Chapter 9: Muscular System

I. Structure of a Skeletal Muscle

A. Introduction

1. A skeletal muscle is an organ of the muscular system.
2. A skeletal muscle is composed of skeletal muscle tissue, nervous tissue, blood, and connective tissues.

B. Connective Tissue Coverings

1. Fascia is dense connective tissue that separates individual skeletal muscles.
2. A tendon is a cordlike structure that consists of dense connective tissue.
3. Tendons connect a muscle to a bone.
4. An aponeurosis is a sheetlike structure composed of dense connective tissue.
5. Epimysium is a layer of connective tissue that closely surrounds a skeletal muscle.
6. Perimysium is connective tissue that separates muscles into fascicles.
7. A fascicle is a section of a muscle.
8. Endomysium is connective tissue that surrounds individual muscle cells.
9. Deep fascia is fascia that surrounds or penetrates muscles.
10. Subcutaneous fascia is fascia just beneath the skin.
11. Subserous fascia is connective tissue layer of the serous membranes covering organs in various body cavities and lining those cavities.

C. Skeletal Muscle Fibers

1. A skeletal muscle fiber is a single muscle cell.
2. The sarcolemma is the plasma membrane of a muscle cell.
3. The sarcoplasm is the cytoplasm of a muscle cell.

4. The sarcoplasm contains many small nuclei, mitochondria and myofibrils.
5. Myofibrils are threadlike structures and are located in the sarcoplasm.
6. Myofibrils play a fundamental role in the muscle contraction mechanism.
7. Thick myofilaments are composed of myosin.
8. Thin myofilaments are composed of actin.
9. The organization of myofilaments produces the alternating light and dark striation characteristic of skeletal muscles.
10. A sarcomere is a repeating pattern of a myofibril.
11. Myofibrils may be thought of as sarcomeres joined end to end.
12. I bands are composed of thin actin filaments.
13. Z lines are structures that connect that anchor I bands.
14. A bands are composed of thick myosin filaments overlapping thin actin filaments.
15. The H zone is a central region of an A band that only contains thick filaments.
16. The M line is a region of an A band which consists of proteins that help hold the thick filaments in place.
17. Titin connects proteins that connect myosin filaments to Z lines.
18. A sarcomere extends from one Z line to another Z line.
19. Each myosin molecule consists of two twisted protein strands with globular parts called cross-bridges that project outward along their lengths.
20. Thin filaments consist of double strands of actin twisted into a helix.
21. Actin has a binding site to which the cross-bridges of a myosin molecule can attach.
22. Troponin and tropomyosin associate with actin filaments.
23. Sarcoplasmic reticulum is endoplasmic reticulum of a muscle fiber.
24. Transverse tubules are membranous channels that extend into the sarcoplasm as invaginations continuous with the sarcolemma and contains extracellular fluid.

25. Cisternae are enlarged portions of sarcoplasmic reticulum.

26. A triad is formed by one transverse tubule and two cisternae.

II. Skeletal Muscle Contraction

A. Neuromuscular Junction

1. Each skeletal muscle is connected to an extension of a motor neuron.
2. A motor neuron passes out from brain or spinal cord.
3. Normally, a skeletal muscle fiber contracts only upon stimulation by a motor neuron.
4. A neuromuscular junction is the site where the axon and muscle fiber meet.
5. A motor end plate is a specialized portion of the muscle cell membrane that is extensively folded.
6. A motor unit is a motor neuron and the muscle fibers it controls.
7. A synaptic cleft separates the membranes of the neuron and the membrane of the muscle fiber.
8. Synaptic vesicles store neurotransmitters.

