Unit 6: The Muscular System

I. The Muscular System
   A. Muscles are responsible for all types of body movement
      B. Three basic muscle types are found in the body
      1. Skeletal muscle
         2. Cardiac muscle
         3. Smooth muscle

II. Characteristics of Muscles
   A. Skeletal and smooth muscle cells are elongated (muscle cell = muscle fiber)
      B. Contraction of muscles is due to the movement of microfilaments
      C. All muscles share some terminology
      1. Prefixes myo and mys refer to "muscle"
         2. Prefix sarco refers to "flesh"

III. Comparison of Skeletal, Cardiac, and Smooth Muscles
   A. Skeletal Muscle Characteristics
      1. Most are attached by tendons to bones
         2. Cells are multinucleate
         3. Striated–have visible banding
         4. Voluntary–subject to conscious control
         5. Connective Tissue Wrappings of Skeletal Muscle
            a. Cells are surrounded and bundled by connective tissue
               (1) Endomysium–encloses a single muscle fiber
                  (2) Perimysium–wraps around a fascicle (bundle) of muscle fibers
                  (3) Epimysium–covers the entire skeletal muscle
                  (4) Fascia–on the outside of the epimysium
      6. Skeletal Muscle Attachments
         a. Epimysium blends into a connective tissue attachment
            (1) Tendons–cord-like structures
               (a) Mostly collagen fibers
                  (b) Often cross a joint due to toughness and small size
            (2) Aponeuroses–sheet-like structures

(a) Attach muscles indirectly to bones, cartilages, or connective tissue coverings

b. Sites of muscle attachment

(1) Bones

(2) Cartilages

(3) Connective tissue coverings

B. Smooth Muscle Characteristics

1. Lacks striations
2. Spindle-shaped cells
3. Single nucleus
4. Involuntary–no conscious control
5. Found mainly in the walls of hollow organs

C. Cardiac Muscle Characteristics

1. Striations
2. Usually has a single nucleus
3. Branching cells
4. Joined to another muscle cell at an intercalated disc
5. Involuntary
6. Found only in the heart

D. Skeletal Muscle Functions

1. Produce movement
2. Maintain posture
3. Stabilize joints
4. Generate heat

IV. Microscopic Anatomy of Skeletal Muscle

A. Sarcolemma–specialized plasma membrane

B. Myofibrils–long organelles inside muscle cell

C. Sarcoplasmic reticulum–specialized smooth endoplasmic reticulum

D. Myofibrils are aligned to give distinct bands

1. I band = light band
   a. Contains only thin filaments
2. A band = dark band
   a. Contains the entire length of the thick filaments
3. At rest, there is a bare zone that lacks actin filaments called the H zone

E. Sarcomere–contractile unit of a muscle fiber

F. Organization of the sarcomere

G. Myofilaments
1. Thick filaments = myosin filaments
a. Composed of the protein myosin
b. Has ATPase enzymes
c. Myosin filaments have heads (extensions, or cross bridges)
d. Myosin and actin overlap somewhat
2. Thin filaments = actin filaments
a. Composed of the protein actin
b. Anchored to the Z disc
H. Sarcoplasmic reticulum (SR)
1. Stores and releases calcium
2. Surrounds the myofibril
I. Stimulation and Contraction of Single Skeletal Muscle Cells
1. Excitability (also called responsiveness or irritability)–ability to receive and respond to a stimulus
2. Contractility–ability to shorten when an adequate stimulus is received
3. Extensibility–ability of muscle cells to be stretched
4. Elasticity–ability to recoil and resume resting length after stretching
5. The Nerve Stimulus and Action Potential
a. Skeletal muscles must be stimulated by a motor neuron (nerve cell) to contract
b. Motor unit–one motor neuron and all the skeletal muscle cells stimulated by that neuron
c. Neuromuscular junction
(1) Association site of axon terminal of the motor neuron and muscle
(2) Synaptic cleft
(a) Gap between nerve and muscle
(b) Nerve and muscle do not make contact
(c) Area between nerve and muscle is filled with interstitial fluid
d. Transmission of Nerve Impulse to Muscle
(1) Neurotransmitter–chemical released by nerve upon arrival of nerve impulse

(a) The neurotransmitter for skeletal muscle is acetylcholine (ACh)

(2) Acetylcholine attaches to receptors on the sarcolemma

(3) Sarcolemma becomes permeable to sodium (Na+)

