Chapter 13
Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.
Muscular System

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Points to ponder

• What are the three types of muscle tissue?
• What are the functions of the muscular system?
• How are muscles named and what are the muscles of the human body?
• How are skeletal muscles and muscle fibers structured?
• How do skeletal muscles contract?
• How do skeletal muscle cells acquire ATP for contraction?
• What is rigor mortis?
• What are some common muscular disorders?
• What are some serious muscle diseases?
• How do the skeletal and muscular system help maintain homeostasis?
• How are these two systems related to other systems in maintaining homeostasis?
Review: Types of muscle tissue

1. **Smooth** – involuntary muscle found in hollow organs and vessels

2. **Cardiac** – involuntary muscle found in the heart

3. **Skeletal** – voluntary muscle that is attached to the skeleton
13.1 Overview of the Muscular System

Review: Types of muscle tissue

Skeletal muscle
- has striated cells with multiple nuclei.
- occurs in muscles attached to skeleton.
- functions in voluntary movement of body.

Cardiac muscle
- has branching, striated cells, each with a single nucleus.
- occurs in the wall of the heart.
- functions in the pumping of blood.
- is involuntary.

Smooth muscle
- has spindle-shaped cells, each with a single nucleus.
- cells have no striations.
- functions in movement of substances in lumens of body.
- is involuntary.
- is found in blood vessel walls and walls of the digestive tract.

Figure 13.1 The three classes of muscles in humans.
What are the functions of skeletal muscles?

1. Support the body by allowing us to stay upright
2. Allow for movement by attaching to the skeleton
3. Help maintain a constant body temperature
4. Assist in movement in the cardiovascular and lymphatic vessels
5. Protect internal organs and stabilize joints
How are skeletal muscles attached?

- **Tendon** – connective tissue that connects muscle to bone
- **Origin** – attachment of a muscle on a stationary bone
- **Insertion** – attachment of a muscle on a bone that moves

Figure 13.2 Connecting muscle to bone.
How do skeletal muscles work?

- **Antagonistic** – muscles that work in opposite pairs

- **Synergistic** – muscles working in groups for a common action

*Figure 13.3* Skeletal muscles often work in pairs.
Examples of how skeletal muscles are named

- **Size** – the gluteus maximus is the largest buttock muscle

- **Shape** – the deltid is triangular (Greek letter delta is Δ)

- **Location** – the frontalis overlies the frontal bone

- **Direction of muscle fiber** – the rectus abdominis is longitudinal (rectus means straight)
Examples of how skeletal muscles are named

- **Attachment** – the brachioradialis is attached to the brachium and radius

- **Number of attachments** – the biceps brachii has 2 attachments

- **Action** – the extensor digitorum extends the digits
13.1 Overview of the Muscular System

Muscles of the human body

Figure 13.5 The major skeletal muscles of the human body.
Muscle fibers/cells

• Terminology for cell structure
  – The plasma membrane is called the **sarcolemma**.
  
  – The cytoplasm is called the sarcoplasm.
  
  – The SER of a muscle cell is called the **sarcoplasmic reticulum** and stores calcium.
Muscle fibers/cells

- Terminology for structure within a whole muscle
  - Muscle fibers are arranged in bundles called fascicles.
  - Myofibrils are bundles of myofilaments that run the length of a fiber.
  - Myofilaments are proteins (actin and myosin) that are arranged in repeating units.
  - Sarcomeres are the repeating units of actin and myosin found along a myofibril.
13.2 Skeletal Muscle Fiber Contraction

Visualizing muscle structure

A muscle contains bundles of muscle fibers, and a muscle fiber has many myofibrils.

A myofibril has many sarcomeres.

Figure 13.6 The structure of a skeletal muscle fiber.
The sarcomere

• Made of 2 protein myofilaments
  – A thick filament is composed of several hundred molecules of the protein myosin. Each myosin molecule is shaped like a golf club.

  – Primarily, a thin filament consists of two intertwining strands of the protein actin.

  – These filaments slide over one another during muscle contraction.
13.2 Skeletal Muscle Fiber Contraction

The sarcomere

Figure 13.6 The structure of a skeletal muscle fiber.

Sarcomeres are relaxed.

Sarcomeres are contracted.

