Chapter 9 - Muscular System

Three Types of Muscle Tissues

Skeletal Muscle

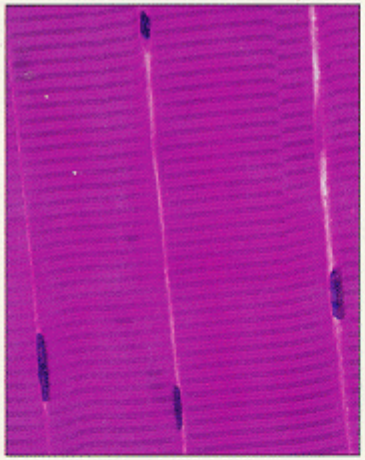
- usually attached to bones
- under conscious control
- striated

Smooth Muscle

- walls of most viscera, blood vessels, skin
- not under conscious control
- not striated

Cardiac Muscle

- wall of heart
- not under conscious control
- striated



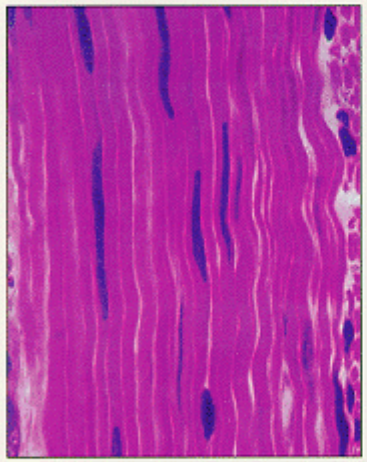
a

TYPE: Skeletal muscle

DESCRIPTION: Long, striated cells with multiple nuclei

COMMON LOCATIONS: In skeletal muscles

FUNCTION: Contraction for voluntary movements



b

TYPE: Smooth muscle

DESCRIPTION: Long, spindle-shaped cells, each with a single nucleus

COMMON LOCATIONS: In hollow organs (e.g., stomach)

FUNCTION: Propulsion of substances along internal passageways

c

TYPE: Cardiac muscle

DESCRIPTION: Branching, striated cells fused at plasma membranes

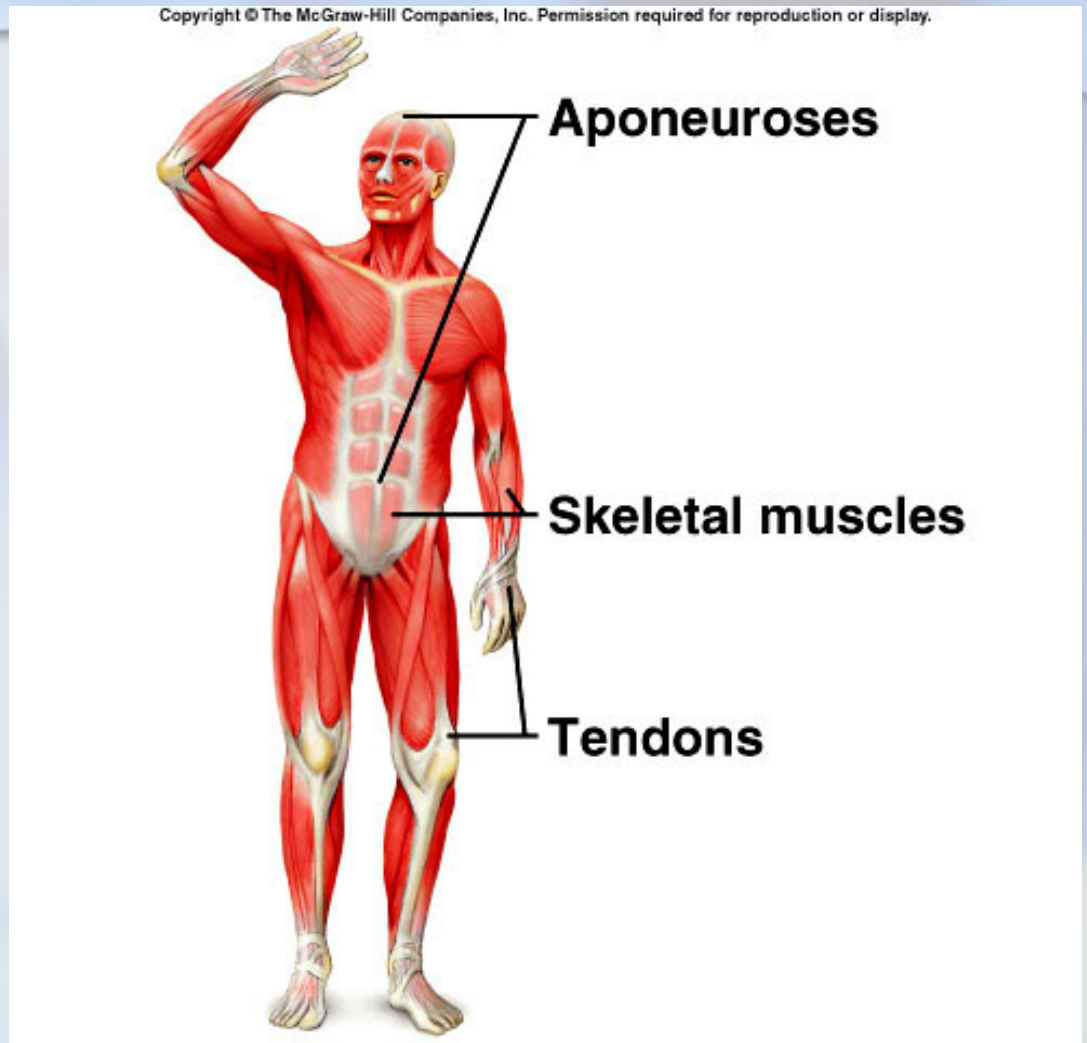
COMMON LOCATIONS: Wall of heart

FUNCTION: Pumping of blood in the circulatory system

Structure of a Skeletal Muscle

Skeletal Muscle

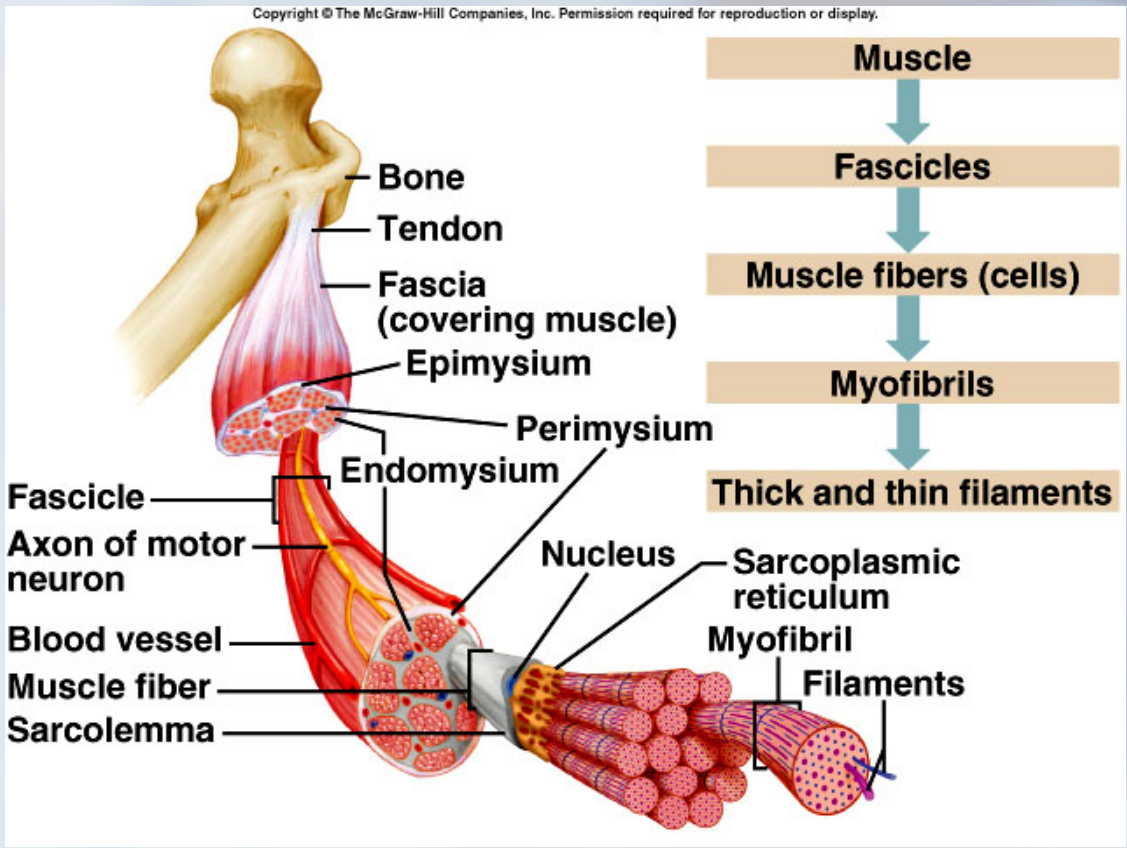
- organ of the muscular system
- skeletal muscle tissue
- nervous tissue
- blood
- connective tissues
- fascia
- tendon
- aponeuroses

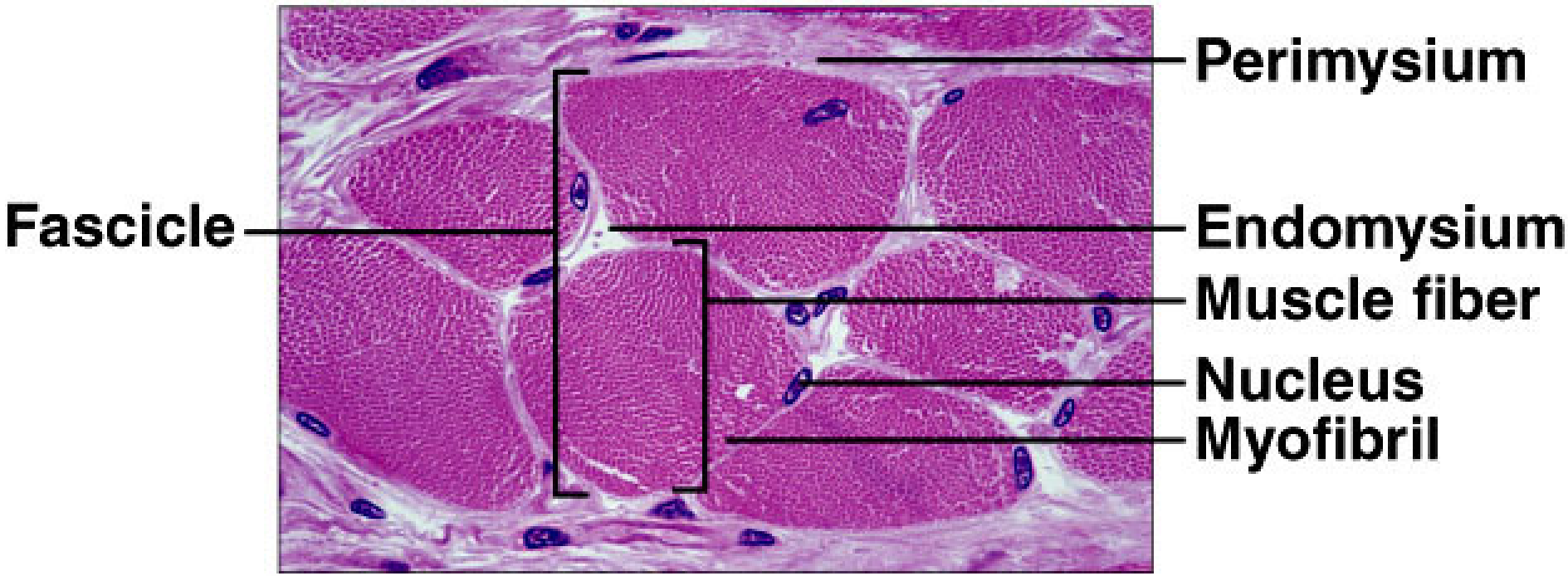


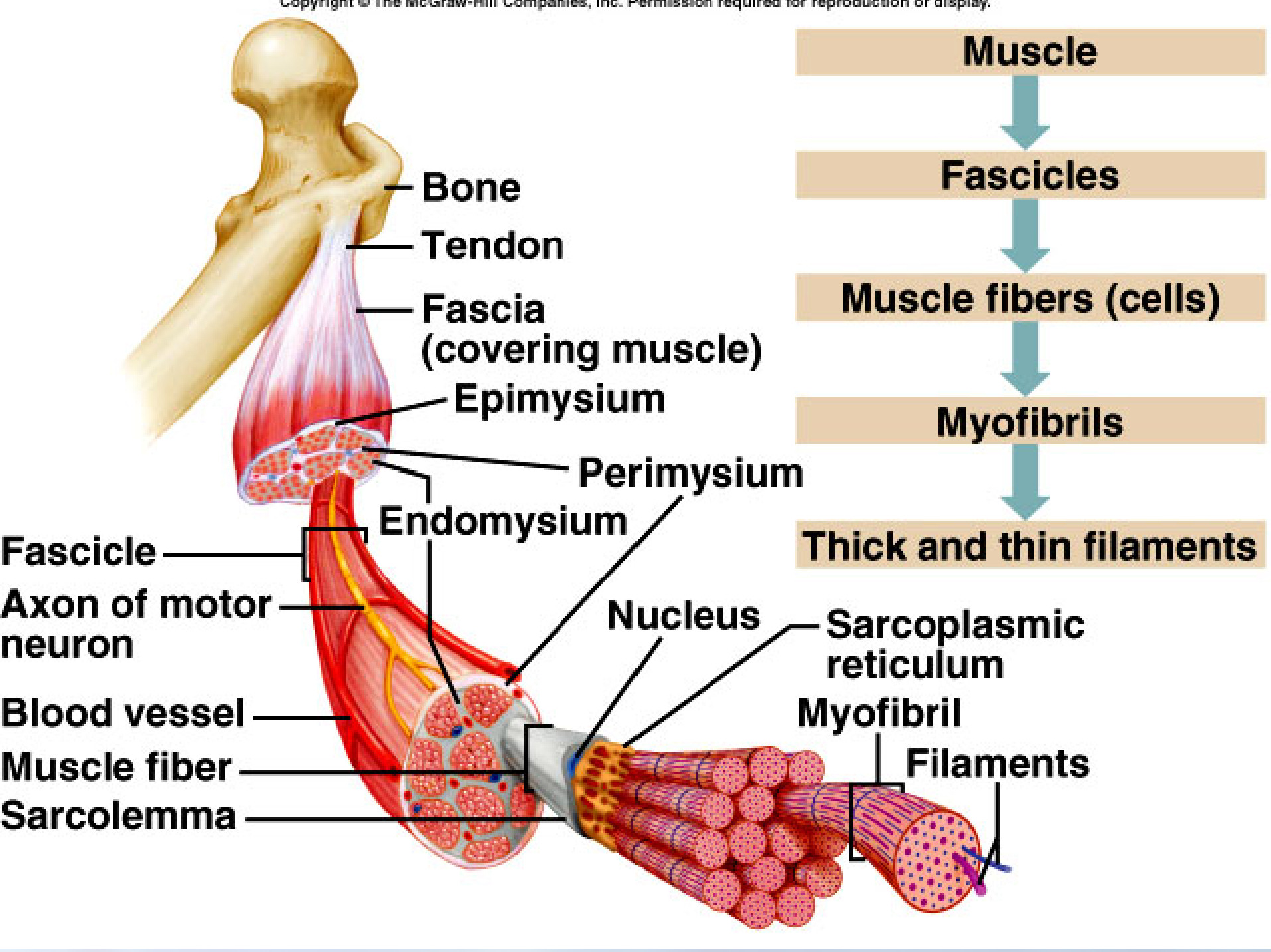
Structure of a Skeletal Muscle

- epimysium
- perimysium
- fascicle
- endomysium

- muscle
- fascicles
- muscle fibers
- myofibrils
- thick and thin filaments

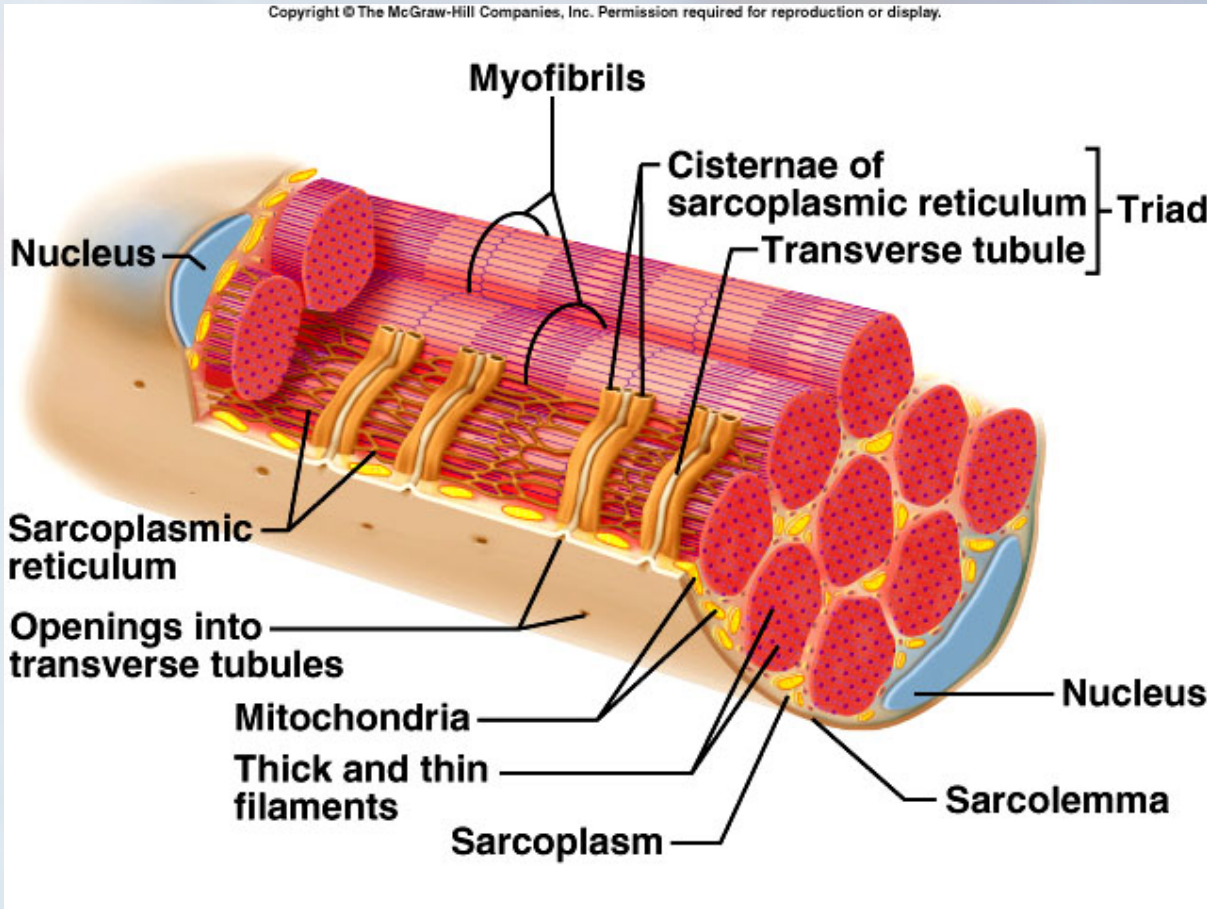




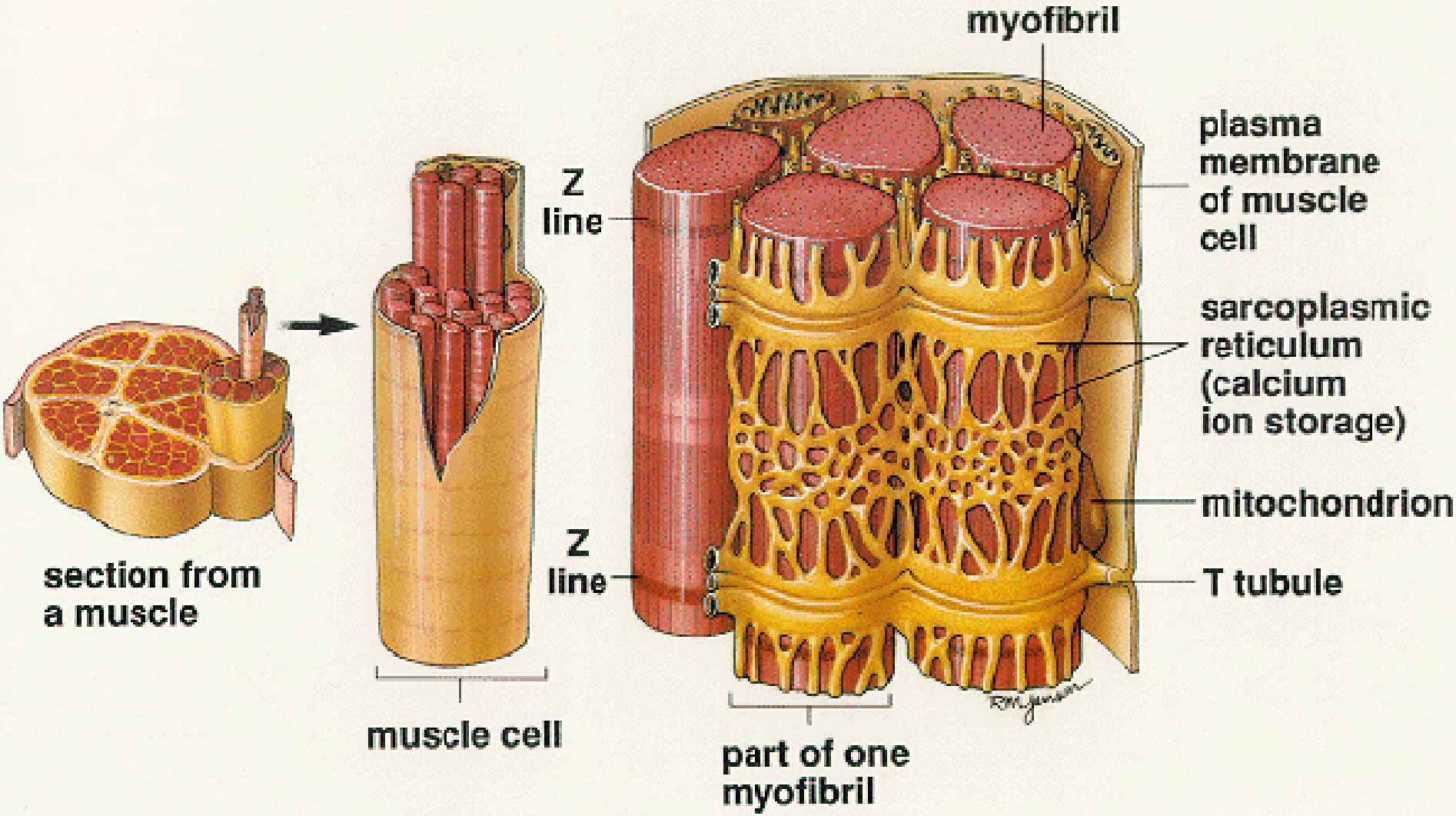


Skeletal Muscle Fiber

- sarcolemma
- sacroplasm
- sarcoplasmic reticulum
- transverse tubule
- triad
  - cisterna of sarcoplasmic reticulum
  - transverse tubule
- myofibril
- actin filaments
- myosin filaments
- sarcomere

