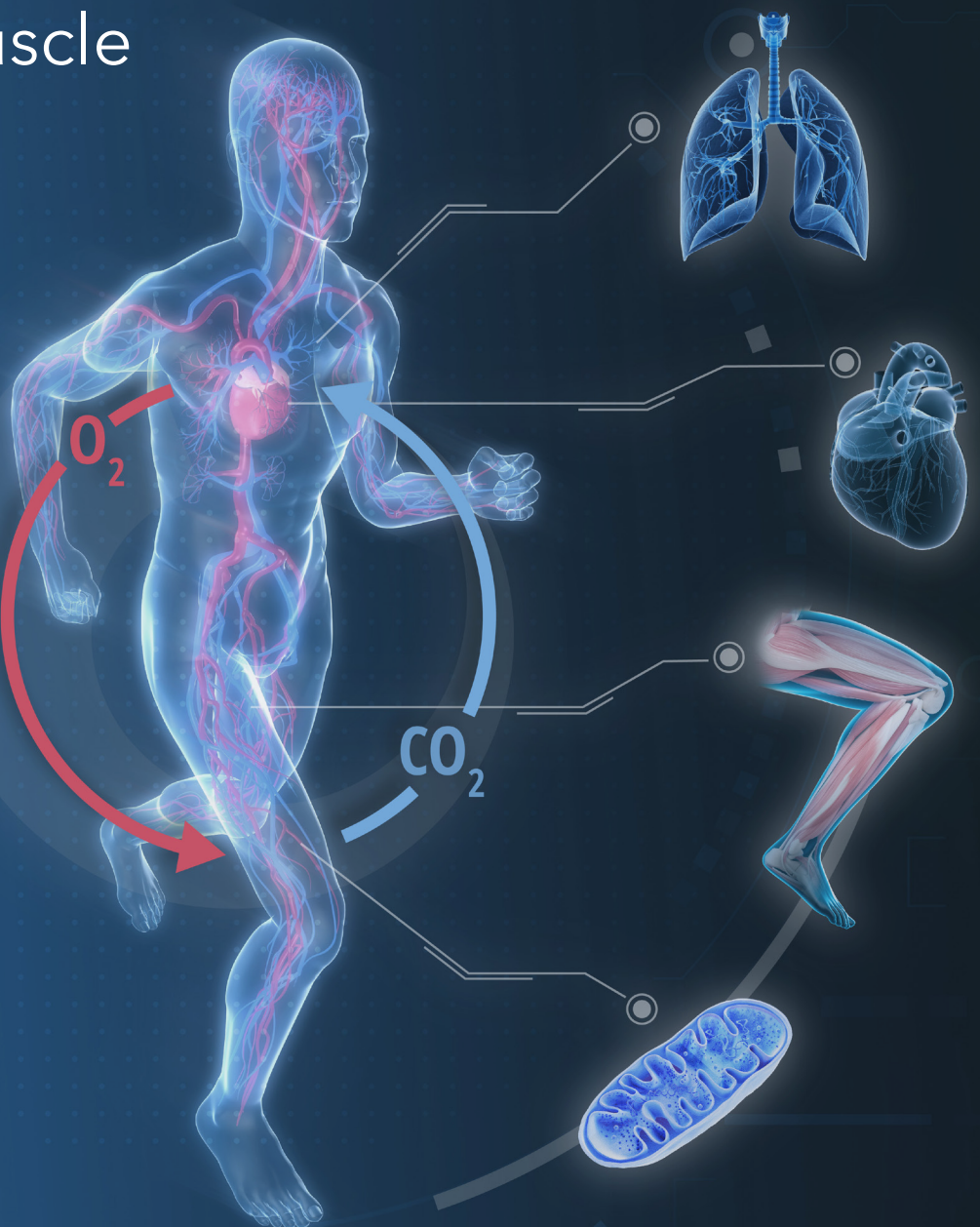


EXERCISE PHYSIOLOGY ILLUSTRATED:

Moving Oxygen
from Air to Muscle



KOLKHORST AND BUONO

TABLE OF CONTENTS

CHAPTER 1

GETTING STARTED IN PHYSIOLOGY OF EXERCISE

“Physiology Is Life!”

What Is Exercise Physiology?

How Did Exercise Physiology Begin?

