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Anaphy] Muscular System - Transes

bs nursing (Southwestern University PHINMA)



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[TRANS] ANAPHY CHAPTER 6: Muscular System

MUSCULAR SYSTEM

KEY TERMS

- **Muscles**
  - responsible for all types of body movement

Three Basic Muscle Types in the body:

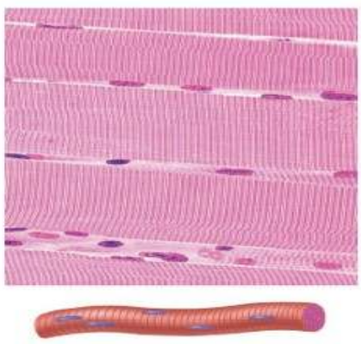
- Skeletal Muscle
- Cardiac Muscle
- Smooth Muscle

MUSCLE TYPES

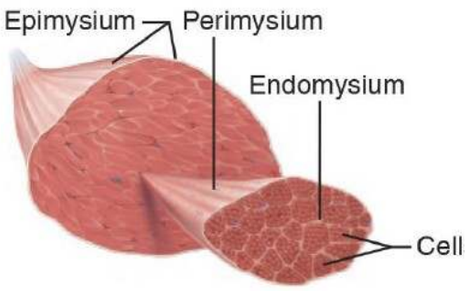
- **Skeletal** and **smooth** muscle cells are elongated (muscle cell = muscle fiber)
- Contraction and shortening of muscles are due to the movement of **microfilaments**
  - **myo-**, **mys-** refer to “muscle”
  - **sacro-** refers to “fresh”

SKELETAL MUSCLE

- **Body Location**
  - Attached to bones, facial muscles, skin
- **Cell Shape and Appearance**



  - Single, very long, cylindrical, multinucleate cells with very obvious striations
- **Connective Tissue Components**



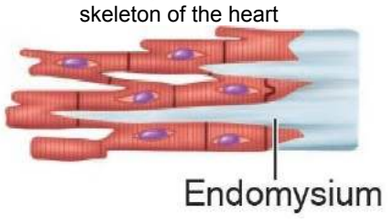
- **Regulation of Contraction**
  - Voluntary
- **Speed of Contraction**
  - Slow to Fast
- **Rhythmic Contraction**
  - No

CARDIAC MUSCLE

- **Body Location**
  - Walls of the heart
- **Cell Shape and Appearance**



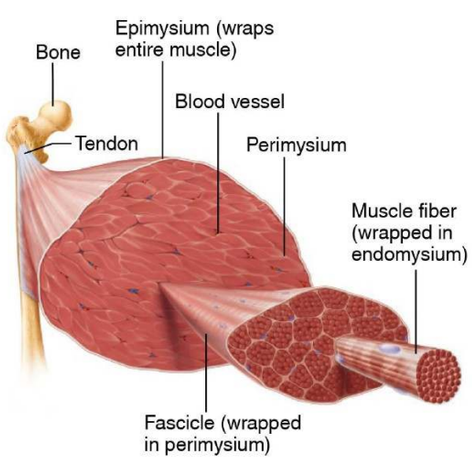
  - Branching chains of cells, uninucleate, striations, intercalated discs
- **Connective Tissue Components**
  - Endomysium attached to the fibrous skeleton of the heart



- **Regulation of Contraction**
  - Involuntary
- **Speed of Contraction**
  - Slow
- **Rhythmic Contraction**
  - Yes

Parts of the Skeletal Muscle

- **Endomysium**
  - encloses a single muscle fiber
- **Perimysium**
  - wraps around a fascicle (bundle) of muscle fibers
- **Epimysium**
  - covers the entire skeletal muscle
- **Fascia**
  - outside of the epimysium



Epimysium

- blends into a connective tissue attachment
- **Tendons**
  - Cordlike structures
  - Mostly collagen fibers

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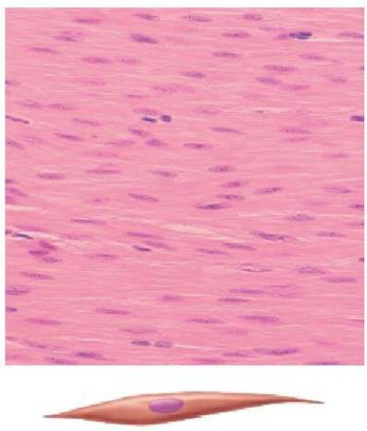
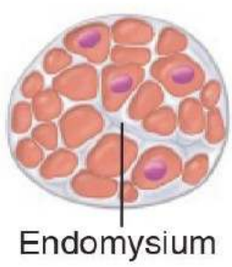
- Often cross a joint because of their toughness and small size
- **Aponeuroses**
  - Sheetlike structures
  - Attach muscles indirectly to bones, cartilages, or connective tissue coverings

SMOOTH MUSCLE

- **Body Location**
  - Walls of hollow **visceral organs**
    - Stomach
    - Urinary bladder
    - Respiratory Passages
- **Cell Shape and Appearance**



  - Single, fusiform, uninucleate, no striations
- **Connective Tissue Components**



- **Regulation of Contraction**
  - Involuntary
- **Speed of Contraction**
  - Very slow
- **Rhythmic Contraction**
  - Yes, in some

MUSCLE FUNCTIONS

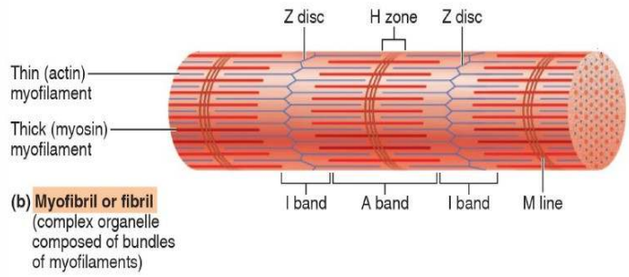
- Maintain posture and body position
- Stabilize joints
- Generate heat

Microscopic anatomy of skeletal muscle

- **Sarcolemma**
  - specialized plasma membrane
- **Myofibrils**
  - long organelles inside muscle cell
  - **Light (I) bands** and **dark (A) bands** give the muscle its striated (banded) appearance

Banding pattern of myofibrils

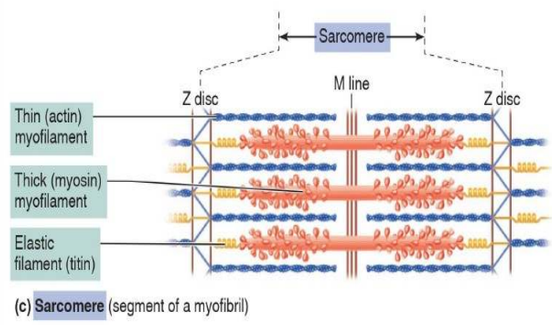
- **I Band** (light band)
  - Contains only thin filaments
  - Z disc is a midline interruption
- **A band** (dark band)
  - Contains the entire length of the thick filaments
  - H zone is a lighter central area
  - M line is in center of H zone