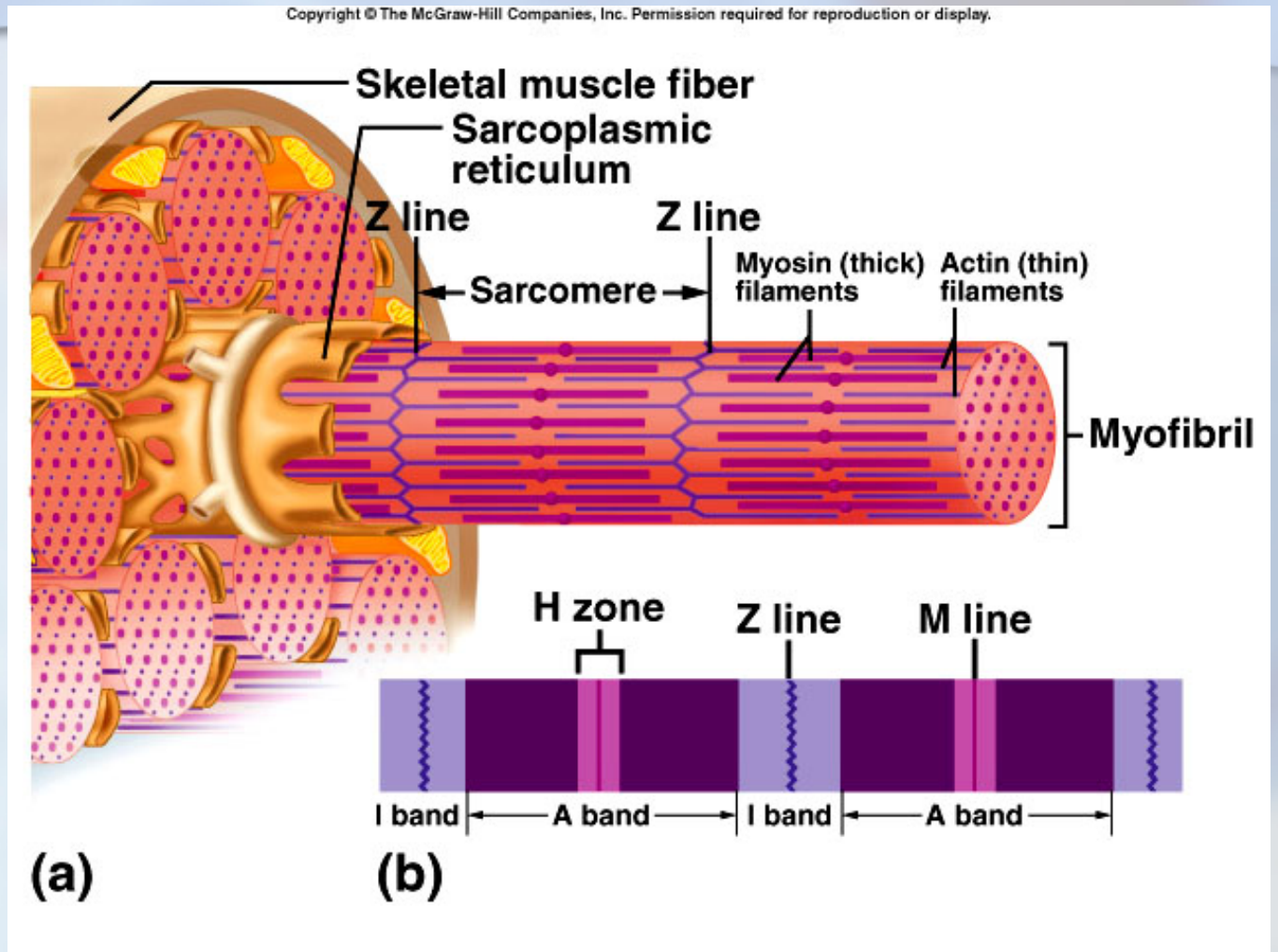


Structure of a Skeletal Muscle



Sarcomere

- I band
- A band
- H zone
- Z line
- M line



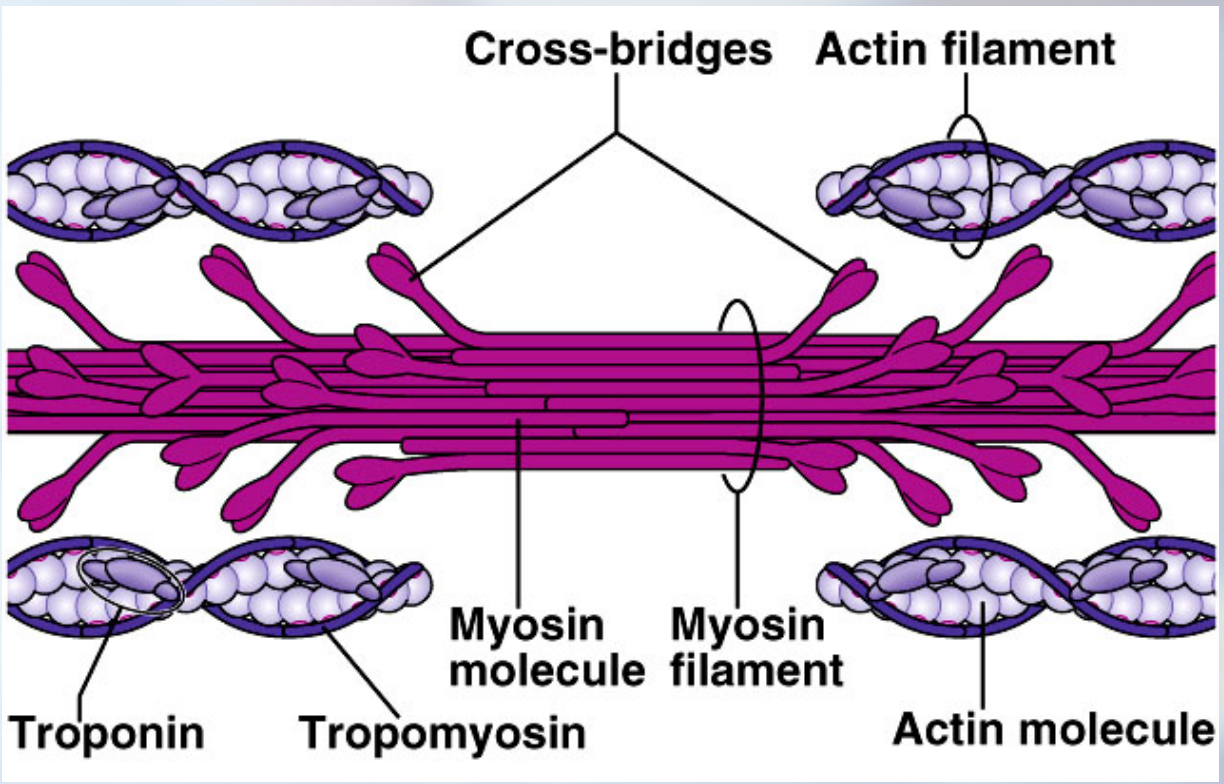
Myofilaments

Thick Filaments

- composed of myosin
- cross-bridges

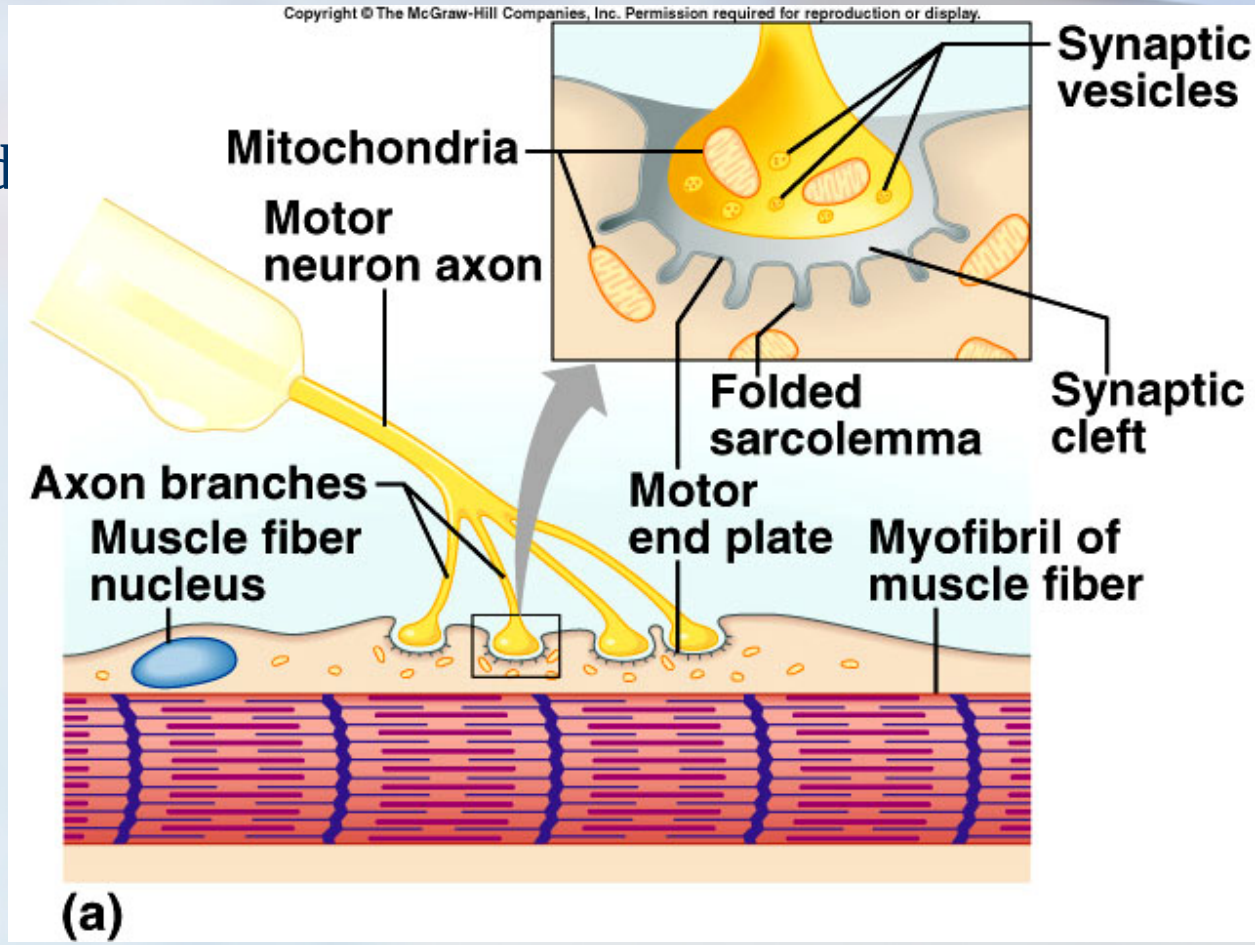
Thin Filaments

- composed of actin
- associated with troponin and tropomyosin



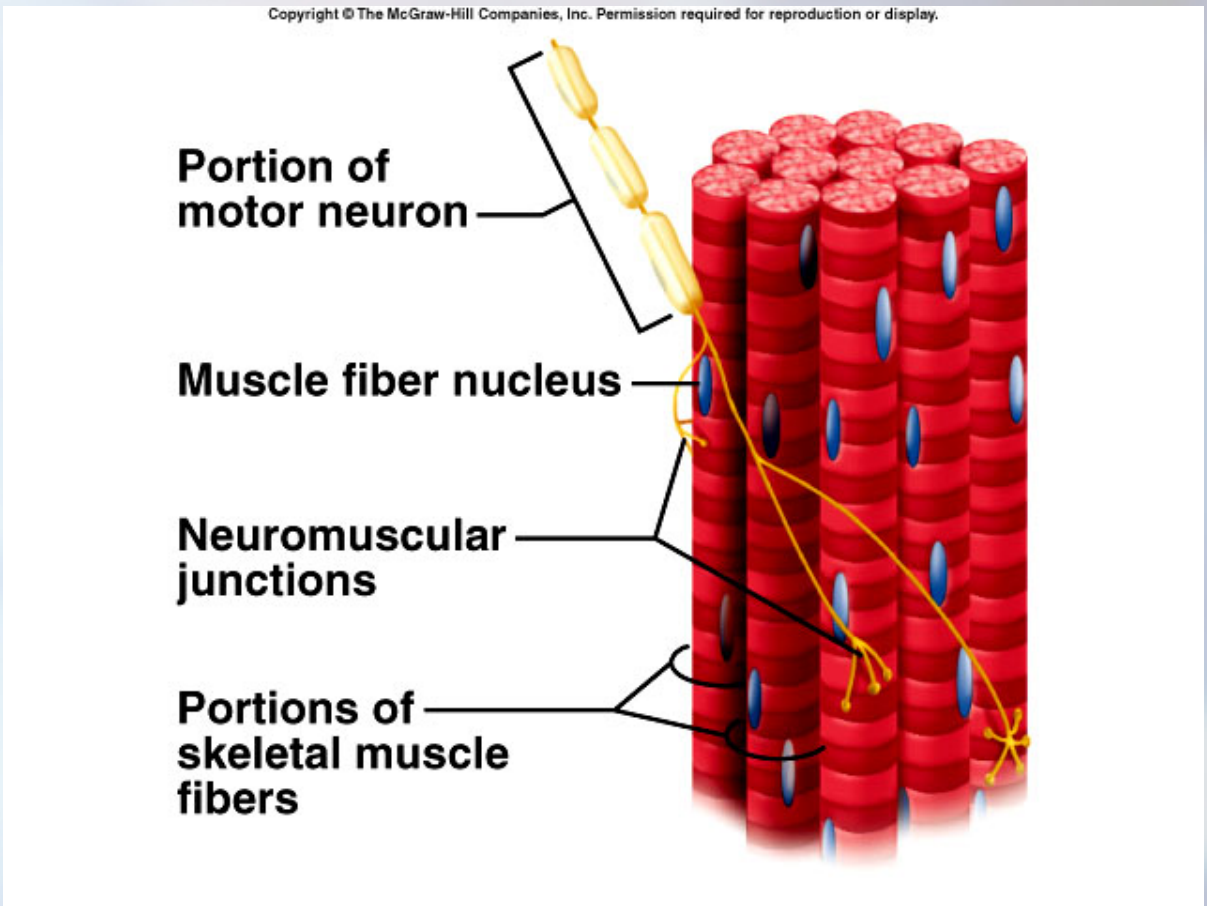
Neuromuscular Junction

- site where axon and muscle fiber communicate
- motor neuron
- motor end plate
- synaptic cleft
- synaptic vesicles
- neurotransmitters



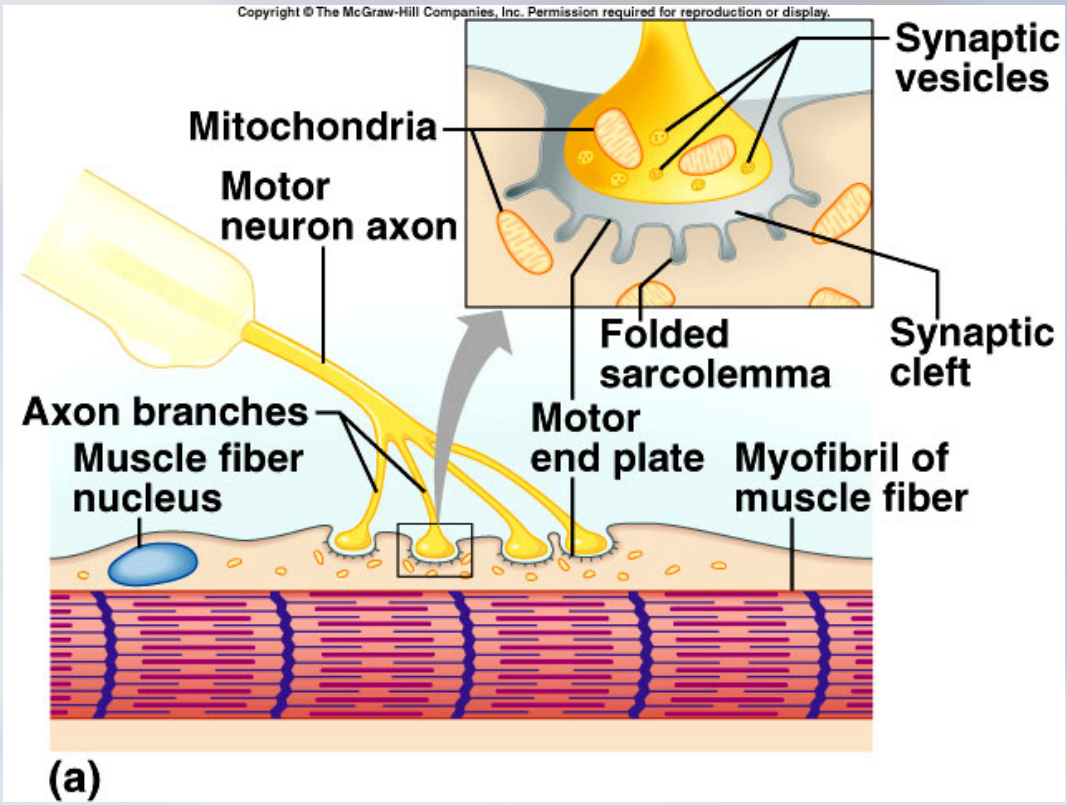
Motor Unit

- single motor neuron
- all muscle fibers controlled by motor neuron



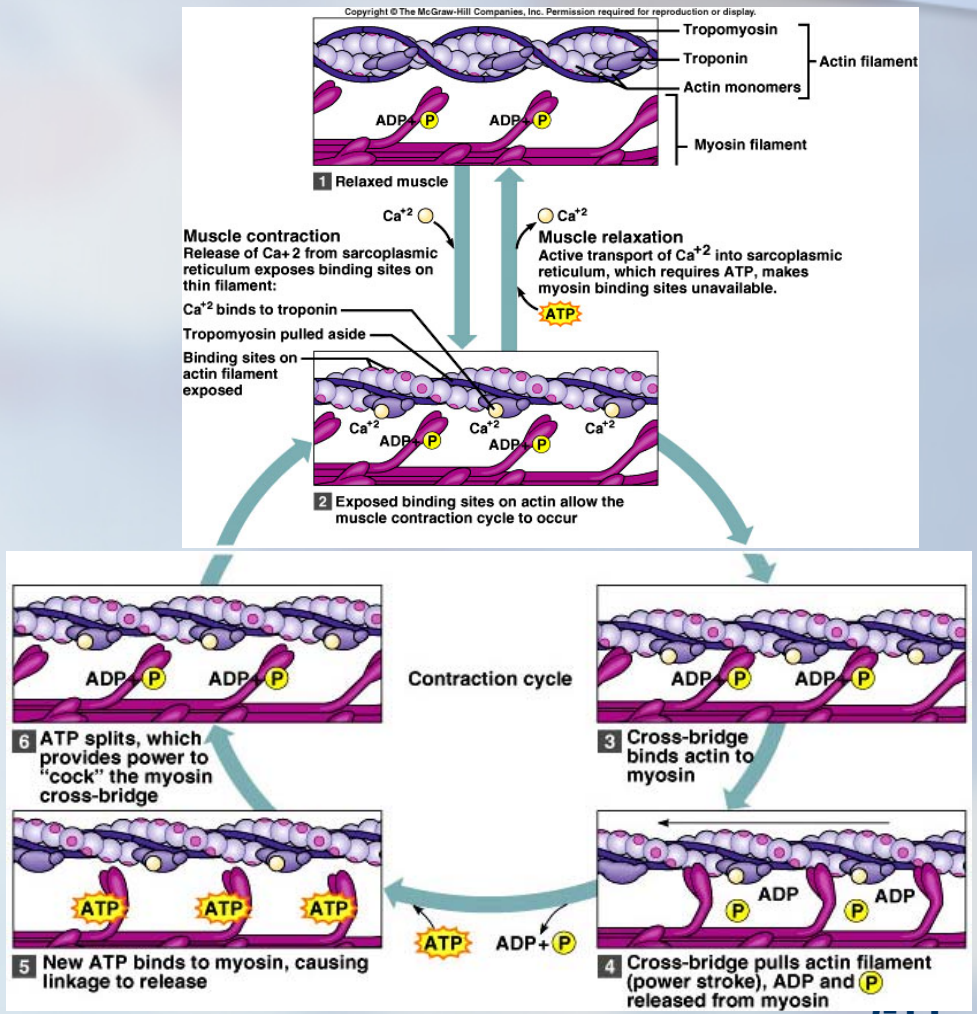
Stimulus for Contraction

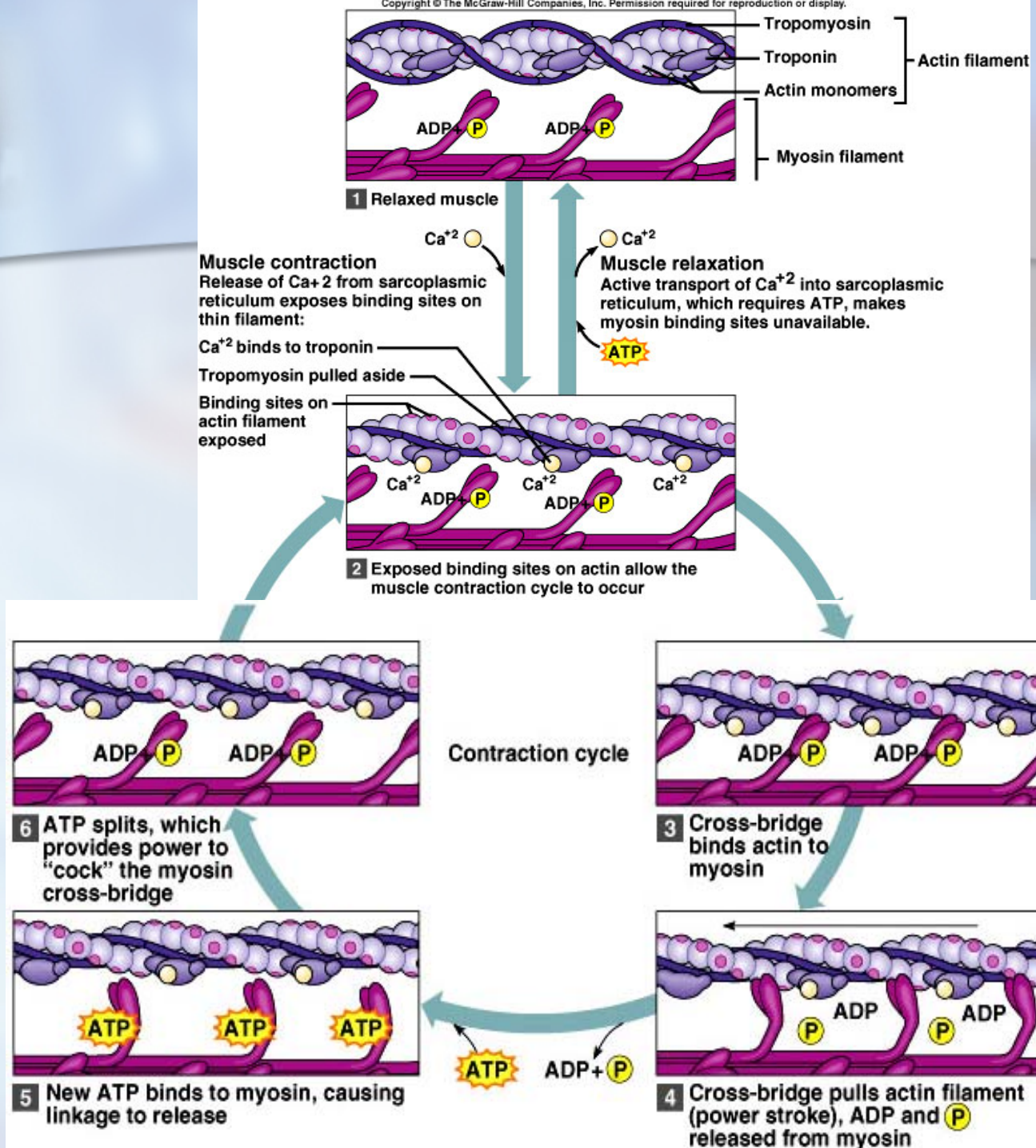
- acetylcholine (ACh)
- nerve impulse causes release of acetylcholine from synaptic vesicles
- binds to acetylcholine receptors on motor end plate
- generates a muscle impulse
- muscle impulse eventually reaches sarcoplasmic reticulum



