

Anatomy & Physiology
The Muscular System

1.1 Introduction

The three types of muscle tissue are skeletal (striated), smooth, and cardiac.

1.2. Structure of skeletal muscle

Individual muscles are the organs of the muscular system. They include skeletal muscle tissue, nervous tissue, blood and connective tissues.

1. Connective tissue coverings
 1. Fascia covers skeletal muscles.
 2. Other connective tissues attach muscles to bones or to other muscles.
 3. A network of connective tissues extends throughout the muscular system.
2. Skeletal fibers
 1. Each skeletal muscle fiber is a single muscle cell.
 2. The cytoplasm contains mitochondria, sarcoplasmic reticulum, and myofibrils of actin and myosin.
 3. The organization of actin and myosin filaments produces striations.
 4. Transverse tubules extend inward from the cell membrane and associate with the sarcoplasmic reticulum.
3. Neuromuscular junction
 1. Motor neurons stimulate muscle fibers to contract.
 2. In response to an impulse, the end of a motor neuron axon secretes a neurotransmitter, which stimulates the muscle fiber to contract.

1.3 Skeletal Muscle Contraction

Muscle fiber contraction results from a sliding movement of actin and myosin filaments.

1. Role of actin and myosin
 1. Heads of myosin filaments form cross-bridge linkages with actin filaments.
 2. The reaction between the actin and myosin filaments generates the force of contraction.
2. Stimulus for contraction

1. Acetylcholine released from the distal end of a motor neuron axon stimulates a skeletal muscle fiber.
 2. Acetylcholine causes the muscle fiber to conduct an impulse over the surface of the fiber that reaches deep within the fiber through the transverse tubules.
 3. The impulse signals the sarcoplasmic reticulum to release calcium ions.
 4. Cross-bridge linkages form between actin and myosin, and the cross-bridges pull on the actin filaments, shortening the fiber.
 5. The muscle fiber relaxes when myosin heads release from actin, breaking the cross-bridges (ATP is needed, but is not broken down) and when calcium ions are actively transported (requiring ATP breakdown) back into the sarcoplasmic reticulum.
 6. Acetylcholinesterase breaks down acetylcholine.
3. Energy sources for contraction
 1. ATP supplies the energy for muscle contraction
 2. Creatine phosphate stores energy that can be used to synthesize ATP.
 3. ATP is needed for muscle relaxation.
 4. Oxygen supply and cellular respiration
 1. Aerobic respiration requires oxygen.
 2. Red blood cells carry oxygen to body cells.
 3. Myoglobin in muscle cells helps maintain oxygen availability.
 5. Oxygen debt
 1. During rest or moderate exercise, muscles receive enough oxygen to respire aerobically.
 2. During strenuous exercise, oxygen deficiency may cause lactic acid to be produced. Lactic acid dissociates to form lactate.
 3. Oxygen debt is the amount of oxygen required to convert lactate to glucose and to restore supplies of ATP and creatine phosphate.
 6. Muscle fatigue
 1. A fatigued muscle loses its ability to contract.
 2. Muscle fatigue may be due in part to increased production of lactic acid.
 7. Heat production
 1. More than half of the energy released during cellular respiration is lost as heat.
 2. Muscle action is an important source of body heat.

1.4 Muscular Responses

1. Threshold stimulus is the minimal stimulation required to elicit a muscular contraction.
2. Recording a muscle contraction
 1. A twitch is a single, short contraction reflecting stimulation of a muscle fiber.
 2. A myogram is a recording of an electrically stimulated isolated muscle.
 3. The latent period, the time between stimulus and responding muscle contraction, is followed by a period of contraction and a period of relaxation.
3. Summation
 1. A rapid series of stimuli may produce summation of twitches.
 2. Very rapid stimulation can lead to partial or complete tetanic contraction.
4. Recruitment of motor units
 1. One motor neuron and the muscle fibers associated with it constitute a motor unit.
 2. All the muscle fibers of a motor unit contract together.
 3. Recruitment increases the number of motor units being activated in a whole muscle.
 4. The many motor units in a whole muscle are controlled by different motor neuron which respond to different thresholds of stimulation.
 5. At a low intensity of stimulation, small numbers of motor units contract.
 6. At increasing intensities of stimulation, other motor units are recruited until the muscle contracts with maximal force.
5. Sustained contractions
 1. Summation and recruitment together can produce a sustained contraction of increasing strength.
 2. Even when a muscle is at rest, its fibers usually remain partially contracted.

