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

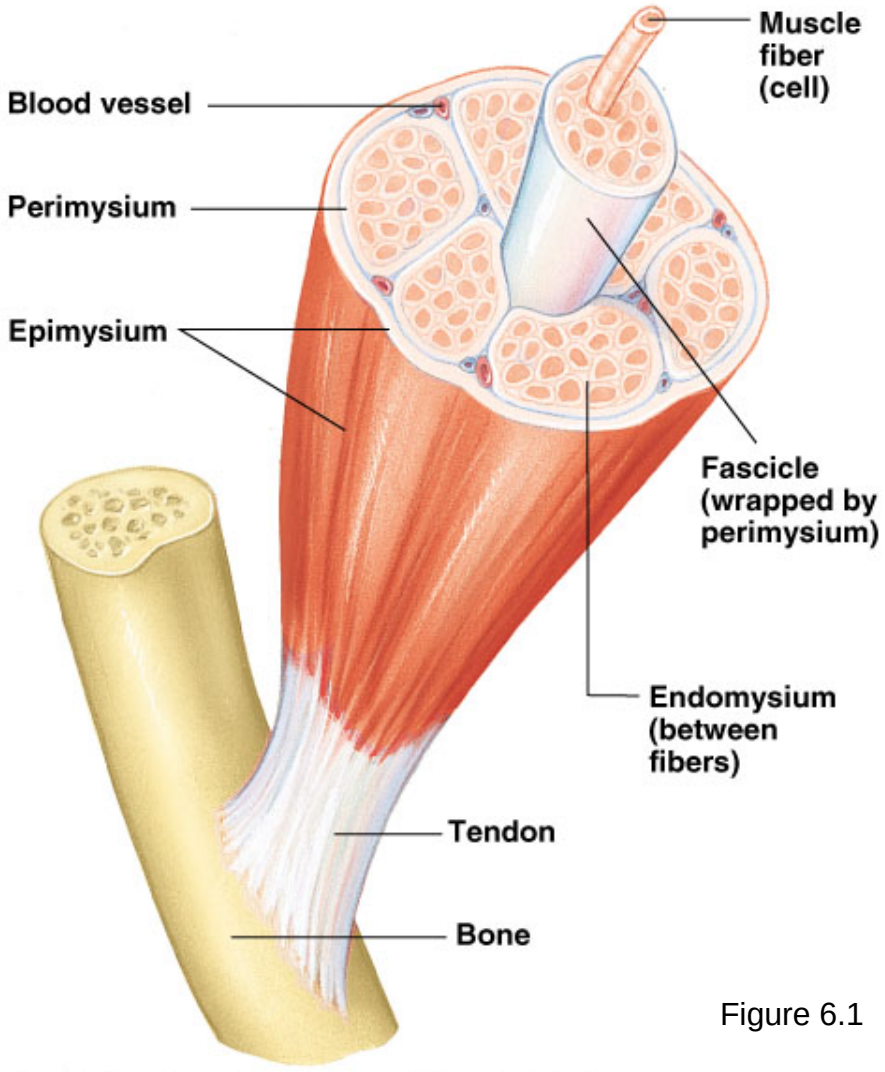


Figure 6.1

Connective Tissue Wrappings of Skeletal Muscle

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

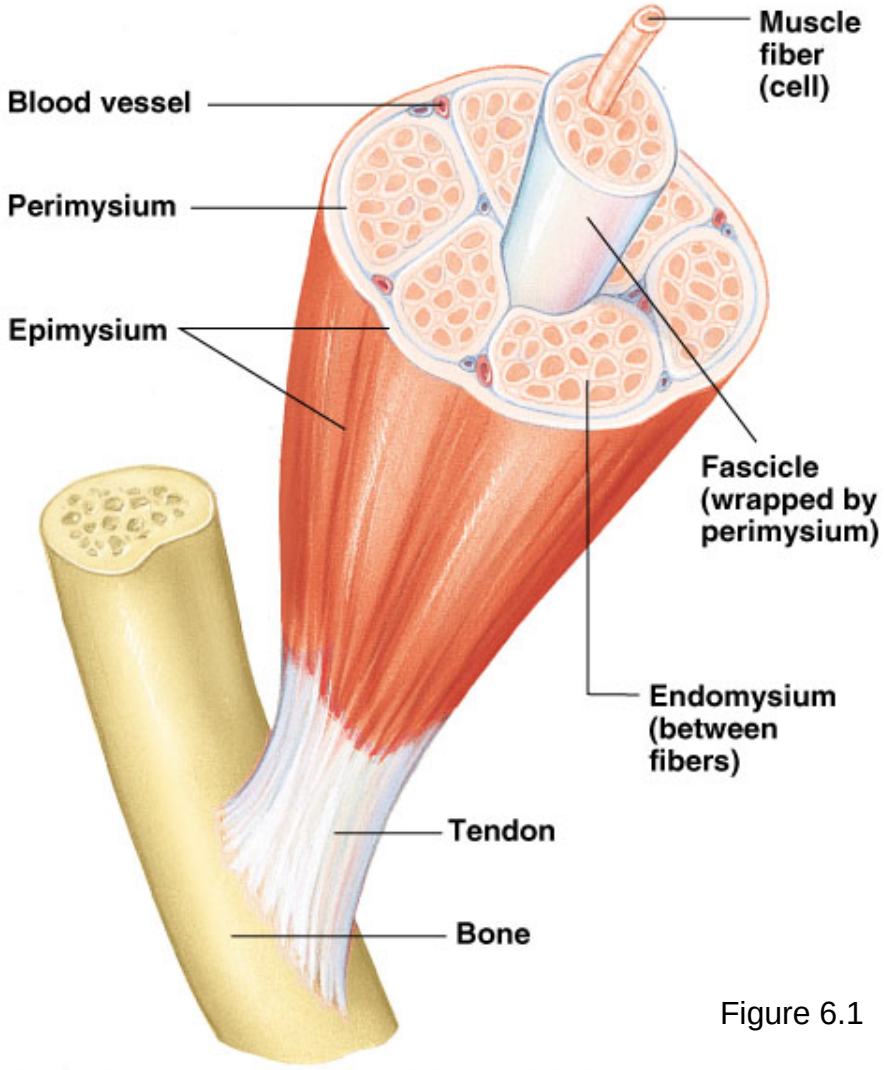


Figure 6.1

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

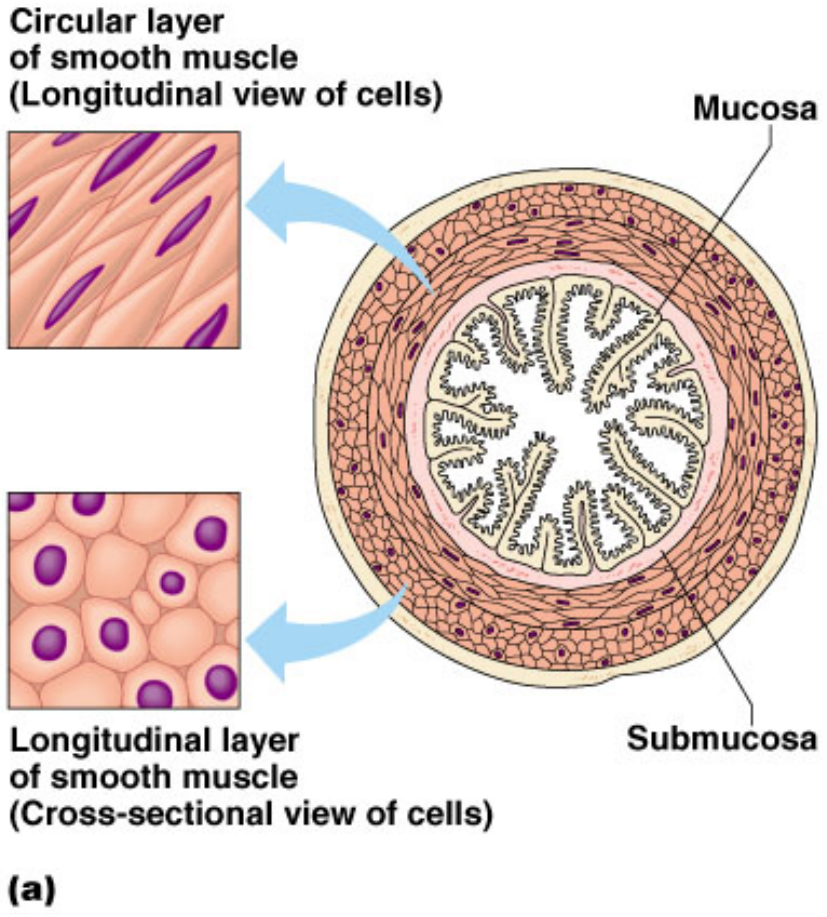


Figure 6.2a

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!