Excitation Contraction Coupling

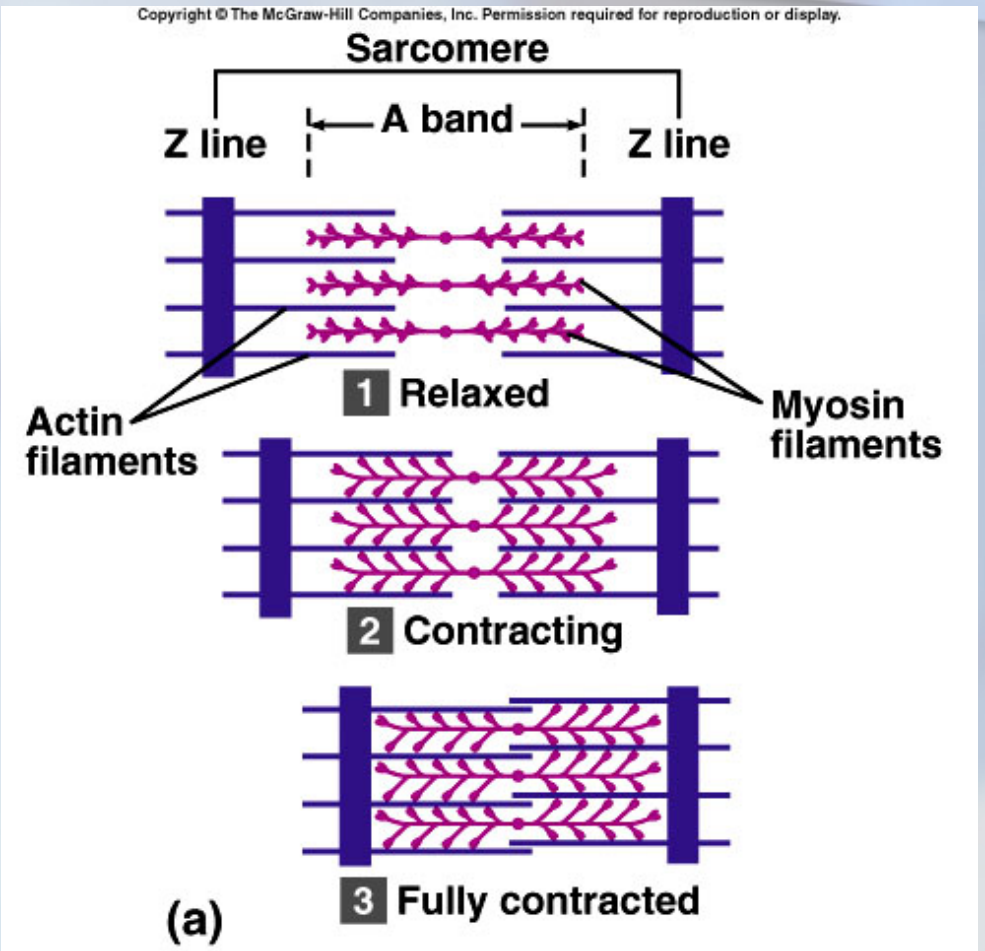
- muscle impulses cause sarcoplasmic reticulum to release calcium ions into cytosol
- calcium binds to troponin to change its shape
- position of tropomyosin is altered
- binding sites on actin exposed
- actin and myosin bind





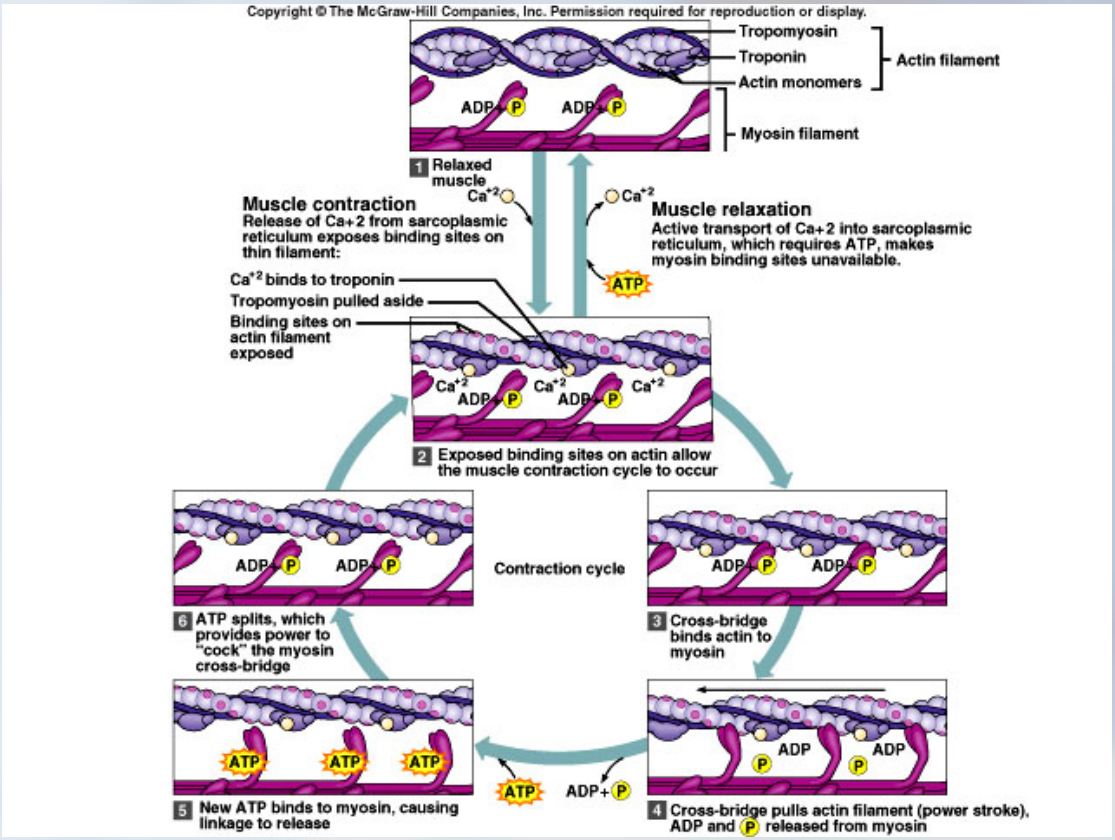
Sliding Filament Theory

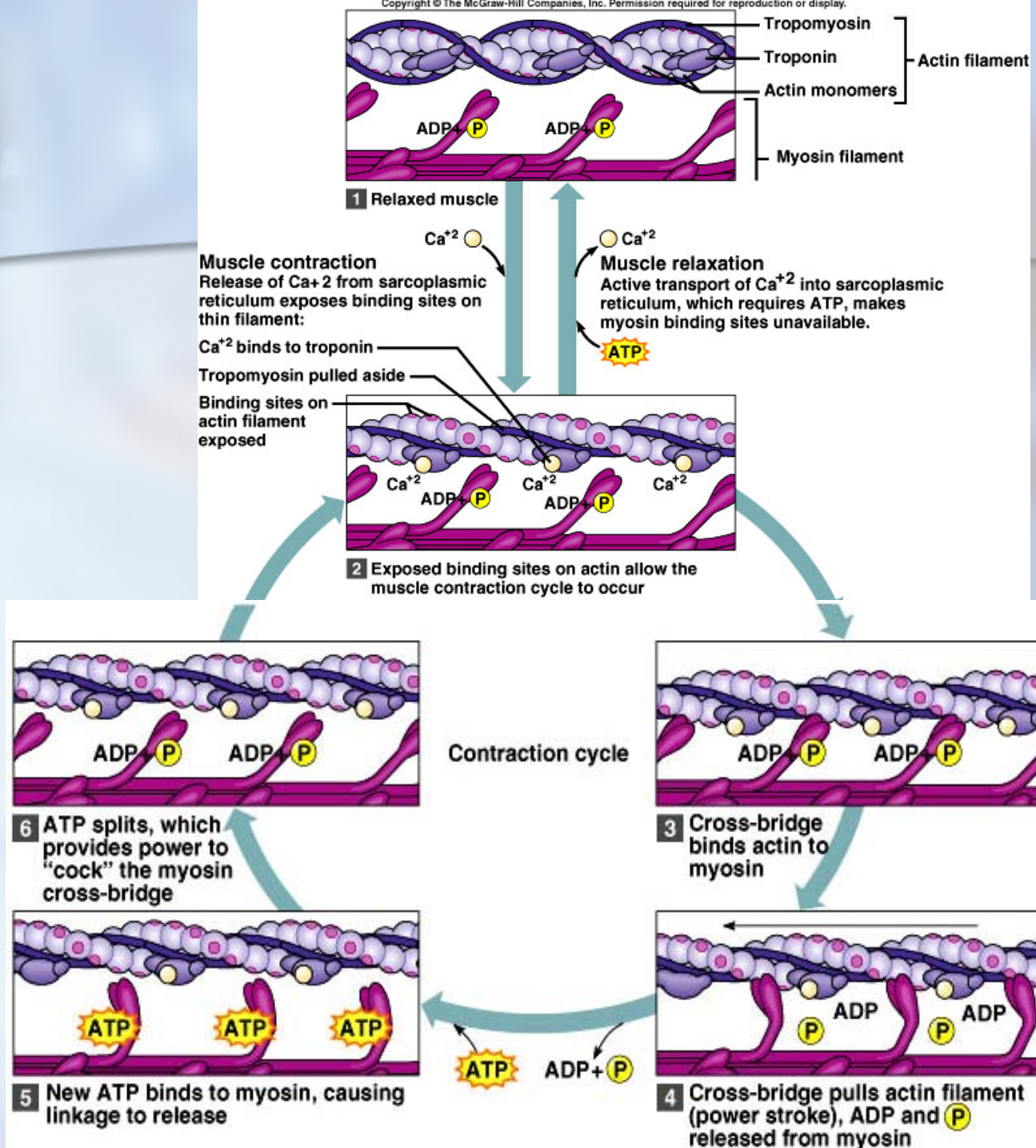
- When sarcromeres shorten, thick and thin filaments slide past one another
- H zones and I bands get narrower
- Z lines move closer together



Cross-bridge Cycling

- actin and myosin cross-bridge bind
- myosin cross-bridge pulls actin
- ADP and phosphate released from myosin
- new ATP binds to myosin
- linkage between actin and myosin cross-bridge break
- ATP splits
- myosin cross-bridge goes back to original position





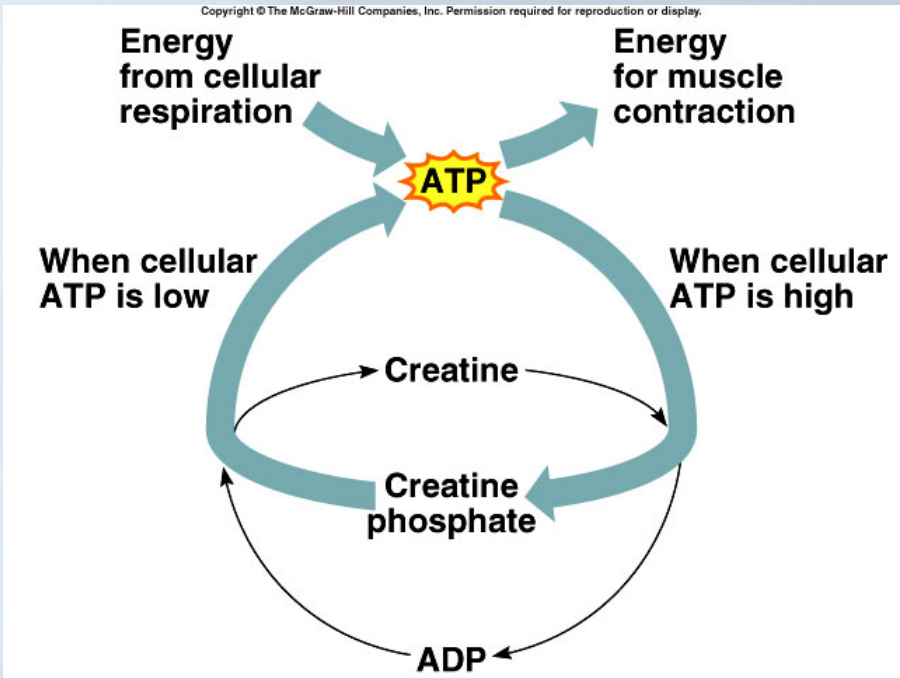
Relaxation

- acetylcholinesterase – breaks down acetylcholine
- muscle impulse stops
- calcium moves back into sarcoplasmic reticulum
- myosin and actin binding prevented

Energy Sources for Contraction

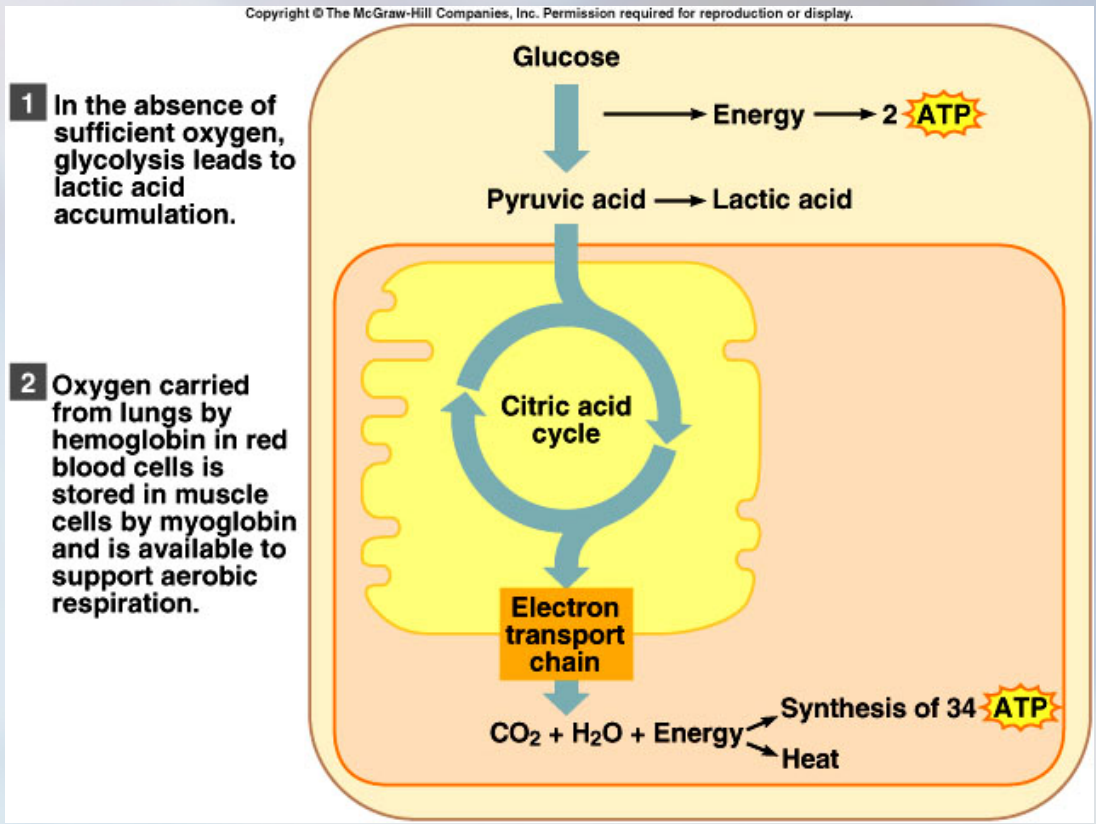
1) Creatine phosphate **2) Cellular respiration**

- **creatine phosphate – stores energy that quickly converts ADP to ATP**



Oxygen Supply and Cellular Respiration

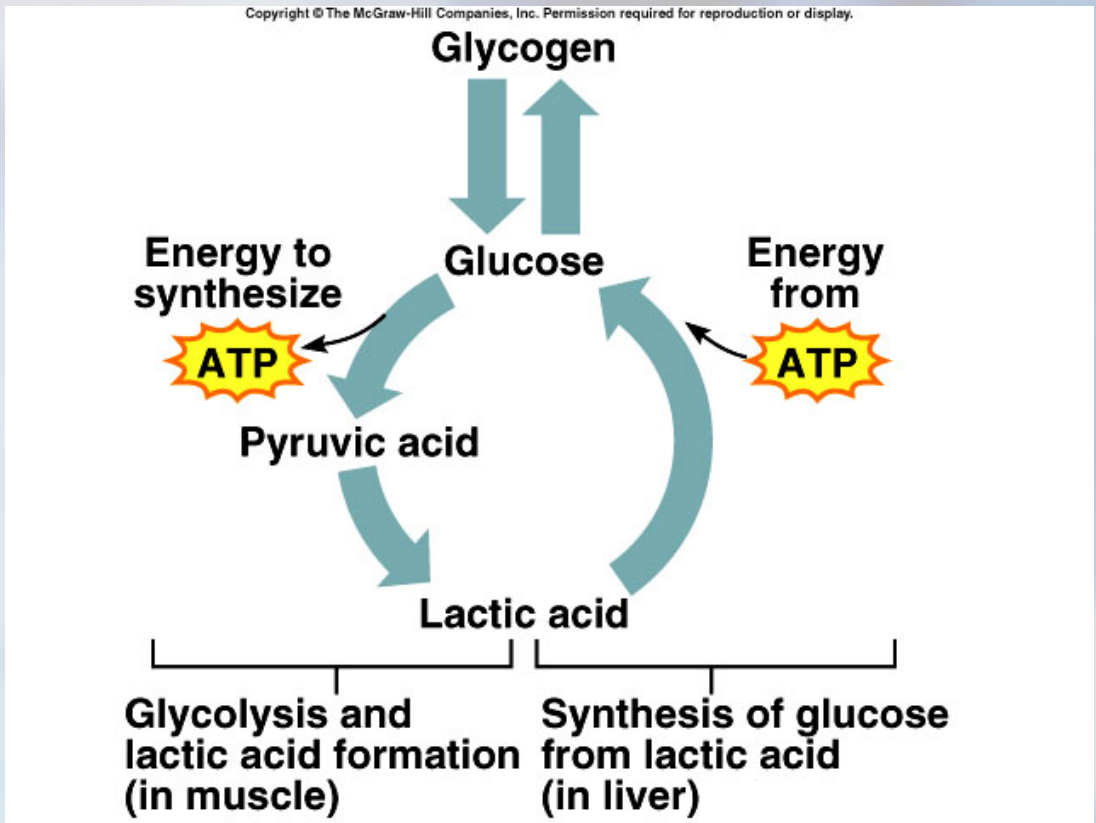
- **Anaerobic Phase**
  - **glycolysis**
  - **produces little ATP**
- **Aerobic Phase**
  - **citric acid cycle**
  - **electron transport chain**
  - **produces most ATP**
  - **myoglobin stores extra oxygen**



Oxygen Debt

Oxygen debt – amount of oxygen needed by liver to convert lactic acid to glucose

- **oxygen not available**
- **glycolysis continues**
- **pyruvic acid converted to lactic acid**
- **liver converts lactic acid to glucose**



Muscle Fatigue

- inability to contract
- commonly caused from
  - decreased blood flow
  - ion imbalances
  - accumulation of lactic acid
- cramp – sustained, involuntary contraction

Heat Production

- by-product of cellular respiration
- muscle cells are major source of body heat
- blood transports heat throughout body

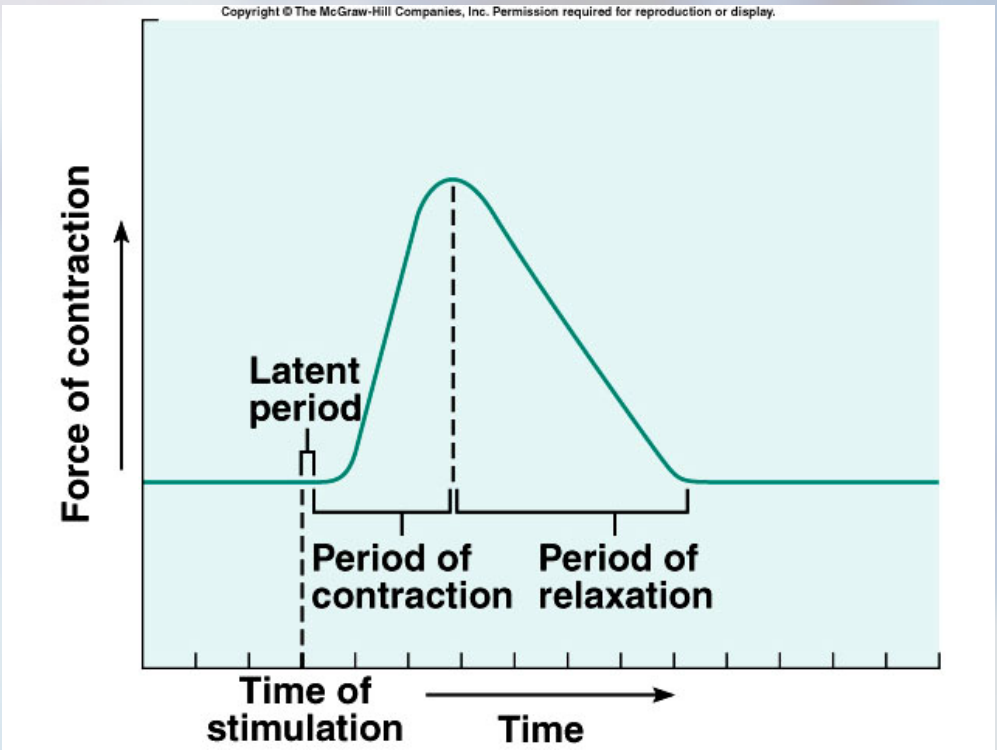
Muscular Responses

Threshold Stimulus

- **minimal strength required to cause contraction**

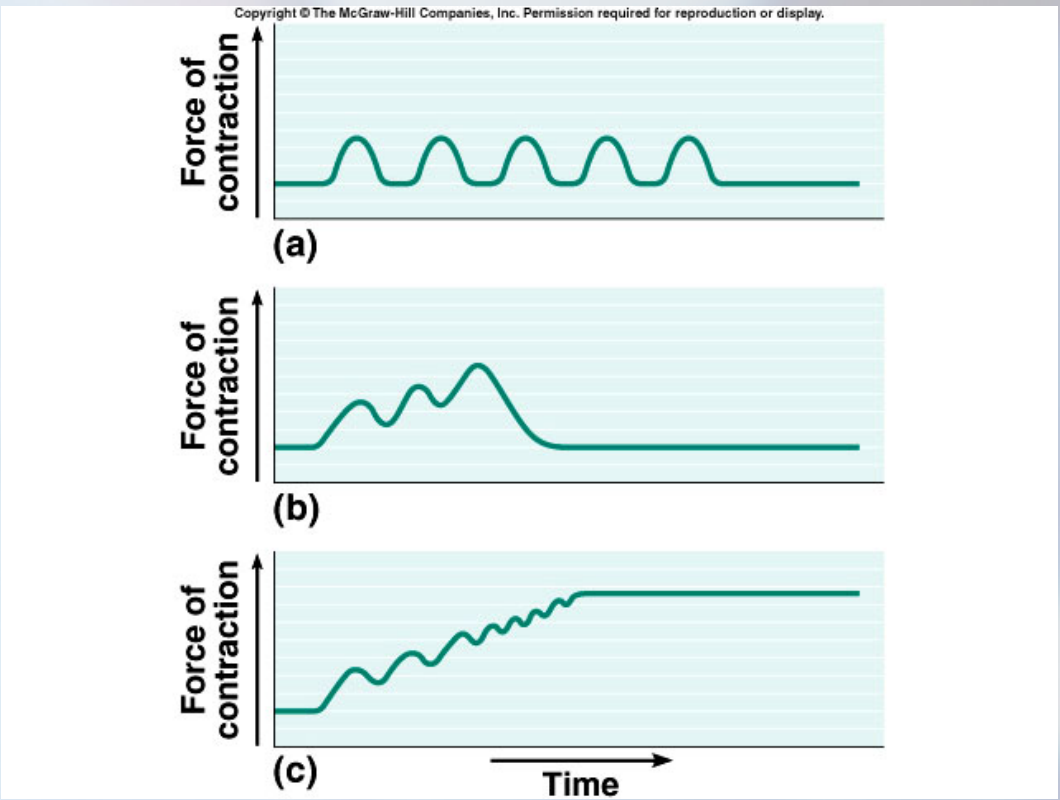
Recording a Muscle Contraction

- **twitch**
- **latent period**
- **period of contraction**
- **period of relaxation**
- **refractory period**
- **all-or-none response**



