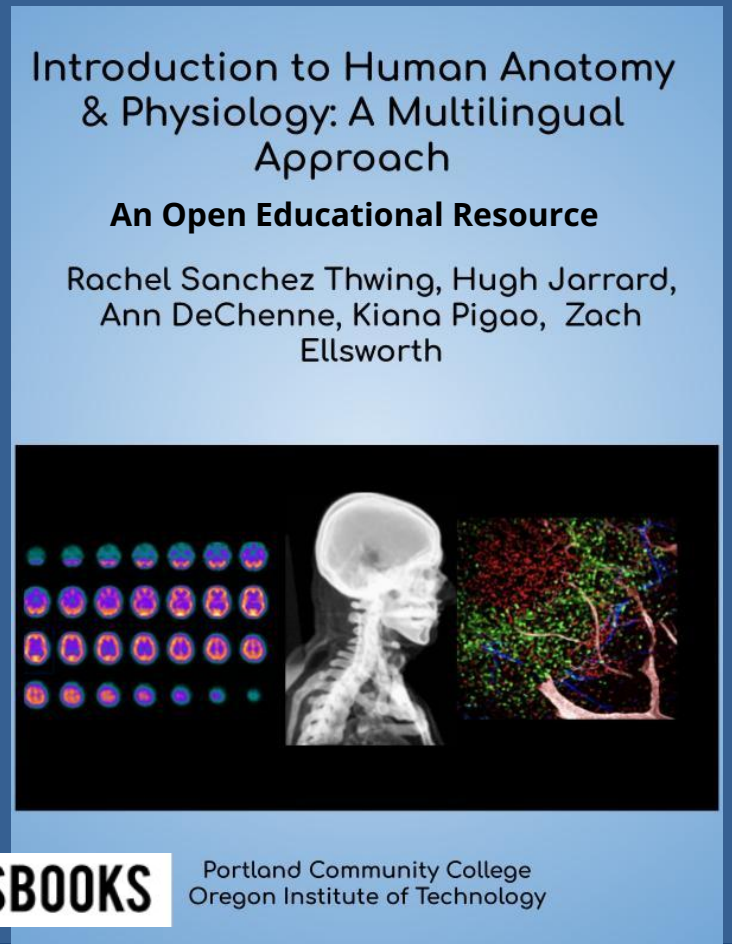
Muscular System: Physiology of Contraction; Major Muscles



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Created for US DOE Grant # STM461-OIT/EPO-001, administered by Oregon Tech Department of Educational Programs and Outreach (OT EPO) and Willamette Education School District (WESD).

Lesson 3: Muscle Contraction

Learning Objectives:

Describe the sequence of events from neuronal stimulation that lead to muscle contraction, control its strength and duration, and allow cessation.

Describe how the frequency of action potentials from a motor neuron affects tension produced in the skeletal muscle.

Identify the major muscles by anatomical name.

See the Muscular System Wordlist!

- Can be found in accompanying materials to this lecture
- Materials are available in English, Spanish, Russian, Vietnamese, Filipino, East African French, Kiswahili (Swahili) and Chinese.

Module 4 Muscular System Word List

Microscopic Structure:
actin
endomysium
epimysium
fascicle
intercalated disc
motor end-plate
myofibril
myosin
perimysium
sarcomere
sarcolemma
synaptic cleft
T-tubule
Thick filament (myosin)
Thin filament (actin)
Tropomyosin
Troponin

Muscle type:
Cardiac muscle
Skeletal muscle
Smooth muscle

Major Muscles of the Body:
Orbicularis oculi m.
Buccinator m.
Orbicularis oris m.
Sternocleidomastoid m.
Frontalis m.
Temporalis m.
Occipitalis m.
Trapezius m.
Latissimus dorsi m.
Deltoid m.
External oblique m.
Rectus abdominis m.
Pectoralis major m.
Triceps brachii m.
Biceps brachii m.
Brachioradialis m.
Supinator m.
Pronator teres m.
Quadriceps femoris
Rectus femoris m.
Vastus lateralis m.
Vastus medialis m.
Vastus intermedius m.
Biceps femoris m.
Gluteus maximus m.
Tibialis anterior m.
Gastrocnemius m.
Soleus m.

