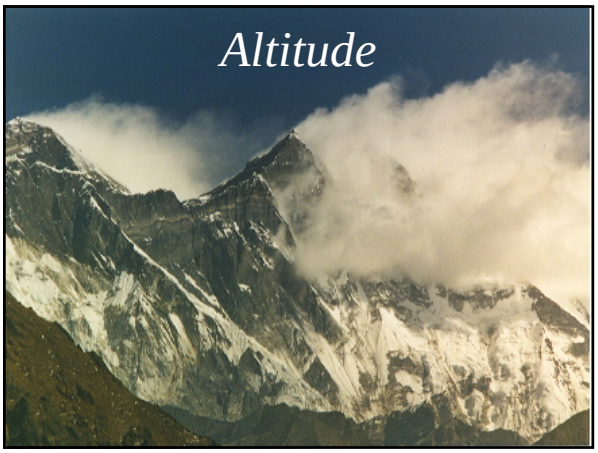
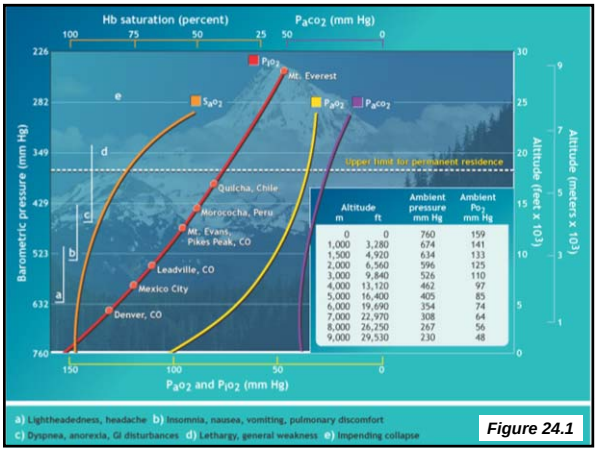
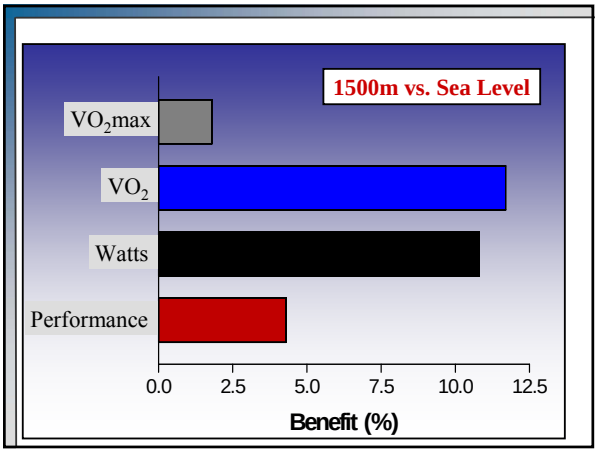
Thermoregulation & Extreme Environments



The Stress of Altitude

- Reduced PO_2
- O_2 Transport Cascade
  - Progressive change in environments oxygen pressure & various body areas
- Oxygen loading at altitude:
  - Hemoglobin saturation not really influenced until ~ 3000m
    - ✓Does this mean there is no affect on performance?





Acclimatization

- Immediate (acute) responses to altitude:
  - Hyperventilation
  - Increased CV response (↑BP)
  - Catecholamine response
    - ✓Increased norepinephrine (↑HR)
    - ✓Increased sympathoadrenal activity (regulates SV, vascular resistance, & substrate use)
  - Fluid loss
    - ✓Sensory functions
    - ✓Myocardial functions

Acclimatization (cont.)

- Longer-term (chronic) adjustments to altitude:
  1. Acid-base readjustment
     - ✓ Reduced buffering and the "Lactate Paradox"
       - ✓ Reduction in lactate despite lower tissue oxygenation
       - ✓ Reduced epinephrine
       - ✓ Reduced CNS drive
  2. Hematologic changes
     - ✓ PV decrease
     - ✓ RBC production increased (polycythemia)
  3. Changes in body mass & composition

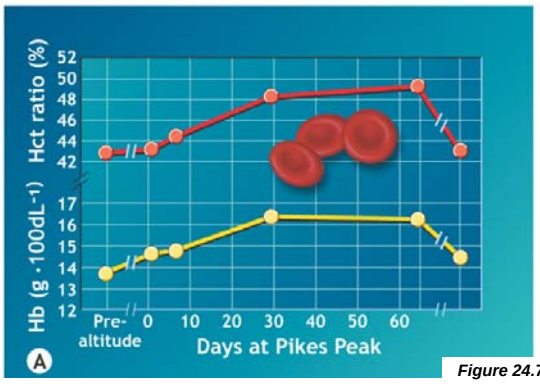


Figure 24.7a

Acclimatization (cont.)