- **Sarcomere**
  - Contractile unit of a muscle fiber
  - Structural and functional unit of skeletal muscle

Organization of sarcomere

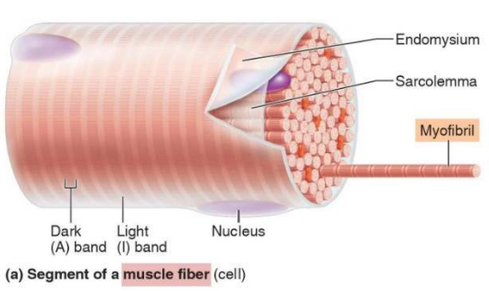
- Myofilaments produce banding (striped) pattern
  - **Thick filaments** = myosin filaments
  - **Thin filaments** = actin filaments
- **Thick Filaments**
  - Composed of myosin
  - Contain ATPase enzymes to split ATP to release energy for muscle contractions
  - Possess projections known as **myosin heads**
- **Cross Bridges**
  - They link thick and thin filaments during contraction
- **Thin Filaments**
  - Composed of contractile protein **actin**
    - Anchored to **Z disc**
  - **H zone**
    - zone that lacks actin filaments within A band
    - disappear as actin; myosin filaments overlap



- **Sarcoplasmic reticulum (SR)**
  - Specialized smooth endoplasmic reticulum
  - Surrounds the myofibril
  - Stores and releases calcium
    - Calcium provides the final "go" for contraction

Special functional properties of skeletal muscles

- **Irritability** (also called responsiveness)
  - ability to receive and respond to a stimulus



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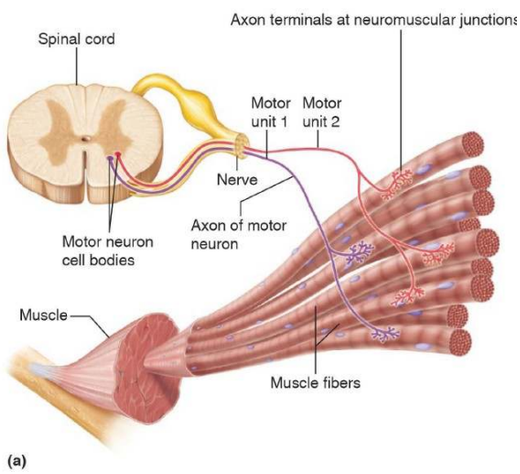
- **Contractility**
  - ability to forcibly shorten when an adequate stimulus is received
- **Extensibility**
  - ability of muscle cells to be stretched
- **Elasticity**
  - ability to recoil and resume resting length after stretching

NERVE STIMULUS AND ACTION POTENTIAL

- Skeletal muscles must be stimulated by a motor neuron (nerve cell) to contract
- **Motor unit**
  - one motor neuron and all the skeletal muscle cells stimulated by that neuron
- **Neuromuscular Junction**
  - Association site of axon terminal of the motor neuron and sarcolemma of a muscle
- **Neurotransmitter**
  - Chemical released by nerve upon arrival of nerve impulse in the axon terminal
  - **Acetylcholine** (Ach)
    - neurotransmitter that stimulates skeletal muscle
- **Synaptic Cleft**
  - Gap between nerve and muscle filled with interstitial fluid
    - Although very close, the nerve and muscle do not make contact



(a)

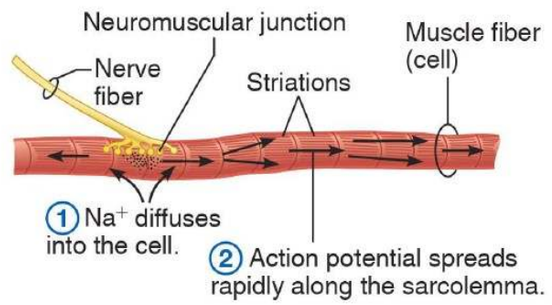
Events at the neuromuscular junction

- **Step 1**
  - Nerve impulse reaches the **axon terminal** of the motor neuron
- **Step 2**
  - **Calcium channels** open, and calcium ions enter the axon terminal
- **Step 3**
  - Calcium ion entry causes some synaptic vesicles to release **acetylcholine** (ACh)
- **Step 4**
  - ACh diffuses across the synaptic cleft and attaches to receptors on the sarcolemma of the muscle cell
- **Step 5**
  - If enough ACh is released, the sarcolemma becomes temporarily more permeable to sodium ions (Na^+)
  - More sodium ions enter than potassium ions leave
  - Entry of sodium ions produces an imbalance in which interior has more positive ions (depolarization), thereby opening more Na^+ channels
- **Step 6**
  - Depolarization opens more sodium channels that allow sodium ions to enter the cell
  - An action potential is created
  - Once begun, the action potential is unstoppable
  - Conducts the electrical impulse from one end of the cell to the other
- **Step 7**
  - Acetylcholinesterase (AChE) breaks down acetylcholine into acetic acid and choline
  - AChE ends muscle contraction
    - A single nerve impulse produces only one contraction

CELL RETURNS TO ITS RESTING STATE WHEN

- Potassium ions (K^+) diffuse out of the cell
- Sodium-potassium pump moves sodium and potassium ions back to their original positions

ACTION POTENTIAL PROCESS



(b)

Sliding filament theory

OCCURS WHEN:

- Calcium ions ($Ca2^+$) bind regulatory proteins on thin filaments and expose myosin-binding sites, allowing the myosin heads on the thick filaments to attach
- Each cross-bridge pivots, causing the thin filaments to slide toward the center of the sarcomere
- Contraction occurs, and the cell shortens
- During a contraction, a cross bridge attaches and detaches several times
- ATP provides the energy for the sliding process, which continues as long as calcium ions are present

Graded responses

- different degrees of skeletal muscle shortening
- **Muscle Fiber Contraction**
  - “all-or-none”
  - the muscle fiber (not the whole muscle) will contract to its fullest extent when stimulated adequately

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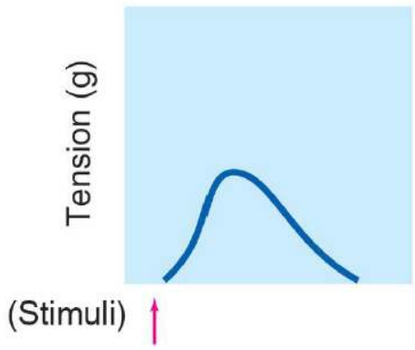
GRADED RESPONSES CAN BE PRODUCED IN **TWO WAYS:**

- changing the **frequency** of muscle stimulation
- changing the **number** of muscle cells being stimulated at one time