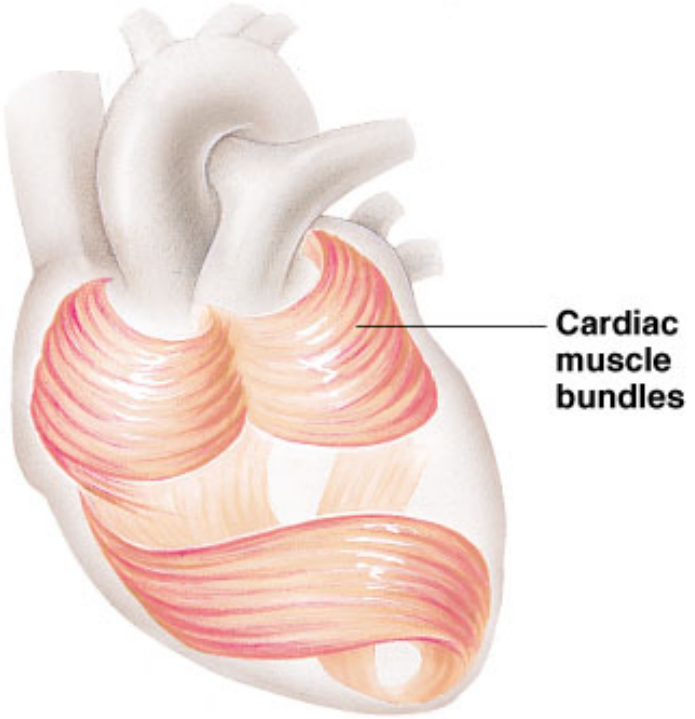


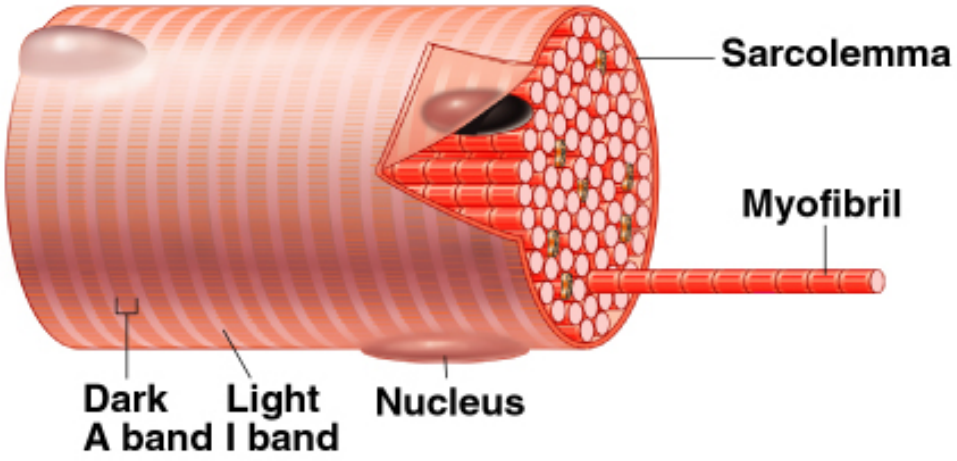
Figure 6.2b

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

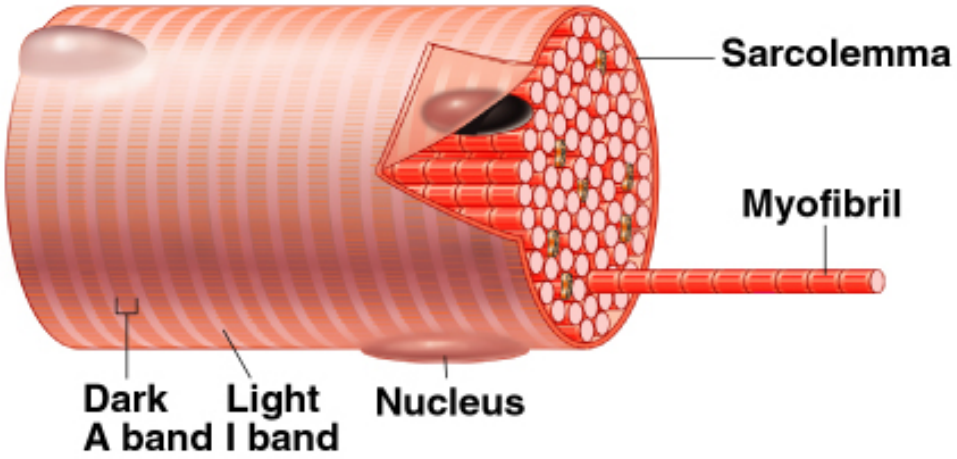


(a) Segment of a muscle fiber (cell)

Figure 6.3a

Microscopic Anatomy of Skeletal Muscle

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

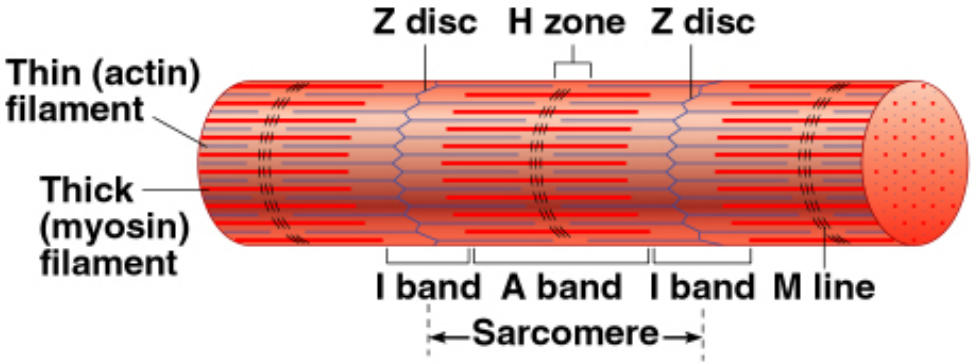


(a) Segment of a muscle fiber (cell)

Figure 6.3a

Microscopic Anatomy of Skeletal Muscle

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

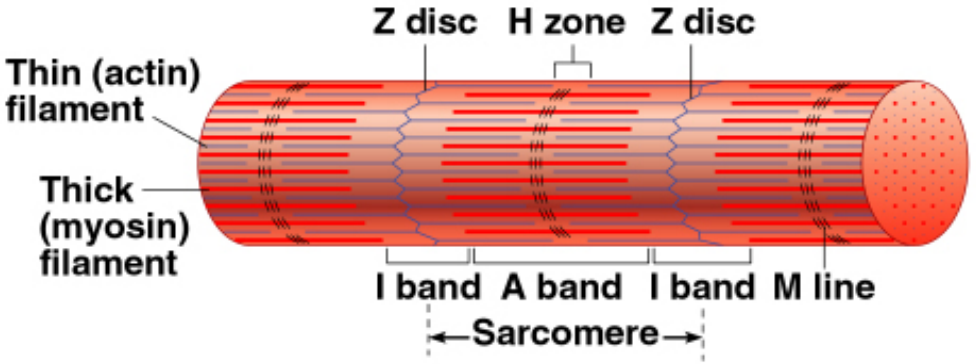


(b) Myofibril or fibril
(complex organelle composed of bundles of myofilaments)

Figure 6.3b

Microscopic Anatomy of Skeletal Muscle

- Sarcomere
  - Contractile unit of a muscle fiber

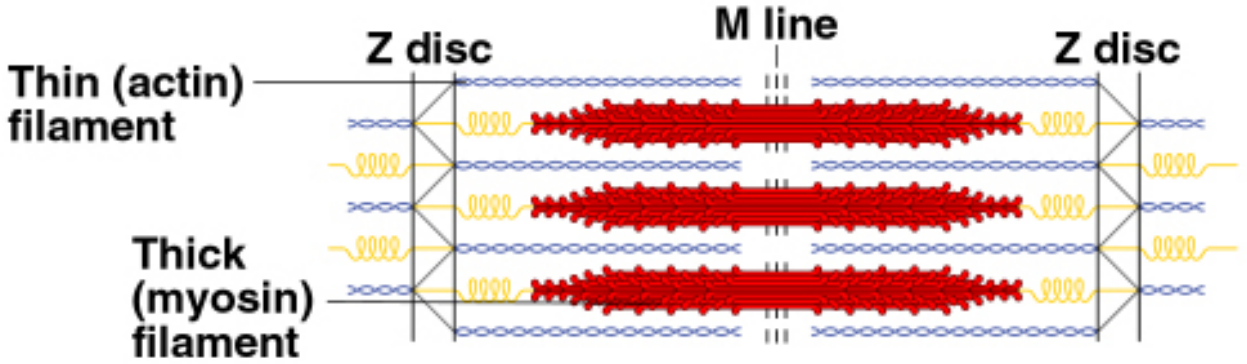


(b) Myofibril or fibril
(complex organelle composed of bundles of myofilaments)

Figure 6.3b

Microscopic Anatomy of Skeletal Muscle

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



(c) **Sarcomere** (segment of a myofibril)

Figure 6.3c

Microscopic Anatomy of Skeletal Muscle

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

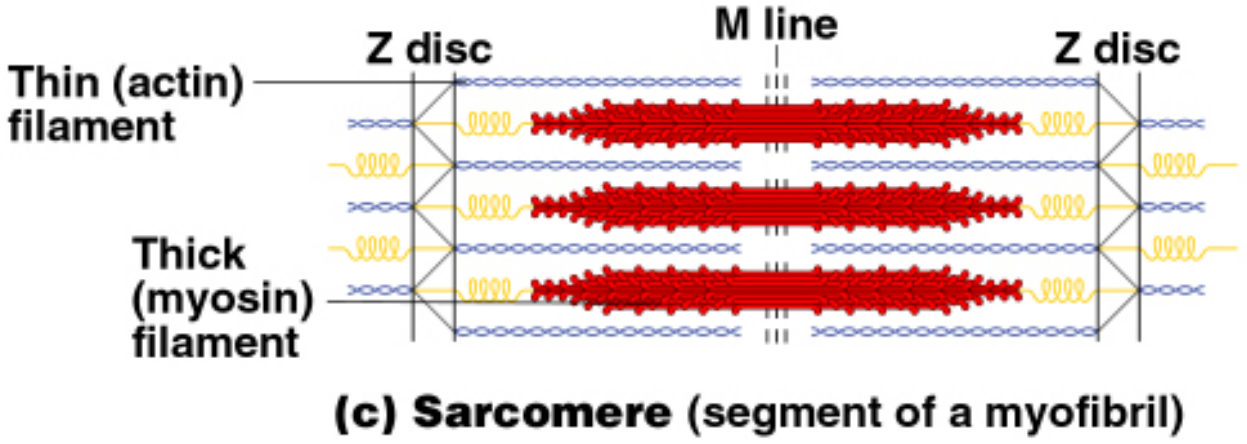


Figure 6.3c

Microscopic Anatomy of Skeletal Muscle

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

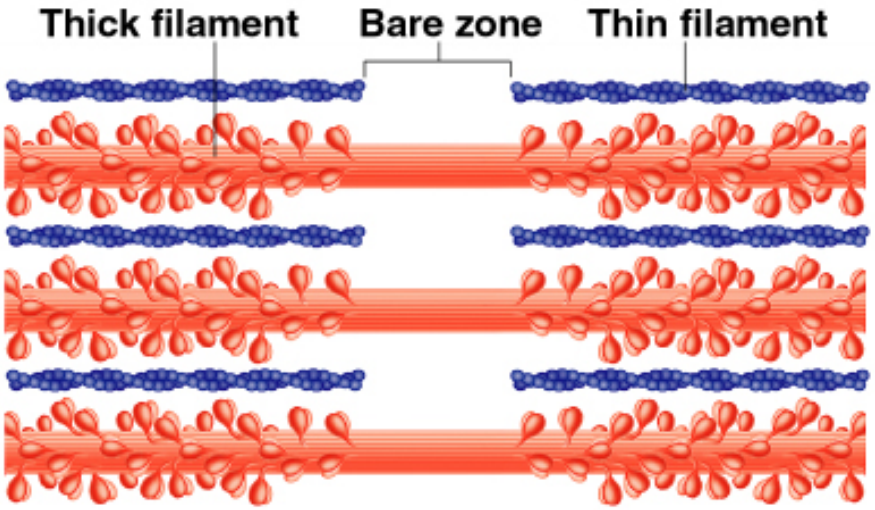


Figure 6.3d

(d) Myofilament structure (within one sarcomere)