Summation

- process by which individual twitches combine
- produces sustained contractions
- can lead to tetanic contractions



Recruitment of Motor Units

- recruitment - increase in the number of motor units activated

- whole muscle composed of many motor units

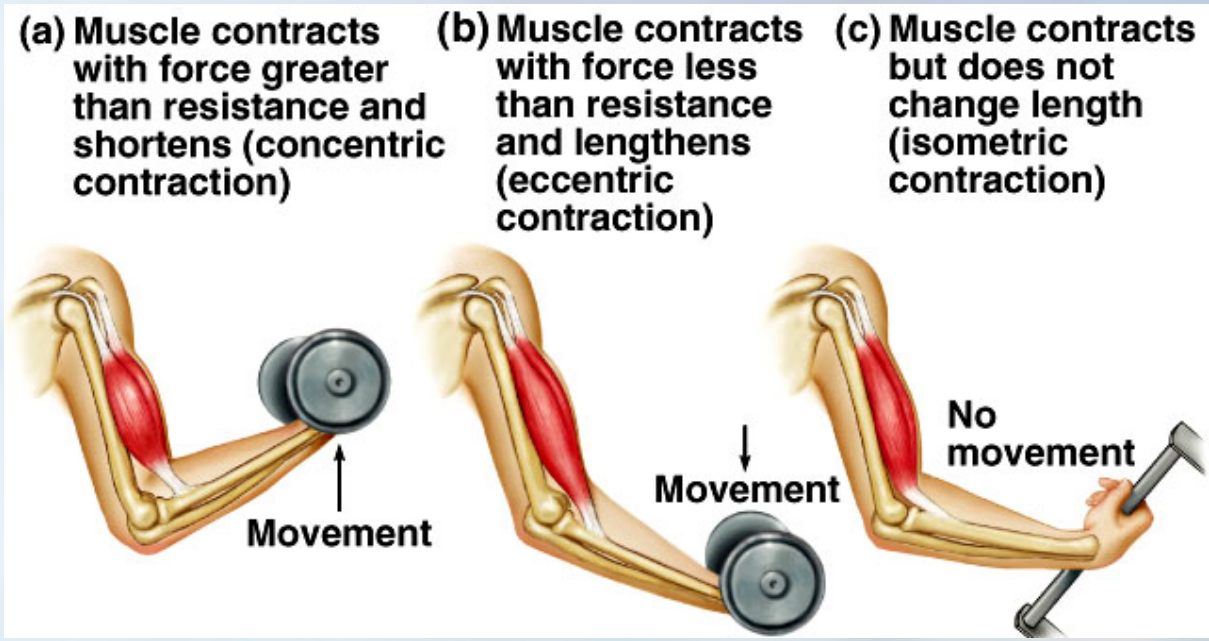
- as intensity of stimulation increases, recruitment of motor units continues until all motor units are activated

Sustained Contractions

- smaller motor units recruited first
- larger motor units recruited later
- produces smooth movements
- muscle tone – continuous state of partial contraction

Types of Contractions

- isotonic – muscle contracts and changes length
  - eccentric – lengthening contraction
- concentric – shortening contraction
- isometric – muscle contracts but does not change length



Fast and Slow Twitch Muscle Fibers

Slow-twitch fibers (type I)

- always oxidative
- resistant to fatigue
- red fibers
- most myoglobin
- good blood supply

Fast-twitch glycolytic fibers (type II)

- white fibers (less myoglobin)
- poorer blood supply
- susceptible to fatigue

Fast-twitch fatigue-resistant fibers (type IIb)

- intermediate fibers
- oxidative
- intermediate amount of myoglobin
- pink to red in color

Smooth Muscle Fibers

Compared to skeletal muscle fibers

- shorter
- single nucleus
- elongated with tapering ends
- myofilaments randomly organized
- no striations
- lack transverse tubules
- sarcoplasmic reticula not well developed

Types of Smooth Muscle

Visceral Smooth Muscle

- single-unit smooth muscle
- sheets of muscle fibers
- fibers held together by gap junctions
- exhibit rhythmicity
- exhibit peristalsis
- walls of most hollow organs

Multiunit Smooth Muscle

- fibers function separately
- irises of eye
- walls of blood vessels

Smooth Muscle Contraction

- Resembles skeletal muscle contraction
  - interaction between actin and myosin
  - both use calcium and ATP
  - both depend on impulses
- Different from skeletal muscle contraction
  - smooth muscle lacks troponin
  - smooth muscle depends on calmodulin
  - two neurotransmitters affect smooth muscle
    - acetlycholine and norepinephrine
  - hormones affect smooth muscle
  - stretching can trigger smooth muscle contraction
  - smooth muscle slower to contract and relax
  - smooth muscle more resistant to fatigue

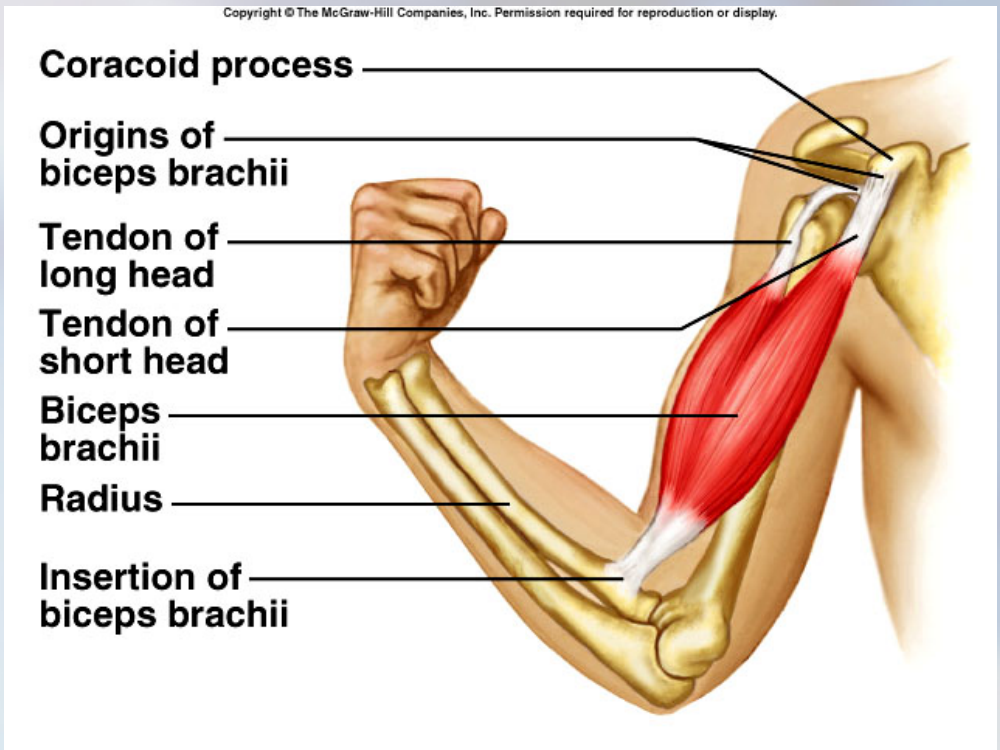
Cardiac Muscle

- only in the heart
- muscle fibers joined together by intercalated discs
- fibers branch
- network of fibers contracts as a unit
- self-exciting and rhythmic
- longer refractory period than skeletal muscle

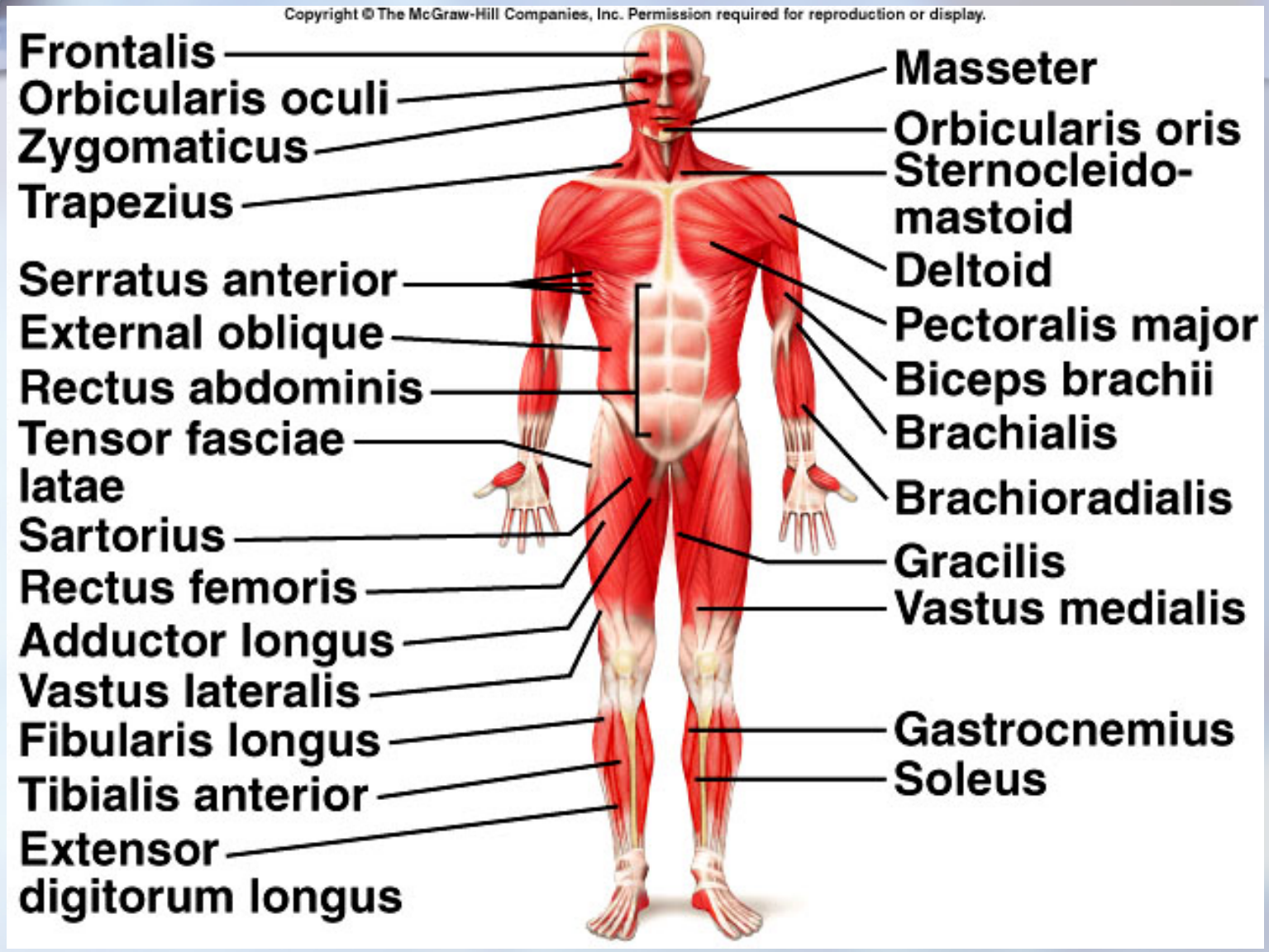
Skeletal Muscle Actions

- origin – immovable end
- insertion – movable end

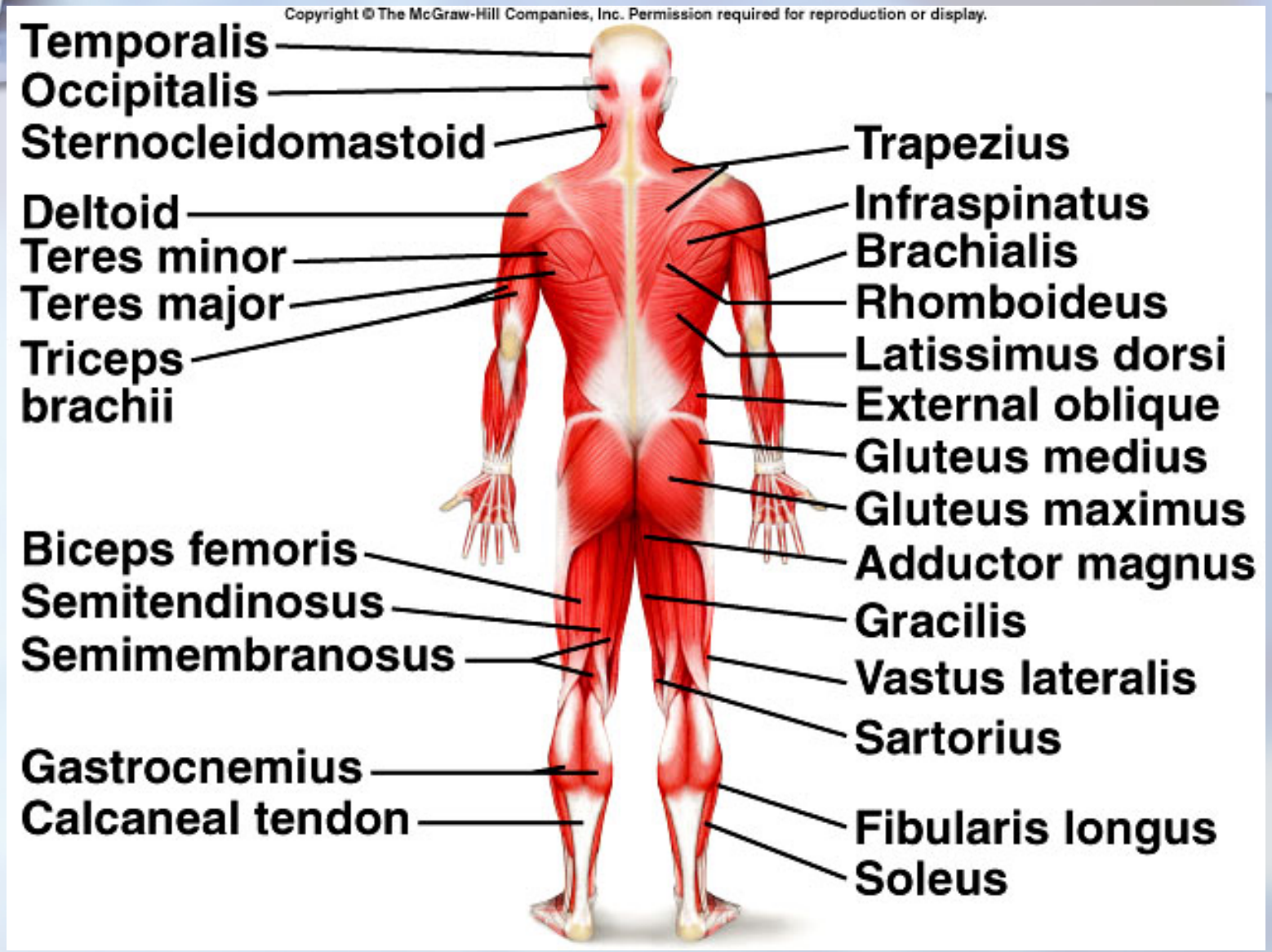
- prime mover (agonist) – primarily responsible for movement
- synergists – assist prime mover
- antagonist – resist prime mover's action and cause movement in the opposite direction



Major Skeletal Muscles



Major Skeletal Muscles



Muscles of Facial Expression

TABLE 9.3 Muscles of Facial Expression

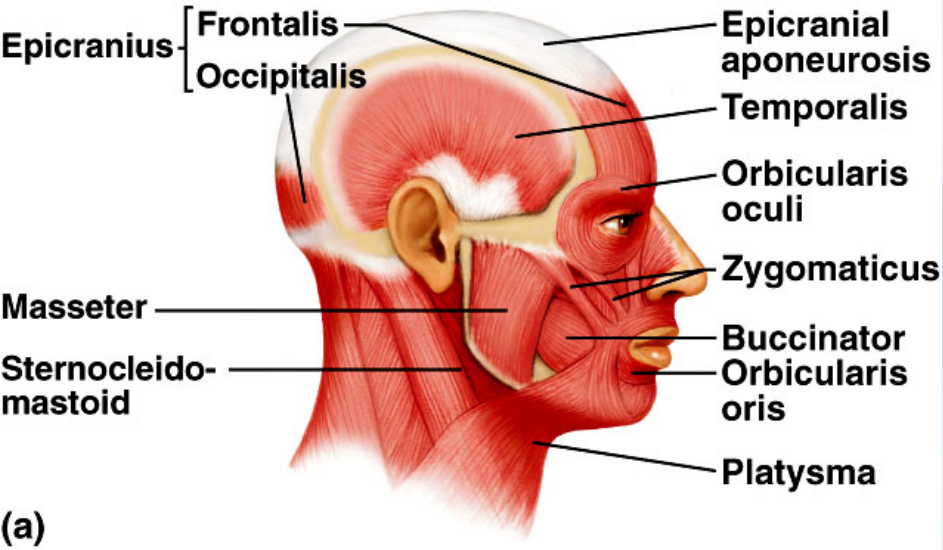
Muscle	Origin	Insertion	Action	Nerve Supply
Epicranius	Occipital bone	Skin and muscles around eye	Raises eyebrow as when surprised	Facial n.
Orbicularis oculi	Maxillary and frontal bones	Skin around eye	Closes eye as in blinking	Facial n.
Orbicularis oris	Muscles near the mouth	Skin of central lip	Closes lips, protrudes lips as for kissing	Facial n.
Buccinator	Outer surfaces of maxilla and mandible	Orbicularis oris	Compresses cheeks inward as when blowing air	Facial n.
Zygomaticus	Zygomatic bone	Orbicularis oris	Raises corner of mouth as when smiling	Facial n.
Platysma	Fascia in upper chest	Lower border of mandible	Draws angle of mouth downward as when pouting	Facial n.

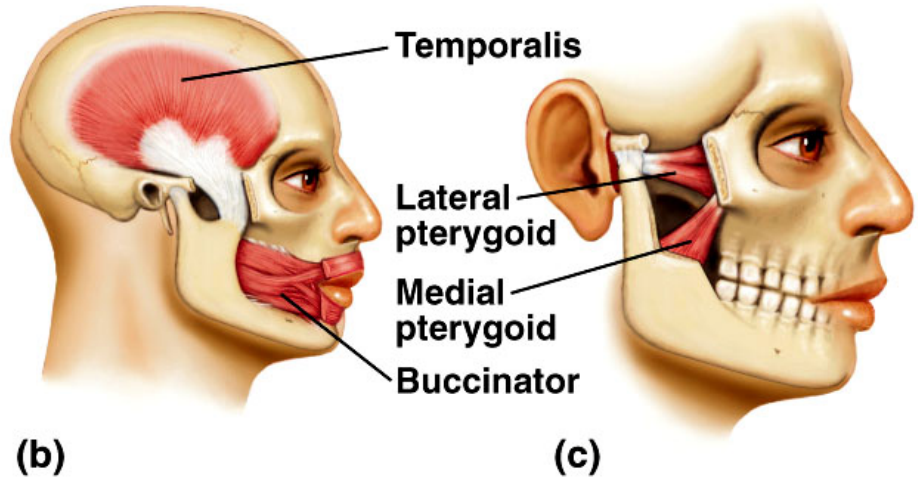
Muscles of Mastication

TABLE 9.4 Muscles of Mastication

Muscle	Origin	Insertion	Action	Nerve Supply
Masseter	Lower border of zygomatic arch	Lateral surface of mandible	Elevates mandible	Trigeminal n.
Temporalis	Temporal bone	Coronoid process and anterior ramus of mandible	Elevates mandible	Trigeminal n.
Medial pterygoid	Sphenoid, palatine, and maxillary bones	Medial surface of mandible	Elevates mandible and moves it from side to side	Trigeminal n.
Lateral pterygoid	Sphenoid bone	Anterior surface of mandibular condyle	Depresses and protracts mandible and moves it from side to side	Trigeminal n.

Muscles of Facial Expression and Mastication





Muscles That Move the Head and Vertebral Column

TABLE 9.5 Muscles That Move the Head and Vertebral Column

Muscle	Origin	Insertion	Action	Nerve Supply
Sternocleidomastoid	Anterior surface of sternum and upper surface of clavicle	Mastoid process of temporal bone	Pulls head to one side, flexes neck or elevates sternum	Accessory, C2 and C3 cervical nerves
Splenius capitis	Spinous processes of lower cervical and upper thoracic vertebrae	Occipital bone	Rotates head, bends head to one side, or extends neck	Cervical nerves
Semispinalis capitis	Processes of lower cervical and upper thoracic vertebrae	Occipital bone	Extends head, bends head to one side, or rotates head	Cervical and thoracic spinal nerves
Erector spinae				
Iliocostalis (lateral) group				
Iliocostalis lumborum	Iliac crest	Lower six ribs	Extends lumbar region of vertebral column	Lumbar spinal nerves
Iliocostalis thoracis	Lower six ribs	Upper six ribs	Holds spine erect	Thoracic spinal nerves
Iliocostalis cervicis	Upper six ribs	Fourth through sixth cervical vertebrae	Extends cervical region of vertebral column	Cervical spinal nerves
Longissimus (intermediate) group				
Longissimus thoracis	Lumbar vertebrae	Thoracic and upper lumbar vertebrae and ribs 9 and 10	Extends thoracic region of vertebral column	Spinal nerves
Longissimus cervicis	Fourth and fifth thoracic vertebrae	Second through sixth cervical vertebrae	Extends cervical region of vertebral column	Spinal nerves
Longissimus capitis	Upper thoracic and lower cervical vertebrae	Mastoid process of temporal bone	Extends and rotates head	Cervical spinal nerves
Spinalis (medial) group				
Spinalis thoracis	Upper lumbar and lower thoracic vertebrae	Upper thoracic vertebrae	Extends vertebral column	Spinal nerves
Spinalis cervicis	Ligamentum nuchae and seventh cervical vertebra	Axis	Extends vertebral column	Spinal nerves
Spinalis capitis	Upper thoracic and lower cervical vertebrae	Occipital bone	Extends vertebral column	Spinal nerves

Muscles That Move the Pectoral Girdle

TABLE 9.6 Muscles That Move the Pectoral Girdle

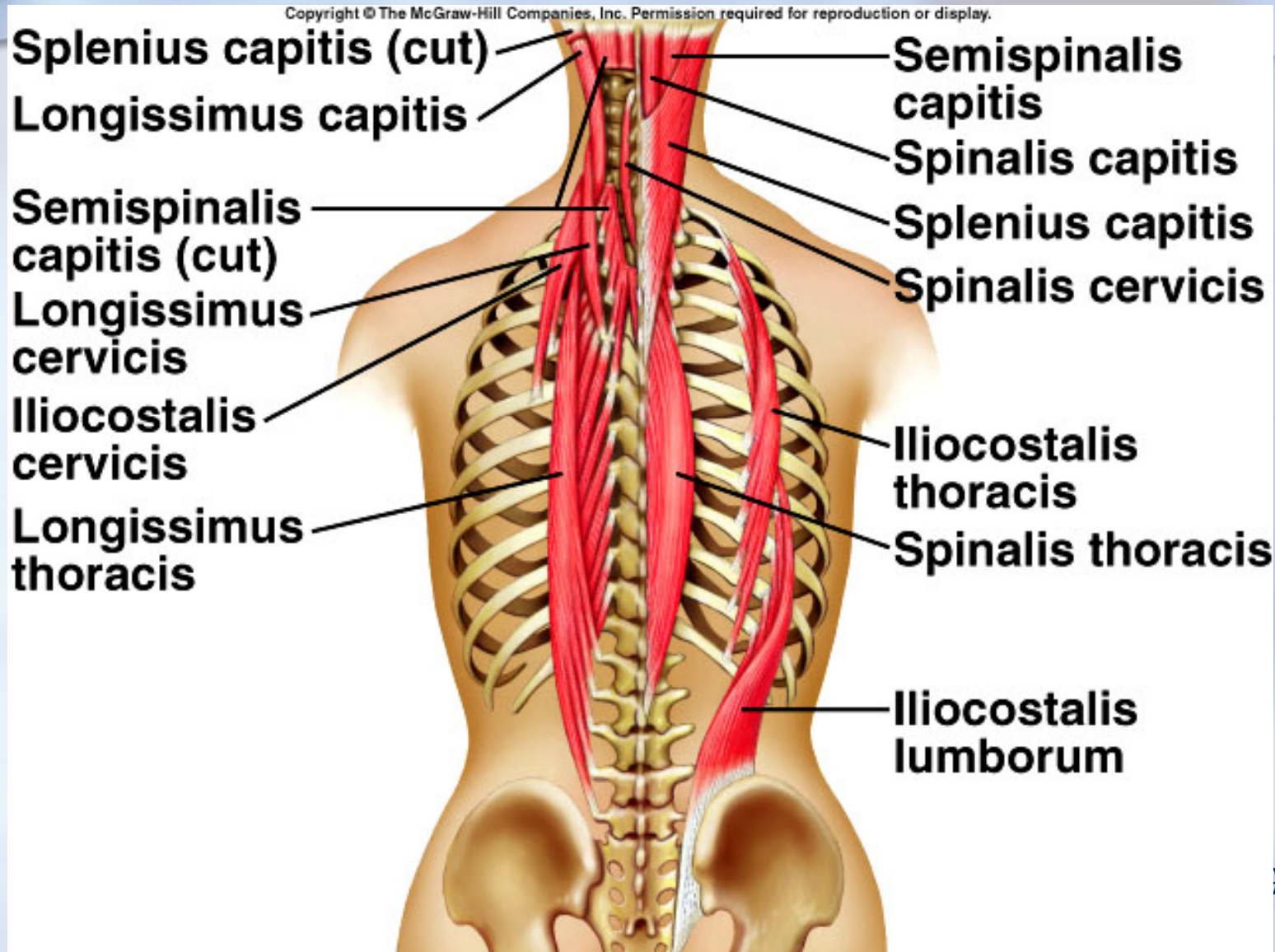
Muscle	Origin	Insertion	Action	Nerve Supply
Trapezius	Occipital bone and spines of cervical and thoracic vertebrae	Clavicle, spine, and acromion process of scapula	Rotates scapula; various fibers raise scapula, pull scapula medially, or pull scapula and shoulder downward	Accessory n.
Rhomboideus major	Spines of upper thoracic vertebrae	Medial border of scapula	Raises and adducts scapula	Dorsal scapular n.
Levator scapulae	Transverse processes of cervical vertebrae	Medial margin of scapula	Elevates scapula	Dorsal scapular and cervical nerves
Serratus anterior	Outer surfaces of upper ribs	Ventral surface of scapula	Pulls scapula anteriorly and downward	Long thoracic n.
Pectoralis minor	Sternal ends of upper ribs	Coracoid process of scapula	Pulls scapula forward and downward or raises ribs	Pectoral n.

