

# CHAPTER 12

## MUSCULAR SYSTEM

### **LEARNING OUTCOMES**

#### **12.1 Overview of the Muscular System**

1. List the three types of muscles and provide a function for each.
2. Describe the general structure of a skeletal muscle.
3. Identify the major skeletal muscles of the human body.

#### **12.2 Skeletal Muscle Fiber Contraction**

1. Identify the structures of a muscle fiber.
2. Explain how the sliding filament model is responsible for muscle contraction.
3. Summarize how activities within the neuromuscular junction control muscle fiber contraction.

#### **12.3 Whole Muscle Contraction**

1. List the stages of a muscle twitch and explain what is occurring in each stage.
2. Explain how summation and tetanus increase the strength of whole muscle contraction.
3. Summarize how muscle cells produce ATP for muscle contraction.
4. Distinguish between fast-twitch and slow-twitch muscle fibers.

#### **12.4 Muscular Disorders**

1. Distinguish between common muscle conditions such as strains and sprains.
2. Summarize the causes of fibromyalgia, muscular dystrophy, myasthenia gravis, and muscle cancer.

#### **12.5 Homeostasis**

1. Summarize the role of muscular and skeletal systems in movement.
2. Summarize the role of the muscular system in body temperature homeostasis.

### **EXTENDED LECTURE OUTLINE**

#### **12.1 Overview of the Muscular System**

The muscular system is involved with movement. All muscles contract or shorten, which causes movement.

##### **Types of Muscles**

Smooth muscle fibers are spindle-shaped cells, each with a single nucleus. There are no striations.

Contraction of smooth muscle is involuntary. Smooth muscle is located in the walls of hollow organs and blood vessels. Cardiac muscle forms the heart wall. Its fibers are generally uninucleated, striated, tubular, and branched. Cardiac fibers relax completely between contractions, which prevents fatigue. Intercalated disks connect cardiac muscle cells. Skeletal muscle fibers are tubular, multinucleated, and striated.

Skeletal muscle contraction is voluntary. Fibers run the length of the muscle.

##### **Skeletal Muscles of the Body**

Skeletal muscles are attached to the skeleton, and their contraction causes the movement of bones at a joint.

##### **Functions of Skeletal Muscles**

Skeletal muscles support the body, make bones move, help maintain a constant body temperature, assist movement of fluids in cardiovascular and lymphatic vessels, and help protect internal organs and stabilize joints.

##### **Basic Structure of Skeletal Muscles**

A whole muscle contains bundles of skeletal muscle fibers called fascicles. Within a fascicle, each fiber is surrounded by connective tissue, and the fascicle itself is also surrounded by connective tissue. Muscles are covered with fascia, a type of connective tissue that extends beyond the muscle and becomes its tendon, anchoring the muscle to the bone.

##### **Skeletal Muscles Work in Pairs**

The origin of a muscle is the end attaching to the immovable bone; the insertion of a muscle is the end attaching to the movable bone. Muscles are frequently grouped as synergists and antagonists. One muscle, the prime mover, does most of the work for any particular movement.

##### **Names and Actions of Skeletal Muscles**

Skeletal muscles are named according to their size, shape, location, direction of fibers, attachment, number of attachments, or action.

## 12.2 Skeletal Muscle Fiber Contraction

The alternating dark and light bands gives skeletal muscle a striated appearance.

### **Muscle Fibers and How They Slide**

The plasma membrane of a muscle fiber is its sarcolemma. Its endoplasmic reticulum is called the sarcoplasmic reticulum, which stores calcium. The sarcolemma invaginates into T tubules that contact the sarcoplasmic reticulum. Calcium ions ( $\text{Ca}^{+}$ ) are needed for muscle contraction. Within muscle fibers are the contractile myofibrils.

### **Myofibrils and Sarcomeres**

Myofibrils are cylindrical structures within muscle fibers. Myofilaments that make up myofibrils are arranged such that they exhibit striations. Striations are grouped into contractile units called sarcomeres. Within sarcomeres, thick filaments are made up of myosin, and thin filaments are made up of actin.

