The Muscular System
The Muscular System

- Muscles are responsible for all types of body movement – they contract or shorten and are the machine of the body

- Three basic muscle types are found in the body

  - Skeletal muscle
  - Cardiac muscle
  - Smooth muscle
Characteristics of Muscles

- Muscle cells are elongated (muscle cell = muscle fiber)
- Contraction of muscles is due to the movement of microfilaments
- All muscles share some terminology
  - Prefix myo refers to muscle
  - Prefix mys refers to muscle
  - Prefix sarco refers to flesh
Skeletal Muscle Characteristics

- Most are attached by tendons to bones
- Cells are multinucleate
- Striated – have visible banding
- Voluntary – subject to conscious control
- Cells are surrounded and bundled by connective tissue = great force, but tires easily
Connective Tissue Wrappings of Skeletal Muscle

- **Endomysium** – around single muscle fiber
- **Perimysium** – around a fascicle (bundle) of fibers
Connective Tissue Wrappings of Skeletal Muscle

- Epimysium – covers the entire skeletal muscle
- Fascia – on the outside of the epimysium
Skeletal Muscle Attachments

- Epimysium blends into a connective tissue attachment
  - Tendon – cord-like structure
  - Aponeuroses – sheet-like structure
- Sites of muscle attachment
  - Bones
  - Cartilages
  - Connective tissue coverings
Smooth Muscle Characteristics

- Has no striations
- Spindle-shaped cells
- Single nucleus
- Involuntary – no conscious control
- Found mainly in the walls of hollow organs
- Slow, sustained and tireless

Figure 6.2a
Cardiac Muscle Characteristics

- Has striations
- Usually has a single nucleus
- Joined to another muscle cell at an intercalated disc
- Involuntary
- Found only in the heart
- Steady pace!
Function of Muscles

- Produce movement
- Maintain posture
- Stabilize joints
- Generate heat
Microscopic Anatomy of Skeletal Muscle

- Cells are multinucleate
- Nuclei are just beneath the sarcolemma

(a) Segment of a muscle fiber (cell)
Microscopic Anatomy of Skeletal Muscle

- Sarcolemma – specialized plasma membrane
- Sarcoplasmic reticulum – specialized smooth endoplasmic reticulum

(a) Segment of a muscle fiber (cell)
Microscopic Anatomy of Skeletal Muscle

- Myofibril
  - Bundles of myofilaments
  - Myofibrils are aligned to give distinct bands
    - I band = light band
    - A band = dark band

Figure 6.3b
Microscopic Anatomy of Skeletal Muscle

- **Sarcomere**
  - Contractile unit of a muscle fiber

Figure 6.3b

(b) **Myofibril or fibril**
(complex organelle composed of bundles of myofilaments)
Microscopic Anatomy of Skeletal Muscle

- Organization of the sarcomere
  - Thick filaments = myosin filaments
    - Composed of the protein myosin
    - Has ATPase enzymes

Figure 6.3c
Microscopic Anatomy of Skeletal Muscle

- Organization of the sarcomere
  - Thin filaments = actin filaments
  - Composed of the protein actin

Figure 6.3c
Microscopic Anatomy of Skeletal Muscle

- Myosin filaments have heads (extensions, or cross bridges)
- Myosin and actin overlap somewhat

Figure 6.3d
Properties of Skeletal Muscle Activity (single cells or fibers)

- Irritability – ability to receive and respond to a stimulus
- Contractility – ability to shorten when an adequate stimulus is received
Nerve Stimulus to Muscles

- Skeletal muscles must be stimulated by a nerve to contract (motor neuron)

- Motor unit
  - One neuron
  - Muscle cells stimulated by that neuron
Neuromuscular junctions – association site of nerve and muscle

Figure 6.5b
Nerve Stimulus to Muscles

- Synaptic cleft – gap between nerve and muscle
  - Nerve and muscle do not make contact
  - Area between nerve and muscle is filled with interstitial fluid

Figure 6.5b
Transmission of Nerve Impulse to Muscle

- Neurotransmitter – chemical released by nerve upon arrival of nerve impulse
  - The neurotransmitter for skeletal muscle is acetylcholine
- Neurotransmitter attaches to receptors on the sarcolemma
- Sarcolemma becomes permeable to sodium (Na⁺)
Transmission of Nerve Impulse to Muscle

- Sodium rushing into the cell generates an action potential
- Once started, muscle contraction cannot be stopped
The Sliding Filament Theory of Muscle Contraction

- Activation by nerve causes myosin heads (crossbridges) to attach to binding sites on the thin filament.
- Myosin heads then bind to the next site of the thin filament.

Figure 6.7
The Sliding Filament Theory of Muscle Contraction

- This continued action causes a sliding of the myosin along the actin.
- The result is that the muscle is shortened (contracted).