- Longer-term adjustments to altitude *(cont.)*:
  4. Cellular adaptations
     - ✓ Capillary adjustments in length and diameter
     - ✓ Increased myoglobin
     - ✓ Increased mitochondrial density
     - ✓ Increased 2,3 DPG

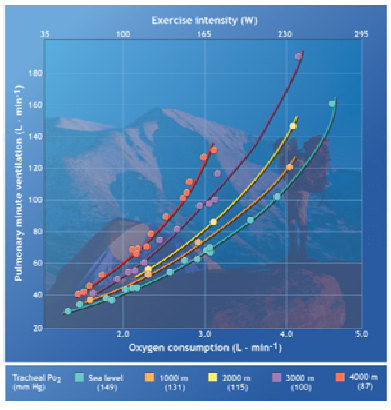


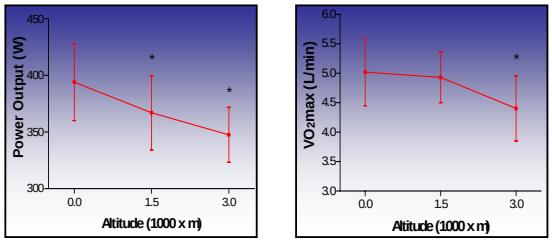
Figure 24.5

Acclimatization (cont.)

- Time requirements:
  - Depends on altitude
  - Acclimatization to a specific altitude does not ensure acclimatization to a higher altitude
  - Physiological changes observed at altitude diminish within 2-3 weeks after return to sea level

Physiologic Capacities at Altitude

- VO_2max:
  - Decreased with as little as 590m
  - Rate of decrease ~ 7 to 9% / 1000m



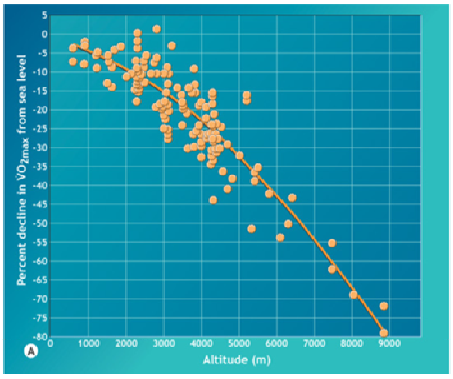


Figure 24.8a

Physiologic Capacities at Altitude

- Circulatory factors:
  - Lowered max HR & SV not offset by higher Hb concentrations after acclimatization
  - Submax exercise:
    - ✓Increased HR offsets decreased SV
  - Both reduced at max

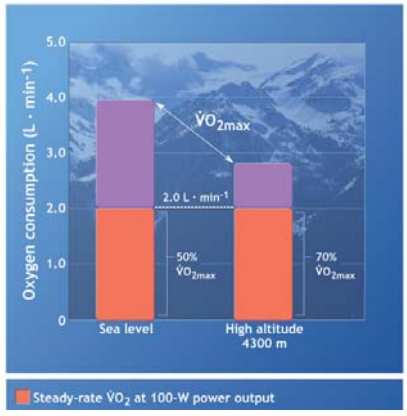


Figure 24.3

Physiologic Capacities at Altitude

- Performance:
  - May not influence events lasting shorter than 2 minutes
  - Longer events = poor results

20km Performance Trial

Trial	*Sea Level*	*1500m*	*3000m*
Performance VO_2 ***(L·min^{-1})***	4.12±0.11	3.85±0.09	3.48±0.13*
Performance VO_2 ***(ml·kg^{-1}·min^{-1})***	58.45±2.42	54.94±1.73	49.74±2.23*^
Average SaO_2 (%)	95.7±0.3#	88.8±1.2#	83.3±0.8#
Performance Average Power Output ***(W)***	295.7±9.68#	266.9±15.21#	240.6±12.64#
Average lactate ***(mmol·L^{-1})***	4.8±0.3	5.1±0.7	5.1±0.9
Performance Times ***(min)***	29.88±0.49	31.23±0.83	32.60±0.74*