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 neruron)
- Motor unit
  - One neuron
  - Muscle cells stimulated by that neuron

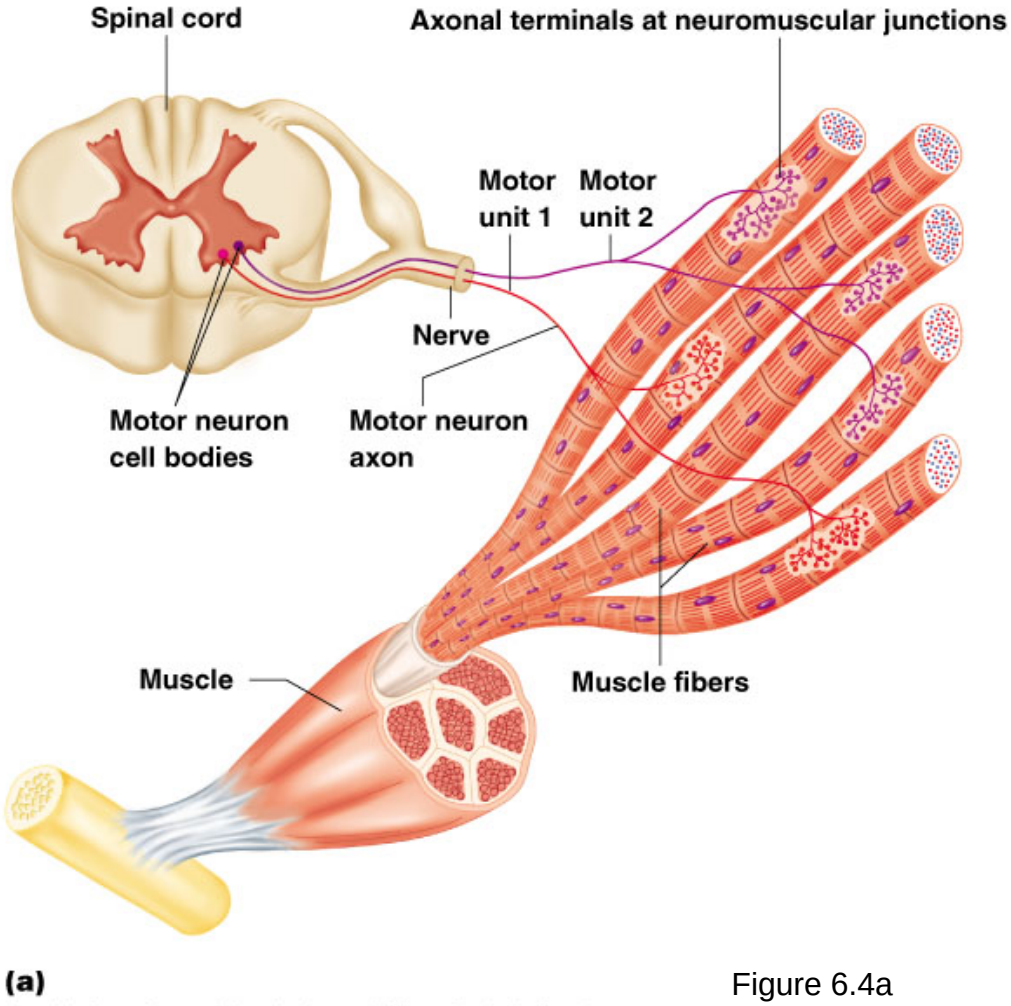


Figure 6.4a

Nerve Stimulus to Muscles

- Neuromuscular junctions – association site of nerve and muscle

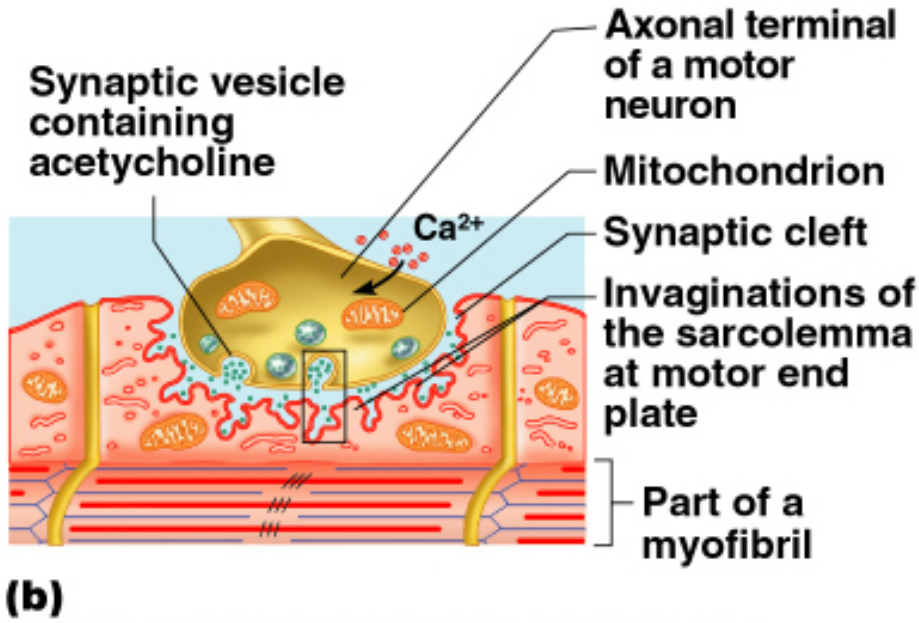


Figure 6.5b

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

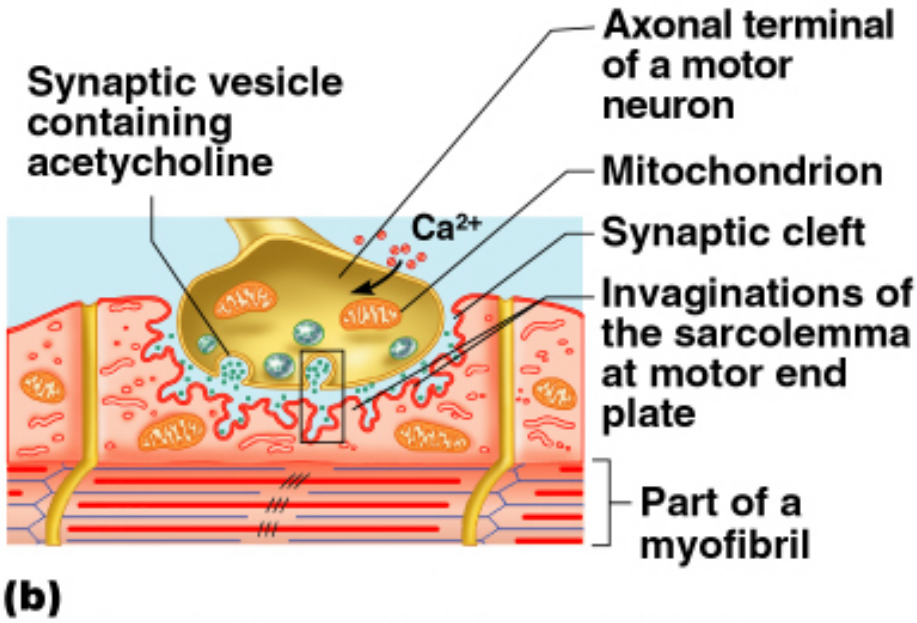


Figure 6.5b

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

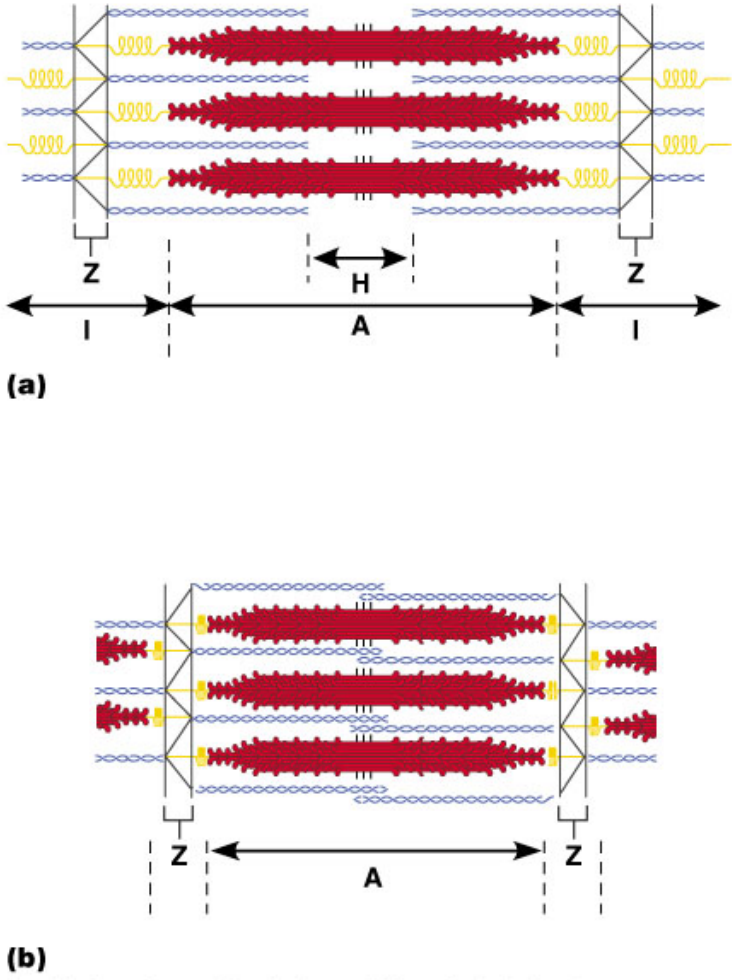


Figure 6.7

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)