Muscle Actions:
abduction
adduction
flexion
insertion
origin
pronation
supination

Muscle contraction:
acetylcholine
autorhythmicity
contractility
depolarize
excitability
excitation-contraction coupling
motor unit
neuromuscular junction (NMJ)
neurotransmitter
power stroke
twitch
tetanus
twitch
voltage-gated sodium channels
wave summation

Disruptions in Homeostasis:
atrophy
fibrosis
hypertrophy
paralysis

Nerve-Muscle: System Relationship

A skeletal muscle cannot contract unless stimulated by a nerve.

Motor unit
one motor neuron and all muscle fibers it supplies

- Contract at once
- Larger motor neurons supply a larger number of muscle fibers than small motor neurons

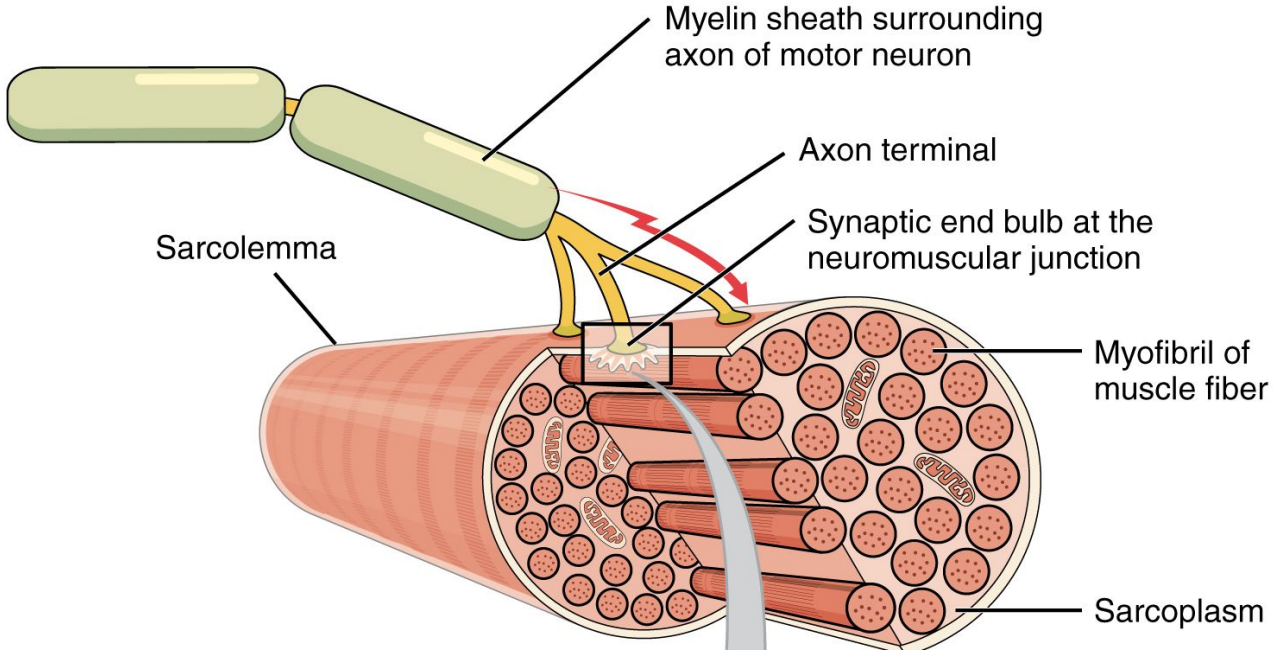


Figure 10.6 **Motor End Plate Innervation**

Nerve-Muscle: Neuromuscular Junction

Neuromuscular junction (NMJ)

where a nerve fiber specifically meets a muscle fiber

- Axon terminal
  swelling at end of nerve fiber
- Synaptic cleft
  gap between fibers
  - Motor End Plate
    Location of ACh-receptors in the muscle fiber sarcolemma