Returning to Sea Level

- Aerobic capacity
  - Possible negative effects
  1. Loss of muscle mass
  2. Reductions in max HR & SV

Altitude Training

- Acclimatization improvements specific to altitudes
- Inability to train at sea level intensity
- Live High, Train Low (LHTL) & other theories
- Intermittent exposure

Altitude Research & Training

Figure 24.10

Altitude Research & Training

Thermal Stress

Mechanisms of Thermoregulation

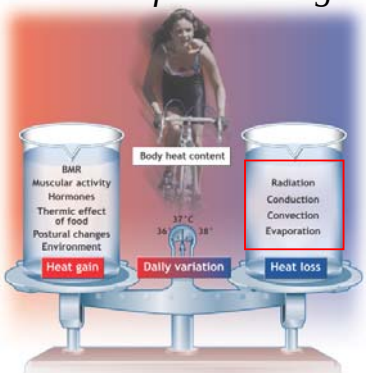


Figure 25.1

Hypothalamic Regulation

- Hypothalamus
  - Central coordinating center for temperature regulation
    - ✓37°C ± 1°C
- Body's regulation occurs by either:
  - Thermal skin receptors
  - Blood temperature perfusing the hypothalamus

*Thermoregulation in **Heat Stress***

- Heat loss:
  1. Radiation
     - ✓ Electromagnetic heat waves
  2. Conduction
     - ✓ Direct contact between molecules
  3. Convection
     - ✓ Movement of warmer molecules replaced by cooler molecules
  4. Evaporation

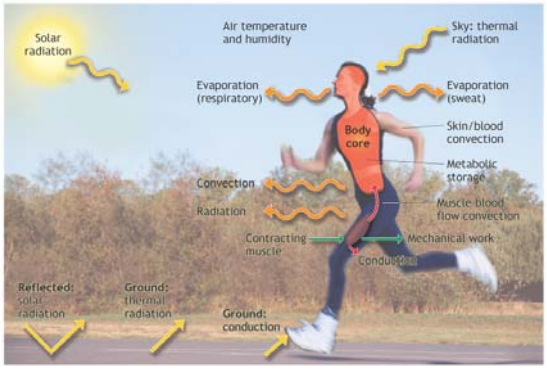


Figure 25.3

Heat Loss

- Integration of heat-dissipating mechanisms
  - Circulation:
    - ✓Blood redirected to skin to dissipate heat
  - Evaporation:
    - ✓Begins seconds after vigorous exercise
    - ✓Cooled blood returns to core to absorb heat
  - Hormonal adjustments:
    - ✓Vasopressin and aldosterone help maintain blood volume

Heat Loss & Retention

- Clothing

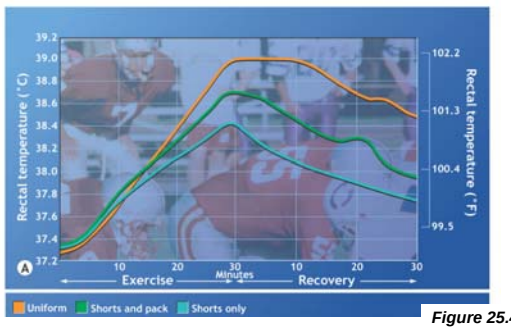


Figure 25.4a

*Thermoregulation & Exercise in the **HEAT***

- Circulatory adjustments:
  - Vascular constriction & dilation
  - Maintenance of BP
- Core temperature during exercise:
  - Increases as intensity increases
  - Greater the fitness, greater the heat production
    - ✓However, better cooling response

Dehydration

- Greater the exercise duration & intensity, greater the fluid loss
- Physiological performance decreases with as little as 2% loss in BW
- Danger of diuretics
  - Greater loss of H_2O from plasma than sweating