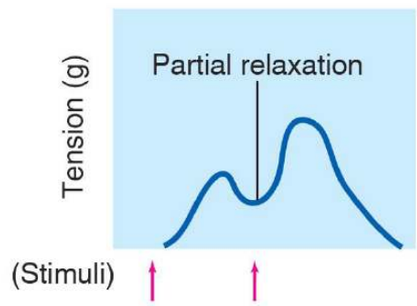
MUSCLE RESPONSE TO INCREASINGLY RAPID STIMULATION

- **Muscle Twitches**
  - Single, brief, jerky contraction
  - Not a normal muscle function



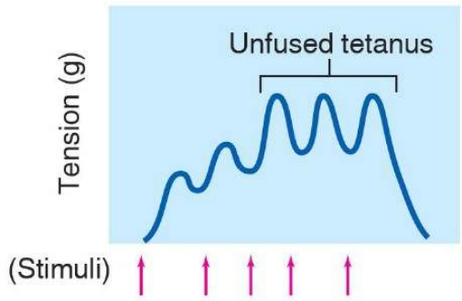
(a) Twitch

- **Summed Contraction**
  - nerve impulses are delivered at a rapid rate
  - contractions are “summed” (added) together; one contraction is immediately followed by another



(b) Summing of contractions

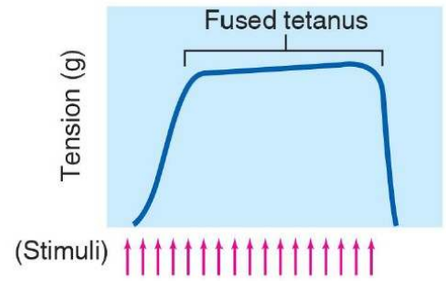
- **Unfused Tetanus**



(c) Unfused (incomplete) tetanus

  - Partial relaxation between stimuli
  - contractions are stronger and smoother

- **Fused Tetanus**
  - No relaxation between stimuli
  - Smooth, sustained contraction



(d) Fused (complete) tetanus

MUSCLE RESPONSE TO STRONGER STIMULI

- Muscle force depends upon the number of fibers stimulated
- Contraction of more fibers results in greater muscle tension
- When all motor units are active and stimulated, the muscle contraction is as strong as it can get
-

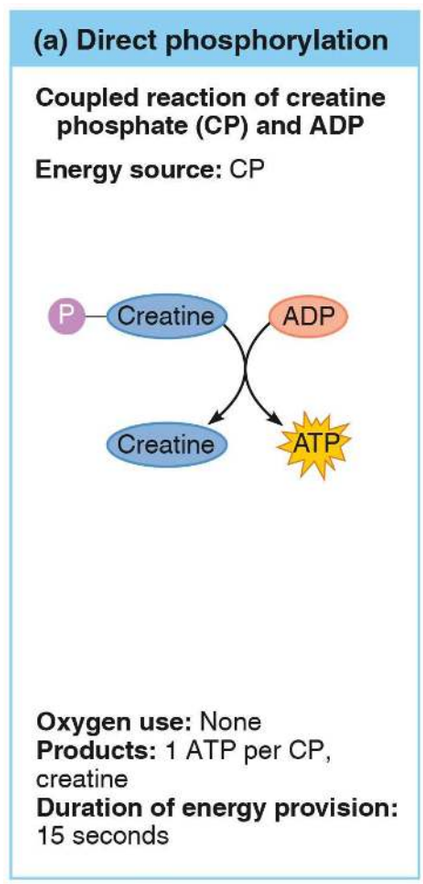
ADENOSINE Triphosphate

- Only energy source that can be used to directly power muscle contraction
- Stored in muscle fibers in small amounts that are quickly used up

THREE PATHWAYS TO GENERATE ATP

1. Direct phosphorylation of ADP by creatine phosphate
2. Aerobic pathway
3. Anaerobic glycolysis and lactic acid formation

Direct phosphorylation of ADP by



creatine phosphate

- “fastest”
- Creatine Phosphate
  - High-energy molecule

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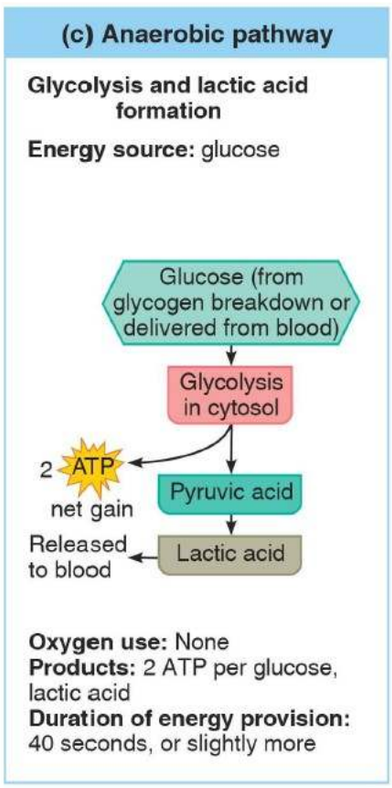
- Transfers a phosphate group to ADP to generate ATP
- Supplies are exhausted in less than 15 seconds

- After ATP is depleted, ADP remains
- 1 ATP is produced per Creatine Phosphate molecule

AEROBIC RESPIRATION



- Supplies ATP at rest and during light/moderate exercise
- **Oxidative Phosphorylation**
  - Series or metabolic pathways that use oxygen; occurs in mitochondria
- **Glucose**
  - broken down into **Carbon Dioxide** and **Water**
  - releases energy (32 ATP)
- Slower reaction

Anaerobic glycolysis and lactic acid formation

- Reaction that breaks down glucose without oxygen
- **Glucose**
  - broken down to pyruvic acid
  - produce 2 ATP
- **Pyruvic acid**
  - converted to lactic acid

MUSCLE FATIGUE AND OXYGEN DEFICIT

- **Muscle Fatigue**
  - Occurs when muscle activity is strenuous and prolonged
- **Suspected Factors that contribute Muscle Fatigue**
  - Ion imbalances
  - Oxygen deficit and lactic acid accumulation
  - Decrease in energy (ATP) supply
- After exercise, the oxygen deficit is repaid by rapid, deep breathing

TYPES OF MUSCLE CONTRACTIONS

Isotonic Contractions

- "Same tone" or tension
- Myofilaments are able to slide past each other during contractions
- The muscle shortens; movement occurs
  - Examples: bending the knee, lifting weights, smiling

Isometric Contractions

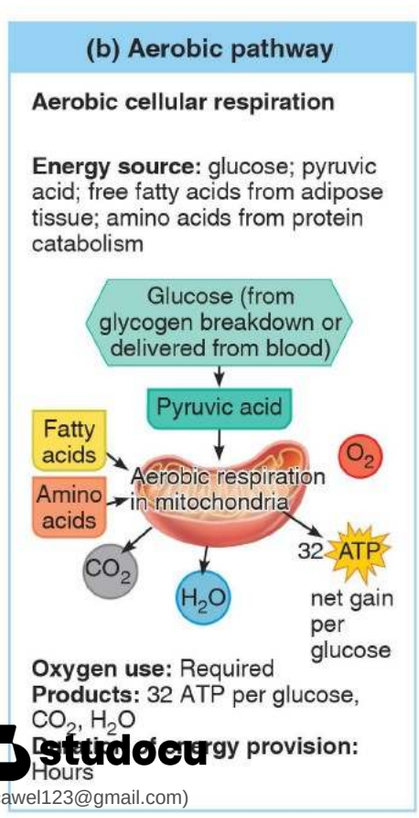
- Muscle filaments are trying to slide, but the muscle is pitted against an immovable object
- Tension increases; muscles do not shorten
  - Example: pushing your palms together in front of you

