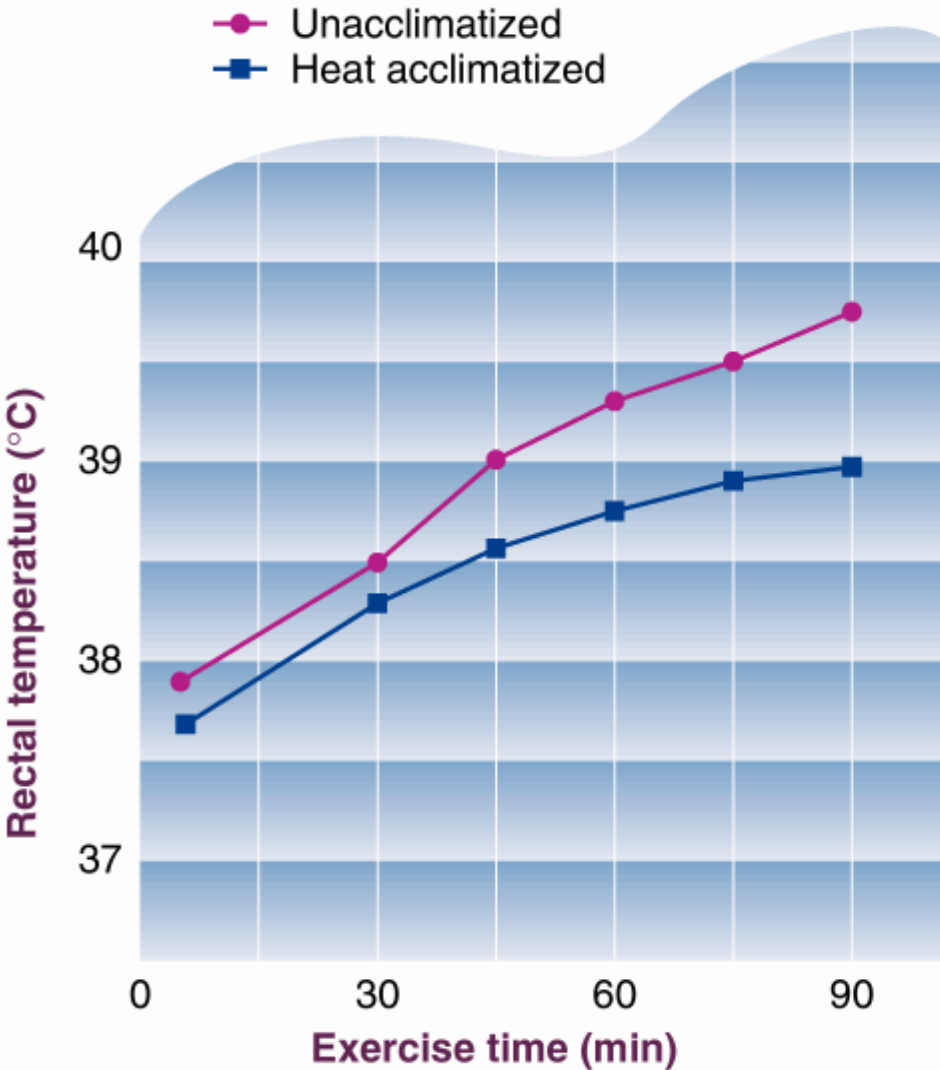
## Achieving Heat Acclimatization

- normal workouts in heat for 5-10 d

# Heat Acclimatization

- ◆ Ability to get rid of excess heat improves
- ◆ Sweating becomes more efficient
- ◆ Blood flow to skin is reduced; more blood is available to muscles
- ◆ Blood volume increases
- ◆ Heart rate increase is less (than nonacclimatized)
- ◆ Stroke volume increases
- ◆ Muscle glycogen usage decreases