(4) Sodium rushes into the cell generating an action potential

(5) Once started, muscle contraction cannot be stopped

J. The Sliding Filament Theory of Muscle Contraction

1. Activation by nerve causes myosin heads (cross bridges) to attach to binding sites on the thin filament

2. Myosin heads then bind to the next site of the thin filament and pull them toward the center of the sarcomere

3. This continued action causes a sliding of the myosin along the actin

4. The result is that the muscle is shortened (contracted)

5. Contraction of Skeletal Muscle

a. Muscle fiber contraction is "all or none"

b. Within a skeletal muscle, not all fibers may be stimulated during the same interval

c. Different combinations of muscle fiber contractions may give differing responses

d. Graded responses–different degrees of skeletal muscle shortening

e. Graded responses can be produced by changing

(1) The frequency of muscle stimulation

(2) The number of muscle cells being stimulated at one time

(3) Types of Graded Responses

(a) Twitch

(b) Single, brief contraction

(c) Not a normal muscle function

(d) Tetanus (summing of contractions)

I. One contraction is immediately followed by another

II. The muscle does not completely return to a resting state
III. The effects are added
IV. Unfused (incomplete) tetanus
A. Some relaxation occurs between contractions
B. The results are summed
V. Fused (complete) tetanus
A. No evidence of relaxation before the following contractions
B. The result is a sustained muscle contraction

K. Muscle Response to Strong Stimuli
1. Muscle force depends upon the number of fibers stimulated
2. More fibers contracting results in greater muscle tension
3. Muscles can continue to contract unless they run out of energy

L. Energy for Muscle Contraction
1. Initially, muscles use stored ATP for energy
a. ATP bonds are broken to release energy
b. Only 4-6 seconds worth of ATP is stored by muscles
2. After this initial time, other pathways must be utilized to produce ATP
3. Direct phosphorylation of ADP by creatine phosphate (CP)
a. Muscle cells store CP
(1) CP is a high-energy molecule
b. After ATP is depleted, ADP is left
c. CP transfers energy to ADP, to regenerate ATP
d. CP supplies are exhausted in less than 15 seconds
4. Aerobic respiration
a. Glucose is broken down to carbon dioxide and water, releasing energy (ATP)
b. This is a slower reaction that requires continuous oxygen

c. A series of metabolic pathways occur in the mitochondria

5. Anaerobic glycolysis and lactic acid formation

a. Reaction that breaks down glucose without oxygen

b. Glucose is broken down to pyruvic acid to produce some ATP

c. Pyruvic acid is converted to lactic acid

d. This reaction is not as efficient, but is fast

(1) Huge amounts of glucose are needed

(2) Lactic acid produces muscle fatigue

M. Muscle Fatigue and Oxygen Deficit

1. When a muscle is fatigued, it is unable to contract even with a stimulus

2. Common cause for muscle fatigue is oxygen debt

a. Oxygen must be "repaid" to tissue to remove oxygen deficit

b. Oxygen is required to get rid of accumulated lactic acid

3. Increasing acidity (from lactic acid) and lack of ATP causes the muscle to contract less

V. Types of Muscle Contractions

A. Isotonic contractions

1. Myofilaments are able to slide past each other during contractions

2. The muscle shortens and movement occurs

B. Isometric contractions

1. Tension in the muscles increases

2. The muscle is unable to shorten or produce movement

VI. Muscle Tone

A. Some fibers are contracted even in a relaxed muscle

B. Different fibers contract at different times to provide muscle tone

C. The process of stimulating various fibers is under involuntary control

VII. Effect of Exercise on Muscles

A. Exercise increases muscle size, strength, and endurance

1. Aerobic (endurance) exercise (biking, jogging) results in stronger, more flexible muscles with greater resistance to fatigue
    a. Makes body metabolism more efficient
        b. Improves digestion, coordination
2. Resistance (isometric) exercise (weight lifting) increases muscle size and strength

VIII. Muscles and Body Movements

A. Movement is attained due to a muscle moving an attached bone

B. Muscles are attached to at least two points

1. Origin
    a. Attachment to a moveable bone
2. Insertion
    a. Attachment to an immovable bone

C. Types of Ordinary Body Movements

1. Flexion
    a. Decreases the angle of the joint
        b. Brings two bones closer together
        c. Typical of hinge joints like knee and elbow
2. Extension
    a. Opposite of flexion
        b. Increases angle between two bones
3. Rotation
    a. Movement of a bone around its longitudinal axis
        b. Common in ball-and-socket joints
        c. Example is when you move atlas around the dens of axis (shake your head "no")
4. Abduction
    a. Movement of a limb away from the midline
5. Adduction
    a. Opposite of abduction
        b. Movement of a limb toward the midline
6. Circumduction
    a. Combination of flexion, extension, abduction, and adduction
        b. Common in ball-and-socket joints
7. Special Movements