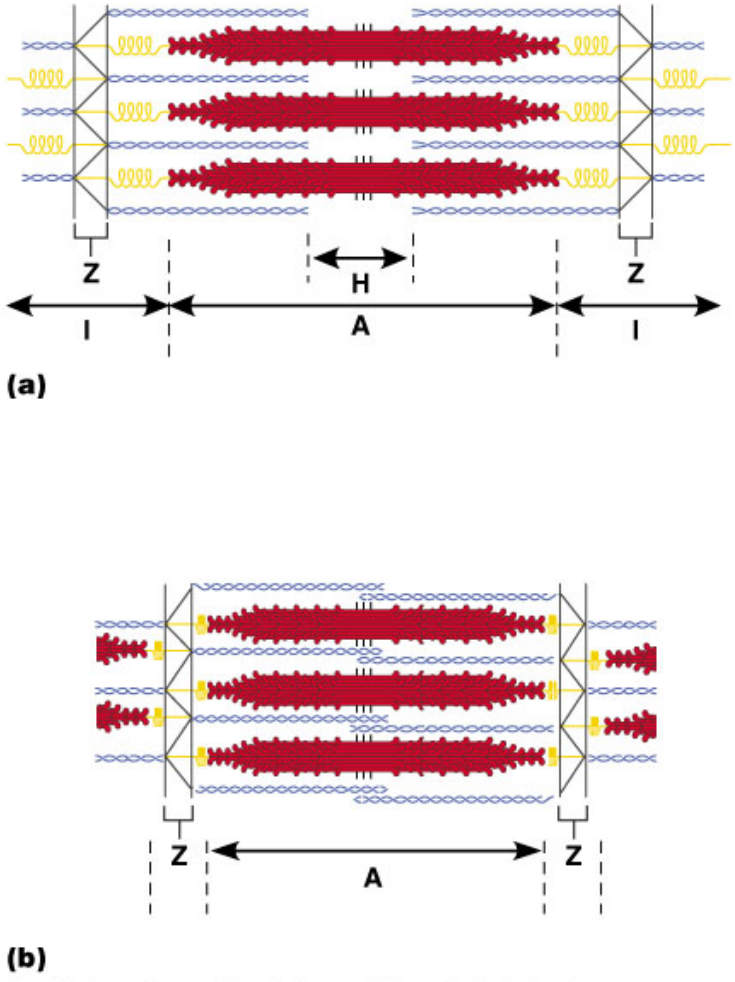


Figure 6.7

The Sliding Filament Theory

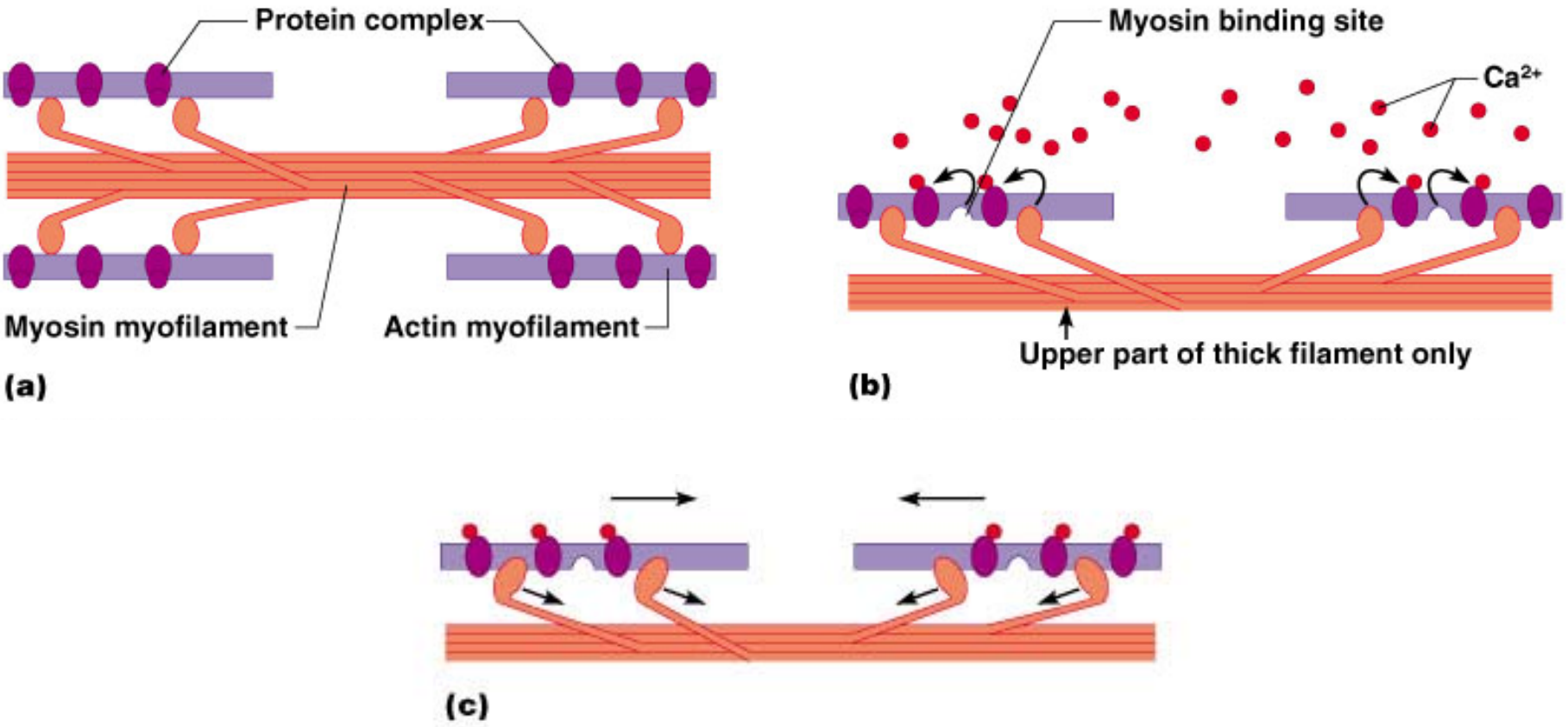


Figure 6.8

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

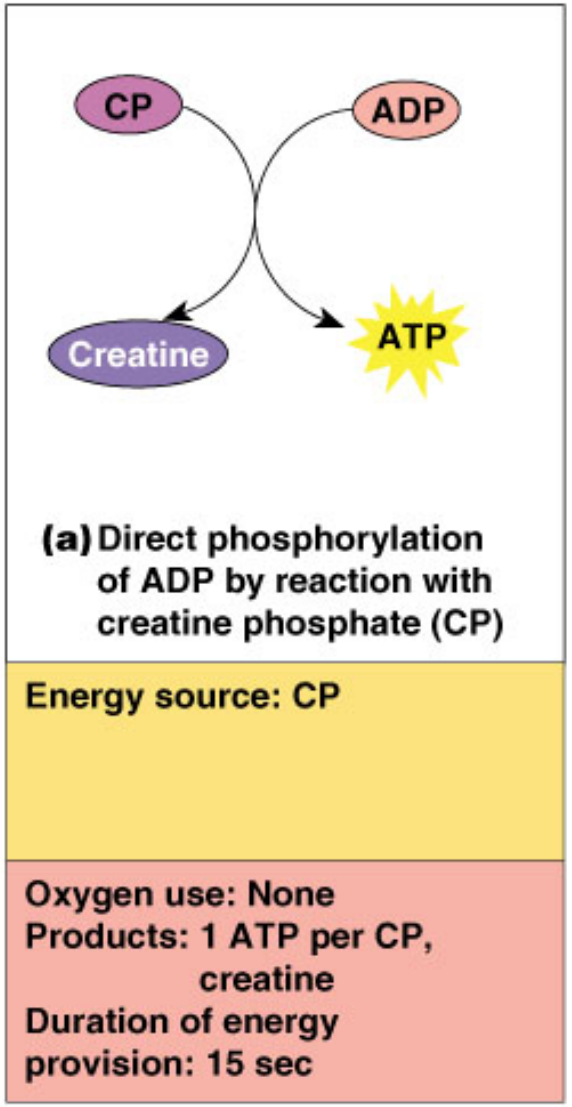


Figure 6.10a

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

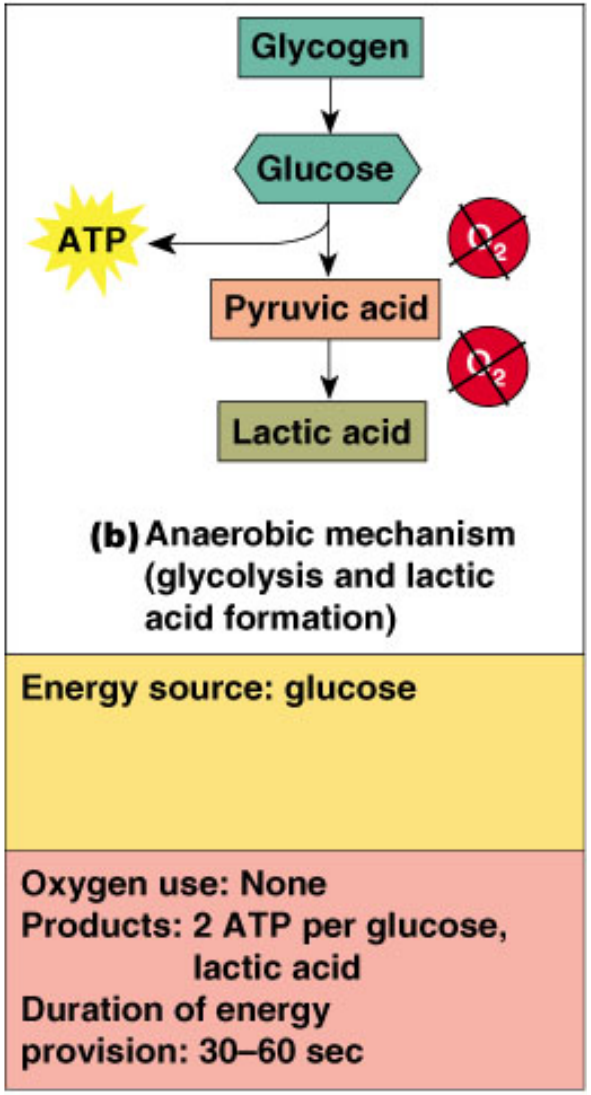


Figure 6.10b

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

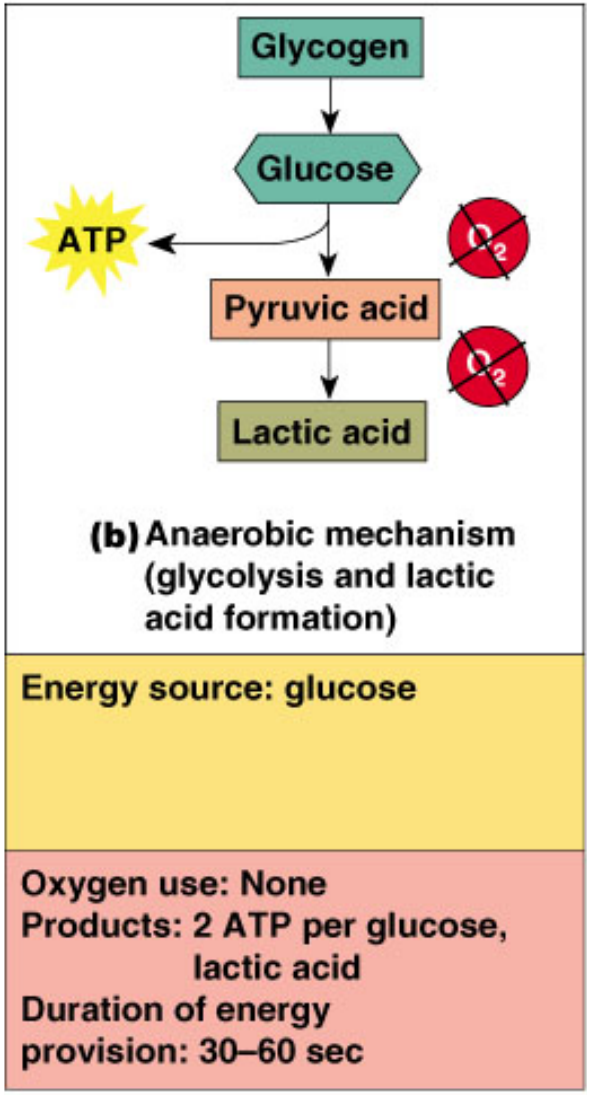


Figure 6.10b