Muscle Tone

- State of continuous partial contractions
- Result of different motor units being stimulated in a systematic way
- remains firm, healthy, and constantly ready for action

effect of exercise on muscles

- increases muscle size, strength, and endurance



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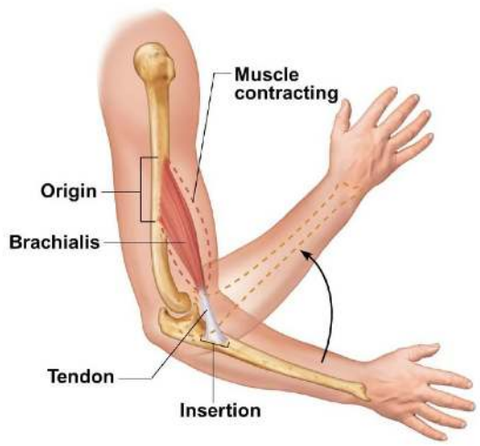
- **Aerobic Exercise** (endurance)
  - Results in stronger, more flexible muscles with greater resistance to fatigue (biking, jogging)
  - More efficient body metabolism
  - Improves digestion, coordination
- **Resistance Exercise** (isometric)
  - Increases muscle size and strength (weight lifting)
  - Individual muscle fibers enlarge

Muscle Movements, Roles, and Names

FIVE GOLDEN RULES OF SKELETAL MUSCLE ACTIVITY
1. With a few exceptions, all skeletal muscles cross at least one joint.
2. Typically, the bulk of a skeletal muscle lies proximal to the joint crossed.
3. All skeletal muscles have at least two attachments: the origin and the insertion.
4. Skeletal muscles can only pull; they never push.
5. During contraction, a skeletal muscle insertion moves toward the origin

- Muscles are attached to no fewer than two points
- **Origin**
  - Attachment to an immovable or less movable bone
- **Insertion**
  - Attachment to a movable bone
- When the muscle contracts, the insertion moves toward the origin
- Body movement occurs when muscles contract across joints



types of body movements

SPECIAL MOVEMENTS

- Certain movements do not fit into any of the previous categories
- occur at only a few joints.

flexion

- Decreases the angle of the joint
- Brings two bones closer together
- Typical of bending **hinge joints** (e.g., knee and elbow) **or ball-and-socket joints** (e.g., the hip)

Extension

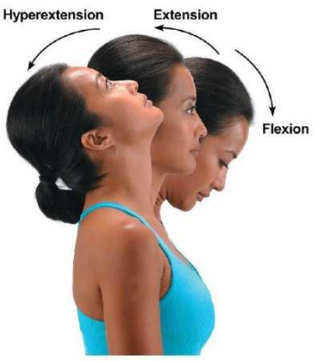
- Opposite of flexion
- Increases the angle between two bones
- Typical of straightening the elbow or knee

Hyperextension

- extension beyond 180°



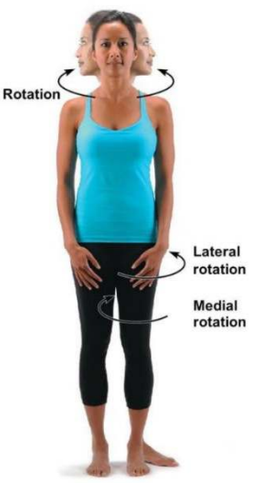
(a) Flexion, extension, and hyperextension of the shoulder and knee



(b) Flexion, extension, and hyperextension

rotation

- Movement of a bone around its longitudinal axis
- Common in ball-and-socket joints
- Example: moving the atlas around the dens of axis (i.e., shaking your head “no”)



(c) Rotation

abduction

- Movement of a limb away from the midline

Adduction

- Movement of a limb toward the midline

Circumduction

- Combination of flexion, extension, abduction, and adduction
- Common in ball-and-socket joints
- Proximal end of bone is stationary, and distal end moves in a circle

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(d) Abduction, adduction, and circumduction

Dorsiflexion

- Lifting the foot so that the superior surface approaches the shin (toward the dorsum)

Plantar flexion

- Pointing the toes away from the head



(e) Dorsiflexion and plantar flexion

Inversion

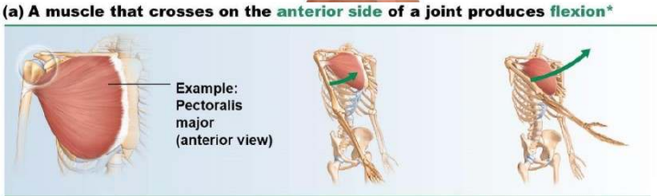
- Turning sole of foot medially

Eversion

- Turning sole of foot laterally



(a) A muscle that crosses on the anterior side of a joint produces flexion*



*These generalities are reversed for the knee and ankle because the lower limb is rotated during development. The muscles that cross these joints posteriorly produce flexion, and those that cross anteriorly produce extension.

Supination

- Forearm rotates laterally so palm faces anteriorly
- Radius and ulna are parallel

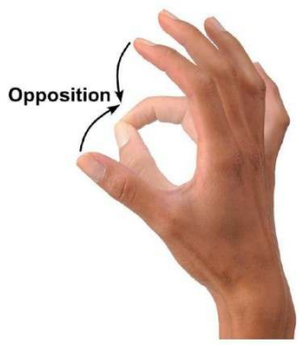




Pronation

- Forearm rotates medially so palm faces posteriorly
- Radius and ulna cross each other like an X





(h) Opposition

Opposition

- Moving the thumb to touch the tips of other fingers on the same hand

Interactions of Skeletal Muscles in the Body

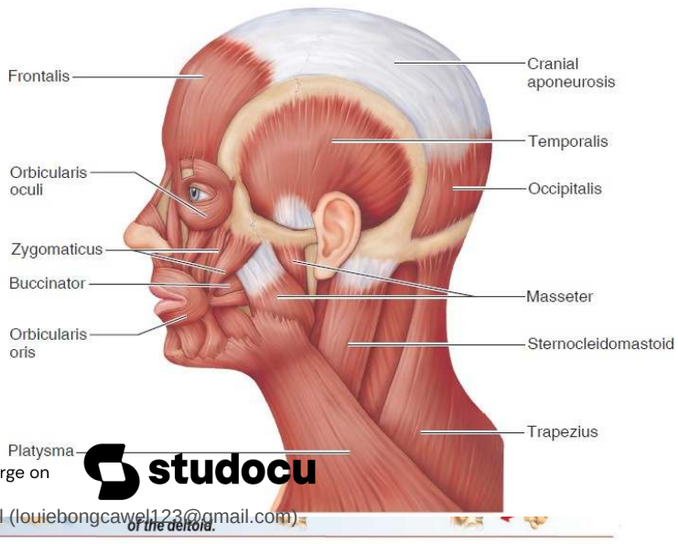
- Muscles can only pull as they contract—not push
- In general, groups of muscles that produce opposite actions lie on opposite sides of a joint