Muscles That Move the Arm

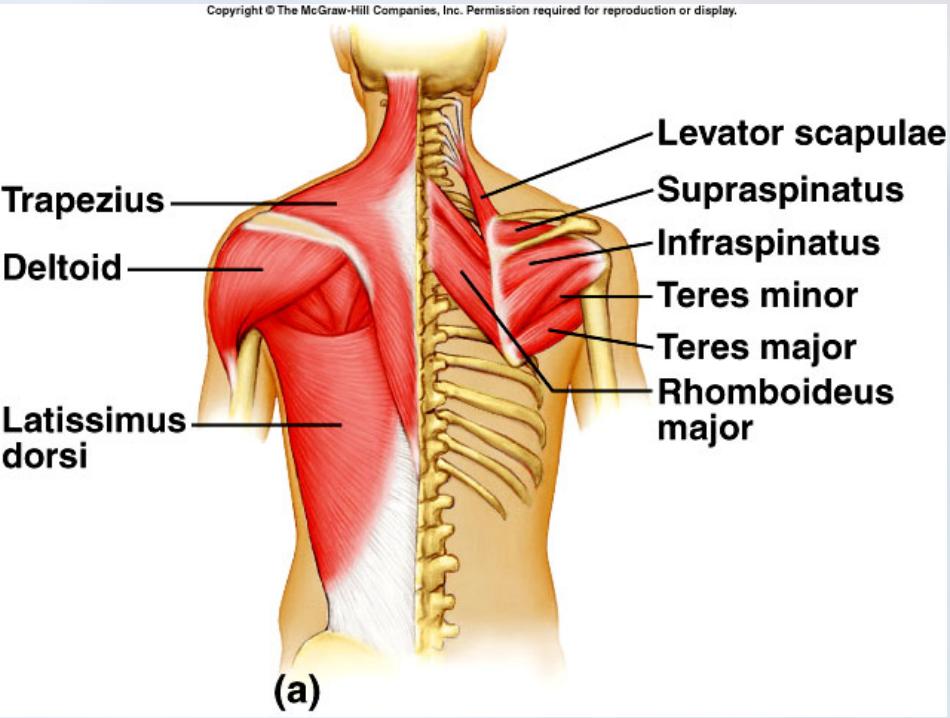
TABLE 9.7 Muscles That Move the Arm

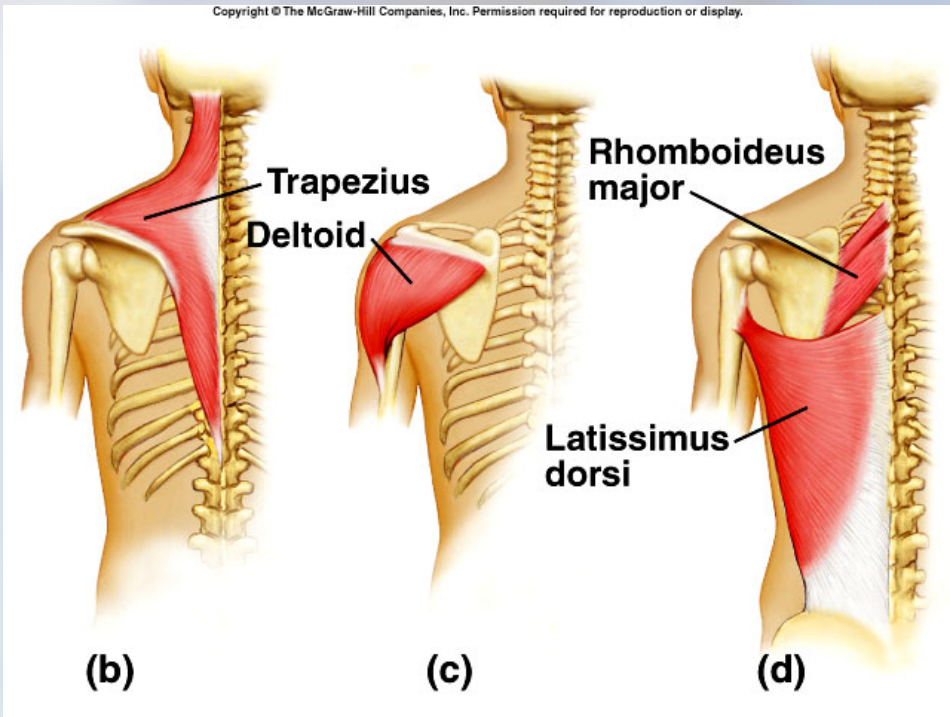
Muscle	Origin	Insertion	Action	Nerve Supply
Coracobrachialis	Coracoid process of scapula	Shaft of humerus	Flexes and adducts the arm	Musculocutaneus n.
Pectoralis major	Clavicle, sternum, and costal cartilages of upper ribs	Intertubercular groove of humerus	Flexes, adducts, and rotates arm medially	Pectoral n.
Teres major	Lateral border of scapula	Intertubercular groove of humerus	Extends, adducts, and rotates arm medially	Lower subscapular n.
Latissimus dorsi	Spines of sacral, lumbar, and lower thoracic vertebrae, iliac crest, and lower ribs	Intertubercular groove of humerus	Extends, adducts, and rotates the arm medially, or pulls the shoulder downward and back	Thoracodorsal n.
Supraspinatus	Posterior surface of scapula above spine	Greater tubercle of humerus	Abducts the arm	Suprascapular n.
Deltoid	Acromion process, spine of the scapula, and the clavicle	Deltoid tuberosity of humerus	Abducts, extends, and flexes arm	Axillary n.
Subscapularis	Anterior surface of scapula	Lesser tubercle of humerus	Rotates arm medially	Subscapular n.
Infraspinatus	Posterior surface of scapula below spine	Greater tubercle of humerus	Rotates arm laterally	Suprascapular n.
Teres minor	Lateral border of scapula	Greater tubercle of humerus	Rotates arm laterally	Axillary n.

Deep Muscles of the Back and Neck

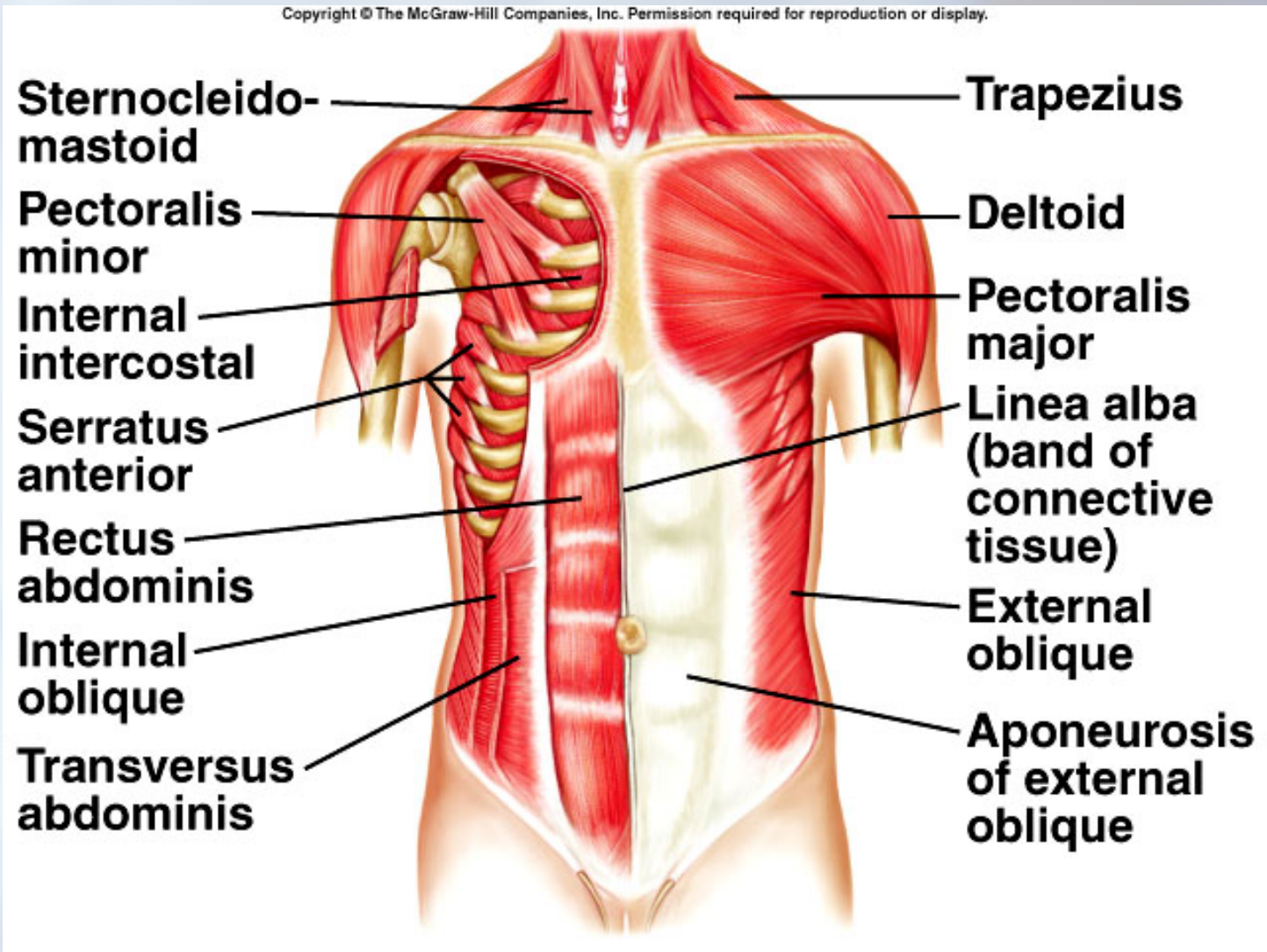


Muscles of the Shoulder and Back





Muscles of the Anterior Chest and Abdominal Wall



Muscles That Move the Forearm

TABLE 9.8 Muscles That Move the Forearm

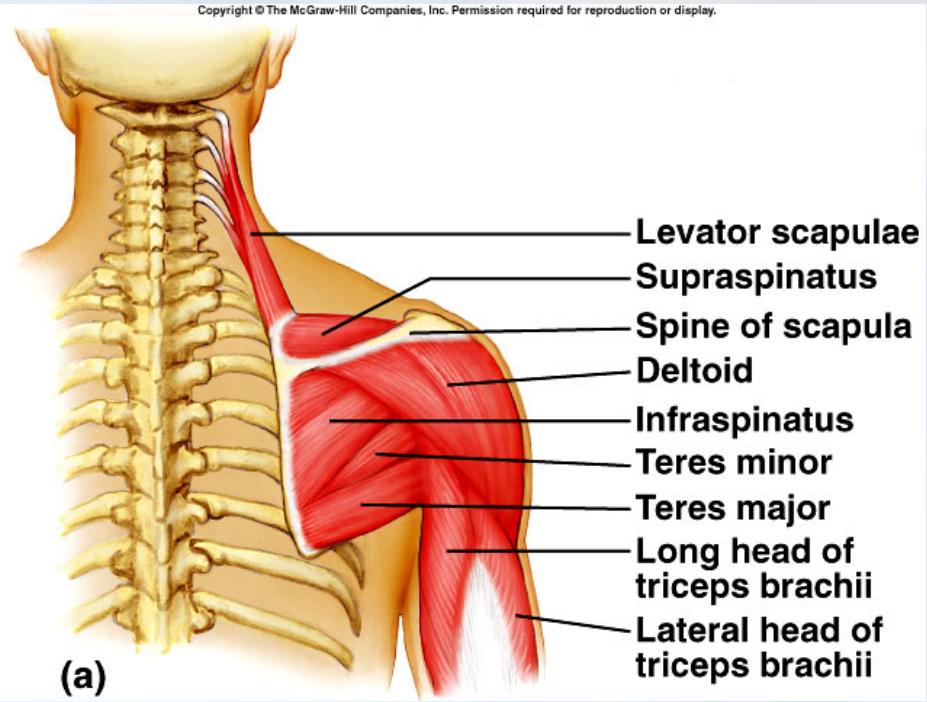
Muscle	Origin	Insertion	Action	Nerve Supply
Biceps brachii	Coracoid process and tubercle above glenoid cavity of scapula	Radial tuberosity of radius	Flexes forearm at elbow and rotates hand laterally	Musculocutaneous n.
Brachialis	Anterior shaft of humerus	Coronoid process of ulna	Flexes forearm at elbow	Musculocutaneous, median, and radial nerves
Brachioradialis	Distal lateral end of humerus	Lateral surface of radius above styloid process	Flexes forearm at elbow	Radial n.
Triceps brachii	Tubercle below glenoid cavity and lateral and medial surfaces of humerus	Olecranon process of ulna	Extends forearm at elbow	Radial n.
Supinator	Lateral epicondyle of humerus and crest of ulna	Lateral surface of radius	Rotates forearm laterally	Radial n.
Pronator teres	Medial epicondyle of humerus and coronoid process of ulna	Lateral surface of radius	Rotates forearm medially	Median n.
Pronator quadratus	Anterior distal end of ulna	Anterior distal end of radius	Rotates forearm medially	Median n.

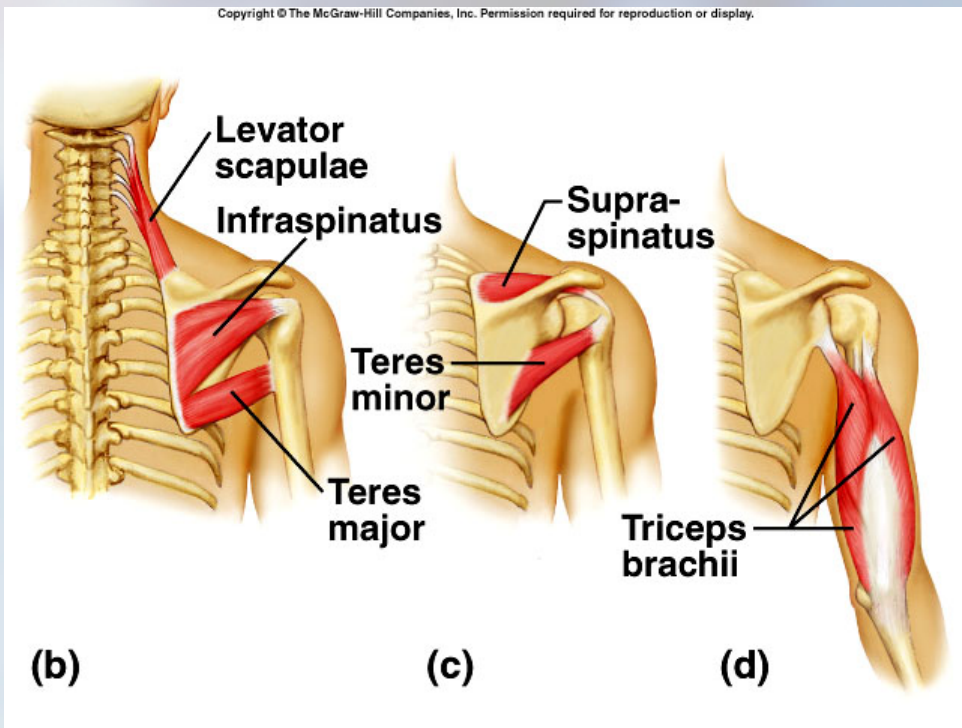
Muscles That Move the Hand

TABLE 9.9 Muscles That Move the Hand

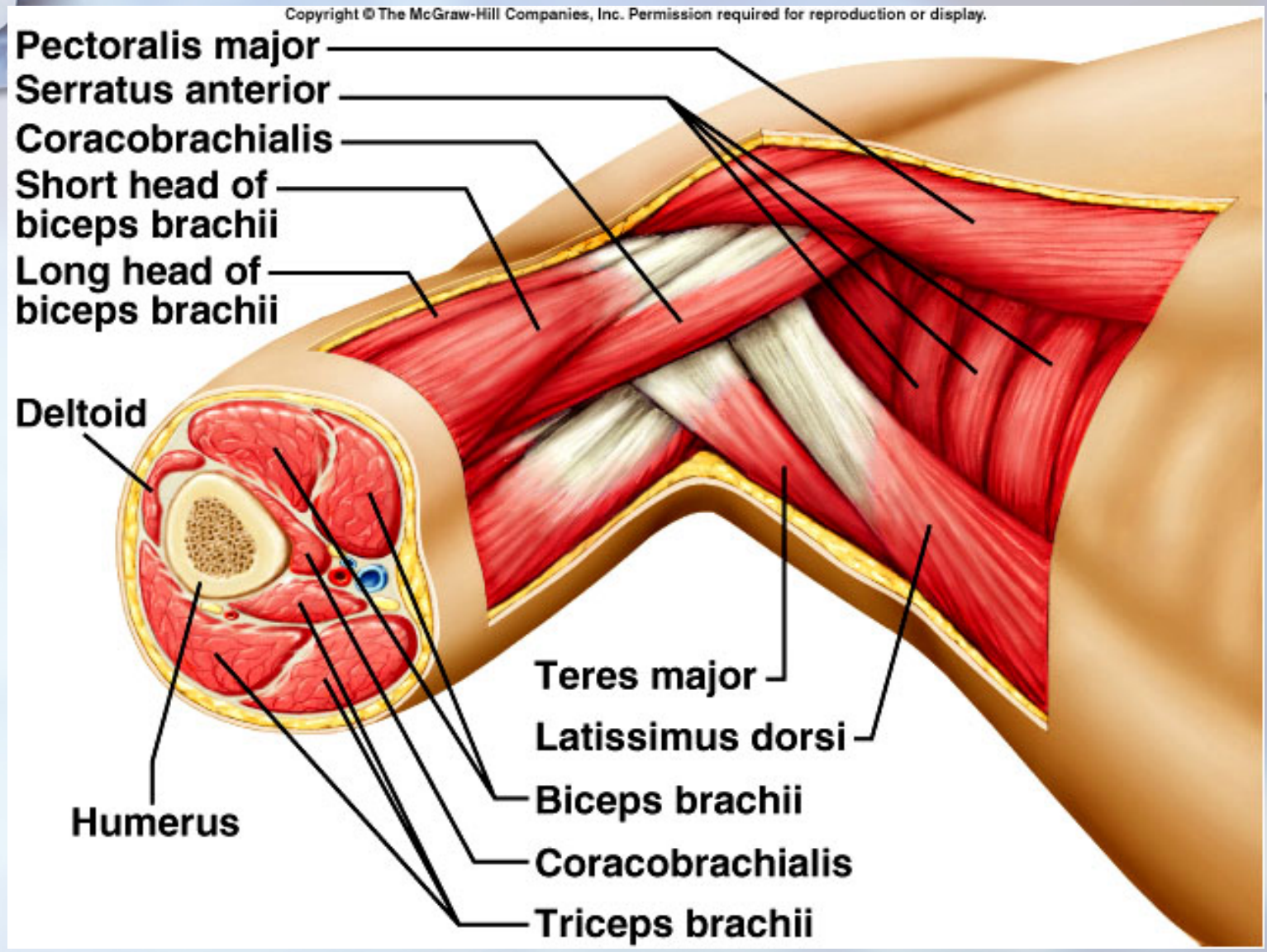
Muscle	Origin	Insertion	Action	Nerve Supply
Flexor carpi radialis	Medial epicondyle of humerus	Base of second and third metacarpals	Flexes wrist and abducts hand	Median n.
Flexor carpi ulnaris	Medial epicondyle of humerus and olecranon process	Carpal and metacarpal bones	Flexes wrist and adducts hand	Ulnar n.
Palmaris longus	Medial epicondyle of humerus	Fascia of palm	Flexes the wrist	Median n.
Flexor digitorum profundus	Anterior surface of ulna	Bases of distal phalanges in fingers 2–5	Flexes distal joints of fingers	Median and ulnar nerves
Flexor digitorum superficialis	Medial epicondyle of humerus, coronoid process of ulna, and radius	Tendons of fingers	Flexes fingers and wrist	Median n.
Extensor carpi radialis longus	Distal end of humerus	Base of second metacarpal	Extends wrist and abducts hand	Radial n.
Extensor carpi radialis brevis	Lateral epicondyle of humerus	Base of second and third metacarpals	Extends wrist and abducts hand	Radial n.
Extensor carpi ulnaris	Lateral epicondyle of humerus	Base of fifth metacarpal	Extends wrist and adducts hand	Radial n.
Extensor digitorum	Lateral epicondyle of humerus	Posterior surface of phalanges in fingers 2–5	Extends fingers	Radial n.