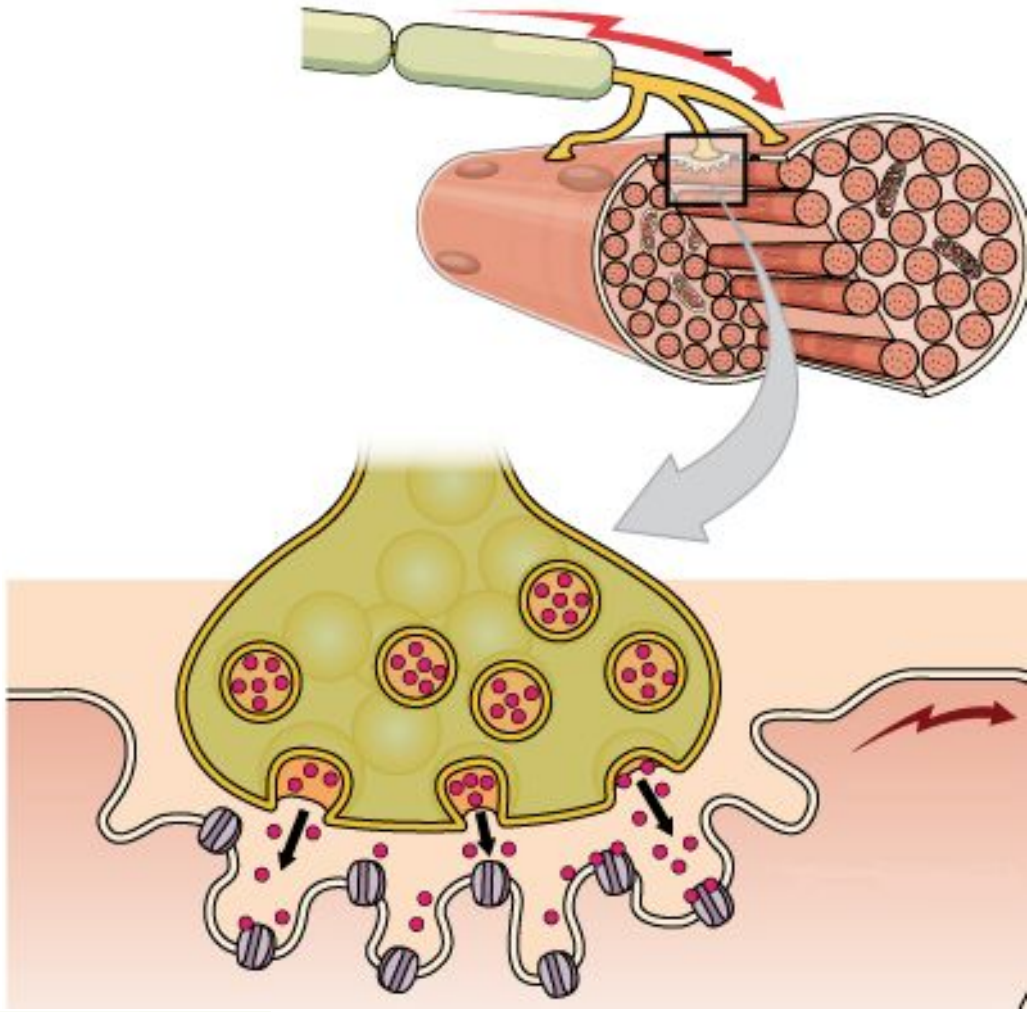
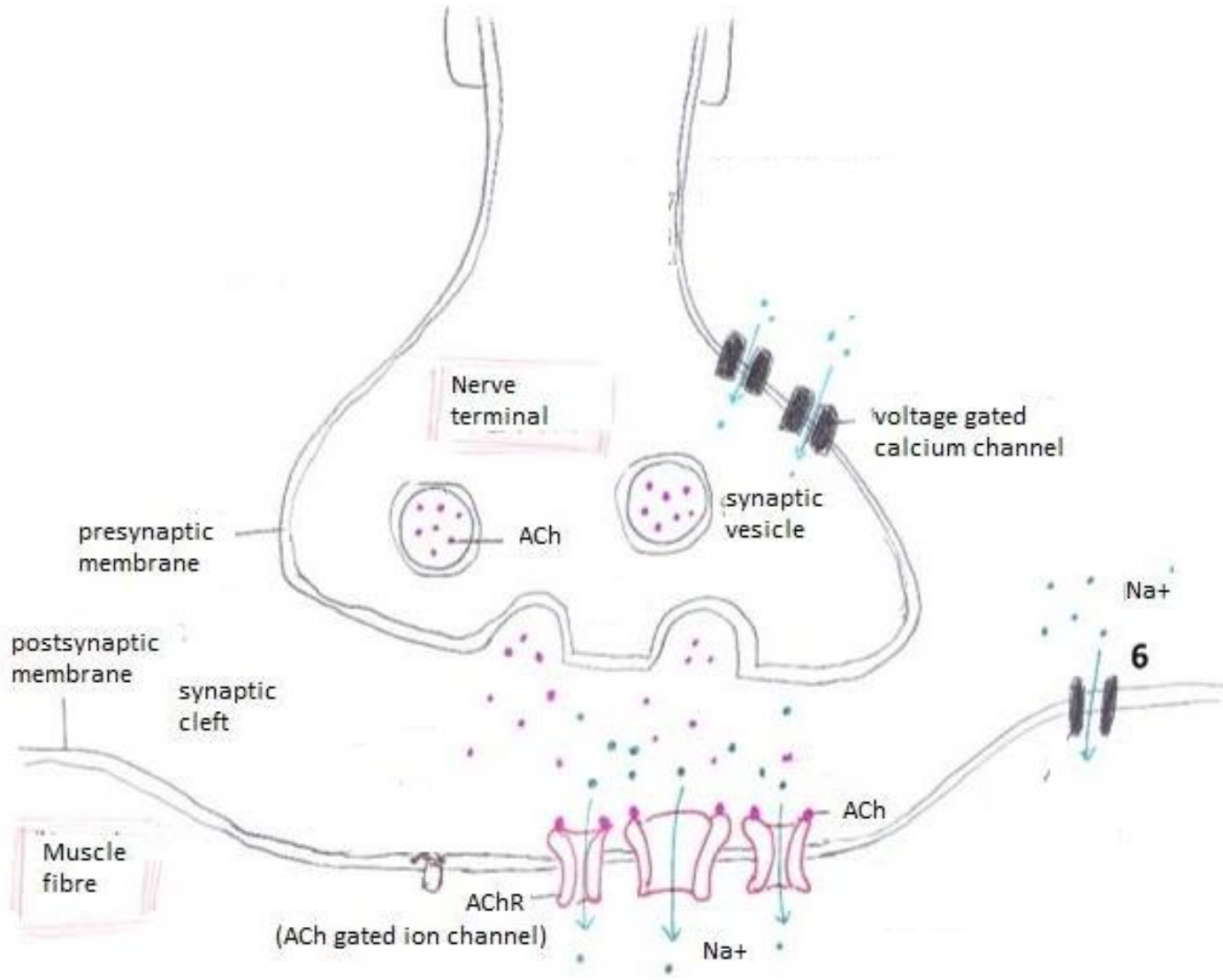