- **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 or reducers undesirable movements
- **Fixator**
  - specialized synergists that hold a bone still or stabilize the origin of a prime move

naming skeletal muscles

Criteria for naming muscles

- **Direction of Muscle Fibers**



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- Ex. rectus (straight)
- **Relative size of the Muscle**
  - Ex. maximus (largest)
- **Location of the Muscle**
  - Ex. temporalis (temporal bone)
- **Number of Origins**
  - Ex. triceps (three heads)
- **Location of the Muscle's Origin and Insertion**
  - Ex. sterno (on the sternum)
- **Shape of the Muscle**
  - Ex. deltoid (triangular)
- **Action of the Muscle**
  - Ex. flexor and extensor (flexes or extends a bone)

Arrangement of fascicles

Common patterns of fascicle arrangement

- **Circular**
  - Concentric rings
- **Convergent**
  - Converge on a single insertion tendon
- **Parallel**
  - Length of fascicles run parallel to the long axis of the muscle
- **Fusiform**
  - Modified parallel arrangement resulting in a spindle-shaped muscle
- **Pennate**
  - Short fascicles attach obliquely to a central tendon

Gross anatomy of skeletal muscles

Superficial Anterior Muscles of the Body

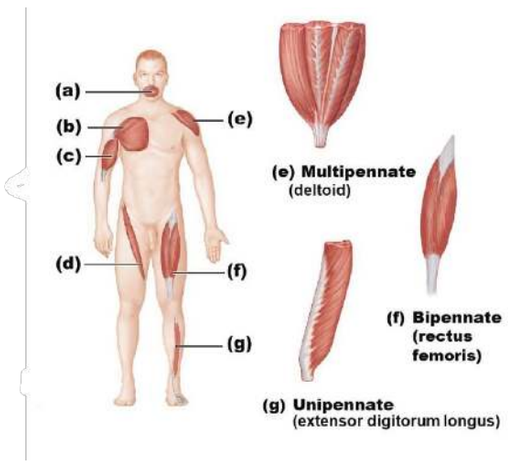
Head/neck muscles

frontalis

- **Origin:** cranial aponeurosis
- **Insertion:** skin of eyebrows
- **Primary Action(s):** raises eyebrows

Orbicularis oculi

- **Origin:** frontal bone and maxilla
- **Insertion:** tissue around eyes
- **Primary Action(s):** blinks and closes eye



Orbicularis oris

- **Origin:** mandible and maxilla
- **Insertion:** skin and muscle around mouth
- **Primary Action(s):** closes and protrudes lips

temporalis

- **Origin:** temporal bone
- **Insertion:** mandible
- **Primary Action(s):** closes jaw

zygomaticus

- **Origin:** zygomatic bone
- **Insertion:** skin and muscle at corner of lips
- **Primary Action(s):** raises corner of mouth

masseter

- **Origin:** temporal bone
- **Insertion:** mandible
- **Primary Action(s):** closes jaw

buccinator

- **Origin:** maxilla and mandible near molars
- **Insertion:** orbicularis oris
- **Primary Action(s):** compresses cheek (as in sucking); holds food between teeth during chewing

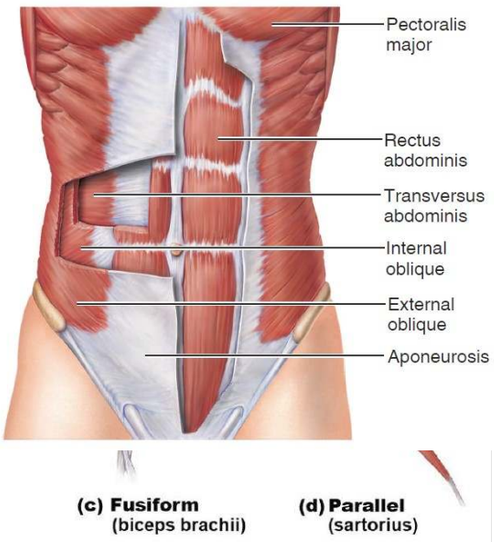
Sternocleidomastoid

- **Origin:** sternum and clavicle
- **Insertion:** temporal bone (mastoid process)
- **Primary Action(s):** flexes neck; laterally rotates head

platysma

- **Origin:** connective tissue covering of superior chest muscles
- **Insertion:** tissue around mouth
- **Primary Action(s):** tenses skin of neck (as in shaving)

Trunk muscles



Pectoralis major

- **Origin:** sternum, clavicle, and 1st and 6th ribs
- **Insertion:** proximal humerus
- **Primary Action(s):** adducts and flexes humerus

Rectus abdominis

- **Origin:** pubis
- **Insertion:** sternum and 5th to 7th ribs
- **Primary Action(s):** flexes vertebral column

External oblique

- **Origin:** lower eight ribs
- **Insertion:** iliac crest
- **Primary Action(s):** flexes and rotates vertebral column

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ARM/SHOULDER MUSCLES

Biceps brachii

- **Origin:** scapula of shoulder girdle
- **Insertion:** proximal radius
- **Primary Action(s):** flexes elbow and supinates forearm

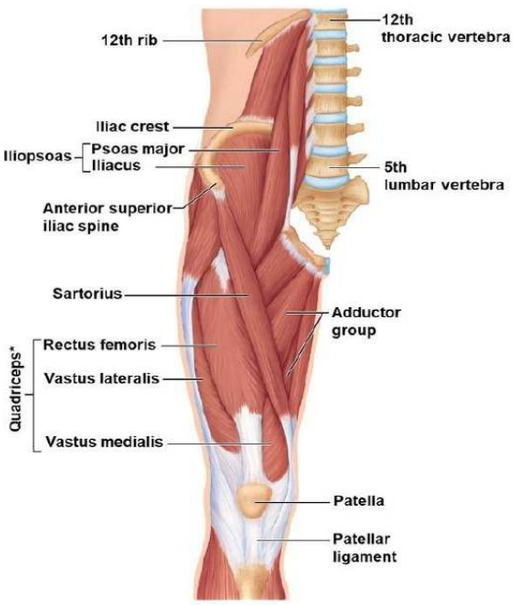
brachialis

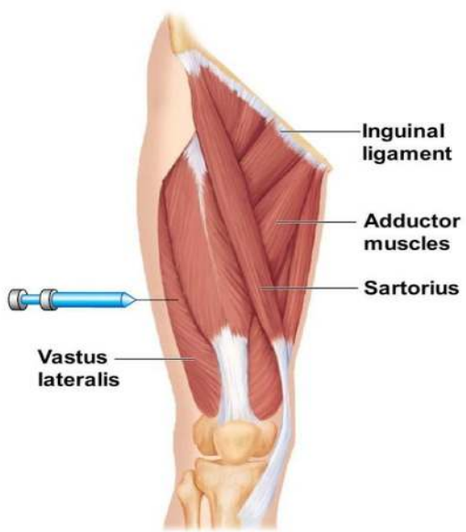
- **Origin:** distal humerus
- **Insertion:** proximal ulna
- **Primary Action(s):** flexes elbow

deltoid

- **Origin:** scapular spine and clavicle
- **Insertion:** humerus (deltoid tuberosity)
- **Primary Action(s):** abducts arm