Muscles of the Shoulder and Arm

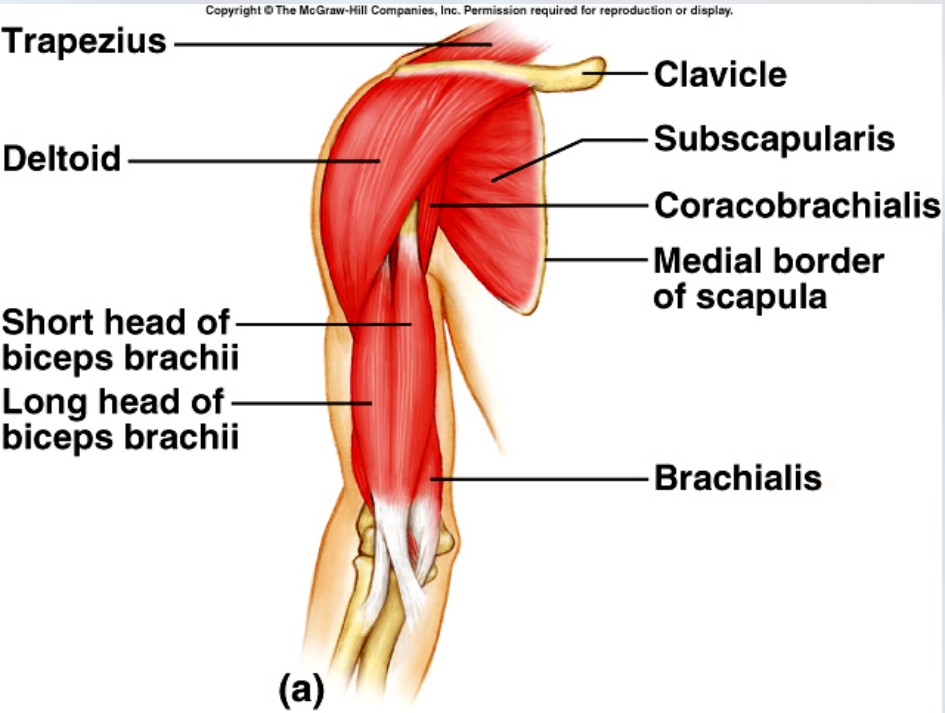


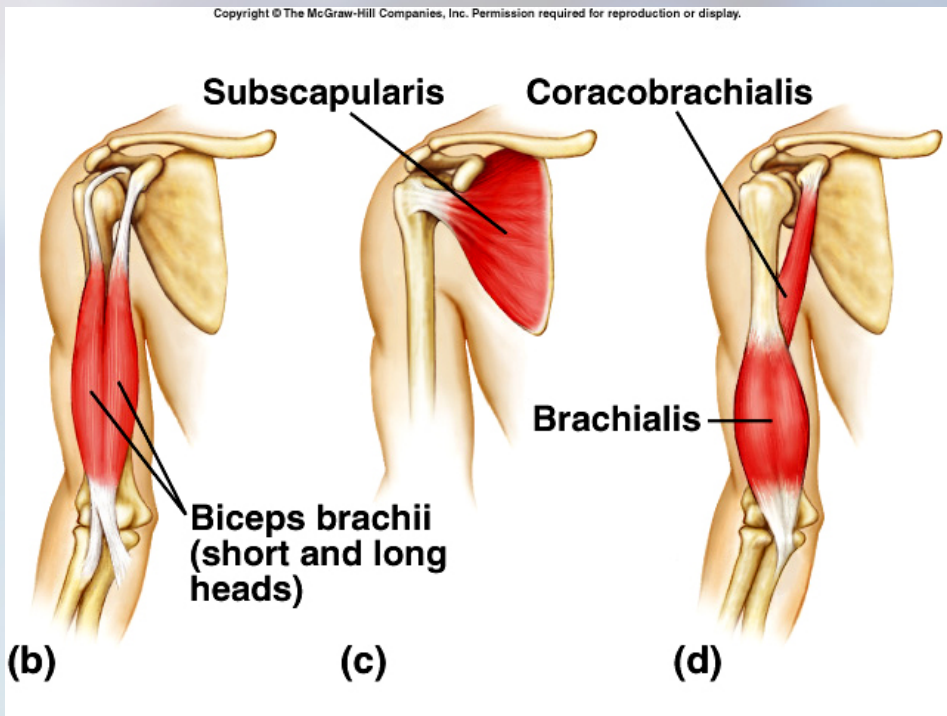


Cross Section of the Arm

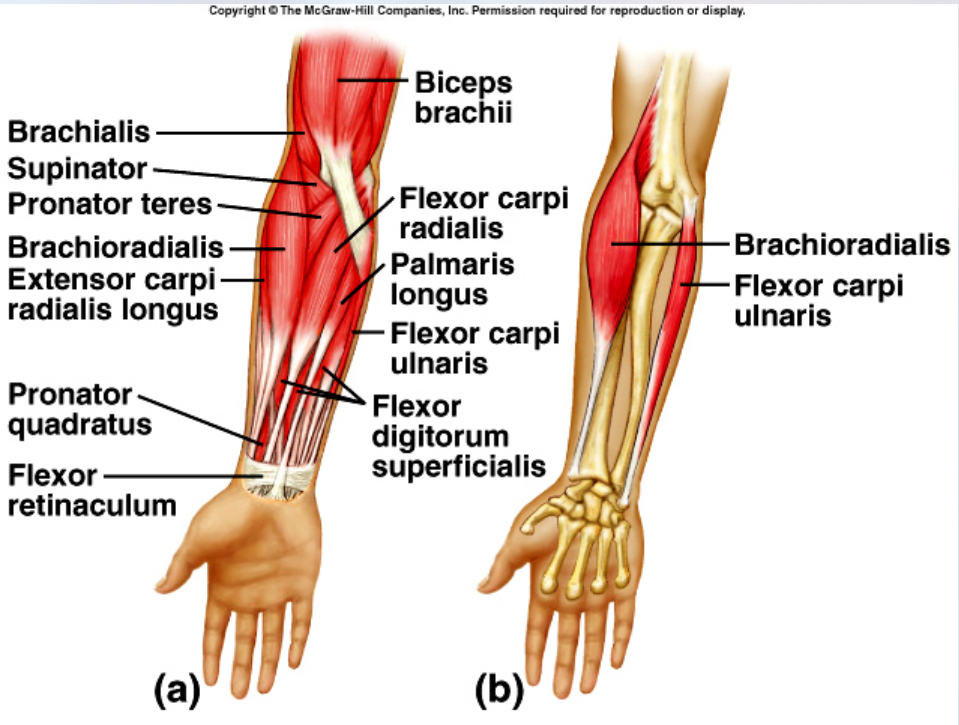


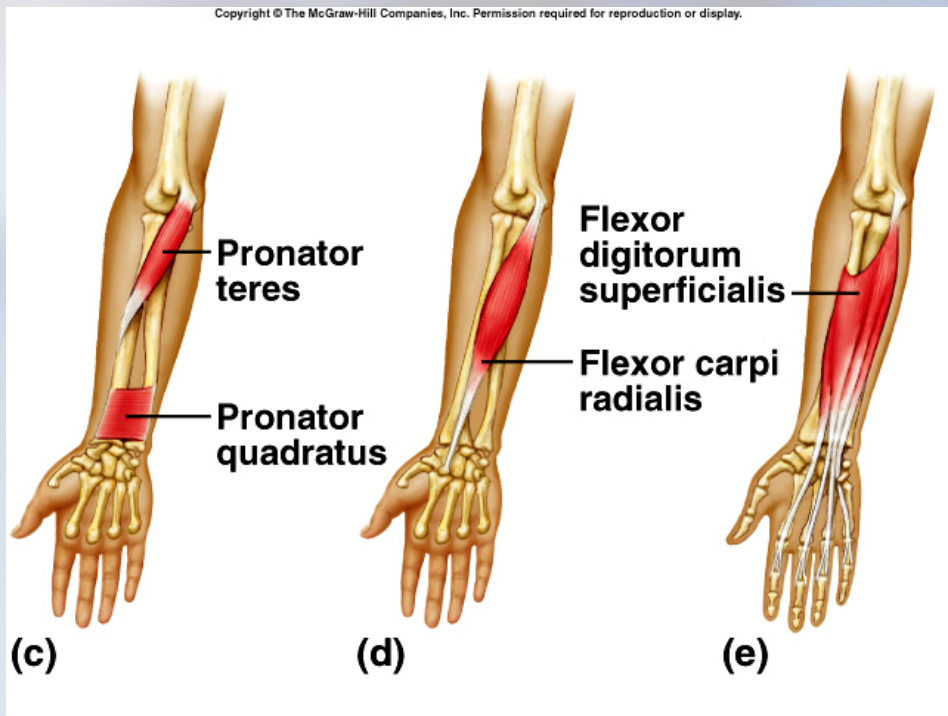
Muscles of the Shoulder and Arm



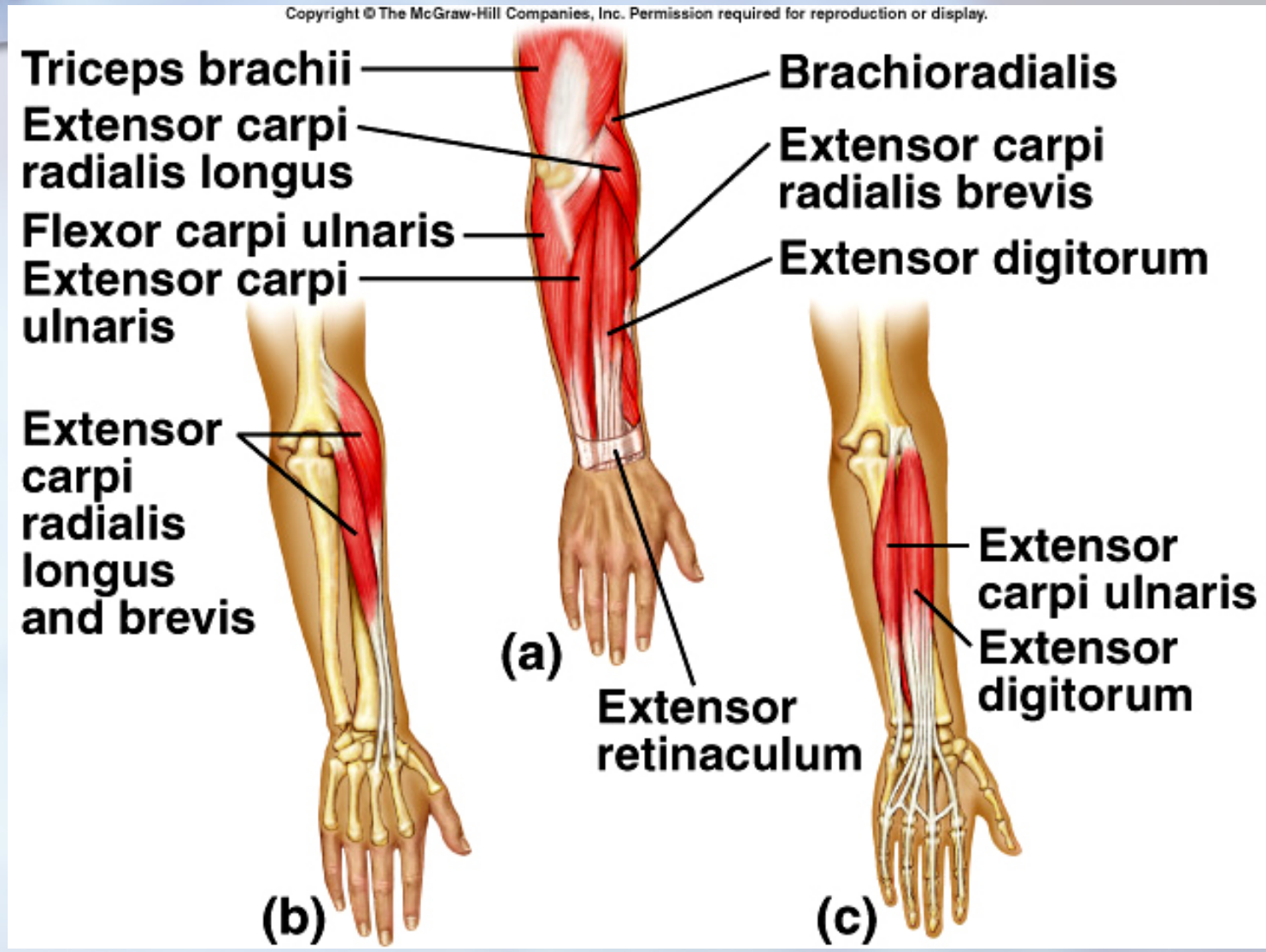


Muscles of the Arm and Forearm

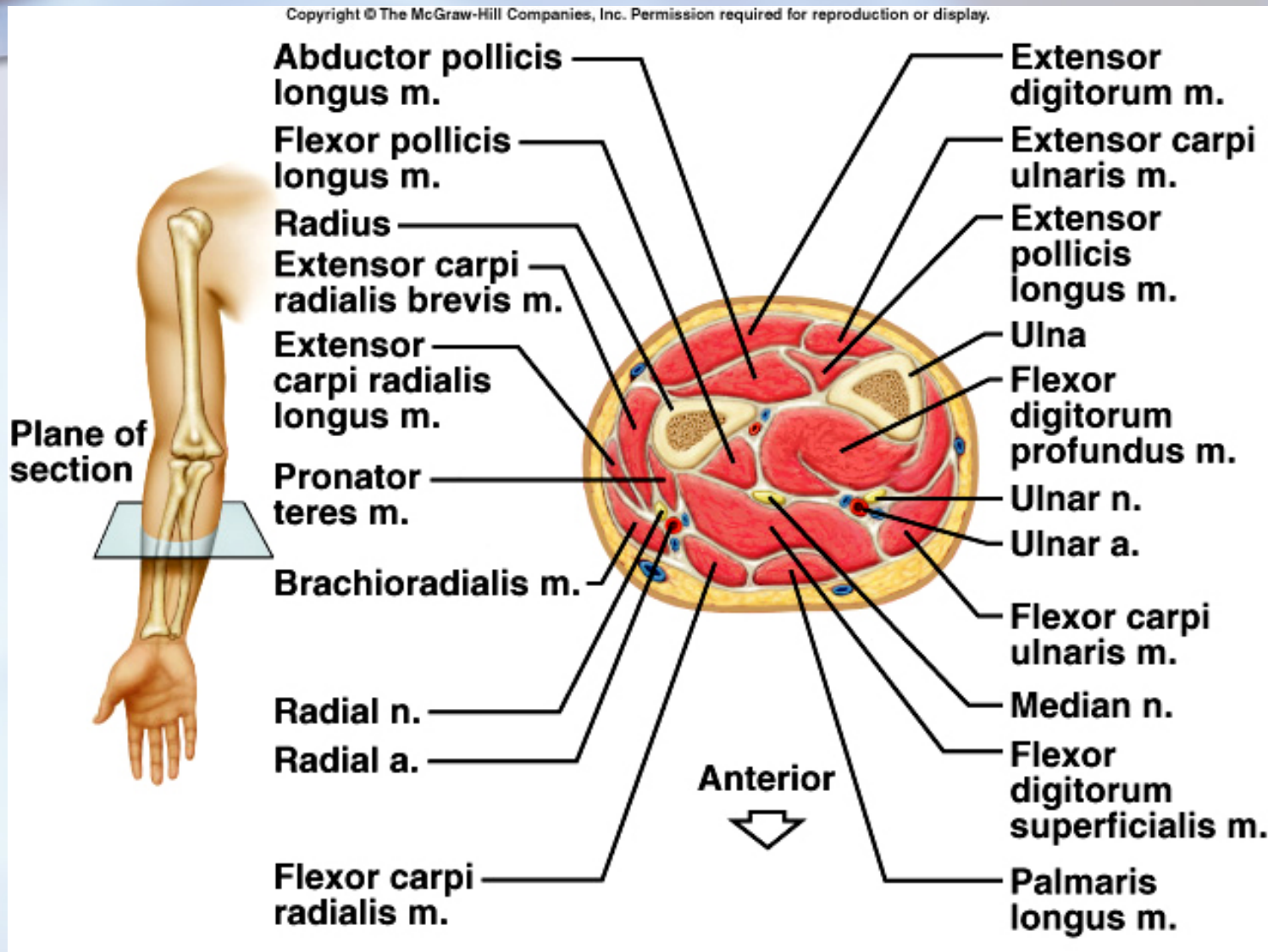




Muscles of the Arm and Forearm



Cross Section of the Forearm

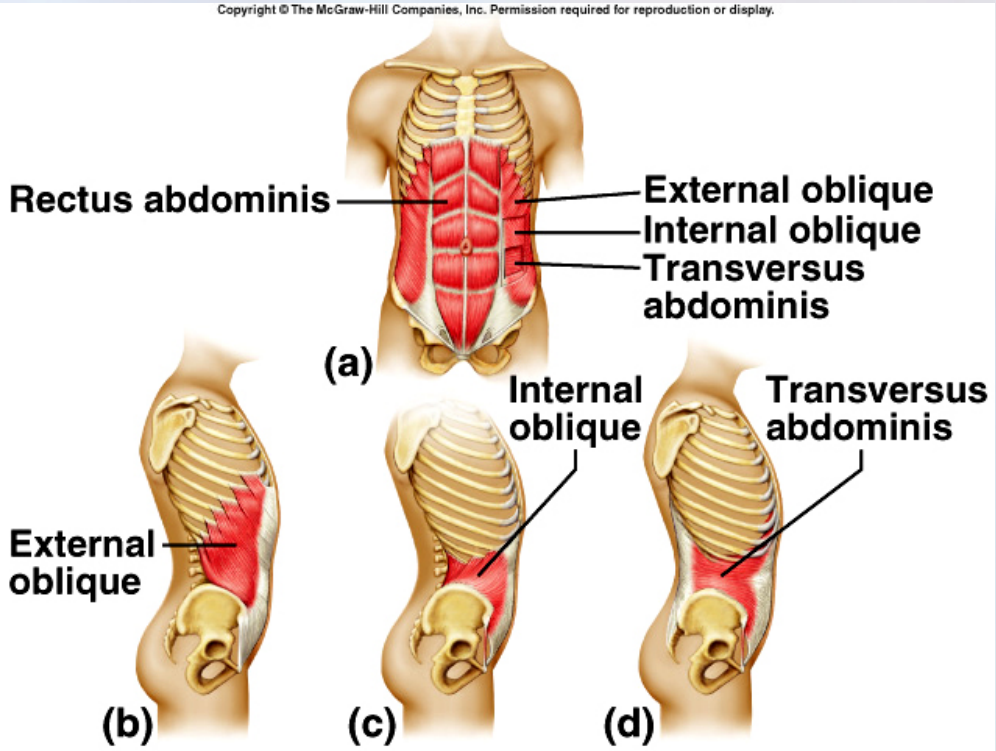


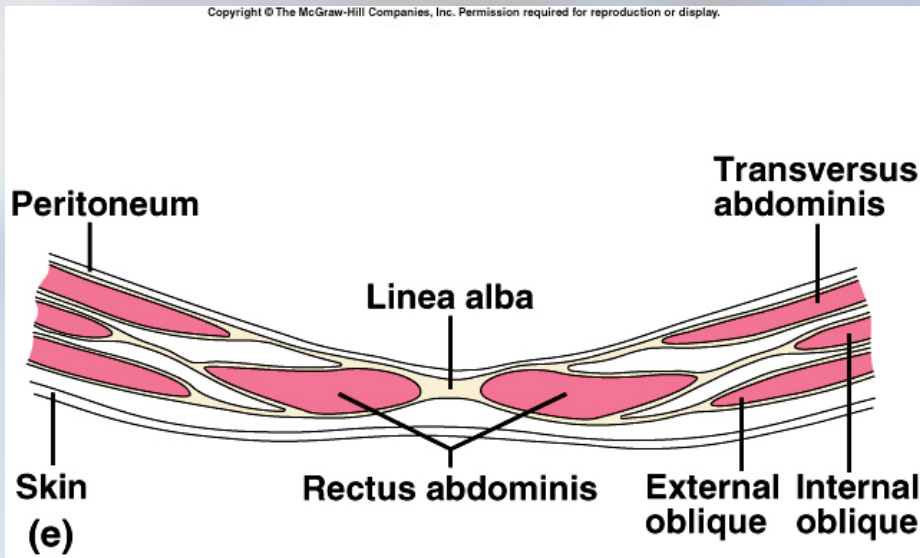
Muscles of the Abdominal Wall

TABLE 9.10 Muscles of the Abdominal Wall

Muscle	Origin	Insertion	Action	Nerve Supply
External oblique	Outer surfaces of lower ribs	Outer lip of iliac crest and linea alba	Tenses abdominal wall and compresses abdominal contents	Intercostal nerves 7–12
Internal oblique	Crest of ilium and inguinal ligament	Cartilages of lower ribs, linea alba, and crest of pubis	Same as above	Intercostal nerves 7–12
Transversus abdominis	Costal cartilages of lower ribs, processes of lumbar vertebrae, lip of iliac crest, and inguinal ligament	Linea alba and crest of pubis	Same as above	Intercostal nerves 7–12
Rectus abdominis	Crest of pubis and symphysis pubis	Xiphoid process of sternum and costal cartilages	Same as above; also flexes vertebral column	Intercostal nerves 7–12

Muscles of the Abdominal Wall



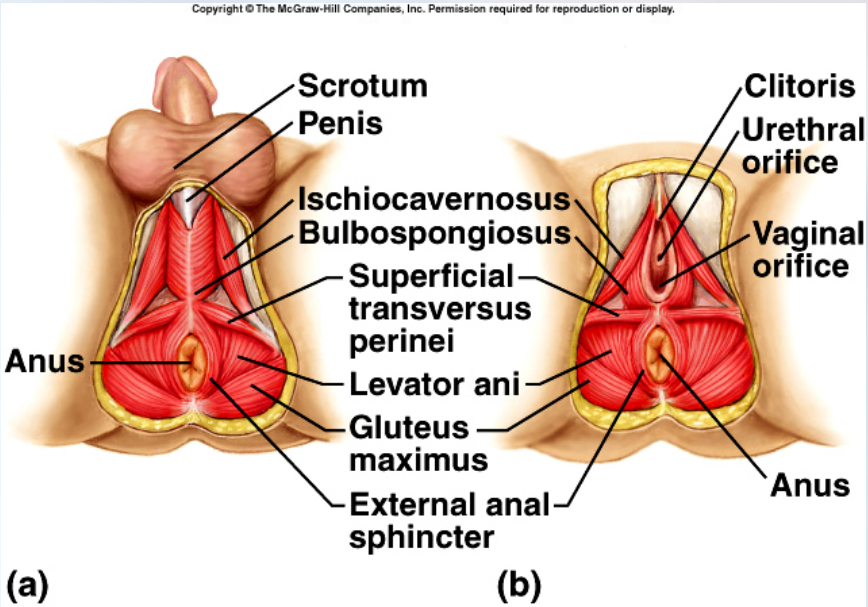


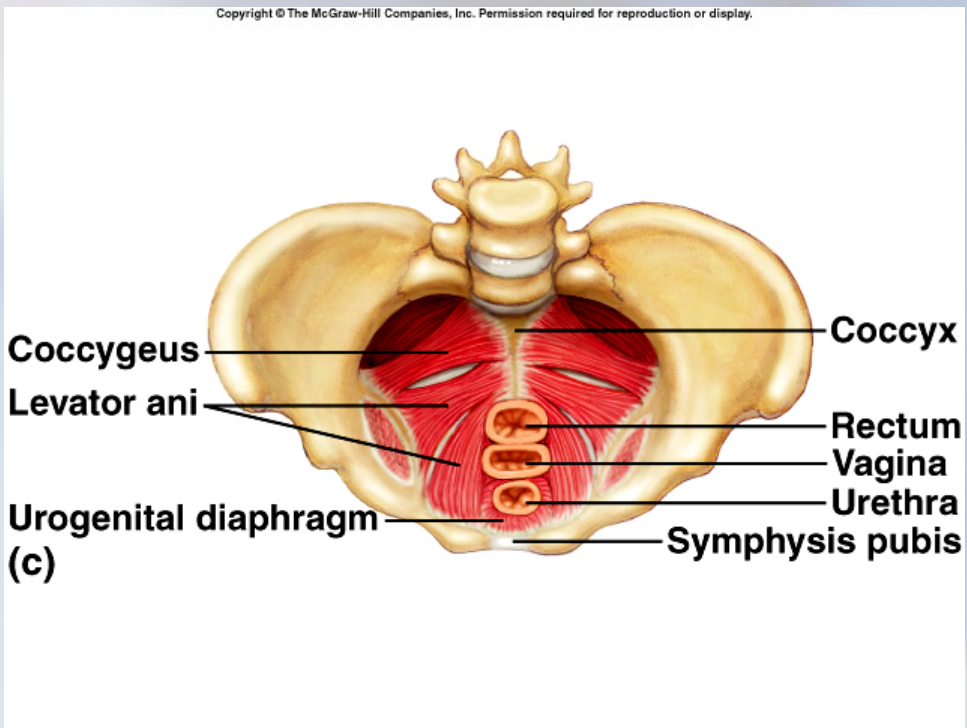
Muscles of the Pelvic Outlet

TABLE 9.11 Muscles of the Pelvic Outlet

Muscle	Origin	Insertion	Action	Nerve Supply
Levator ani	Pubic bone and ischial spine	Coccyx	Supports pelvic viscera and provides sphincterlike action in anal canal and vagina	Pudendal n.
Coccygeus	Ischial spine	Sacrum and coccyx	Same as above	S4 and S5 nerves
Superficial transversus perinei	Ischial tuberosity	Central tendon	Supports pelvic viscera	Pudendal n.
Bulbospongiosus	Central tendon	Males: Urogenital diaphragm and fascia of penis Females: Pubic arch and root of clitoris	Males: Assists emptying of urethra Females: Constricts vagina	Pudendal n.
Ischiocavernosus	Ischial tuberosity	Pubic arch	Assists function of bulbospongiosus	Pudendal n.
Sphincter urethrae	Margins of pubis and ischium	Fibers of each unite with those from other side	Opens and closes urethra	Pudendal n.