B. Stimulus for Contraction

1. Acetylcholine is the neurotrasnmitter that motor neurons use to control skeletal muscle.
2. ACh is synthesized in the cytoplasm of the motor neuron and is stored in synaptic vesicles in axons.
3. When a nerve impulse reaches the end of an axon, acetylcholine is released into the synaptic cleft.
4. ACh combines with ACh receptors on the motor end plate, and stimulates the muscle fiber.
5. A muscle impulse is an electrical signal that is like a nerve impulse.
6. A muscle impulse changes the muscle cell membrane in a way that transmits the impulse in all directions along and around the muscle cell.
7. Ultimately the muscle impulse reaches the sarcoplasmic reticulum and cisternae.

C. Excitation Contraction Coupling

1. The sarcoplasmic reticulum has a high concentration of calcium.
2. In response to a muscle impulse, the membranes become more permeable to calcium, and the calcium diffuses out of the cisternae into the cytosol of the muscle fiber.
3. When a muscle fiber is at rest, the troponin-tropomyosin complexes block the binding sites on the actin molecules.
4. Calcium ions bind to troponin, changing its shape and altering the position of the tropomyosin.
5. The movement of the tropomyosin molecule exposes the binding sites of the actin filaments, allowing linkages to form between myosin cross-bridges and actin.

D. The Sliding Filament Theory

1. The functional unit of skeletal muscles is the sarcomere.
2. According to the sliding filament theory, when sarcomeres shorten, the thick and thin filaments slide past one another.
3. As contraction occurs, the H zones and the I bands get narrower and the Z lines move closer together.

E. Cross-bridge Cycling

1. The force that shortens the sarcomeres comes from cross-bridges pullin on the actin filaments.
2. A myosin cross-bridge attaches to actin in order to pull n the actin filament.
3. The cross-bridge can release, straighten, and combine with another binding site further down the actin filament, and pull again.
4. Myosin cross-bridges contain the enzyme ATPase.
5. ATPase catalyzes the breakdown of ATP to ADP.
6. The force for muscle contraction is provided by the breakdown of ATP into ADP.
7. Breaking down of ATP puts the myosin cross-bridge in a “cocked” position.

8. When a muscle is stimulated to contract, a cocked cross-bridge attaches to actin and pulls the actin filament toward the center of the sarcomere, shortening the muscle.

9. When another ATP binds, the cross-bridge is released, and then breaks down the ATP to return to the cocked position.

10. The cross-bridge cycle may repeat over and over as long as ATP is present and nerve impulses cause ACh release at the neuromusclular junction.

F. Relaxation

1. In order for a muscle fiber to relax, acetylcholine must be decomposed by an enzyme called acetylcholinesterase.

2. The action of acetycholinesterase prevents a single nerve impulse from continuously stimulating a muscle fiber.

3. When acetylcholine is broken down, the stimulus to the sarcolemma and the membranes within the muscle fiber ceases.

4. The calcium pump moves calcium back into the sarcoplasmic reticulum.

5. When calcium is removed from the cytoplasm, the cross-bridge linkages break and tropomyosin rolls back into its groove, preventing any cross-bridge attachment.

6. ATP is necessary for both muscle contraction and relaxation.

7. The trigger for contraction is the increase in cytosolic calcium in response to stimulation by ACh from a motor neuron.

G. Energy Sources for Contraction

1. Creatine phosphate is an energy source available to generate ATP from ADP.

2. Creatine phosphate contains a high energy phosphate bond.

3. As ATP is decomposed to ADP, the energy from creatine phosphate is transferred back to ADP to produce ATP.

4. After creatine phosphate is used, a muscle cell must depend on cellular respiration of glucose as a source of energy for synthesizing ATP.

5. Typically a muscle stores glucose in the form of glycogen.

H. Oxygen Supply and Cellular Respiration

1. Glycolysis occurs in the cytoplasm and is anaerobic.
2. Glycolysis releases a few ATP molecules.
3. The complete break down of glucose occurs in mitochondria and requires oxygen.
4. The citric acid cycle and electron transport chain produce water, carbon dioxide and a large amount of ATP.
5. Oxygen is carried in the blood stream bound to hemoglobin.
6. Myoglobin is red in color.
7. Myoglobin stores oxygen in muscle tissue.