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

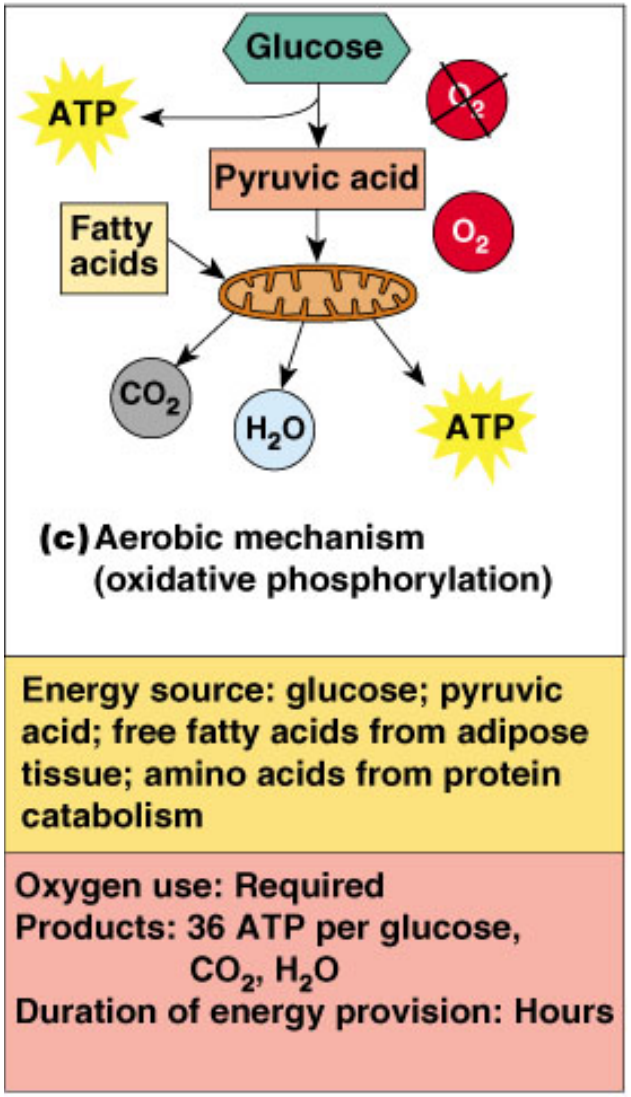


Figure 6.10c

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

Muscles and Body Movements

- Movement is attained due to a muscle moving an attached bone

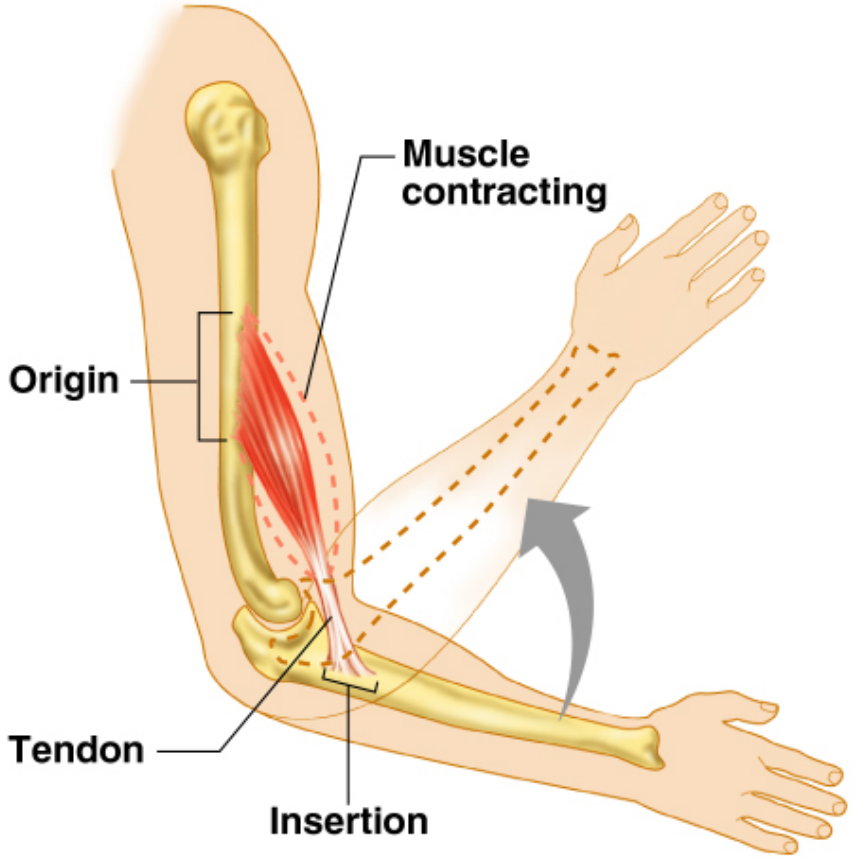


Figure 6.12

Muscles and Body Movements

- Muscles are attached to at least two points
  - Origin – attachment to a moveable bone
  - Insertion – attachment to an immovable bone