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The beginning of muscle contraction: The sliding filament model

1. Nerve impulses travel down a motor neuron to a neuromuscular junction.

2. Acetylcholine (ACh) is released from the neuron and binds to the muscle fiber.

3. This binding stimulates the fiber causing calcium to be released from the sarcoplasmic reticulum.
The beginning of muscle contraction

13.2 Skeletal Muscle Fiber Contraction

Figure 13.7 Motor neurons and skeletal muscle fibers join neuromuscular junctions.

a. One motor axon goes to Several muscle fibers.

b. Asynaptic cleft exists between an axon terminal and a muscle fiber.

c. Neurotransmitter (ACh) diffuses across synaptic cleft and binds to receptors in sarcolemma.

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Muscle contraction continued…

4. Released calcium combines with **troponin**, a molecule associated with actin.

5. This causes the **tropomyosin** threads around actin to shift and expose myosin binding sites.

6. Myosin heads bind to these sites forming cross-bridges.

7. ATP binds to the myosin heads and is used for energy to pull the actin filaments towards the center of the sarcomere – contraction now occurs.
**13.2 Skeletal Muscle Fiber Contraction**

Visualizing the roles of calcium and myosin in muscle contraction

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Figure 13.8 The role of calcium ions and ATP during muscular contraction.

1. ATP is split when myosin head is unattached.

2. ADP + P are bound to myosin as myosin head attaches to actin.

3. Upon ADP + P releases, power stroke occurs: head bends and pulls actin.

4. Binding of fresh ATP causes myosin head to return to resting position.

Function of Ca$^{2+}$

Troponin—Ca$^+$ complex pulls tropomyosin away, exposing myosin-binding sites.
What role does ATP play in muscle contraction and rigor mortis?

- ATP is needed to attach and detach the myosin heads from actin.

- After death, muscle cells continue to produce ATP through fermentation and muscle cells can continue to contract.

- When ATP runs out, some myosin heads are still attached and cannot detach, causing rigor mortis.

- Rigor mortis and body temperature may be used to estimate time of death.
Terms to describe whole muscle contraction

- **Motor unit** – a nerve fiber and all of the muscle fibers it stimulates

- **Muscle twitch** – a single contraction lasting a fraction of a second

- **Summation** – an increase in muscle contraction until the maximal sustained contraction is reached
Terms to describe whole muscle contraction

- **Tetanus** – maximal sustained contraction

- **Muscle tone** – a continuous, partial contraction of alternate muscle fibers causing the muscle to look firm
Figure 13.9 The three phases of a single muscle twitch and how summation and tetanus increase the force of contraction.
13.3 Whole Muscle Contraction

Where are the fuel sources for muscle contraction?

- Stored in the muscle
  - Glycogen
  - Fat
- In the blood
  - Glucose
  - Fatty acids

Figure 13.10 The sources of energy for muscle contraction.
What are the sources of ATP for muscle contraction?

- Limited amounts of ATP are stored in muscle fibers.

- Creatine phosphate pathway (CP) – fastest way to acquire ATP but only sustains a cell for seconds; builds up when a muscle is resting

- Fermentation – fast-acting but results in lactate build up

- Cellular respiration (aerobic) – not an immediate source of ATP but the best long term source
13.3 Whole Muscle Contraction

Acquiring ATP for muscle contraction

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Figure 13.11 The three pathways by which muscle cells produce the ATP energy needed for contraction.
Muscle fibers come in 2 forms

Fast-twitch fibers

- Rely on CP and fermentation (anaerobic)
- Adapted for strength
- Light in color
- Few mitochondria
- Little or no myoglobin
- Fewer blood vessels than slow-twitch
Muscle fibers come in 2 forms

**Slow-twitch fibers**

- Rely on aerobic respiration
- Adapted for endurance
- Dark in color
- Many mitochondria
- Myoglobin
- Many blood vessels
13.3 Whole Muscle Contraction

Types of muscle fibers

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Figure 13.12 Fast-twitch and slow-twitch muscle fibers differ in structure.

Fast-twitch muscle fiber
- is anaerobic
- has explosive power
- fatigues easily

Slow-twitch muscle fiber
- is aerobic
- has steady power
- has endurance

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Exercise, exercise, exercise

• Exercise increases muscle strength, endurance, and flexibility.