I. Oxygen Debt

1. Lactic acid threshold is a rapid increase in blood levels of lactic acid.
2. Under anaerobic conditions, glycolysis breaks down glucose into pyruvic acid and converts it to lactic acid.
3. Lactic acid is carried by the blood to the liver.
4. Liver cells can convert lactic acid to glucose.
5. Oxygen debt reflects the amount of oxygen liver cells require to convert the accumulated lactic acid into glucose, plus the amount the muscle cells require to resynthesized ATP and creatine phosphate, and restore their original concentrations.

J. Muscle Fatigue

1. Fatigue is the condition in which a muscle fiber cannot contract.
2. Fatigue may result from decreased blood flow, ion imbalances across the sarcolemma, and the psychological loss f the desire to continue to exercise.
3. A cramp is a painful condition in which a muscle undergoes a sustained, involuntary contraction.
4. Physically fit people make less lactic acid because the strenuous exercise of aerobic training stimulated new capillaries to grow within the muscles, supplying more oxygen and nutrients.

K. Heat Production

1. Heat is a by-product of cellular respiration.
2. Blood transports heat throughout the body, which helps to maintain body temperature.

III. Muscle Responses

A. Introduction

1. One way to observe muscle contraction is to remove a single muscle fiber from a skeletal muscle and connect it to a device that measures contraction.
2. An electrical impulse is usually used to produce muscle contraction.

B. Threshold Stimulus

1. Threshold stimulus is the minimal stimulus needed to start a muscle contraction.
2. An impulse in a motor neuron normally releases enough ACh to bring the muscle fibers in its motor unit to threshold.

C. Recording a Muscle Contraction

1. A twitch is the response of a single muscle fiber to the ACh released by a single action potential.
2. A myogram is a recording of the events of a muscle twitch.
3. Three periods of a muscle fiber contraction are latent, contraction, and relaxation.
4. During the period of contraction, a muscle fiber is generating force or contracting.
5. The latent period is the period before contraction.
6. The period of relaxation is the period in which a muscle fiber is decreasing tension.
7. The refractory period is the period in which a muscle fiber is unresponsive to stimulation.
8. An all-or-none response is one in which a muscle fiber contracts completely or not at all.

9. The length to which a muscle is stretched before stimulation affects the force it will develop when stimulated.

10. If a muscle is stretched well beyond its normal resting length, the force will decrease.

11. At very short muscle lengths, the sarcomere becomes compressed and shortening is not possible.

12. In the whole muscle, the degree of tension reflects the frequency at which individual fibers are stimulated and how many fibers take part in the overall contraction of the muscle.

D. Summation

1. Twitches in a muscle can combine to become sustained.
2. Summation is the combination of the force of individual twitches.
3. Tetanic contractions are contractions that lack relaxation.

E. Recruitment of Motor Units

1. The fewer muscle fibers in the motor units, the more precise the movements can be produced in a particular muscle.
2. All muscle fibers in a motor unit are stimulated at the same time.
3. Multiple motor unit summation is recruitment.
4. Recruitment is an increase in the number of activated motor units.
5. As the intensity of stimulation increases, recruitment continues until all possible motor units are activated in a muscle.

F. Sustained Contractions

1. During sustained contractions, smaller motor units tend to be recruited earlier.
2. The larger motor units respond later and more forcefully.
3. Muscle movements are smooth because the spinal cord stimulates contraction in different set of motor units at different times.
4. Muscle tone is the amount of sustained contractions in a muscle.
5. Muscle tone is important for maintaining posture.