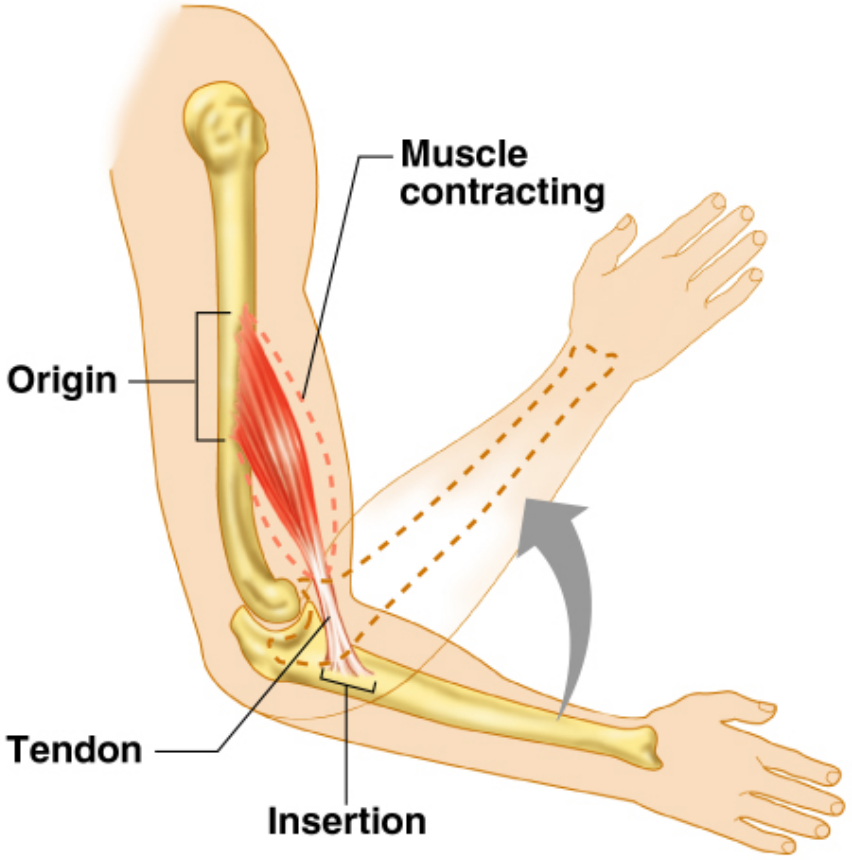


Figure 6.12

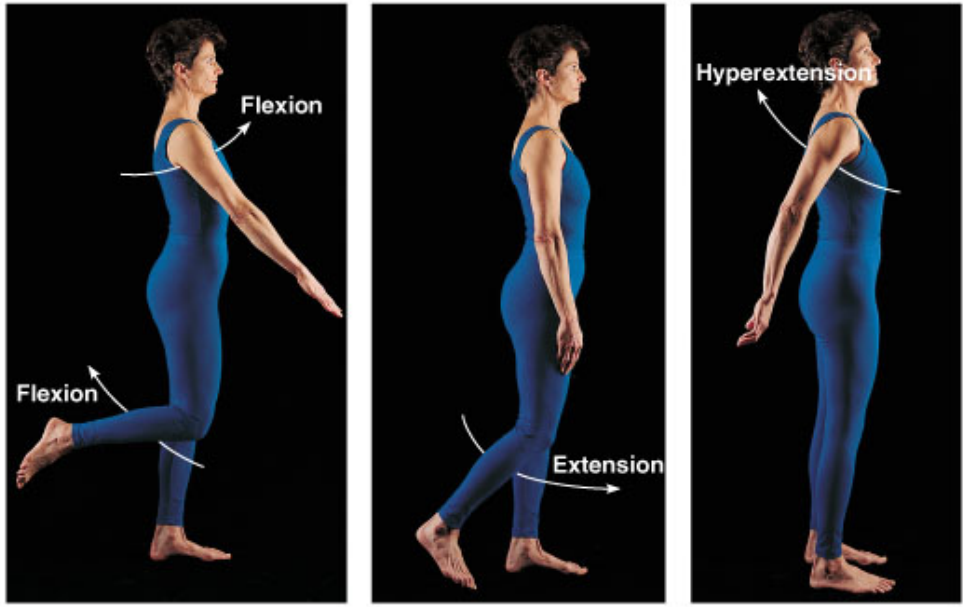
Effects of Exercise on Muscle

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

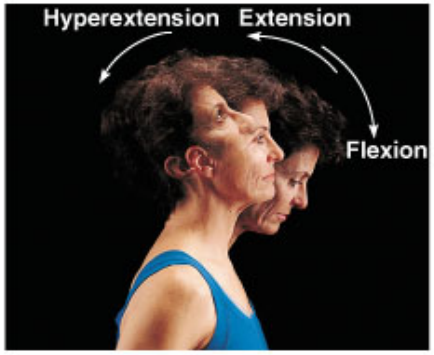
Types of Ordinary Body Movements

- 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)

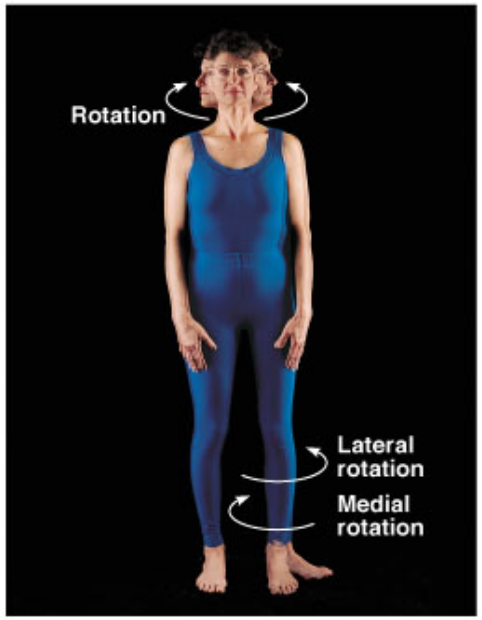
Body Movements



(a) Flexion and extension of the shoulder and knee



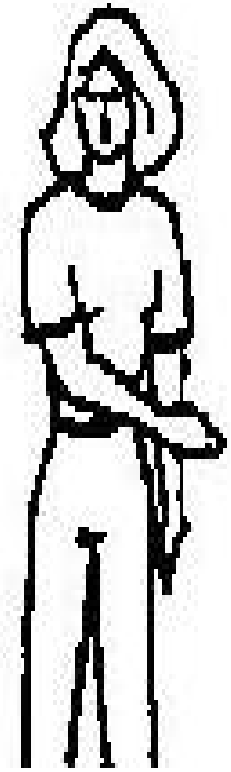
(b) Flexion, extension, and hyperextension