Hip/thigh/leg muscles





iliopsoas

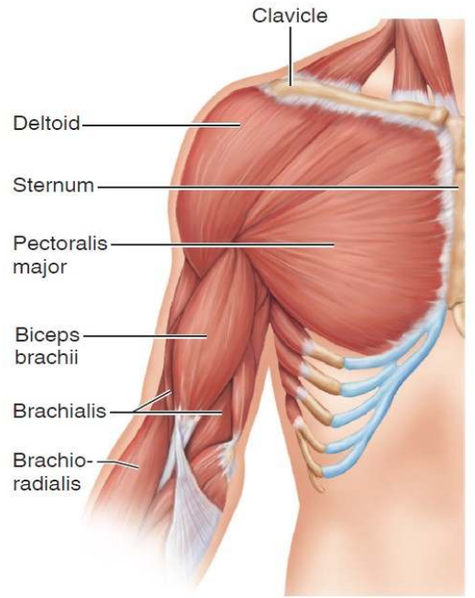
- **Origin:** ilium and lumbar vertebrae
- **Insertion:** femur (lesser trochanter)
- **Primary Action(s):** flexes hip

Adductor muscles

- **Origin:** pelvis
- **Insertion:** proximal femur
- **Primary Action(s):** adduct and medially rotate thigh

sartorius

- **Origin:** ilium
- **Insertion:** proximal tibia
- **Primary Action(s):** flexes thigh on hip



Quadriceps group (vastus medialis, intermedius, lateralis, rectus femoris)

- **Origin:** Vasti: femur
  Rectus femoris: pelvis
- **Insertion:** tibial tuberosity via patellar ligament
- **Primary Action(s):** all extend knee; rectus femoris flexes hip on thigh

Tibialis anterior

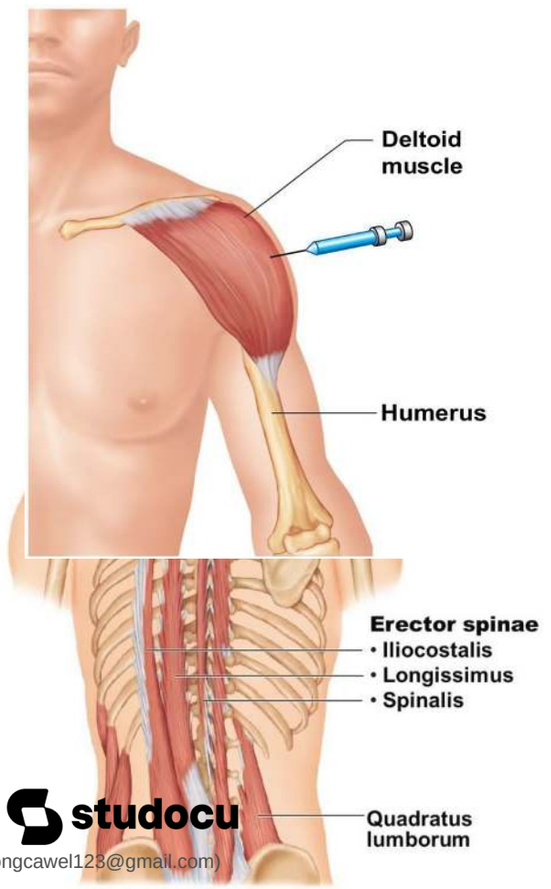
- **Origin:** proximal tibia
- **Insertion:** first cuneiform (tarsal) and first metatarsal on foot
- **Primary Action(s):** dorsiflexes and inverts foot

Extensor digitorum longus

- **Origin:** proximal tibia and fibula
- **Insertion:** distal toes 2-5
- **Primary Action(s):** extends toes

Fibularis muscles

- **Origin:** fibula
- **Insertion:** metatarsals of foot



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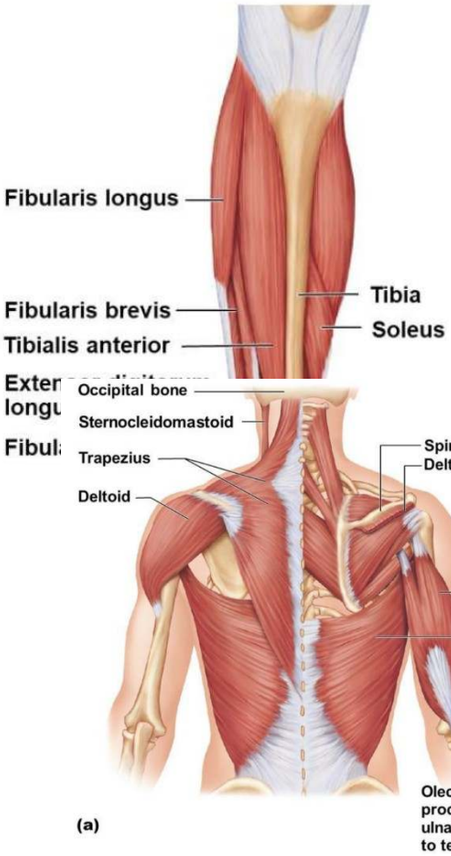


- **Primary**

Action(s): plantar flex and evert foot

SUPERFICIAL POSTERIOR MUSLES OF THE BODY

HEAD/NECK/TRUNK/SHOULDER MUSCLES

OCCIPITALIS

- **Origin:** occipital and temporal bones
- **Insertion:** cranial aponeurosis
- **Primary Action(s):** fixes aponeurosis and pulls scalp posteriorly

trapezius

- **Origin:** occipital bone and all cervical and thoracic vertebrae
- **Insertion:** scapular spine and clavicle
- **Primary Action(s):** raises, retracts, and rotates scapula

Latissimus dorsi

- **Origin:** lower spine and iliac crest
- **Insertion:** proximal humerus
- **Primary Action(s):** extends and adducts humerus

Erector spinae*

- **Origin:** iliac crests, ribs 3-12, and vertebrae
- **Insertion:** ribs, thoracic and cervical vertebrae
- **Primary Action(s):** extends and laterally flexes spine