Figure 6.7
The Sliding Filament Theory

Figure 6.8
Contraction of a Skeletal Muscle

- Muscle fiber contraction is "all or none"
- Within a skeletal muscle, not all fibers may be stimulated during the same interval
- Different combinations of muscle fiber contractions may give differing responses
- Graded responses – different degrees of skeletal muscle shortening, rapid stimulus = constant contraction or tetanus
Muscle Response to Strong Stimuli

- Muscle force depends upon the number of fibers stimulated
- More fibers contracting results in greater muscle tension
- Muscles can continue to contract unless they run out of energy
Energy for Muscle Contraction

- Initially, muscles used stored ATP for energy
  - Bonds of ATP are broken to release energy
  - Only 4-6 seconds worth of ATP is stored by muscles
- After this initial time, other pathways must be utilized to produce ATP
Energy for Muscle Contraction

- Direct phosphorylation
  - Muscle cells contain creatine phosphate (CP)
    - CP is a high-energy molecule
  - After ATP is depleted, ADP is left
  - CP transfers energy to ADP, to regenerate ATP
  - CP supplies are exhausted in about 20 seconds

Figure 6.10a

Slide 6.24
Energy for Muscle Contraction

- Anaerobic glycolysis
  - Reaction that breaks down glucose without oxygen
  - Glucose is broken down to pyruvic acid to produce some ATP
  - Pyruvic acid is converted to lactic acid

Figure 6.10b
Energy for Muscle Contraction

- Anaerobic glycolysis (continued)
  - This reaction is not as efficient, but is fast
    - Huge amounts of glucose are needed
    - Lactic acid produces muscle fatigue
Energy for Muscle Contraction

- **Aerobic Respiration**
  - Series of metabolic pathways that occur in the mitochondria
  - Glucose is broken down to carbon dioxide and water, releasing energy
  - This is a slower reaction that requires continuous oxygen

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**Figure 6.10c**

- ATP
- Glucose
- Pyruvic acid
- Fatty acids
- CO₂
- H₂O
- ATP

Energy source: glucose; pyruvic acid; free fatty acids from adipose tissue; amino acids from protein catabolism

Oxygen use: Required
Products: 36 ATP per glucose, CO₂, H₂O
Duration of energy provision: Hours

*Slide 6.25*
Muscle Fatigue and Oxygen Debt

- When a muscle is fatigued, it is unable to contract
- The common reason for muscle fatigue is oxygen debt
  - Oxygen must be “repaid” to tissue to remove oxygen debt
  - Oxygen is required to get rid of accumulated lactic acid
- Increasing acidity (from lactic acid) and lack of ATP causes the muscle to contract less
Types of Muscle Contractions

- **Isotonic contractions**
  - Myofilaments are able to slide past each other during contractions
  - The muscle shortens

- **Isometric contractions**
  - Tension in the muscles increases
  - The muscle is unable to shorten
Muscle Tone

- Some fibers are contracted even in a relaxed muscle
- Different fibers contract at different times to provide muscle tone
- The process of stimulating various fibers is under involuntary control
Movement is attained due to a muscle moving an attached bone.
Muscles and Body Movements

- Muscles are attached to at least two points
  - Origin – attachment to a moveable bone
  - Insertion – attachment to an immovable bone
Effects of Exercise on Muscle

- Results of increased muscle use
  - Increase in muscle size
  - Increase in muscle strength
  - Increase in muscle efficiency
  - Muscle becomes more fatigue resistant
Types of Ordinary Body Movements

- Flexion – decreases angle of joint and brings two bones closer together
- Extension- opposite of flexion
- Rotation- movement of a bone in longitudinal axis, shaking head “no”
- Abduction/Adduction (see slides)
- Circumduction (see slides)
Body Movements

Figure 6.13
(a) Flexion and extension of the shoulder and knee
(b) Flexion, extension, and hyperextension
(c) Rotation
Left:
Abduction – moving the leg away from the midline.

Right:
Circumduction: cone-shaped movement, proximal end doesn’t move, while distal end moves in a circle.

Above – Adduction-moving toward the midline.
Types of Muscles

- Prime mover – muscle with the major responsibility for a certain movement
- Antagonist – muscle that opposes or reverses a prime mover
- Synergist – muscle that aids a prime mover in a movement and helps prevent rotation
Naming of Skeletal Muscles

- Direction of muscle fibers
  - Example: *rectus* (straight)
- Relative size of the muscle
  - Example: *maximus* (largest)
Naming of Skeletal Muscles

- Location of the muscle
  - Example: many muscles are named for bones (e.g., temporalis)

- Number of origins
  - Example: triceps (three heads)
Naming of Skeletal Muscles

- Location of the muscles origin and insertion
  - Example: *sterno* (on the sternum)
- Shape of the muscle
  - Example: *deltoid* (triangular)
- Action of the muscle
  - Example: *flexor* and *extensor* (flexes or extends a bone)
Head and Neck Muscles

- Frontalis
- Cranial aponeurosis
- Orbicularis oculi
- Temporalis
- Occipitalis
- Zygomaticus
- Masseter
- Buccinator
- Sternocleidomastoid
- Orbicularis oris
- Trapezius
- Platysma

Figure 6.14
Trunk Muscles

(a) Deltoid, Clavicle, Sternum, Pectoralis major, Biceps brachii, Brachialis, Brachioradialis

(b) Pectoralis major, Rectus abdominis, Transversus abdominis, Internal oblique, External oblique, Aponeurosis

Figure 6.15

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Deep Trunk and Arm Muscles

Figure 6.16

Slide 6.40
Muscles of the Lower Leg

Figure 6.19

(a) Fibularis longus
(b) Gastrocnemius

- Fibularis brevis
- Tibialis anterior
- Extensor digitorum longus
- Tibia
- Soleus
- Soleus
- Calcaneal (Achilles) tendon
- Medial malleolus
- Lateral malleolus

Slide 6.42
Superficial Muscles: Anterior

Figure 6.20

Slide 6.43
Superficial Muscles: Posterior

Figure 6.21
Disorders relating to the Muscular System

- Muscular Dystrophy: inherited, muscle enlarge due to increased fat and connective tissue, but fibers degenerate and atrophy.
- Duchenne MD: lacking a protein to maintain the sarcolemma.
- Myasthenia Gravis: progressive weakness due to a shortage of acetylcholine receptors.