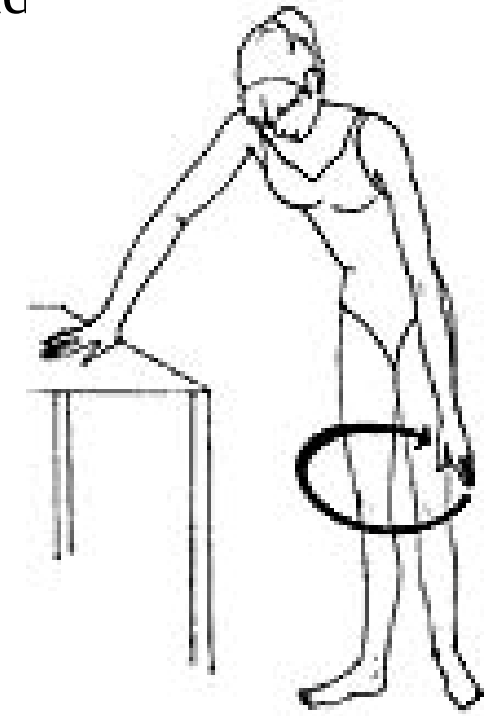


(c) Rotation

Figure 6.13

Left:
Abduction – moving the leg away from the mid





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

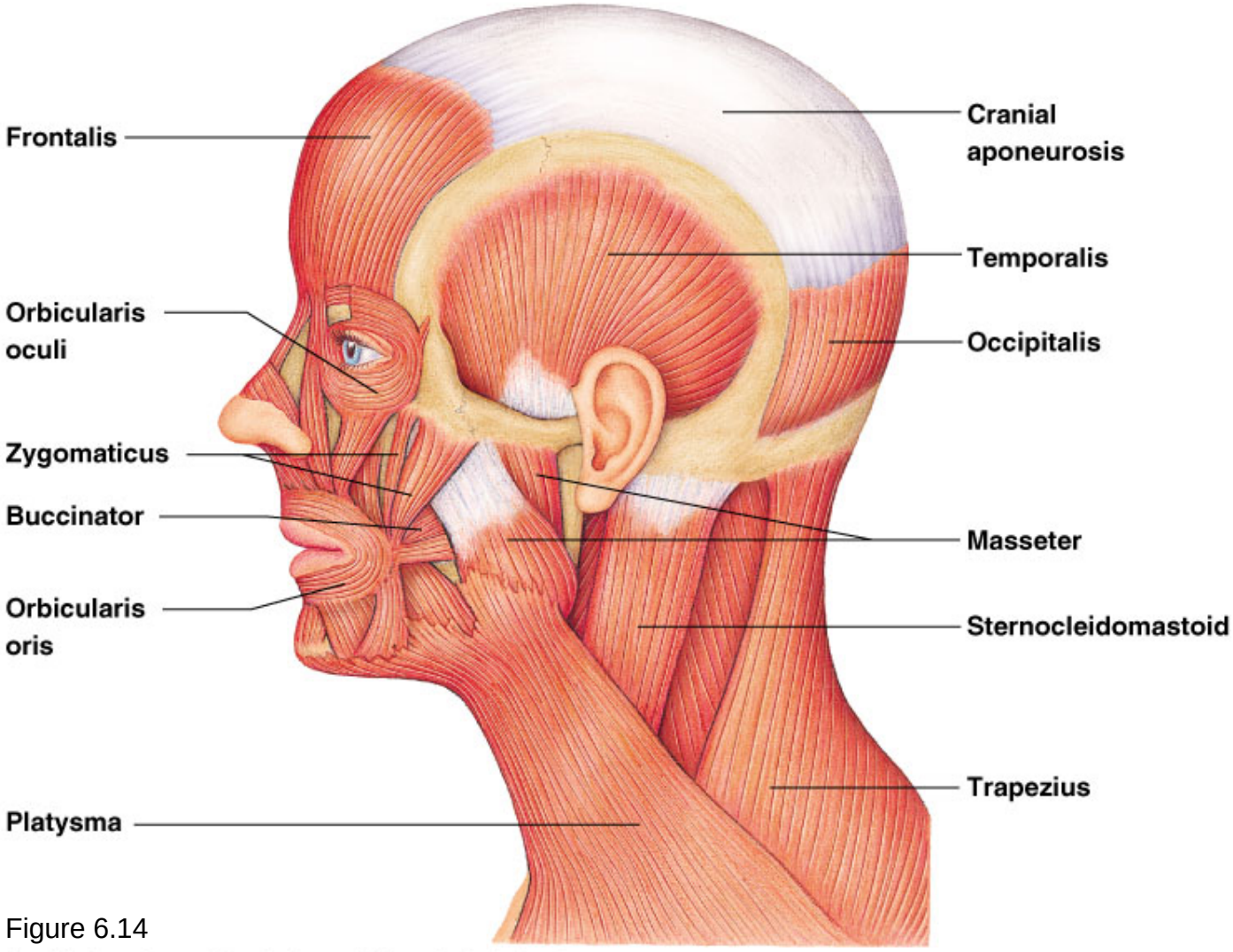


Figure 6.14

Trunk Muscles

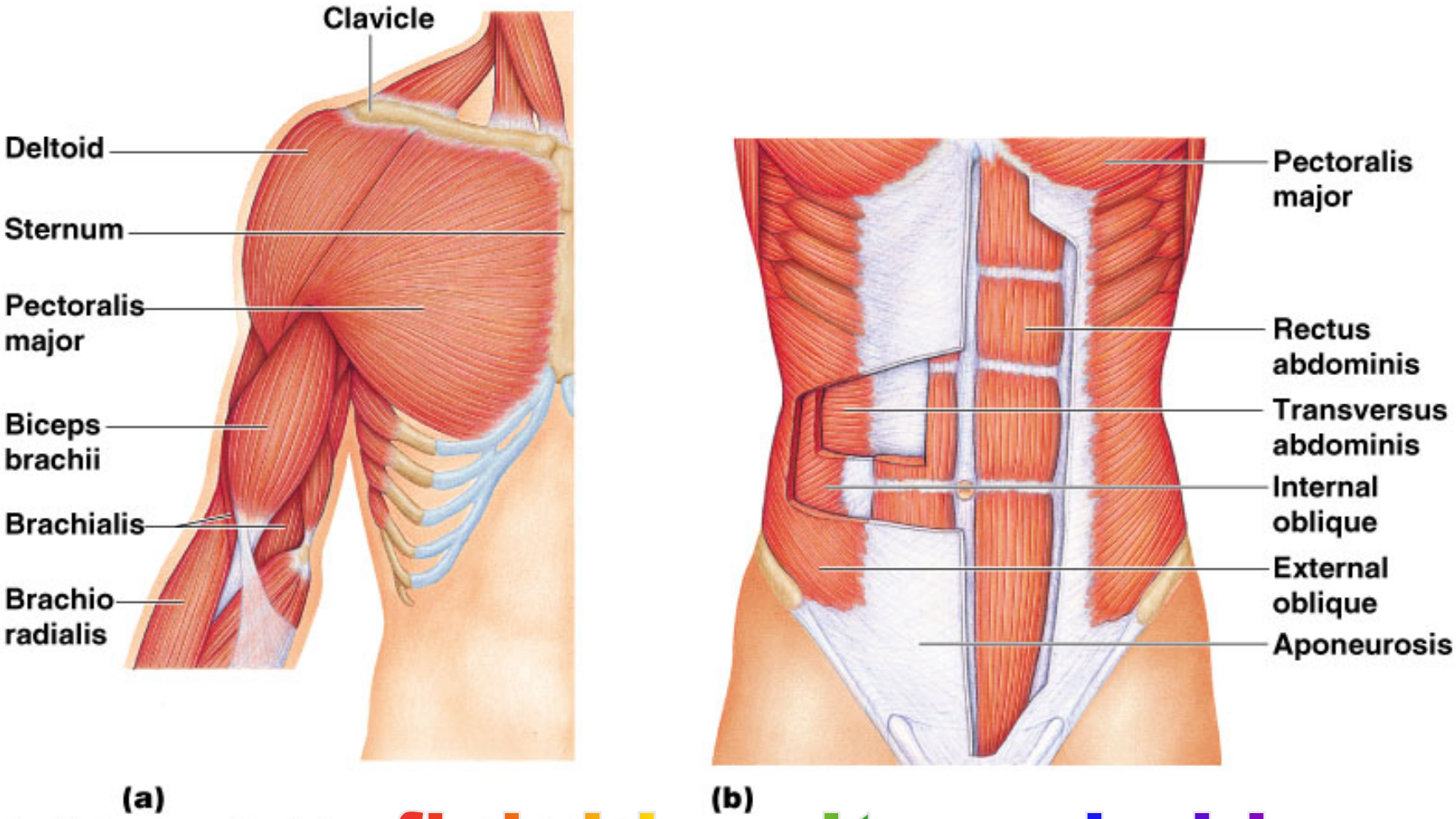


Figure 6.15

Deep Trunk and Arm Muscles

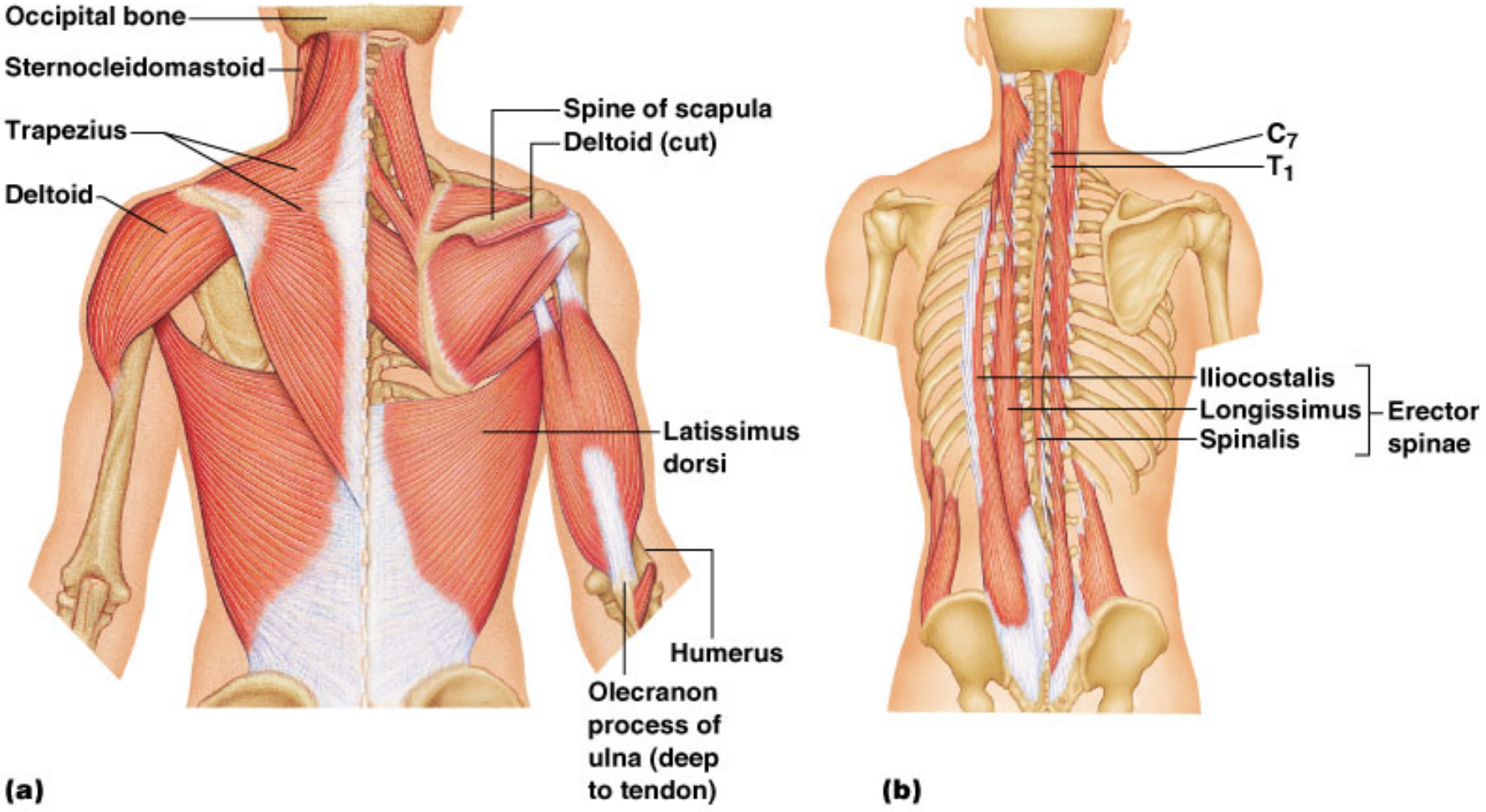


Figure 6.16

Muscles of the Pelvis, Hip, and Thigh