Muscles of Pelvic Outlets and Urogenital Diaphragm





Muscles That Move the Thigh

TABLE 9.12 Muscles That Move the Thigh

Muscle	Origin	Insertion	Action	Nerve Supply
Psoas major	Lumbar intervertebral discs; bodies and transverse processes of lumbar vertebrae	Lesser trochanter of femur	Flexes thigh	Branches of L1-3 nerves
Iliacus	Iliac fossa of ilium	Lesser trochanter of femur	Flexes thigh	Femoral n.
Gluteus maximus	Sacrum, coccyx, and posterior surface of ilium	Posterior surface of femur and fascia of thigh	Extends thigh at hip	Inferior gluteal n.
Gluteus medius	Lateral surface of ilium	Greater trochanter of femur	Abducts and rotates thigh medially	Superior gluteal n.
Gluteus minimus	Lateral surface of ilium	Greater trochanter of femur	Same as gluteus medius	Superior gluteal n.
Tensor fasciae latae	Anterior iliac crest	Iliotibial band (fascia of thigh)	Abducts, flexes, and rotates thigh medially	Superior gluteal n.
Pectineus	Spine of pubis	Femur distal to lesser trochanter	Adducts and flexes thigh	Obturator and femoral nerves
Adductor longus	Pubic bone near symphysis pubis	Posterior surface of femur	Adducts, flexes, and rotates thigh laterally	Obturator n.
Adductor magnus	Ischial tuberosity	Posterior surface of femur	Adducts, extends, and rotates thigh laterally	Obturator and branch of sciatic n.
Gracilis	Lower edge of symphysis pubis	Medial surface of tibia	Adducts thigh and flexes leg at the knee	Obturator n.

Muscles That Move the Leg

TABLE 9.13 Muscles That Move the Leg

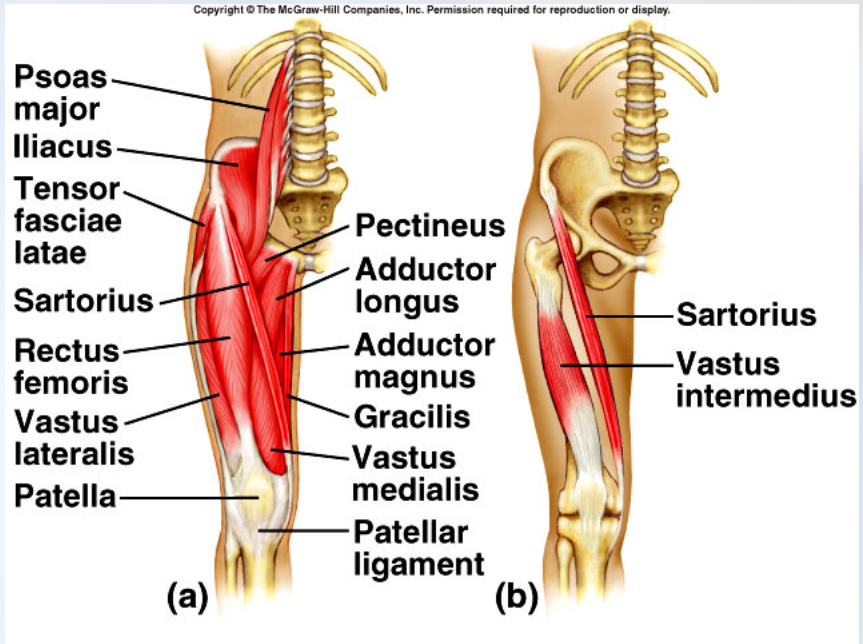
Muscle	Origin	Insertion	Action	Nerve Supply
Hamstring Group				
Biceps femoris	Ischial tuberosity and linea aspera of femur	Head of fibula and lateral condyle of tibia	Flexes and rotates leg laterally and extends thigh	Tibial n.
Semitendinosus	Ischial tuberosity	Medial surface of tibia	Flexes and rotates leg medially and extends thigh	Tibial n.
Semimembranosus	Ischial tuberosity	Medial condyle of tibia	Flexes and rotates leg medially and extends thigh	Tibial n.
Sartorius	Anterior superior iliac spine	Medial surface of tibia	Flexes leg and thigh, abducts and rotates thigh laterally	Femoral n.
Quadriceps Femoris Group				
Rectus femoris	Spine of ilium and margin of acetabulum			
Vastus lateralis	Greater trochanter and posterior surface of femur	Patella by common tendon, which continues as patellar ligament to tibial tuberosity	Extends leg at knee	Femoral n.
Vastus medialis	Medial surface of femur			
Vastus intermedius	Anterior and lateral surfaces of femur			

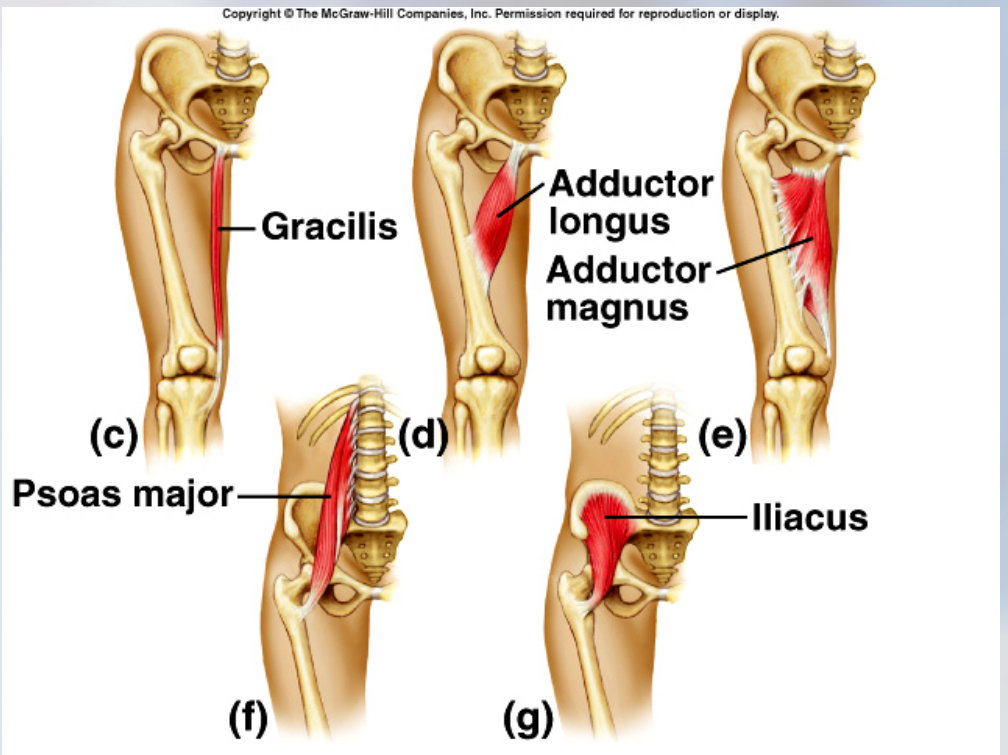
Muscles That Move the Foot

TABLE 9.14 Muscles That Move the Foot

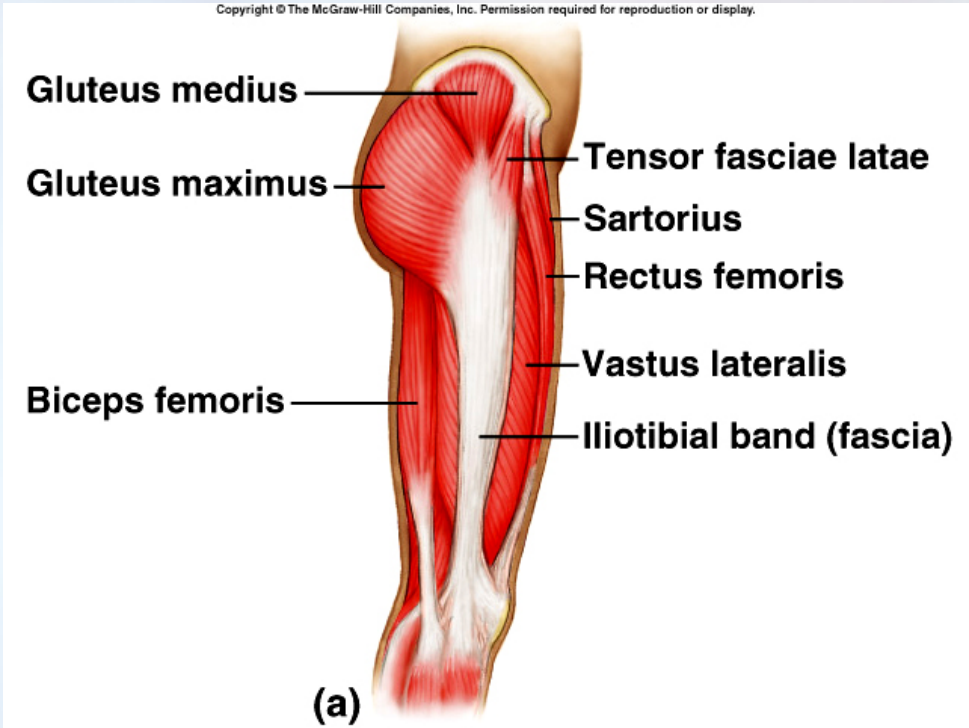
Muscle	Origin	Insertion	Action	Nerve Supply
Tibialis anterior	Lateral condyle and lateral surface of tibia	Tarsal bone (cuneiform) and first metatarsal	Dorsiflexion and inversion of foot	Deep fibular n.
Fibularis tertius	Anterior surface of fibula	Dorsal surface of fifth metatarsal	Dorsiflexion and eversion of foot	Deep fibular n.
Extensor digitorum longus	Lateral condyle of tibia and anterior surface of fibula	Dorsal surfaces of second and third phalanges of four lateral toes	Dorsiflexion and eversion of foot and extension of toes	Deep fibular n.
Gastrocnemius	Lateral and medial condyles of femur	Posterior surface of calcaneus	Plantar flexion of foot and flexion of leg at knee	Tibial n.
Soleus	Head and shaft of fibula and posterior surface of tibia	Posterior surface of calcaneus	Plantar flexion of foot	Tibial n.
Flexor digitorum longus	Posterior surface of tibia	Distal phalanges of four lateral toes	Plantar flexion and inversion of foot and flexion of four lateral toes	Tibial n.
Tibialis posterior	Lateral condyle and posterior surface of tibia and posterior surface of fibula	Tarsal and metatarsal bones	Plantar flexion and inversion of foot	Tibial n.
Fibularis longus	Lateral condyle of tibia and head and shaft of fibula	Tarsal and metatarsal bones	Plantar flexion and eversion of foot; also supports arch	Superficial fibular n.