• It increases cardiorespiratory endurance.

• HDL increases thus improving cardiovascular health.

• The proportion of protein to fat increases favorably.
Exercise, exercise, exercise

- Exercise may prevent certain cancers: colon, breast, cervical, uterine, and ovarian.

- It improves density of bones thus decreasing the likelihood of osteoporosis.

- Exercise enhances mood and may relieve depression.
Anabolic steroids

• Anabolic steroids are a group of steroids that usually increase protein production.

• The most common side effects are high blood pressure, jaundice, acne, and greatly increased risk of cancer.

• Abuse of these drugs may also cause impotence and shrinking of the testicles.

• Anabolic steroid use may lead to increased aggressiveness and violent mood swings.

• Are they worth the risk? Should they be legal to use in athletics?
Common muscle disorders

- **Spasms** – sudden, involuntary muscle contractions that are usually painful

- **Convulsions** (seizures) – multiple spasms of skeletal muscles

- **Cramps** – strong, painful spasms often of the leg and foot
Common muscle disorders

• **Strain** – stretching or tearing of a muscle

• **Sprain** – twisting of a joint involving muscles, ligaments, tendons, blood vessels, and nerves
Muscular diseases

- **Myalgia** – achy muscles due to injury or infection

- **Fibromyalgia** – chronic achy muscles; not well understood

- **Muscular dystrophy** – group of genetic disorders in which muscles progressively degenerate and weaken
Muscular diseases

• **Myasthenia gravis** – autoimmune disorder that attacks the ACh receptor and weakens muscles of the face, neck, and extremities

• **Amyotrophic lateral sclerosis (ALS)** – commonly known as Lou Gehrig’s disease; motor neurons degenerate and die leading to loss of voluntary muscle movement

• **Sarcomas** – cancers that originate in muscle, or the connective tissue associated with muscle
Homeostasis: The skeletal and muscular systems

• Both systems are involved with movement that allows us to respond to stimuli, digestion of food, return of blood to the heart, and moving air in and out of the lungs.

• Both systems protect body parts.

• Bones store and release calcium needed for muscle contraction and nerve impulse conduction.

• Blood cells are produced in the bone.

• Muscles help maintain body temperature.
How the skeletal and muscular systems interact with other body systems

The muscular and skeletal systems work together to maintain homeostasis. The systems listed here in particular also work with these two systems.

**Muscular Systems**
- The muscular system works with the skeletal system to allow movement and support and protection for internal organs. Muscle contraction provides heat to warm the body; bones play a role in Ca\(^{2+}\) balance. These systems specifically help the other systems as mentioned below.

**Cardiovascular System**
- Muscle contraction keeps blood moving in the heart and blood vessels, particularly the veins.

**Urinary System**
- Muscle contraction moves the fluid within ureters, bladder, and urethra. Kidneys activate vitamin D needed for Ca\(^{2+}\) absorption and help maintain the blood level of Ca\(^{2+}\) for muscle contraction.

**Digestive System**
- Muscle contraction accounts for chewing of food and peristaltic movement. The digestive system absorbs ions needed for muscle contraction.

**Nervous System**
- The nervous system coordinates the activity of muscles. Muscle contraction moves eyes, permits speech, and creates facial expressions.

**Endocrine System**
- Growth and sex hormones regulate muscle development. Parathyroid hormone and calcitonin regulate Ca\(^{2+}\) content of bones.

**Respiratory System**
- Respiration provides the oxygen needed for ATP production so muscles can contract. Muscles assist in breathing.

**Reproductive System**
- Muscle contraction moves gametes in oviducts, and uterine contraction occurs during childbirth. Androgens promote muscle growth.

**Digestive System**
- Muscles assist in breathing.

**Urinary System**
- Muscles assist in breathing.

**Cardiovascular System**
- Muscles assist in breathing.

**Muscle contraction keeps blood moving in the heart and blood vessels, particularly the veins.**

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**Growth and sex hormones regulate muscle development. Parathyroid hormone and calcitonin regulate Ca\(^{2+}\) content of bones.**

**Respiration provides the oxygen needed for ATP production so muscles can contract. Muscles assist in breathing.**

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