Quadratus lumborum*

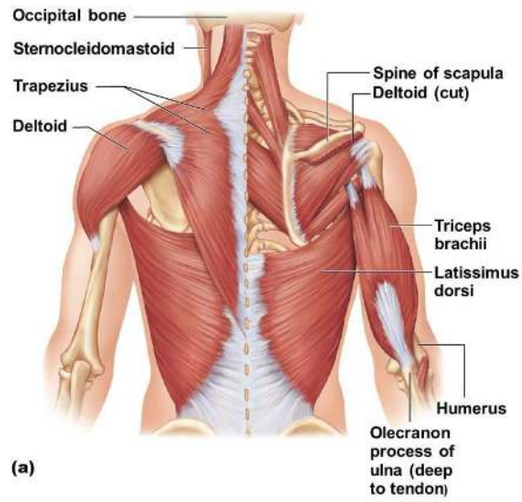
- **Origin:** iliac crest, lumbar fascia
- **Insertion:** transverse processes of upper lumbar vertebrae
- **Primary Action(s):** flexes spine laterally, extends spine

deltoid

- **Origin:** scapular spine and clavicle
- **Insertion:** humerus (deltoid tuberosity)
- **Primary Action(s):** abducts humerus

*Erector spinae and quadratus lumborum are **deep muscles**

Arm/forearm muscles



TRICEPS BRACHII

- **Origin:** shoulder girdle and proximal humerus
- **Insertion:** olecranon process of ulna
- **Primary Action(s):** extends elbow

Flexor carpi radialis

- **Origin:** distal humerus
- **Insertion:** second and third metacarpals
- **Primary Action(s):** flexes wrist and abducts hand

Flexor carpi ulnaris

- **Origin:** distal humerus and posterior ulna
- **Insertion:** carpals of wrist and fifth metacarpal
- **Primary Action(s):** flexes wrist and adducts hand

Flexor digitorium superficialis*

- **Origin:** distal humerus, ulna, and radius
- **Insertion:** middle phalanges of second to fifth fingers
- **Primary Action(s):** flexes wrist and fingers

Extensor carpi radialis

- **Origin:** humerus
- **Insertion:** base of second and third metacarpals
- **Primary Action(s):** extends wrist and abducts hand

Extensor digitorum

- **Origin:** distal humerus
- **Insertion:** distal phalanges of second to fifth fingers
- **Primary Action(s):** extends fingers

*Although its name indicates that it is a superficial muscle, the flexor digitorum superficialis lies deep to the flexor carpi
radialis and is not visible in a superficial view.

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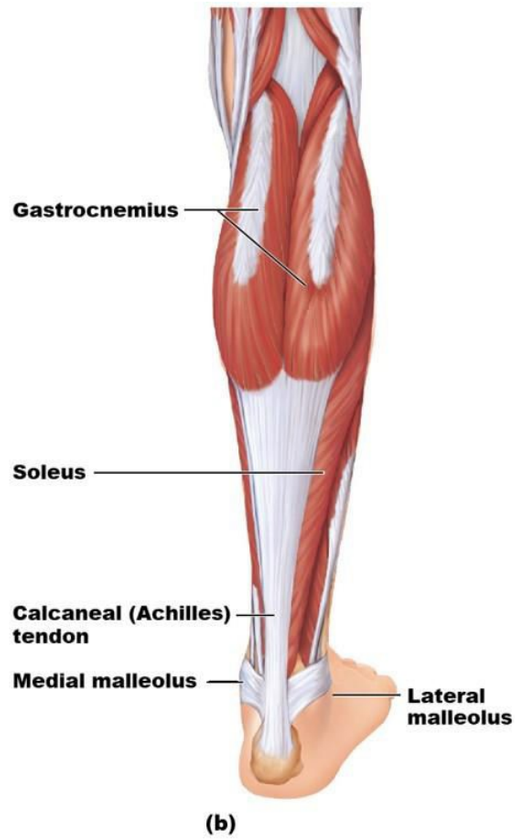
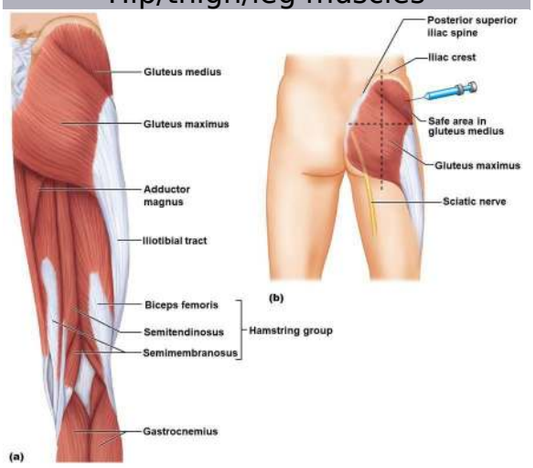


Hip/thigh/leg muscles



Gluteus maximus

- **Origin:** sacrum and ilium
- **Insertion:** proximal femur (gluteal tuberosity)
- **Primary Action(s):** extends hip (when forceful extension is required)

Gluteus medius

- **Origin:** ilium
- **Insertion:** proximal femur
- **Primary Action(s):** abducts thigh; steadies pelvis during walking

Hamstring muscles (biceps femoris, semitendinosus, semimembranosus)

- **Origin:** ischial tuberosity
- **Insertion:** proximal tibia (head of fibula in the case of biceps femoris)
- **Primary Action(s):** flex knee and extend hip

gastrocnemius

- **Origin:** distal femur
- **Insertion:** calcaneus (heel via calcaneal tendon)
- **Primary Action(s):** plantar flexes foot; flexes knee

soleus

- **Origin:** proximal tibia and fibula
- **Insertion:** calcaneus
- **Primary Action(s):** plantar flexes foot

Developmental aspects of the muscular system

- Increasing muscular control reflects the maturation of the nervous system
- Muscle control is achieved in a superior/inferior and proximal/distal direction