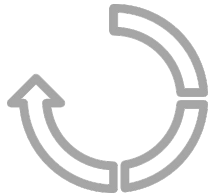
Figure 10.6 **Motor End Plate Innervation**

Nerve-Muscle: NMJ

- Synaptic vesicles contain acetylcholine
- Released and diffuses across synaptic cleft
- Binds to acetylcholine receptors on muscle fiber
- Stimulates muscle fibers to contract
- Acetylcholinesterase breaks down acetylcholine
- Muscle paralysis

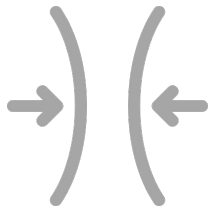


Excitation-Contraction Cycle



Excitation

Process of converting an electrical nerve signal to electrical signal in the muscle fiber



Contraction

The muscle develops tension and may shorten

- The thick and thin filaments slide past each other
- The mechanism of contraction is called the **sliding filament model**

Relaxation

Allows muscles to return to their original length

Excitation: Steps

1. **Nerve signal arrives** at the synapse
2. **Stimulates release** of synaptic vesicles
3. **Acetylcholine (ACh)** enters synaptic cleft
4. **ACh binds its receptors** on the sarcolemma
5. Na+ **ions diffuse** into fiber; K+ ions diffuse out
6. The ion movements excite and open voltage-gated Na+ channels that **initiate action potentials**
7. The **Action Potential spreads** away from neuromuscular junction and into T tubules
8. **Excitation of T tubule** opens Ca2+ channels in the sarcoplasmic reticulum
9. **Ca2+ binds to troponin** molecules on thin filaments
10. **Tropomyosin pulled** to side
11. **Uncovers myosin-binding sites** on thin (actin) filament
12. **Myosin heads bind** to actin