Pioneers in Physiology

Harvard Fatigue Laboratory and Its Legacy

Exercise Physiology in the 1950s and 1960s

Exercise Physiology Comes of Age

Joining a Professional Organization

Using the Scientific Method to Acquire Knowledge

Understanding and Interpreting Scientific Data

Expressing Numbers as Relative or Absolute

Determining Meaningful Differences with Statistics

Summarizing Findings Visually with Graphs

CHAPTER 2

NEURAL CONTROL OF SKELETAL MUSCLE

The Major Divisions of the Human Nervous System

Modifying Movement Through Sensory Information

Muscle Spindles

Golgi Tendon Organs

Types of Movement

Reflexive Movement

Rhythmic Movement

Voluntary Movement

Cerebral Cortex

Subcortical Brain Areas

Brain Stem

Spinal Cord

Exercise Begins and Ends in the Brain

Neurons—The Functional Unit of the Nervous System

Electrical Charge of Neuron Plasma Membranes

Conducting Information as Electrical Signals

Graded Potentials

Action Potentials

The All-or-None Principle

Ion Movement

Refractory Periods Control Action Potentials

Saltatory Conduction Increases Conduction Velocity

Stimulation of Skeletal Muscle at the
Neuromuscular Junction

Stopping the Signal

Motor Unit

CHAPTER 3

THE RESPIRATORY SYSTEM: GETTING OXYGEN FROM AIR TO BLOOD

Ventilation of the Lungs

Conducting Passages

Alveoli

Changes in Lung Volume

Tidal Volume

Minute Ventilation

Tidal Volume and Respiratory Responses to Exercise

External Respiration: Gas Exchange Between
Lungs and Blood

Gas Exchange

Ventilation-Perfusion of the Lungs

Gas Transport in Blood

Transit Time

Oxygen Transport in Blood

Bohr Effect

Carbon Dioxide Transport

Mechanisms for Regulating Ventilation

Ventilatory Control During Rest

Ventilatory Control During Exercise

CHAPTER 4

THE HEART: MOVING OXYGEN AND BLOOD

The Heart: A Muscle Pump with Four Chambers

Heart Valves and One-Directional Blood Flow

Cardiac Cycle

Electrical Activity in the Heart

Action Potentials in Cardiac Fibers

Autorhythmic Cells

Cardiac Conduction System

Autonomic Control of the Heart

Electrocardiogram

Cardiac Muscle Fibers

Using Stem Cell Transplantation to Repair Damaged Hearts

Calcium Controls Cardiac Fiber Contraction

The Rate at Which the Heart Pumps Blood

Cardiac Output

Stroke Volume Equals Venous Return

CHAPTER 5

THE CIRCULATORY SYSTEM AND ITS RESPONSES TO EXERCISE

Cardiovascular Control Center

Cardiac Output Response to Exercise

Increase in Venous Return

Heart Rate Response to Exercise

Increased Work of the Myocardium

The Circulatory System: Transporting Blood And Oxygen

Blood Vessels

Control of Blood Flow During Exercise

Local Factors that Control Blood Flow

Redistribution of Blood

Blood Pressure and Blood Flow

Total Peripheral Resistance

Systolic and Diastolic Pressures

Circulatory Responses to Exercise

Total Peripheral Resistance Response to Exercise

Blood Pressure Response to Exercise

CHAPTER 6

SKELETAL MUSCLE STRUCTURE AND FUNCTION

Skeletal Muscle Anatomy: Making Movement Possible

Gross Anatomy of Skeletal Muscle

Sarcolemma

Skeletal Fibers

Transverse Tubules and Sarcoplasmic Reticulum

Sarcoplasm

Sarcomeres: Functional Units of Skeletal Muscle

Thick Filaments

Thin Filaments

Muscle Action Through Excitation-Contraction

- Excitation-Contraction Coupling
- Contraction-Sarcomere Shortening and Force Development
- Cessation of Muscle Contraction
- Muscle Movement

Performance Characteristics of Skeletal Fibers

- Classifying Muscle Fiber Types
- Fiber Type Characteristics

Control of Force Output

- Size Principle of Motor Unit Recruitment
 - Electromyography (EMG)
- Length-Tension Relationship
- Force-Velocity and Power-Velocity Relationships
- Muscle Architecture
- Stimulating Frequency
- Stretch-Shortening Cycle

Exercise-Induced Muscle Damage

- Phases of Exercise-Induced Muscle Damage
- Repair of Exercise-Induced Muscle Damage
- Muscle Adaptations to Eccentric Exercise
- Delayed-Onset Muscle Soreness

CHAPTER 7

BIOENERGETICS:

HOW MUSCLE USES OXYGEN

Bioenergetics: Energy Flow in Living Organisms

- Laws of Thermodynamics
- Gibbs Energy

Energy Pathways: A Series of Enzymatic Reactions

- Enzymes
- Rate-Limiting Enzymes
- Exergonic and Endergonic Reactions

Energy Fuels Stored in the Body

- Carbohydrates
 - Glycogen
 - Maintaining Blood Glucose Concentration
- Fats
- Proteins

ATP: The Universal Energy Currency

Synthesizing ATP

- Substrate-Level Phosphorylation
 - Glycolysis
- Oxidative Phosphorylation
 - Citric Acid Cycle
 - Electron Transport Chain (ETC)
 - ATP Yield from Carbohydrate Metabolism
 - Fatty Acid Metabolism

CHAPTER 8

ENERGY METABOLISM:

USING OXYGEN DURING EXERCISE

Energy Pathways During Exercise

- ATP Production at Onset of Exercise
- ATP Production for Prolonged Exercise

Matching ATP Production with ATP Use

- Control of ATP Production
- Creatine Shuttle

Influence of Circulating Hormones on ATP Production

- Insulin and Glucagon
- The Catecholamines: Epinephrine and Norepinephrine

Exercise Intensity and Duration Determine Fuel Mixture

Effect of Exercise Intensity on Fuel Utilization

Effects of Exercise Duration on Fuel Utilization

Lactate Release and Removal from Blood During Exercise

Lactate Appearance

Lactate Disappearance

CHAPTER 9

VENTILATORY RESPONSES TO EXERCISE

Oxygen Uptake ($\dot{V}O_2$): A Measure of Energy Expenditure

Calculating $\dot{V}O_2$ from Respiratory Measures

Expressing $\dot{V}O_2$

Determining $\dot{V}O_2$ by Cardiac Output and Arteriovenous O_2 Difference

Arteriovenous Oxygen ($a - \bar{v}O_2$) Difference

Calculating $\dot{V}O_2$ from Cardiac Output and Arteriovenous O_2 Difference

VO₂ Response to Exercise

Oxygen Uptake Kinetics

$\dot{V}O_2$ Response to Constant Work Rate Exercise

Oxygen Deficit

Excess Post-Exercise Oxygen Consumption (EPOC)

Measuring Aerobic Capacity Through Maximal Oxygen Uptake ($\dot{V}O_{2max}$)

$\dot{V}O_{2max}$ in Endurance Athletes

Using $\dot{V}O_{2max}$ to Describe Exercise Intensity

What Limits $\dot{V}O_{2max}$?

Ventilatory Responses to Exercise

$\dot{V}CO_2$ and $\dot{V}E$ Responses to Graded Exercise

Ventilatory Threshold and Lactate Threshold

Respiratory Exchange Ratio (RER)

CHAPTER 10

ENVIRONMENTAL EFFECTS ON EXERCISE PERFORMANCE

Heat Loss Mechanisms of the Body

Temperature-Dependent Heat Loss Mechanisms

Sweat Evaporation

Central Control of Thermal Balance

Temperature Receptors

Setpoint Temperature

Heat Transfer from Muscle During Exercise

Sweat Glands and Sweating

Cardiovascular Responses to Increased Body Temperature

Thermal Stress During Exercise

Exertional Heat Illness

Determining Thermal Stress During Exercise

Heat Index

Responses to Cold Stress During Exercise

Acclimating to Heat Through Exercise

Heat Acclimation's Affect on Core Temperature

Heat Acclimation's Affect on Sweat Rate

Cardiovascular Adaptations to Heat Acclimation

Exercising at Altitude

Cardiorespiratory Adjustments to Low PO_2

Hormonal Adjustments to Low PO_2

Effects of Erythropoietin on Red Blood Cell Production

Effects of Altitude on Exercise Performance

Acclimating to Elevation: "Live High, Train Low"

CHAPTER 11

FATIGUE AND EXERCISE INTOLERANCE

Peripheral Fatigue

- Substrate Depletion Mechanisms of Peripheral Fatigue
- Product Accumulation Mechanisms of Peripheral Fatigue
 - Pi Accumulation
 - Decreased Ca²⁺ Release
- Reactive Oxygen Species (ROS)

Effects of Central Fatigue on Skeletal Muscle Recruitment

- Exercise Intolerance Caused by Peripheral and Central Fatigue
 - Sensory Tolerance Limit of Fatigue
- Role of Central Nervous System Neurotransmitters in Central Fatigue

Power-Duration Relationship and Exercise Intolerance

- Determining the Power-Duration Relationship and Critical Power
- W' Is a Constant
- Factors Affecting Critical Power and W'
- What We Know (Or Think We Know) About Fatigue and Exercise Intolerance