Maintaining Body Fluid

Rehydration & ***Hyperhydration***

- Glycerol
  - When consumed with H_2O facilitates water retention in cells
- Adequacy of rehydration
  - Measuring BW, **not** thirst
- Sports drinks
  - Electrolyte & glucose replacement
- Whole body pre-cooling

Factors modifying heat tolerance

- Factors modifying heat tolerance:
  - Acclimatization
    - ✓7-10 days
  - Training status
    - ✓More efficient sweating
    - ✓Increased PV
    - ✓More dilute sweat
    - ✓Greater skin & GI blood flow

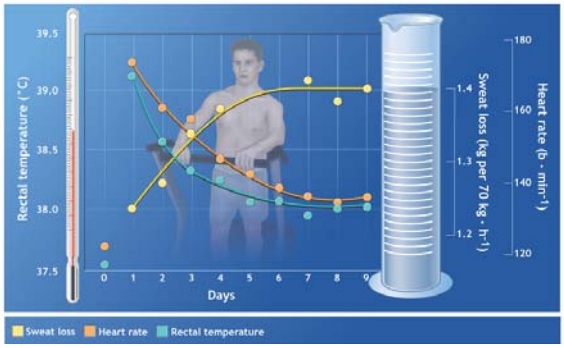


Figure 25.8

Factors modifying heat tolerance

- Age
  - May not be as important as fitness & body composition (distribution)
  - Children
    - ✓More concentrated sweat
    - ✓Lower sweat rate & higher core temperature
- Gender
  - No differences in heat tolerance
  - Women sweat in lower volumes despite having greater activated sweat glands
- Body composition

Complications of Excessive Heat Stress

- Heat cramps
  - Imbalance of electrolytes
- Heat exhaustion
  - Blood pools in periphery
  - Core temperature rises
    - ✓Weak rapid pulse, headache, dizziness, drop in BP
    - ✓Rest & rehydration
- Heat stroke (exertional)
  - Stopped sweating, cold & clammy, altered mental status

*Thermoregulation in **Cold Stress***

- Vascular adjustments
  - Cold receptors restrict blood vessels
- Muscular activity
  - Shivering
- Hormonal output
  - Epinephrine & norepinephrine increase RMR

*Exercise in the **Cold***

- Body fat, exercise, & cold stress
  - Fat insulates
  - ↑BF, greater cold tolerance
- Acclimatization
  - Less capacity than heat
  - Increased blood flow to periphery
  - Blunted depression of immune system with cold exposure
  - Increased non-shivering thermogenisis
- EIA

Wind Chill Index

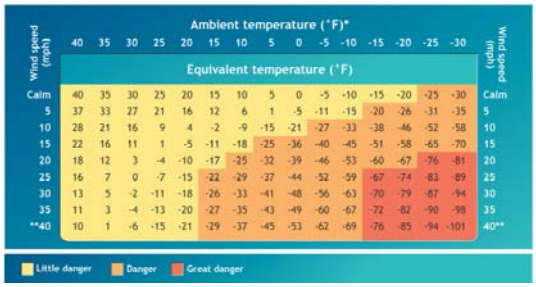


Figure 25.12

Microgravity

Physiologic Adaptations

- Cardiovascular adaptations
  - Decreased fluid volume
  - Decreased heart size
  - Heart rate may increase slightly
  - Decreased peripheral resistance
- Pulmonary adaptations
  - Pulmonary blood flow & ventilation increase
  - Lung volumes decrease
  - Oxygen uptake is unchanged

Physiologic Adaptations (cont.)

- Body fluid adaptations
  - Plasma volume decreases
  - Concentration of electrolytes and RBC increase
  - Decrease in lipids & glucose in plasma
- Sensory system adaptations
  - Adjustments in vestibular, visual, somatosensory, tactile and proprioceptive input are required

Physiologic Adaptations (cont.)

- Musculoskeletal adaptations
  - Increased calcium loss
- Skeletal muscle adaptations
  - Concentric and eccentric strength
    - ✓Post-flight strength decreases
  - Muscle ultrastructure changes
    - ✓Altered muscular coordination
    - ✓Delayed onset muscle soreness
    - ✓General weakness & fatigue

Countermeasure Strategies

Countermeasure Strategies (cont.)

- Space pharmacology
- Lower-body negative pressure (LBNP)
- Nutrition