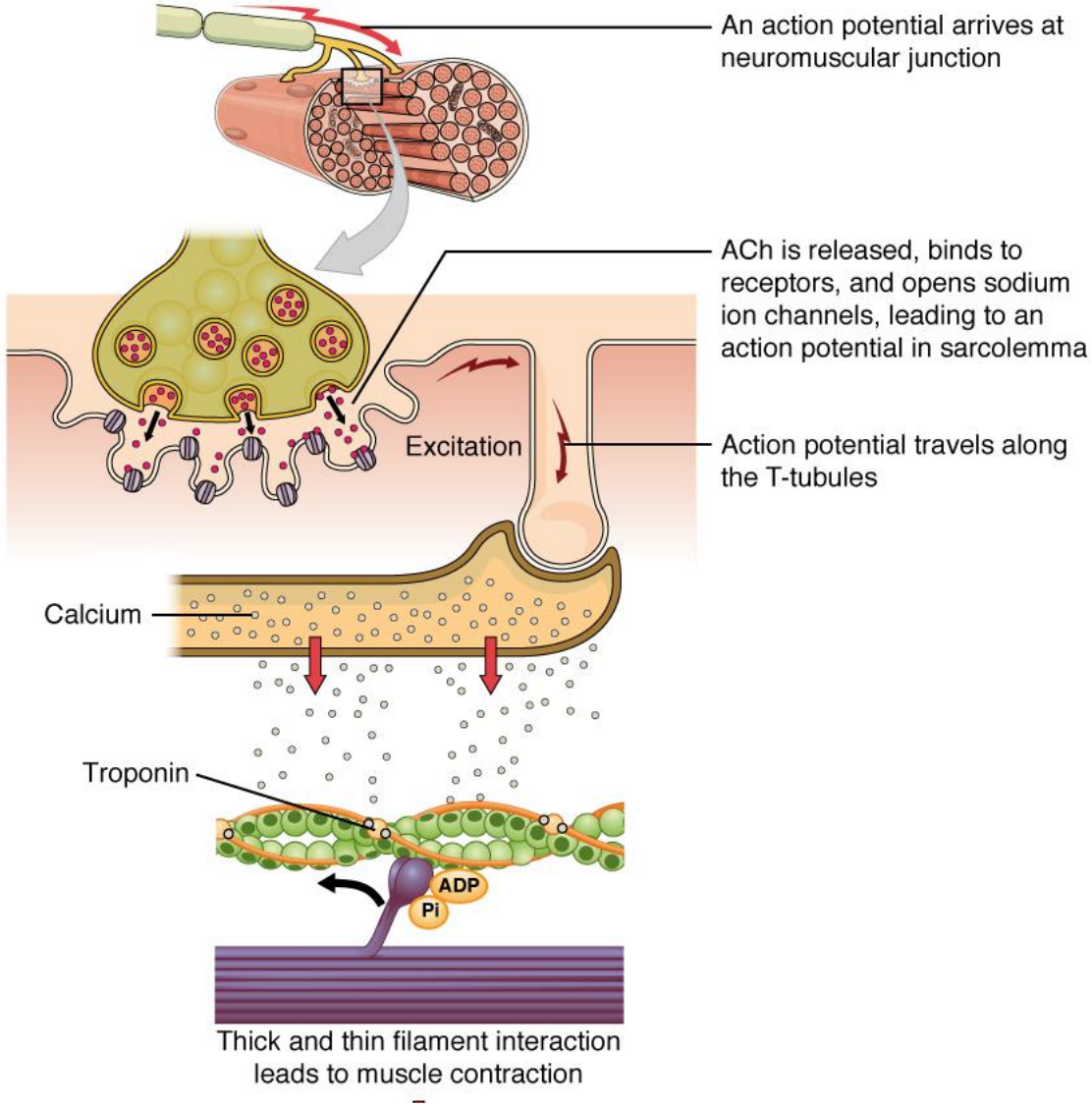


Figure 10.8 **Contraction of a Muscle Fiber** by Openstax College

Contraction: Steps

1. **Myosin heads cock** using ATP
2. Myosin heads form **cross-bridge** with active sites on the thin filaments
3. **Power stroke** Myosin tugs the thin filament while it releases ADP
4. **ATP binding** allows breaking of myosin cross-bridge from actin
5. **Recovery stroke** when the myosin head recocks, ready to bind actin again
6. **Contracted state** when the sarcomere is shorter