a. Dorsiflexion
(1) Lifting the foot so that the superior surface approaches the shin
b. Plantar flexion
(1) Depressing the foot (pointing the toes)
c. Inversion
(1) Turn sole of foot medially
d. Eversion
(1) Turn sole of foot laterally
e. Supination
(1) Forearm rotates laterally so palm faces anteriorly
f. Pronation
(1) Forearm rotates medially so palm faces posteriorly
g. Opposition
(1) Move thumb to touch the tips of other fingers on the same hand

IX. Types of Muscles
A. Prime mover–muscle with the major responsibility for a certain movement
B. Antagonist–muscle that opposes or reverses a prime mover
C. Synergist–muscle that aids a prime mover in a movement and helps prevent rotation
D. Fixator–stabilizes the origin of a prime mover

X. Naming Skeletal Muscles
A. By direction of muscle fibers
1. Example: Rectus (straight)
B. By relative size of the muscle
1. Example: Maximus (largest)
C. By location of the muscle
1. Example: Temporalis (temporal bone)
D. By number of origins
1. Example: Triceps (three heads)
E. By location of the muscle's origin and insertion
1. Example: Sterno (on the sternum)
F. By shape of the muscle
1. Example: Deltoid (triangular)
G. By action of the muscle

1. Example: Flexor and extensor (flexes or extends a bone)

XI. Head and Neck Muscles

A. Facial muscles

1. Frontalis–raises eyebrows
2. Orbicularis oculi–closes eyes, squints, blinks, winks
3. Orbicularis oris–closes mouth and protrudes the lips
4. Buccinator–flattens the cheek, chews
5. Zygomaticus–raises corners of the mouth
6. Chewing muscles
   a. Masseter–closes the jaw and elevates mandible
   b. Temporalis–synergist of the masseter, closes jaw
7. Neck muscles
   a. Platysma–pulls the corners of the mouth inferiorly
   b. Sternocleidomastoid–flexes the neck, rotates the head

B. Muscles of Trunk, Shoulder, Arm

1. Anterior muscles
   a. Pectoralis major–adducts and flexes the humerus
   b. Intercostal muscles
      (1) External intercostals–raise rib cage during inhalation
      (2) Internal intercostals–depress the rib cage to move air out of the lungs when you exhale forcibly
   c. Muscles of the abdominal girdle
      (1) Rectus abdominis–flexes vertebral column and compresses abdominal contents (defecation, childbirth, forced breathing)
      (2) External and internal obliques–flex vertebral column; rotate trunk and bend it laterally
      (3) Transversus abdominis–compresses abdominal contents
2. Posterior muscles
   a. Trapezius–elevates, depresses, adducts, and stabilizes the scapula
   b. Latissimus dorsi–extends and adducts the humerus
   c. Erector spinae–back extension
   d. Quadratus lumborum–flexes the spine laterally
   e. Deltoid–arm abduction

3. Muscles of the Upper Limb
    a. Biceps brachii–supinates forearm, flexes elbow
    b. Brachialis–elbow flexion
    c. Brachioradialis–weak muscle
    d. Triceps brachii–elbow extension (antagonist to biceps brachii)

C. Muscles of Posterior Neck, Trunk, Arm
1. Muscles of the Lower Limb
    a. Gluteus maximus–hip extension
    b. Gluteus medius–hip abduction, steadies pelvis when walking
    c. Iliopsoas–hip flexion, keeps the upper body from falling backward when standing erect
    d. Adductor muscles–adduct the thighs
2. Muscles of the Pelvis, Hip, Thigh
    a. Muscles causing movement at the knee joint
        (1) Hamstring group–thigh extension and knee flexion
            (a) Biceps femoris
            (b) Semimembranosus
            (c) Semitendinosus
        (2) Quadriceps group–extends the knee
            (a) Vastus muscles (three)
            (b) Rectus femoris
        (3) Sartorius–flexes the thigh
3. Muscles causing movement at ankle and foot
    a. Tibialis anterior–dorsiflexion and foot inversion
    b. Extensor digitorum longus–toe extension and dorsiflexion of the foot
    c. Fibularis muscles–plantar flexion, everts the foot
    d. Soleus–plantar flexion

D. Intramuscular Injection Sites