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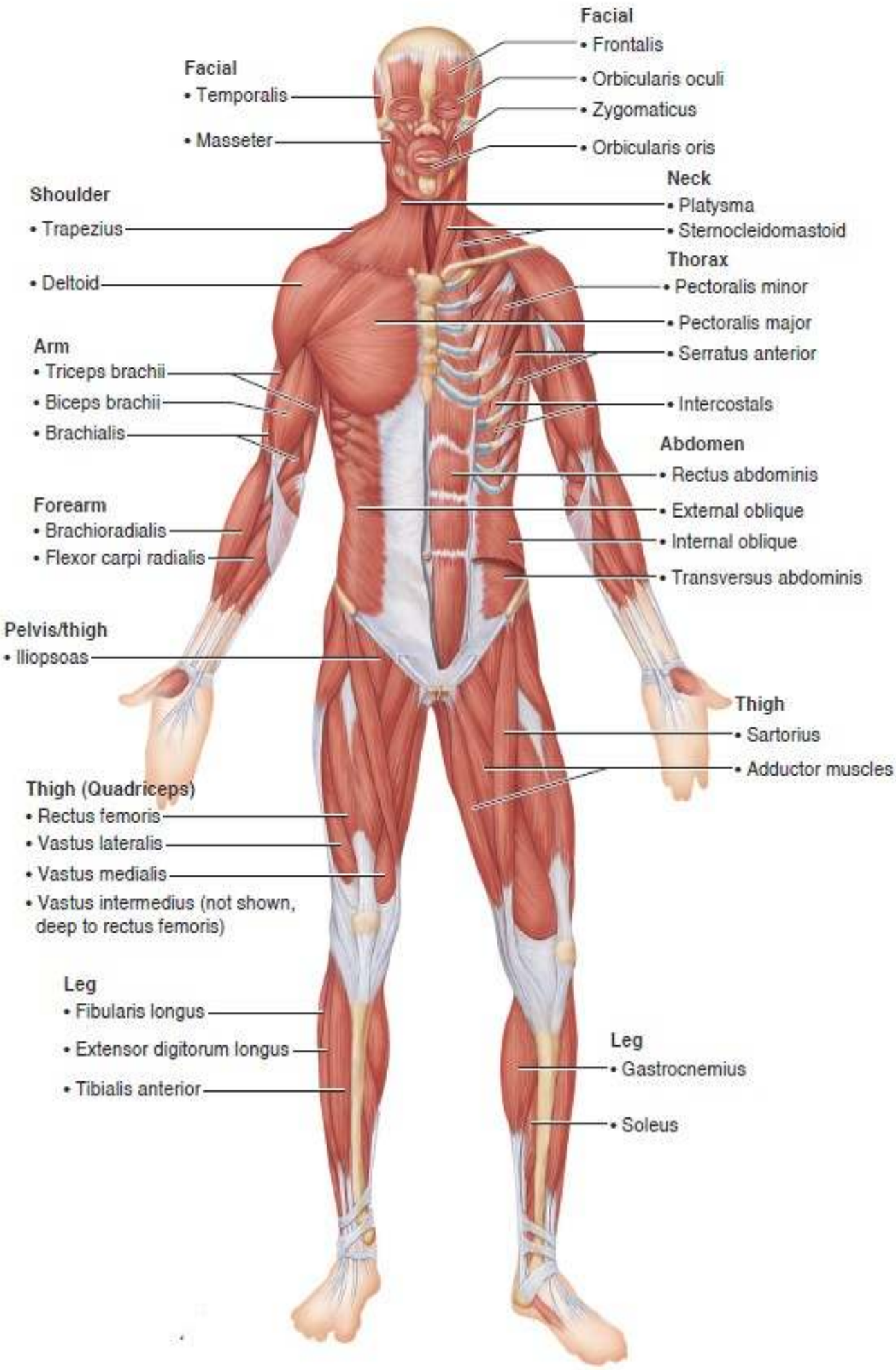
- To remain healthy, muscles must be exercised regularly
- Without exercise, muscles atrophy
- With extremely vigorous exercise, muscles hypertrophy
- As we age, muscle mass decreases' muscles become more sinewy



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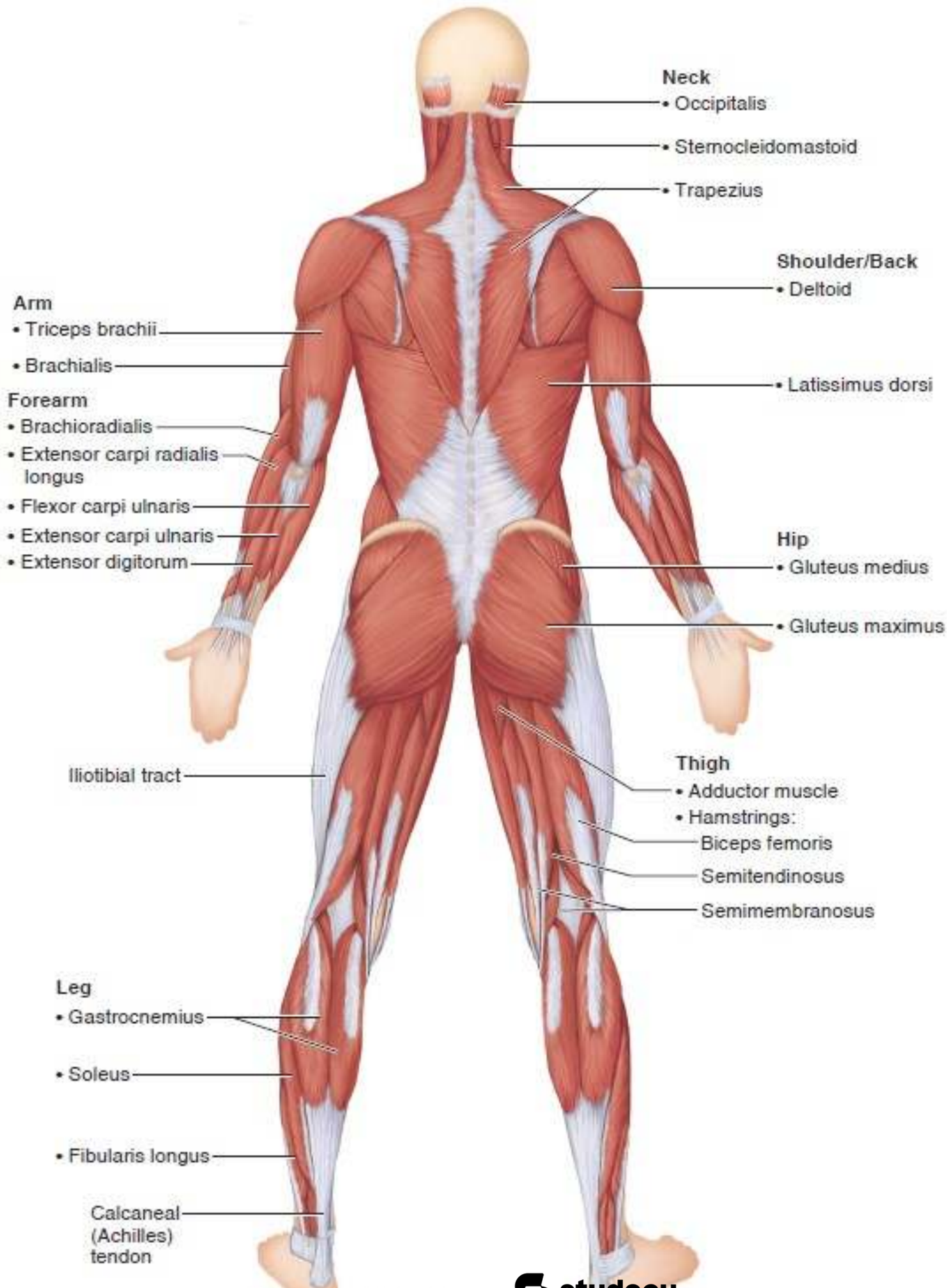

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