### **Myofilaments**

#### **Thick filaments**

A thick filament is composed of several hundred molecules of the protein myosin which is shaped like a golf club, with a straight portion ending in a globular head or cross-bridge.

#### **Thin filaments**

A thin filament consists of two intertwining strands of the protein actin. Tropomyosin and troponin also play a role.

#### **Sliding filaments**

When a nervous impulse reaches a muscle fiber, the sarcoplasmic reticulum releases its stored calcium, and the fiber contracts. The myosin filaments have cross-bridges that pull on the actin filaments, causing them to slide past each other. The sliding filament theory states that the filaments do not change in length as the sarcomere shortens.

### **Control of Muscle Fiber Contraction**

The region where a motor neuron contacts a muscle fiber is called the neuromuscular junction. A motor nerve fiber expands into a synaptic end bulb as it approaches a muscle fiber. When a nerve impulse travels down the neuron, synaptic vesicles storing a neurotransmitter acetylcholine (ACh) move to the end of the bulb, and release ACh into the synaptic cleft. The muscle fiber receives the neurotransmitter at receptor sites. The sarcolemma generates impulses that travel over the sarcolemma to the T tubules and sarcoplasmic reticulum. Stored calcium is released to the cell, triggering contraction. Threads of tropomyosin wind about an actin filament, and troponin occurs at intervals along the threads. When calcium ions are released from the sarcoplasmic reticulum, they combine with troponin, and this causes tropomyosin threads to shift their position on actin, exposing the myosin binding sites. The myosin can now bind to the actin.

## 12.3 Whole Muscle Contraction

In order for the biceps or triceps to contract, individual muscle fibers must be activated by signals from the nervous system.

### **Muscles Have Motor Units**

A nerve fiber, together with all of the muscle fibers it innervates, is called a motor unit. A motor unit obeys the all-or-none law. When a motor unit is stimulated by infrequent electrical impulses, a single contraction occurs that lasts only a fraction of a second. This response is called a muscle twitch. If a motor unit is given a rapid series of stimuli, it can respond to the next stimulus without relaxing completely. Summation is increased muscle contraction until maximal sustained contraction, called tetanus, is achieved. As the intensity of nervous stimulation increases, more motor units of a muscle are activated. This is known as recruitment. At any one time, some motor units contract maximally, while others rest.

### **Muscle Tone**

When some motor units are always contracted but not enough to cause movement, the muscle is firm and solid. It has good tone.

### **Energy for Muscle Contraction**

#### **Fuel Sources for Exercise**

A muscle has four possible energy sources. Two of these are stored in muscle: glycogen and fat. Two of these are acquired from blood: glucose and plasma fatty acids.

#### **Sources of ATP for Muscle Contraction**

Muscle cells store limited amounts of ATP but can acquire more ATP once stored ATP has been used up.

#### **The CP Pathway**

The simplest and fastest way for muscles to produce ATP is to use the CP pathway. Creatine phosphate is converted to creatine with the conversion of ADP to ATP.

#### **Fermentation**

Fermentation produces two ATP from the breakdown of glucose to lactate anaerobically. This pathway most likely begins with glycogen. Formation of lactate is noticeable because it produces muscle aches and fatigue upon exercising.

#### **Cellular Respiration**

Cellular respiration is the slowest and the most efficient way to produce ATP. It is more likely to supply ATP when exercise is submaximal in intensity. It can make use of glucose from the breakdown of glycogen stored in muscle, glucose taken up from blood, and fatty acids.

#### **Fast-Twitch and Slow-Twitch Muscles Fibers**

Fast-twitch fibers tend to rely on CP and fermentation while slow-twitch fibers tend to prefer cellular respiration.

##### **Fast-Twitch Fibers**

Fast-twitch fibers tend to be anaerobic and seem to be designed for strength because their motor units contain many fibers. They are light in color because they have fewer mitochondria, little or no myoglobin, and fewer blood vessels than slow-twitch fibers. They depend on anaerobic energy, causing them to accumulate lactate and to tire easily.