1.5 Smooth Muscle

The contractile mechanism of smooth muscle is similar to that of skeletal muscle.

1. Smooth muscle fibers

- a. Smooth muscle cells contain filaments of actin and myosin, less organized than those in skeletal muscle.
 - b. Types include multiunit smooth muscle and visceral smooth muscle.
 - c. Visceral smooth muscle displays rhythmicity and is self-excitatory.
2. Smooth muscle contraction
- a. Two neurotransmitters - acetylcholine and norepinephrine - and hormones affect smooth muscle function.
 - b. Smooth muscle can maintain contraction longer with a given amount of energy than skeletal muscle can.
 - c. Smooth muscles can change length without changing tension.

1.6 Cardiac Muscle

- 1. Like skeletal muscle cells, cardiac muscles have actin and myosin filaments that are well organized and striated.
- 2. Cardiac muscle twitches last longer than skeletal muscle twitches.
- 3. Intercalated discs connect cardiac muscle cells.
- 4. A network of fibers contracts as a unit
- 5. Cardiac muscle is self-exciting and rhythmic.

1.7 Skeletal Muscle Actions

The type of movement a skeletal muscle produces depends on the way the muscle attaches on either side of a joint.

- 1. Origin and insertion
 - a. The immovable end of a skeletal muscle is its origin, and the moveable end is its insertion.
 - b. Some muscles have more than one origin.
- 2. Interaction of skeletal muscles
 - a. Skeletal muscles function in groups.
 - b. A prime mover is responsible for most of a movement. Synergists aid prime movers. Antagonists can resist the action of a prime mover.
 - c. Smooth movements depend on antagonists giving way to the actions of the prime movers.

1.8 Major Skeletal Muscles

- 1. Muscles of facial expression

- a. These muscles lie beneath the skin of the face and scalp and are used to communicate feelings through facial expression.
 - b. They include the epicranii, orbicularis oculi, orbicularis oris, buccinator, zygomaticus, and platysma.
2. Muscles of mastication
 - a. These muscles attach to the mandible and are used in chewing.
 - b. They include the masseter and temporalis.
3. Muscles that move the head
 - a. Muscles of the neck and upper back move the head.
 - b. They include the sternocleidomastoid, splenius capitis, and semispinalis capitis.
4. Muscles that move the pectoral girdle
 - a. Most of these muscles connect the scapula to nearby bones and are closely associated with muscles that move the arm.
 - b. They include the trapezius, rhomboid major, levator scapulae, serratus anterior, and pectoralis minor.
5. Muscles that move the arm
 - a. These muscles connect the humerus to various regions of the pectoral girdle, ribs, and vertebral column.
 - b. They include the coracobrachialis, pectoralis major, teres major, latissimus dorsi, supraspinatus, deltoid, subscapularis, infraspinatus, and teres minor.
6. Muscles that move the forearm
 - a. These muscles connect the radius and ulna to the humerus or pectoral girdle.
 - b. They include the biceps brachii, brachialis, brachioradialis, triceps brachii, supinator, pronator teres, and pronator quadratus.
7. Muscles that move the hand
 - a. These muscles arise from the distal end of the humerus and from the radius and ulna.
 - b. They include the flexor carpi radialis, flexor carpi ulnaris, palmaris longus, extensor carpi radialis brevis, extensor carpi ulnaris, and extensor digitorum.
8. Muscles of the abdominal wall
 - a. These muscles connect the rib cage and vertebral column to the pelvic girdle.
 - b. They include the external oblique, internal oblique, transversus abdominis, and rectus abdominis.

9. Muscles of the pelvic outlet
 - a. These muscles form the floor of the pelvic cavity and fill the space within the pubic arch.
 - b. They include the levator ani, superficial transversus perinei, bulbospongiosus, and ischiocavernosus.
10. Muscles that move the thigh
 - a. These muscles attach to the femur and to some part of the pelvic girdle.
 - b. They include the psoas major, iliacus, gluteus maximus, gluteus medius, gluteus minimus, tensor fasciae latae, adductor longus, adductor magnus, and gracilis.
11. Muscles that move the leg
 - a. These muscles connect the tibia or fibula to the femur or pelvic girdle.
 - b. They include the biceps femoris, semitendinosus, semimembranosus, sartorius, and quadriceps femoris group.
12. Muscles that move the foot
 - a. These muscles attach the femur, tibia, and fibula to bones of the foot.
 - b. They include the tibialis anterior, fibularis tertius, extensor digitorum longus, gastrocnemius, soleus, flexor digitorum longus, tibialis posterior, and fibularis longus.