G. Types of Contractions

1. An isotonic contraction is a type of contraction that produces movement of a body part.
2. A concentric contraction is an isotonic contraction in which shortening of the muscle occurs.
3. An eccentric contraction is an isotonic contraction in which lengtheninf of the muscle occurs.
4. An isometric contraction is a contraction in which muscle tension increases but no movements of body parts are produced.
5. An example of an isometric contraction is standing.
6. An example of an isotonic contraction is walking.

H. Fast and Slow Twitch Muscle Fibers

1. Type I fibers are slow-twitch fibers.
2. Examples of type I fibers are those in the long muscles of the back.
3. Type I fibers are red in color because they contain a relatively large amount of myoglobin.
4. Type I fibers are resistant to fatigue.
5. Type IIa fibers are fast twitch glycolytic fibers.
6. Type IIa fibers are white in color because they contain relatively small amounts of myoglobin.
7. Type IIb fibers are fast twitch oxidative fibers.
8. A muscles contain a combination of fiber types.

IV. Smooth Muscles

A. Smooth Muscle Fibers

1. Compared to skeletal muscle fibers, smooth muscle fibers are shorter and they have single nuclei.
2. Two major types of smooth muscle are visceral and multiunit.
3. Multiunit smooth muscle is located in the irises and the walls of blood vessels.
4. Visceral smooth muscle is located in the walls of hollow organs except for the heart.
5. Fibers of visceral smooth muscle are connected by gap junctions.

6. Rhythmicity is a pattern of spontaneous repeated contractions.
7. Peristalsis is a wavelike motion produced by smooth muscle contraction.
8. Peristalsis helps force the contents of a tube along its length.

B. Smooth Muscle Contraction

1. Compared to skeletal muscle fibers, smooth muscle fibers lack striations and use calmodulin to bind calcium instead.
2. Two neurotransmitters that affect smooth muscle are acetylcholine and norepinephrine.
3. Hormones affect smooth muscle by stimulating or inhibiting contraction in some cases and lettering the degree of response to neurotransmitters in other cases.
4. Stretching of smooth muscle can trigger contractions.
5. Smooth muscle is slower to contract and slower to relax than skeletal muscle.
6. Unlike skeletal muscle, smooth muscle fibers can change length without changing tautness.

V. Cardiac Muscle

A. Cardiac muscle appears only in the heart.

B. Cardiac muscle is composed of striated cells, forming fibers that are interconnected in branching, three-dimensional networks.

C. Cardiac muscle fibers can contract longer than skeletal muscle fibers.

D. Intercalated discs are membrane junctions that join cardiac muscle fibers together.

E. Intercalated discs allow muscle impulses to travel rapidly from cell to cell.

F. A syncytium is a group of muscle fibers that contract as a unit.

VI. Skeletal Muscle Actions

A. Introduction

1. Skeletal muscles generate a great variety of body movements.

2. The action of each muscle mostly depends upon the kind of joint it is associated with and the way the muscle is attached on either side of that joint.

B. Origin and Insertion

1. The origin of a muscle is the immovable end of the muscle.
2. The insertion of a muscle is the movable end of a muscle.
3. When a muscle contracts, its insertion is pulled toward its origin.
4. The head of a muscle is the part nearest its origin.
5. The origins of the biceps brachii are the attachment to the coracoid process of the scapula, and the attachment to a tubercle above the glenoid cavity of the scapula.
6. The insertion of the bicep brachii is the radial tuberosity of the radius.
7. When the biceps brachii contracts, the elbow bends.

C. Interaction of Skeletal Muscles

1. A prime mover is the muscle primarily responsible for producing an action.
2. A synergist is a muscle that assists the prime mover.
3. An antagonist is a muscle that resists the action of a prime mover.

VII. Major Skeletal Muscles

A. Introduction

1. The name of a muscle may reflect its size, shape, function, number of origins, attachment sites, or direction of its muscle fibers.
2. An example of a muscle named for it size is pectoralis major.
3. An example of a muscle named for its shape is deltoid.
4. An example of a muscle named for its function is extensor digitorum.
5. An example of a muscle named for its number of origins is biceps brachii.
6. An example of a muscle named for it attachments sites is sternocleidomastoid.
7. An example of a muscle named of the direction of its muscle fibers is external oblique.