##### **Slow-Twitch Fibers**

Slow-twitch fibers have a steadier tug and have more endurance despite more units with smaller numbers of fibers. These produce most of their energy aerobically. They have many mitochondria and are dark in color because they contain myoglobin. They contain a reserve of glycogen and fat, for a prolonged production of ATP in the presence of oxygen.

## **12.4 Muscular Disorders**

Muscular disorders are common, but some disorders are life-threatening.

#### **Common Muscular Conditions**

Spasms are involuntary muscle contractions that may cause pain. Cramps are long, painful spasms. A strain is an overstretching of a muscle; a sprain is a twisting of a joint leading to swelling and injury, not only of muscles but also of ligaments, tendons, blood vessels, and nerves.

In tendonitis, the normal gliding motion of a tendon is impaired, the tendon is inflamed, and movement of a joint becomes painful. Bursitis is an inflammation of a bursa.

#### **Muscular Diseases**

##### **Myalgia and Fibromyalgia**

Myalgia refers to achy muscles. Fibromyalgia is a chronic condition, the cause of which is unknown, whose symptoms include achy pain, and tenderness and stiffness of muscles.

##### **Muscular Dystrophy**

Muscular dystrophy is a broad term applied to a group of disorders that are characterized by a progressive degeneration and weakening of muscles. Duchenne muscular dystrophy, caused by the lack of a protein called dystrophin, is an x-linked disorder.

##### **Myasthenia Gravis**

Myasthenia gravis is an autoimmune disease characterized by muscle weakness. The immune system mistakenly produces antibodies that destroy acetylcholine receptors.

##### **Muscle Cancer**

Cancers that originate in muscle or the connective tissue associated with muscle, belong to a group called the soft tissue sarcomas, which may occur in both smooth and skeletal muscles.

Rhabdomyosarcoma is an example of a cancer which originates in the skeletal muscle.

## **12.5 Homeostasis**

This section concentrates on the contribution of both the muscular and skeletal systems to homeostasis.

#### **Both Systems Produce Movement**

The skeletal and muscular systems work together to enable body movement.

#### **Both Systems Protect Body Parts**

The skeletal system plays an important role just by protecting the soft internal organs of your body. The muscular system pads bones and the tendons and bursae reinforce and cushion joints.

#### **Muscles Help Maintain Body Temperature**

The muscular system contributes to body temperature.

### **STUDENT ACTIVITIES**

#### **Physical Therapy As a Career**

1. Invite a physical therapist or PTA to your classroom. Ask them to discuss the educational and vocational requirements needed to become a physical therapist or PTA. Then ask them to describe the types of physical therapy they use for different types of patients. Have them explain what activities they might do during a typical day and invite students to ask questions.

#### **Athletic Department Weight Room**

2. Take your students to your local Athletic Department weight room and have an athletic trainer show some of the muscle-building exercises that are suggested for different sports. Have them show your students how to work different muscle groups, being sure to name muscles, and discuss how muscles work in groups.

#### **Exercise Specialist**

3. Ask a campus coach, athletic trainer, or aerobic dance instructor to come to your class and discuss the importance of aerobic exercise and/or weight training. Request that the speaker include such topics as: what type of exercise to begin if you do not exercise at all; the importance of stretching, as well as types and duration of stretches before and after exercise; the need for a minimum of 20 minutes of aerobic activity; how to determine whether you are achieving aerobic activity; and muscle toning. Demonstrations are useful for this topic.

#### **Measurement of Tetany**

4. Perform a simple, timed experiment to measure the length of time it takes for tetany to occur. Have students stand and hold a pencil between their first finger and thumb with their arm stretched out straight in front of them. Ask them to hold the pencil as long as possible. When tetany occurs, the pencil will drop because the muscle relaxes regardless of the signals being sent to it. Time how long it takes for the students to drop their pencils.

#### **Source of Muscle Energy: Aerobic vs. Anaerobic**

5. Have students “feel the burn” of lactate by performing a simple task such as opening and closing their hand to exhaustion. Have students rest the nondominant hand on a table or desk and close fingers over palm as many times as they can in 30 second trials. Record data from 5 trials. Have students describe how their hands “feel” and how this affected the rate of activity in terms of energy demand and cellular respiration.