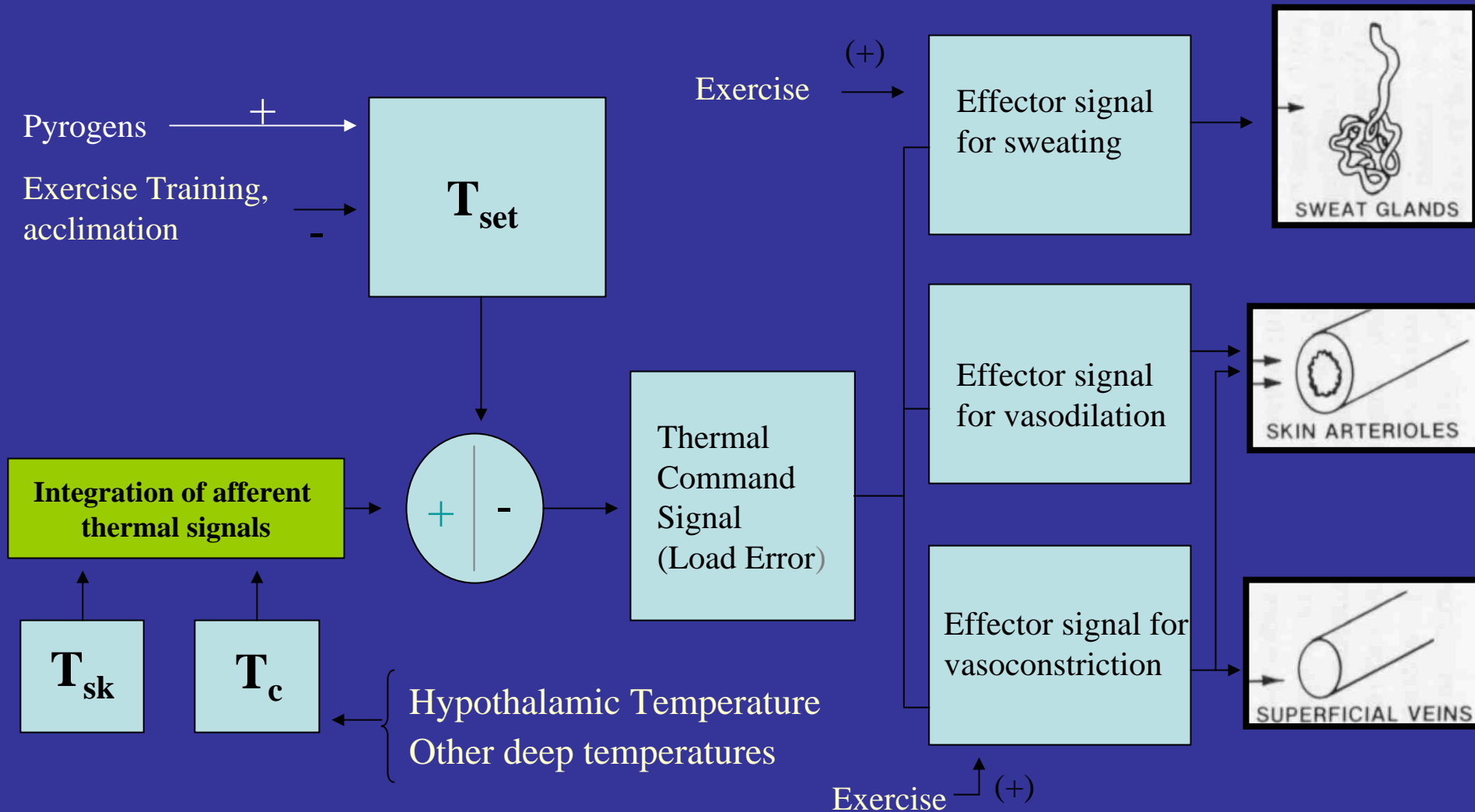
# Heat Acclimatization

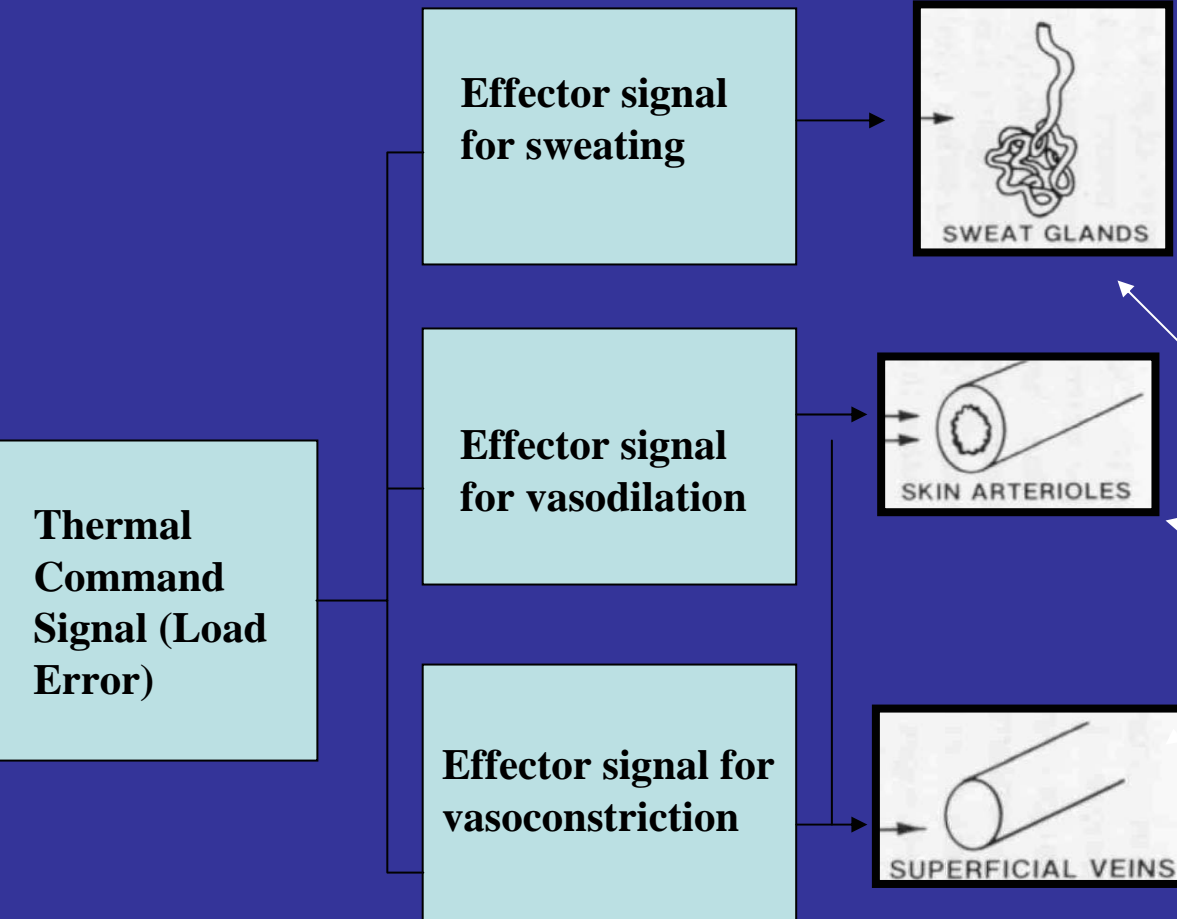


# Exercise Acclimatization

- Exercise in the heat for two weeks at a safe intensity.
- Plasma volume increases 12%.
- Sweating occurs at lower temperature.
- Sweat rate increases as much as 3 times.
- Sweat osmolality decreases.

# Control of All This





What is it that is causing these things to happen?



# Carbohydrate Blend

- The most effective sports drink will contain a blend of sucrose, glucose, and fructose. Drinks with high fructose levels can cause gastrointestinal distress because they slow absorption. Blending all three carbohydrates generally prevents gastrointestinal problems and helps to stimulate fluid absorption.

## Carbohydrate Blend, cont.

- The ACSM suggests that both fluid and carbohydrate requirements can be met by consuming 600-1,200 ml per hour of beverages containing 4-8% carbohydrate in the form of glucose, sucrose, or maltodextrins. Fructose should not be the predominant carbohydrate because it is converted too slowly to glucose to be readily oxidized and so does not improve performance.

# Proper Sodium Levels

- An 8 oz sports drink should contain approximately 100-110mg of sodium. Sodium enhances taste which stimulates voluntary drinking - contributing to an increase in fluid balance. Sodium also contributes to improved absorption and maintenance of body fluids.

# ACSM Fluid Replacement Recommendations

*Before exercise, drink:*

- ~500 ml 2 hr before exercise

*During exercise, drink:*

- early and at regular intervals
- to replace lost fluids (if tolerated)

*After exercise, drink:*

- excess of that lost during exercise

# Fluid Balance

- dehydration impairs endurance performance, minimal effect on power and speed events
- ↓ blood volume will ↓ skin blood flow and heat dissipation
- electrolyte loss accompanies dehydration
- thirst mechanism doesn't keep up with dehydration
- need for water replacement > than electrolyte replacement

# Cardiovascular Exercise in the Heat

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



# Maintaining Fluid Balance

- fluid intake during exercise will:
  - minimize dehydration
  - minimize rise in body temperature
  - reduce CV stress
- cold fluids enhance body cooling and empty faster from stomach
- [CHO] > 6-8% slows absorption from gut