B. Muscles of Facial Expression

1. As a group, muscles of facial expression connect the bones of the skull to connective tissue in region of the overlying skin.
2. For the following muscles, list their origins, insertions, and actions.

   Epicranius –

   Orbicularis oculi

   Orbicularis oris

   Buccinator

   Zygomaticus

   Platysma

C. Muscles of Mastication

1. Muscles of mastication produce chewing movements.
2. For the following muscles, list their origins, insertions, and actions

   Masseter-

   Temporalis

   Medial pterygoid

   Lateral pterygoid

D. Muscles That Move the Head and Vertebral Column

1. For the following muscles, list their origins, insertions, and actions

   Sternocleidomastoid –

   Splenius capitis

   Semispinalis capitis

   Erector spinae

E. Muscles That Move the Pectoral Girdle

1. For the following muscles, list their origins, insertions, and actions

   Trapezius –

   Rhomboideus major

   Levator spinae

   Serratus anterior

   Pectoralis major

F. Muscles That Move the Arm

1. For the following muscles, list their origins, insertions, and actions

    Coracobrachialis –

    Pectoralis major

    Teres major

    Latissimus dorsi

    Supraspinatus

    Deltoid

    Subscapularis

    Infraspinatus

    Teres minor

G. Muscles That Move the Forearm

1. For the following muscles, list their origins, insertions, and actions

    Biceps brachii –

    Brachialis

    Brachioradialis

    Triceps brachii

    Supinator

    Pronator teres

    Pronator quadratus

H. Muscles That Move the Hand

1. For the following muscles, list their origins, insertions, and actions

    Flexor carpi radialis longus –

    Flexor carpi ulnaris

    Palmaris longus

    Flexor digitorum profundus

    Flexor digitorum superficialis

    Extensor carpi radialis

    Extensor carpi radialis brevic

    Extensor carpi ulnaris

    Extensor digitorum

I. Muscles of the Abdominal Wall

1. The linea aspera is a band of connective tissue that extends from the xiphoid process to the symphysis pubis.
2. For the following muscles, list their origins, insertions, and actions

    External oblique –

    Internal oblique

    Transversus abdominis

    Rectus abdominis

J. Muscles of the Pelvic Outlet

1. The pelvic diaphragm forms the floor of the pelvic cavity.
2. The urogenital diaphragm fills the space within the pubic arch.
3. For the following muscles, list their origins, insertions, and actions

    Levator ani –

    Coccygeus

    Superficial transversus perinea

    Bulbospongiosus

    Ischiocavernosus

    Sphincter urethra

K. Muscles That Move the Thigh

1. For the following muscles, list their origins, insertions, and actions

    Psoas major –

    Iliacus

    Gluteus maximus

    Gluteus medius

    Gluteus minimus

    Pectineus

    Adductor longus

    Adductor magnus

    Gracilis

L. Muscles That Move the Leg

1. For the following muscles, list their origins, insertions, and actions

    Biceps femoris –

Semitendinosus

Semimembranosus

Sartorius

Quadriceps femoris group

M. Muscle That Move the Foot

1. For the following muscles, list their origins, insertions, and actions

Tibialis anterior –

Fibularis tertius

Extensor digitorum longus

Gastrocnemius

Soleus

Flexor digitorum longus

Tibialis posterior

Fibularis longus

VIII. Life-Span Changes

A. Signs of aging of the muscular system begin to appear one's forties.

B. At a microscopic level, myoglobin, ATP, and creatine phosphate decline.

C. Connective tissue and adipose tissue begin to replace some muscle tissue.

D. Exercise can help maintain a healthy muscular system

E. According to the National Institute on Aging, exercise should include strength training, aerobics, and stretching.