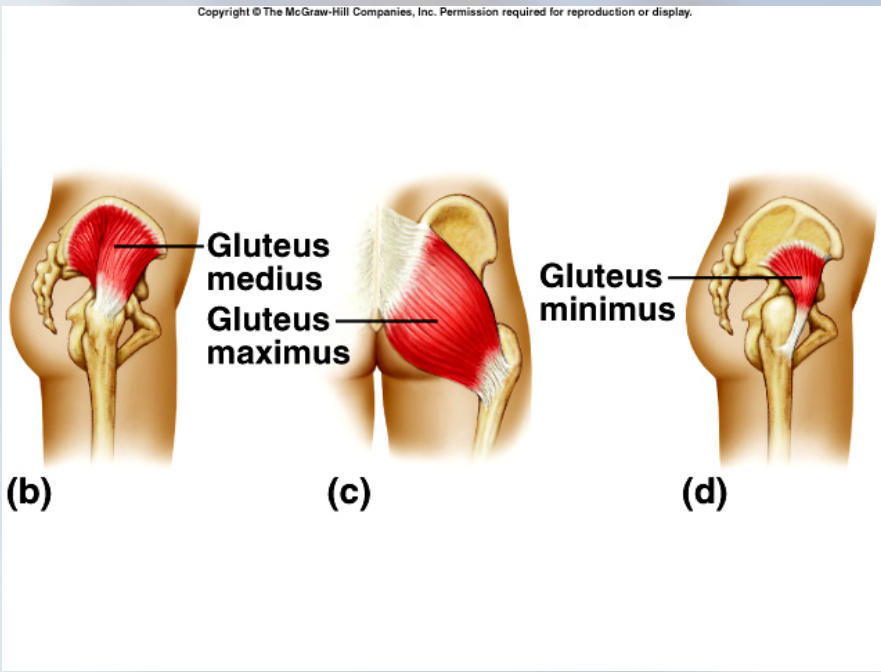
Muscles of the Thigh and Leg



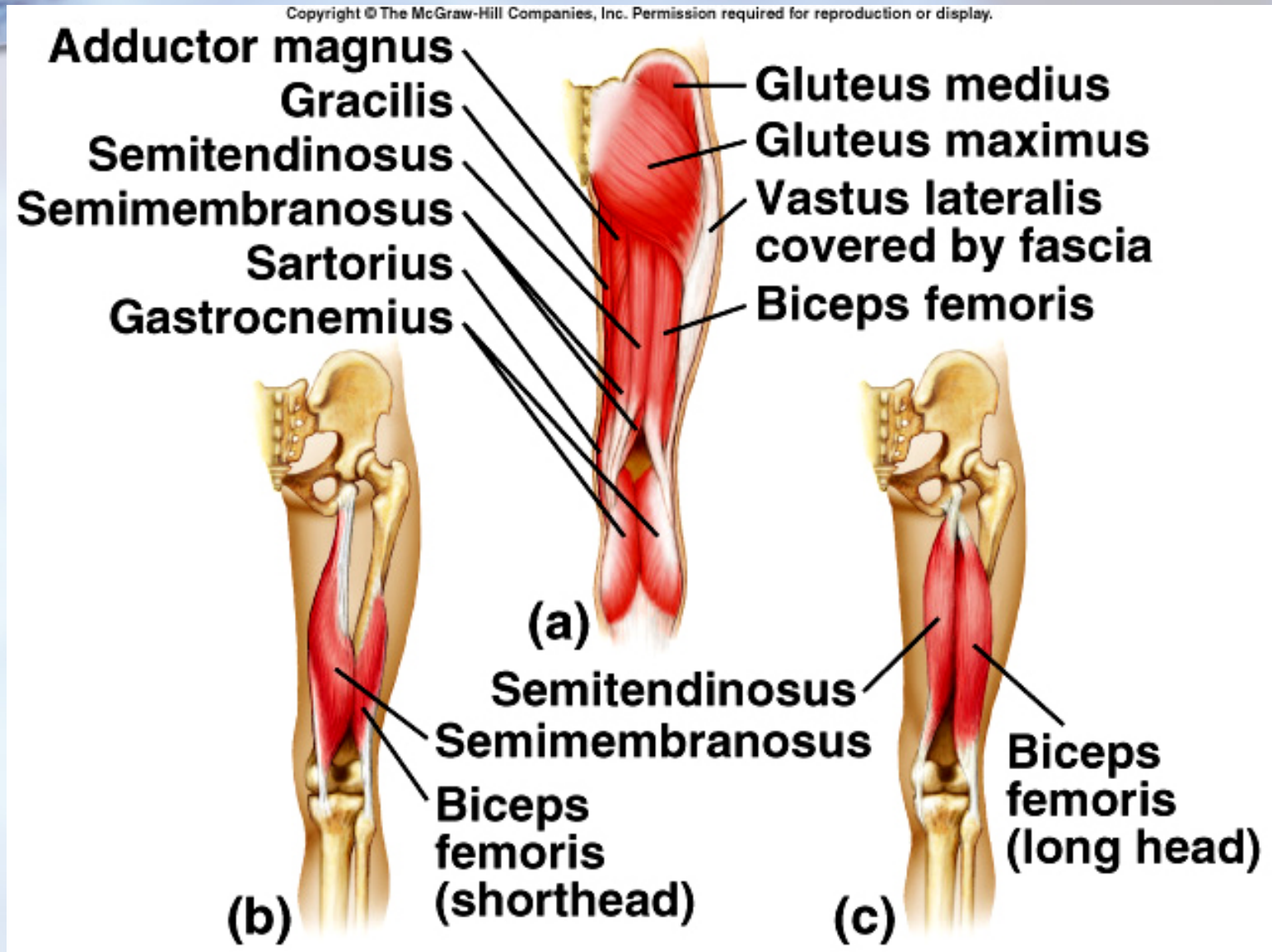


Muscles of the Thigh and Leg

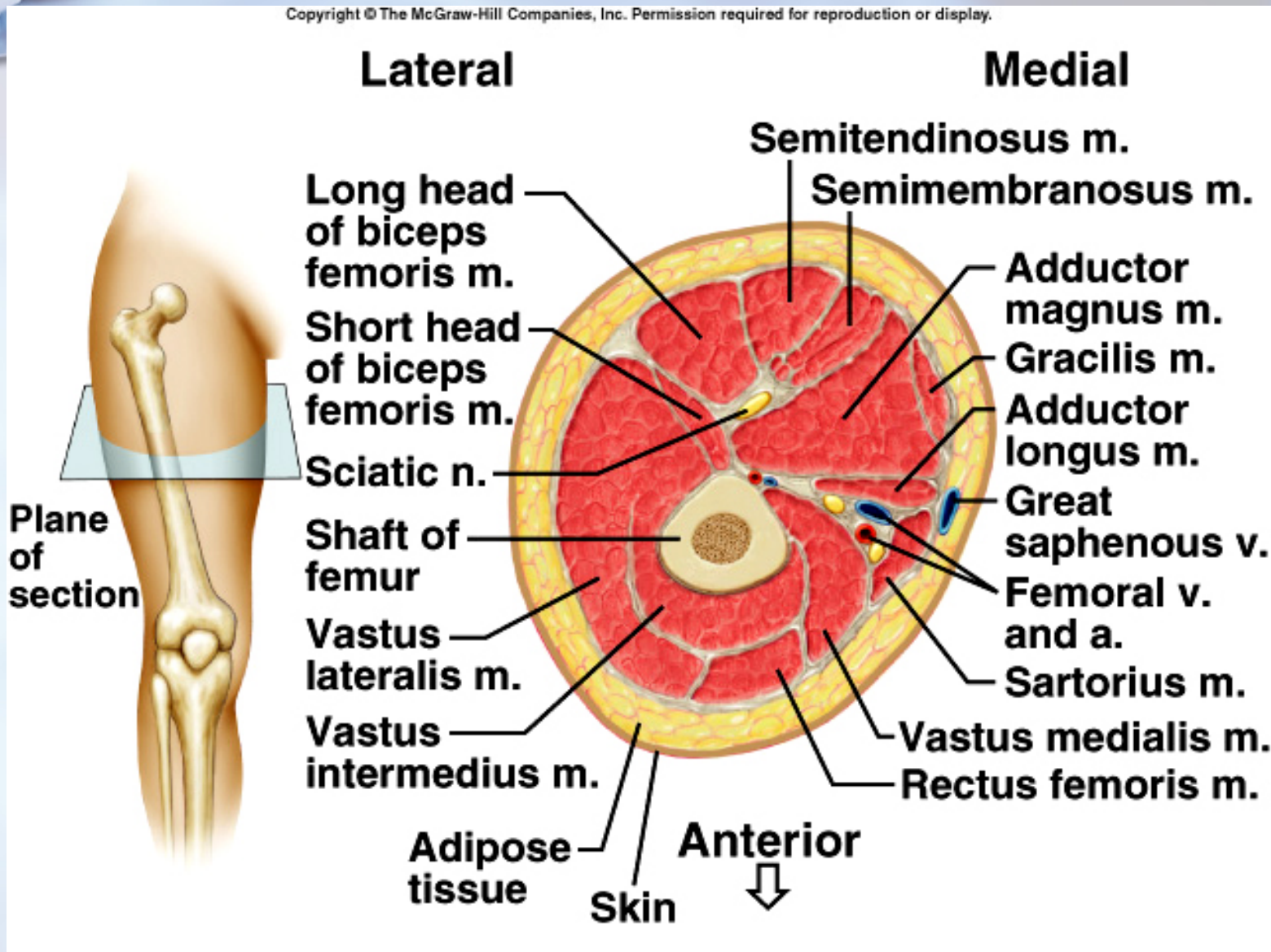




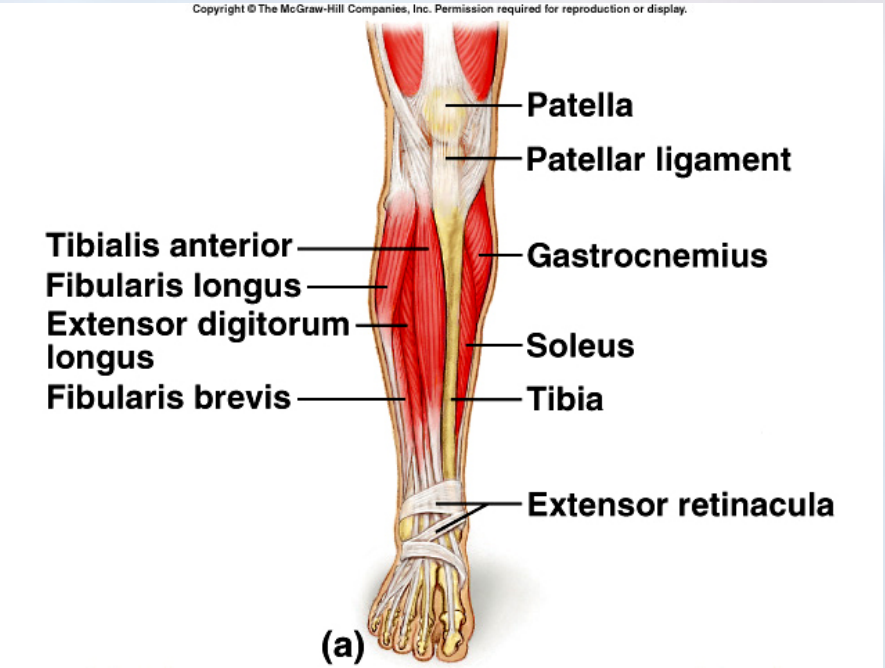
Muscles of the Thigh and Leg

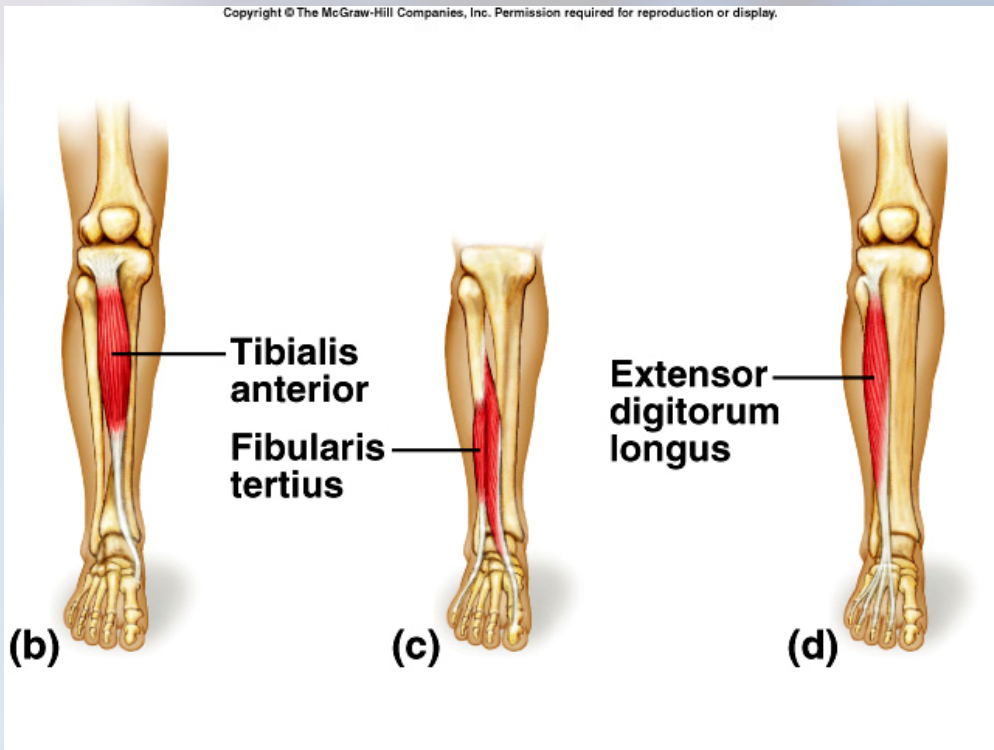


Cross Section of the Thigh

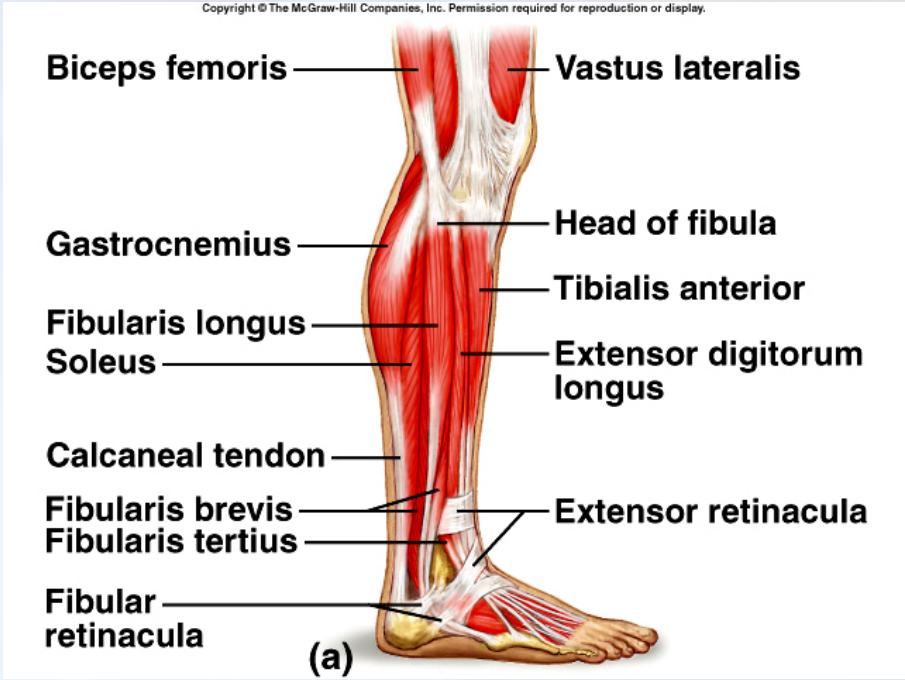


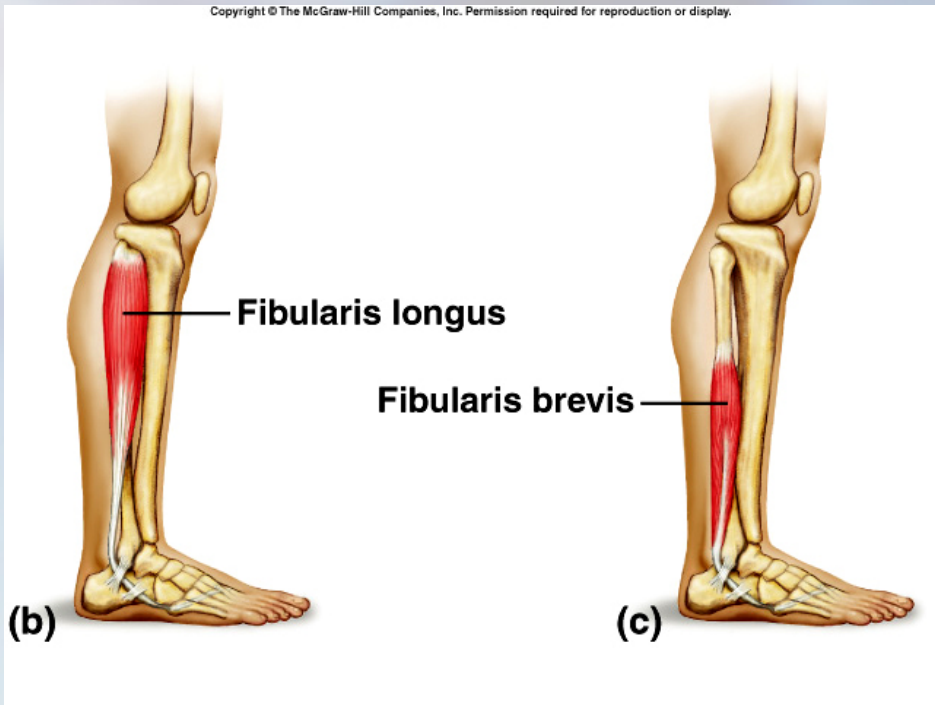
Muscles of the Leg



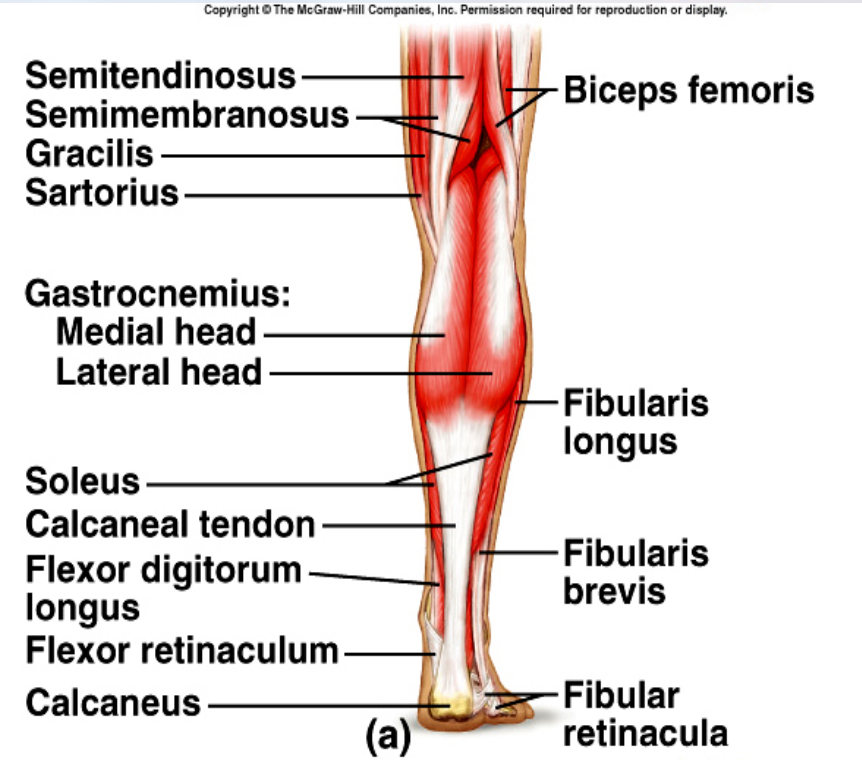


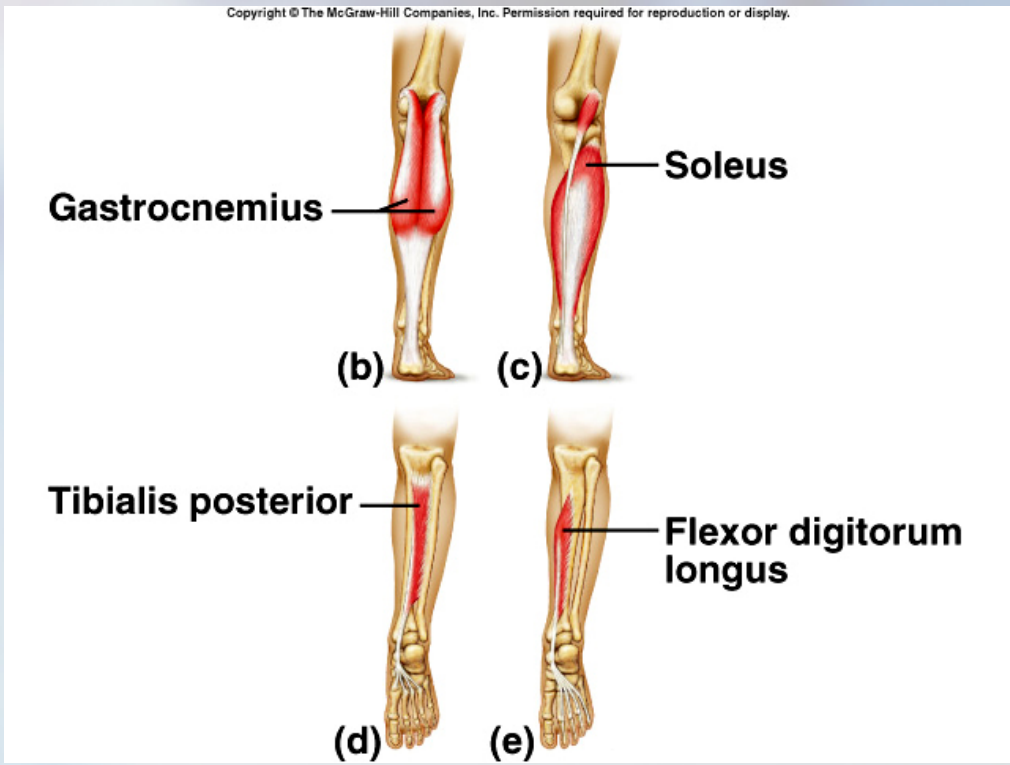
Muscles of the Leg



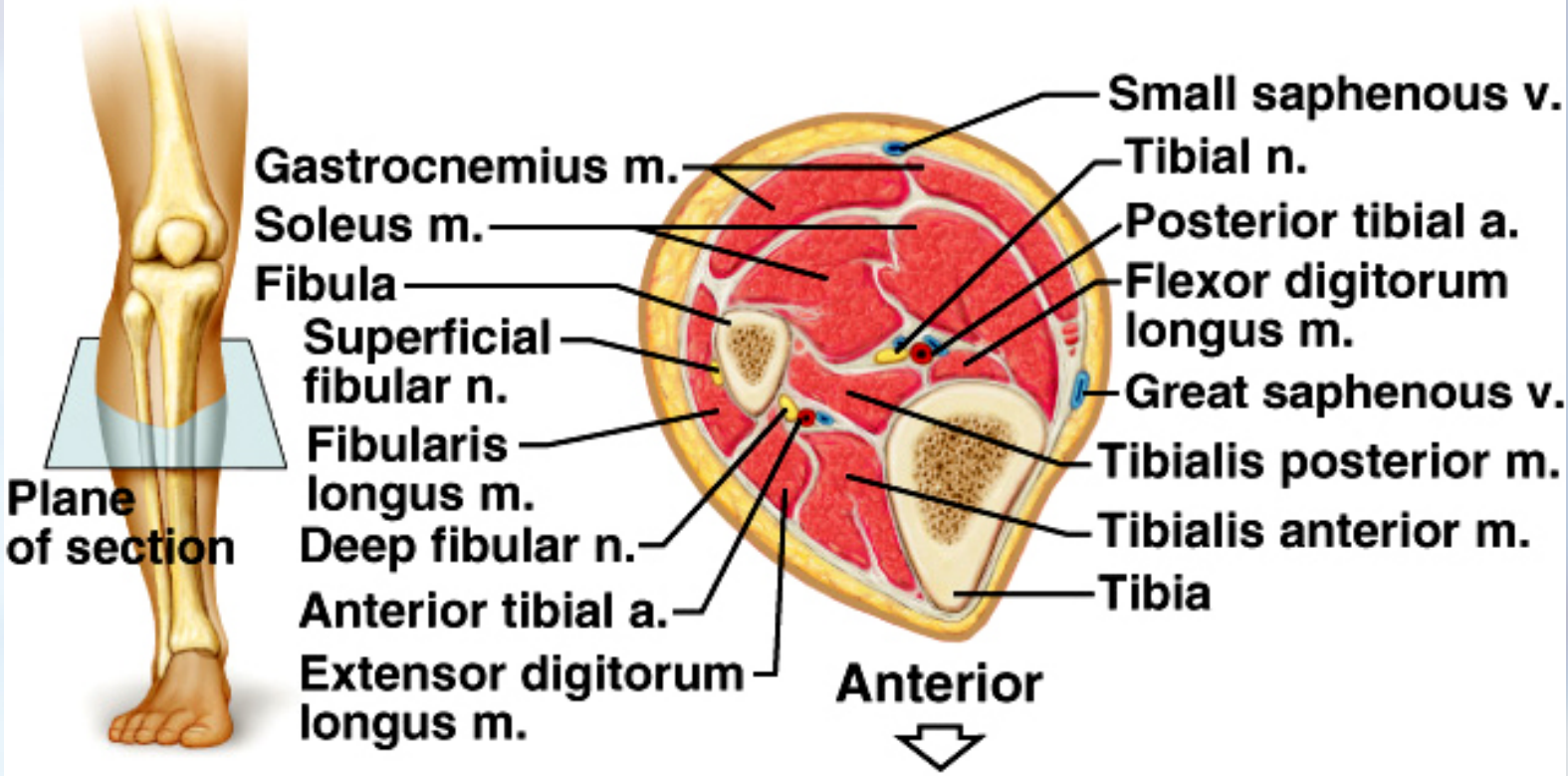


Muscles of the Leg





Cross Section of the Leg



Life-Span Changes

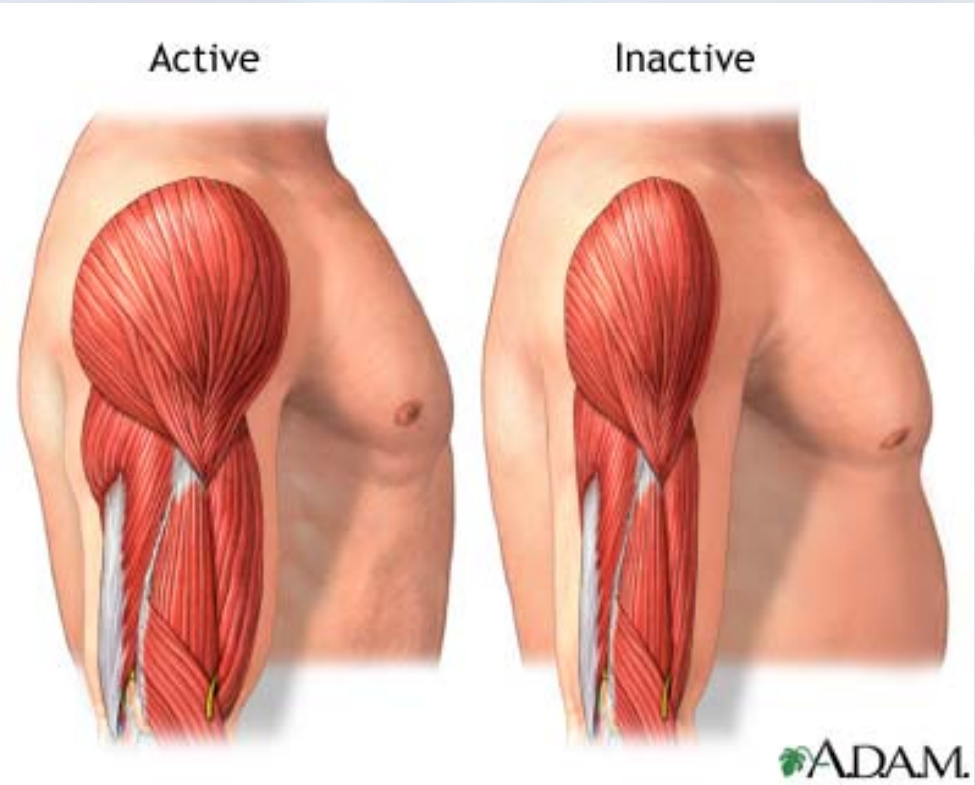
- myoglobin, ATP, and creatine phosphate decline
- by age 80, half of muscle mass has atrophied
- adipose cells and connective tissues replace muscle tissue
- exercise helps to maintain muscle mass and function

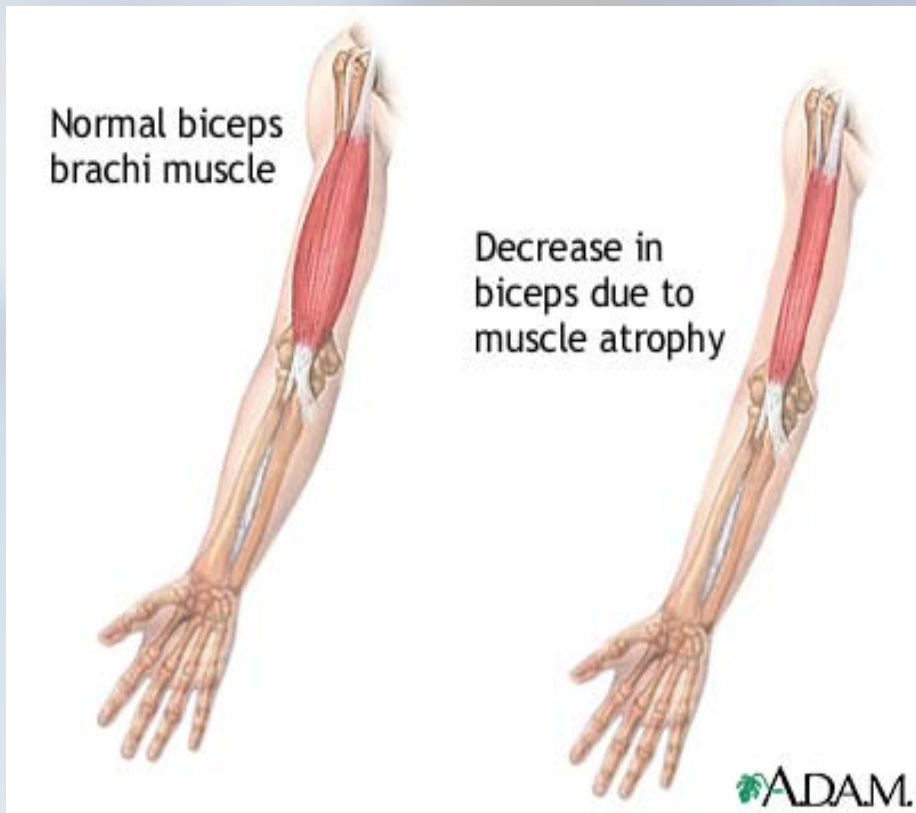
Clinical Application

Myasthenia Gravis

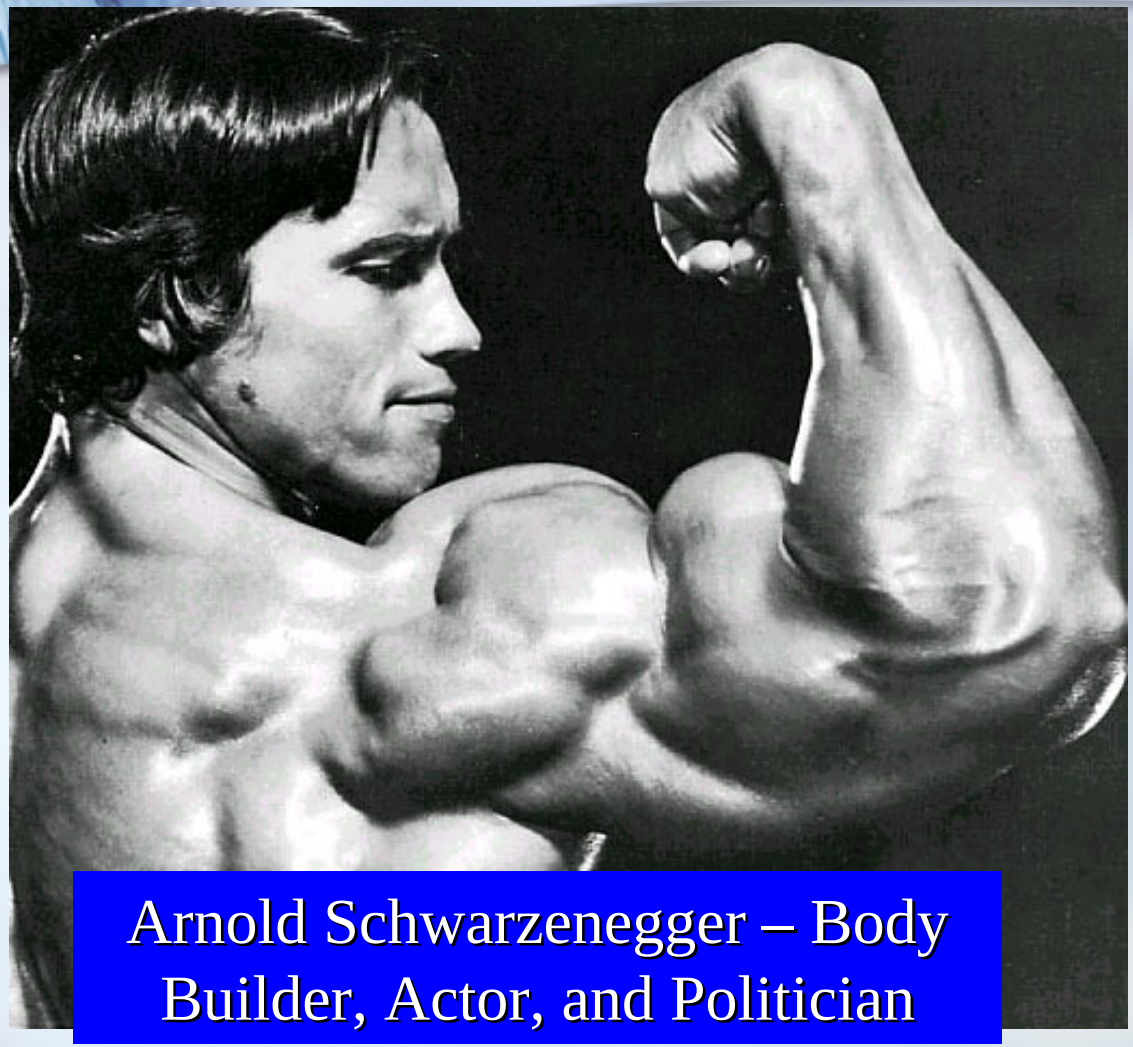
- autoimmune disorder
- receptors for acetylcholine on muscle cells are attacked
- weak and easily fatigued muscles result
- difficulty swallowing and chewing
- ventilator needed if respiratory muscles are affected
- treatments include
  - drugs that boost acetylcholine
  - removing thymus gland
  - immunosuppressant drugs
  - antibodies

Active vs. Inactive Muscle: Muscular Atrophy





Exercise and Diet Stimulates Muscle Development



Arnold Schwarzenegger – Body Builder, Actor, and Politician

Hans and Franz