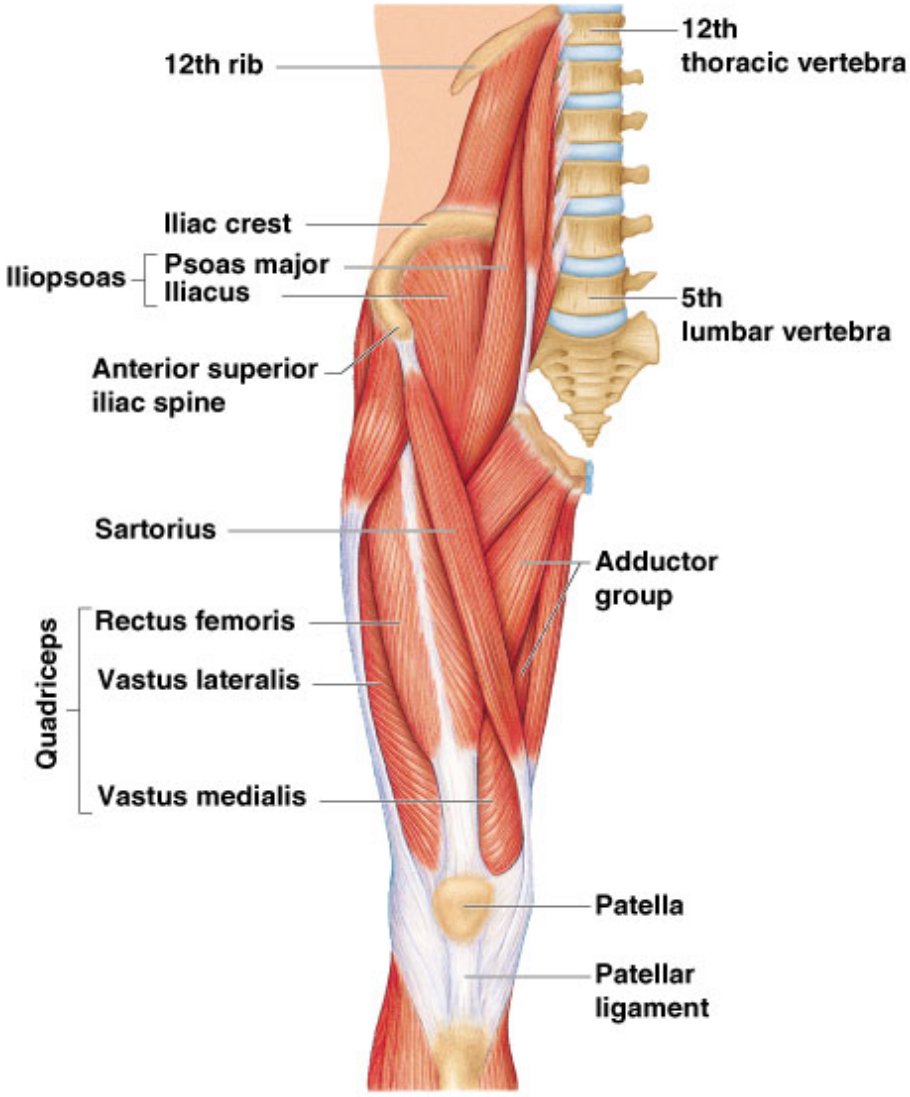


Figure 6.18c

Muscles of the Lower Leg

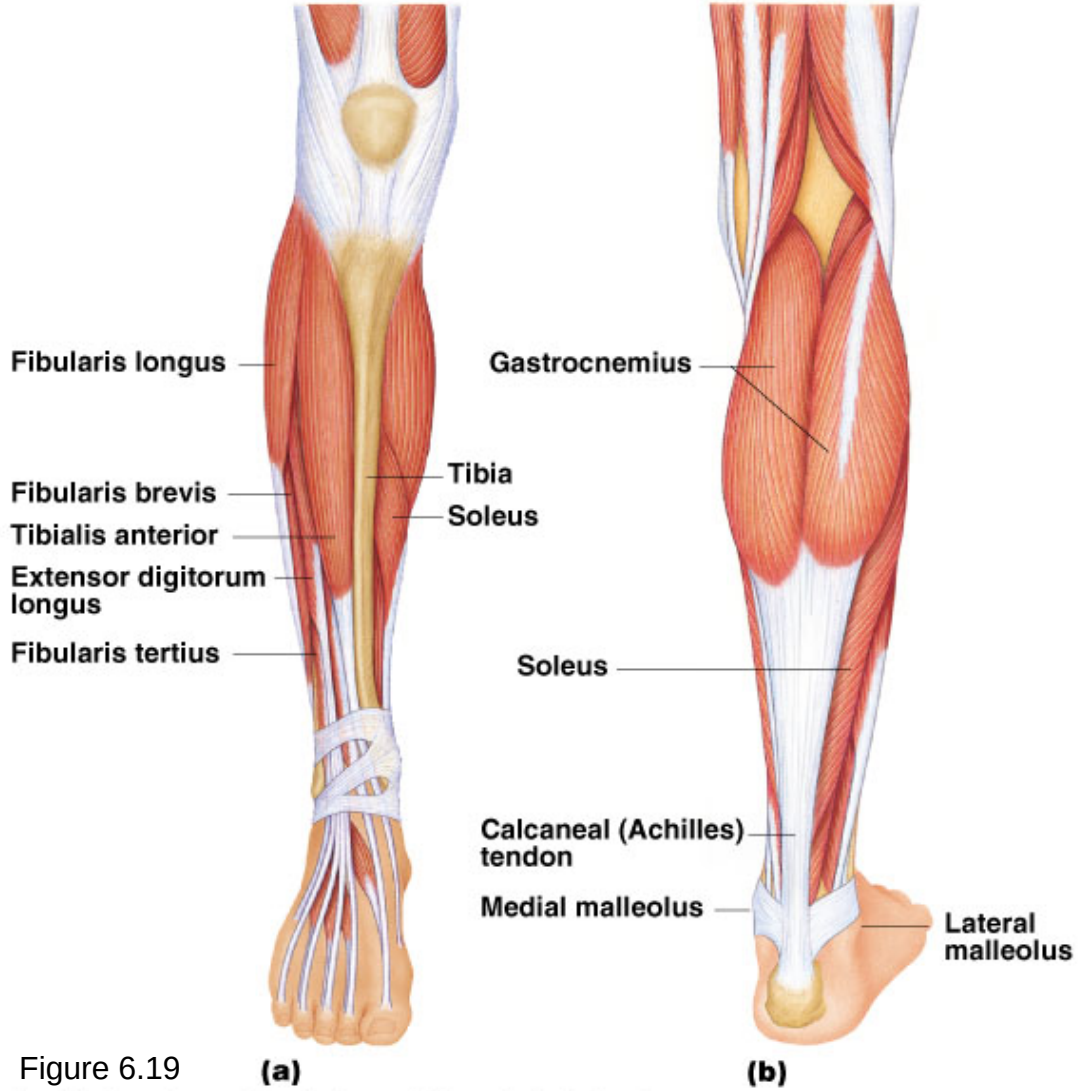


Figure 6.19

Superficial Muscles: Anterior

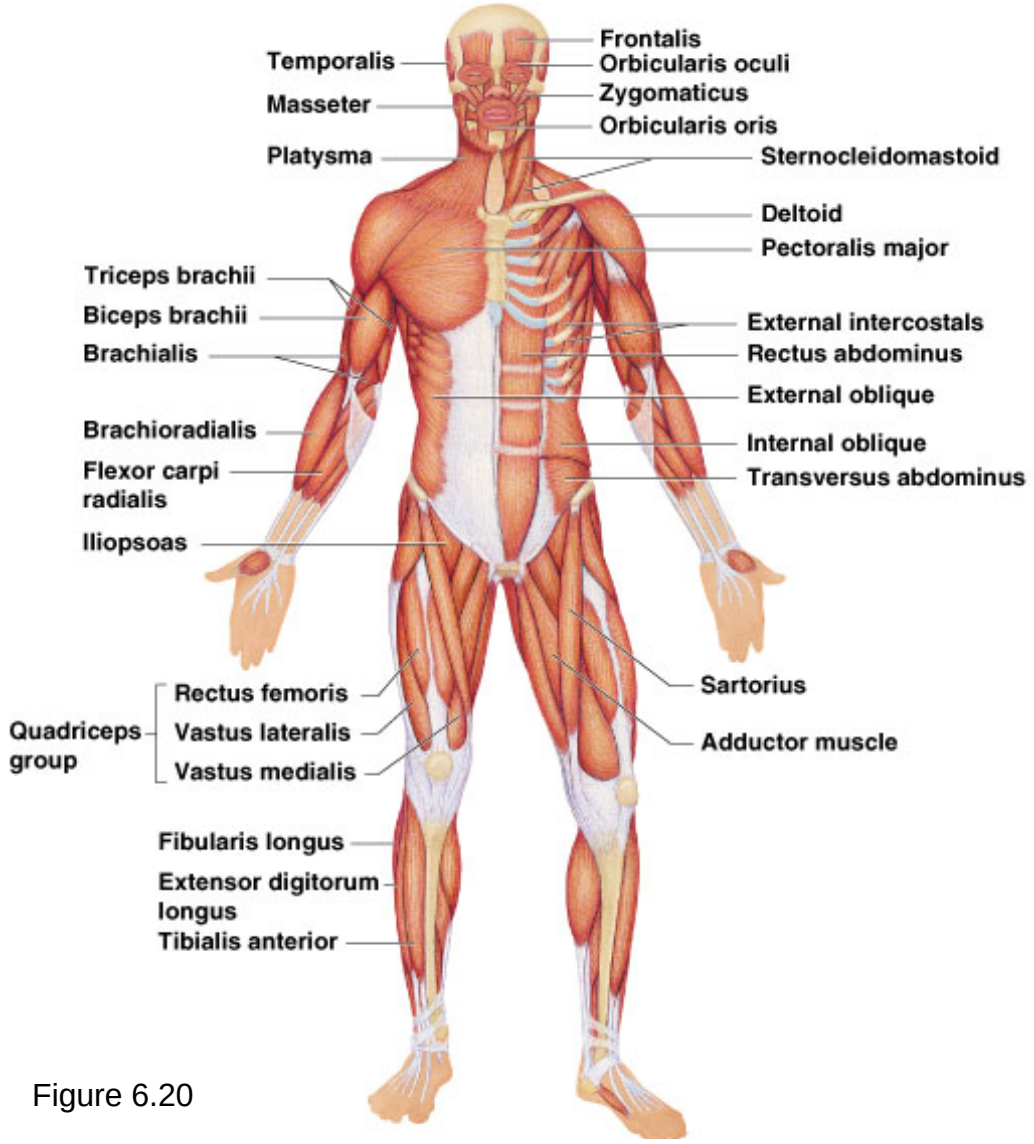


Figure 6.20

Superficial Muscles: Posterior

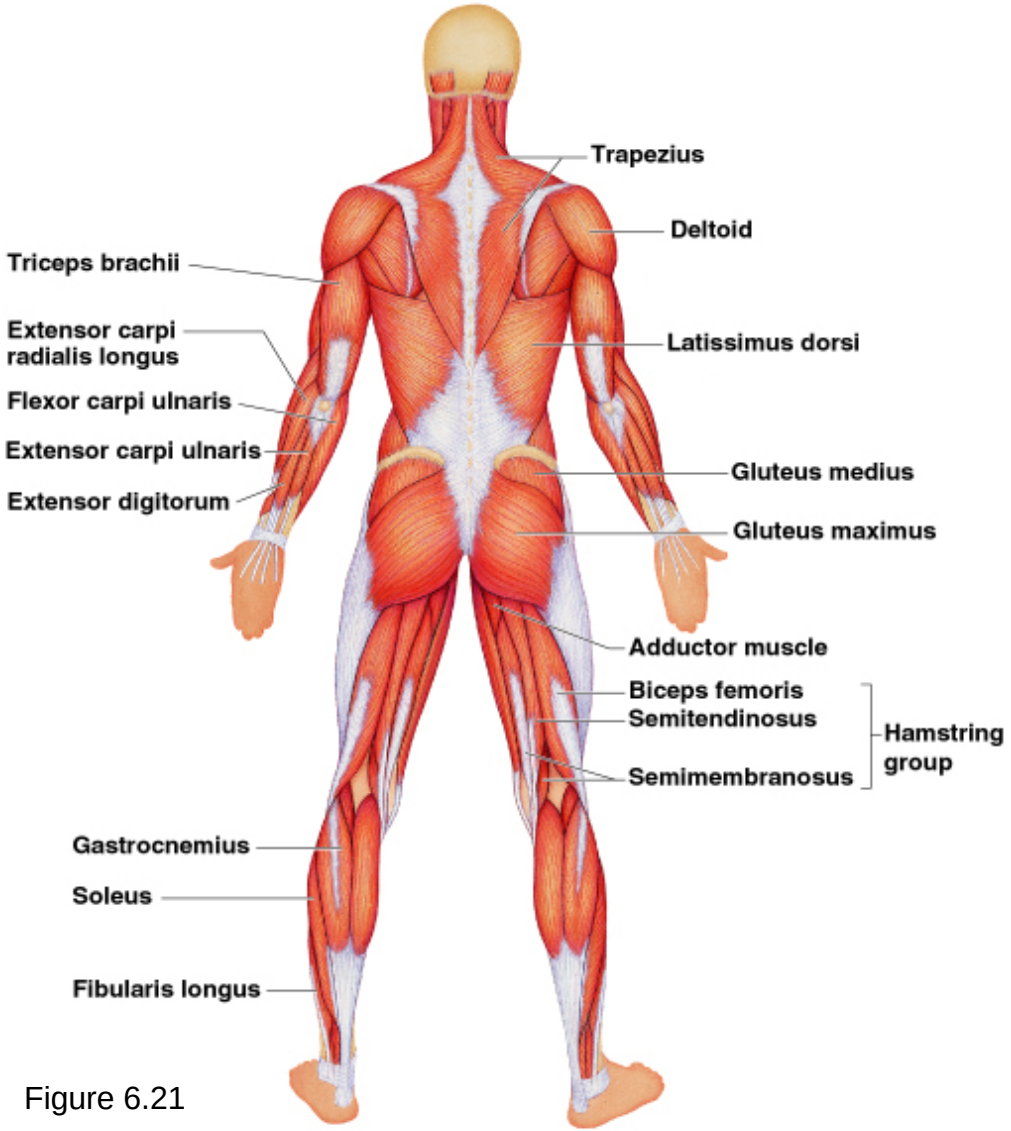


Figure 6.21

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
- Myasthemia Gravis: progressive weakness due to a shortage of acetylcholine receptors