As long as Ca2+ ions remain in the sarcoplasm and ATP is available, the muscle will continue to contract

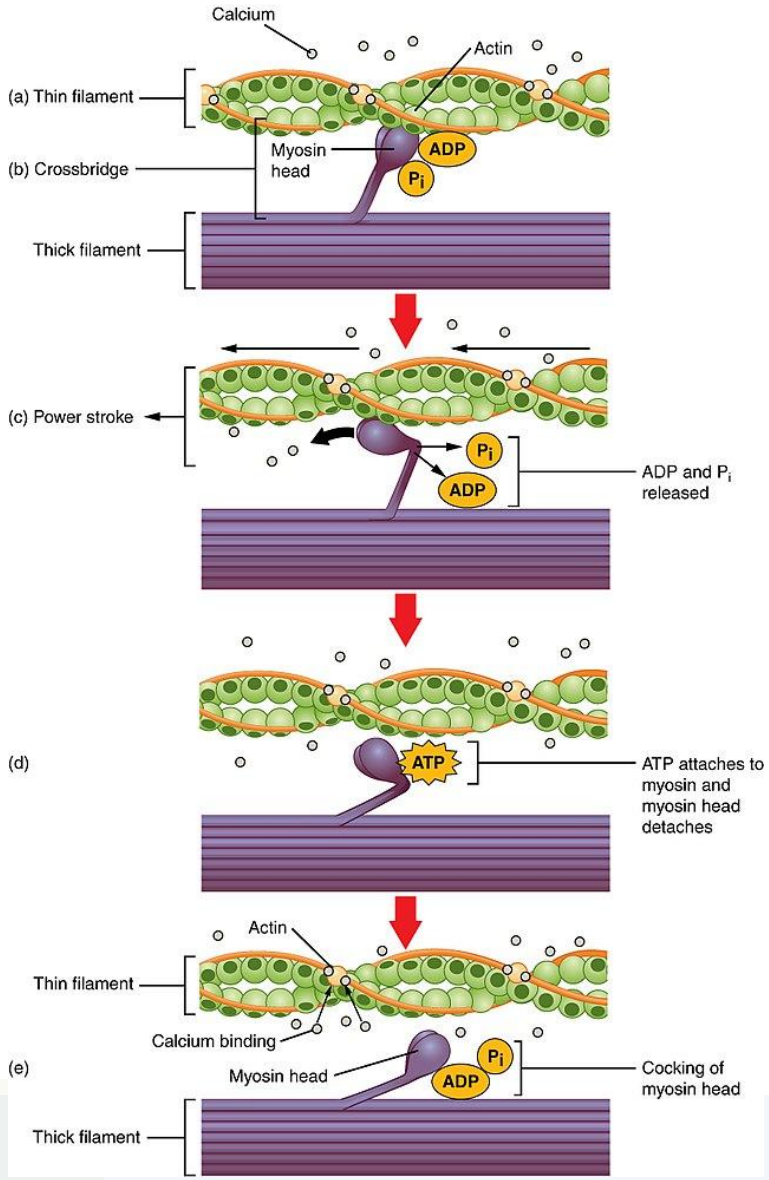


Figure 10.11 **Skeletal Muscle Contraction** by Openstax College

Relaxation: Steps

1. **Nerve Signal stops**, no more ACh released
2. **Synaptic ACh cleared** from synapse (broken down by acetylcholinesterase, diffuses, etc)

3. **Ca2+ reabsorbed** by the sarcoplasmic reticulum by active transport pumps (requires ATP)
4. **Troponin-tropomyosin complex returns to resting position-** blocks myosin binding actin again

5. **Muscle fibers relax**

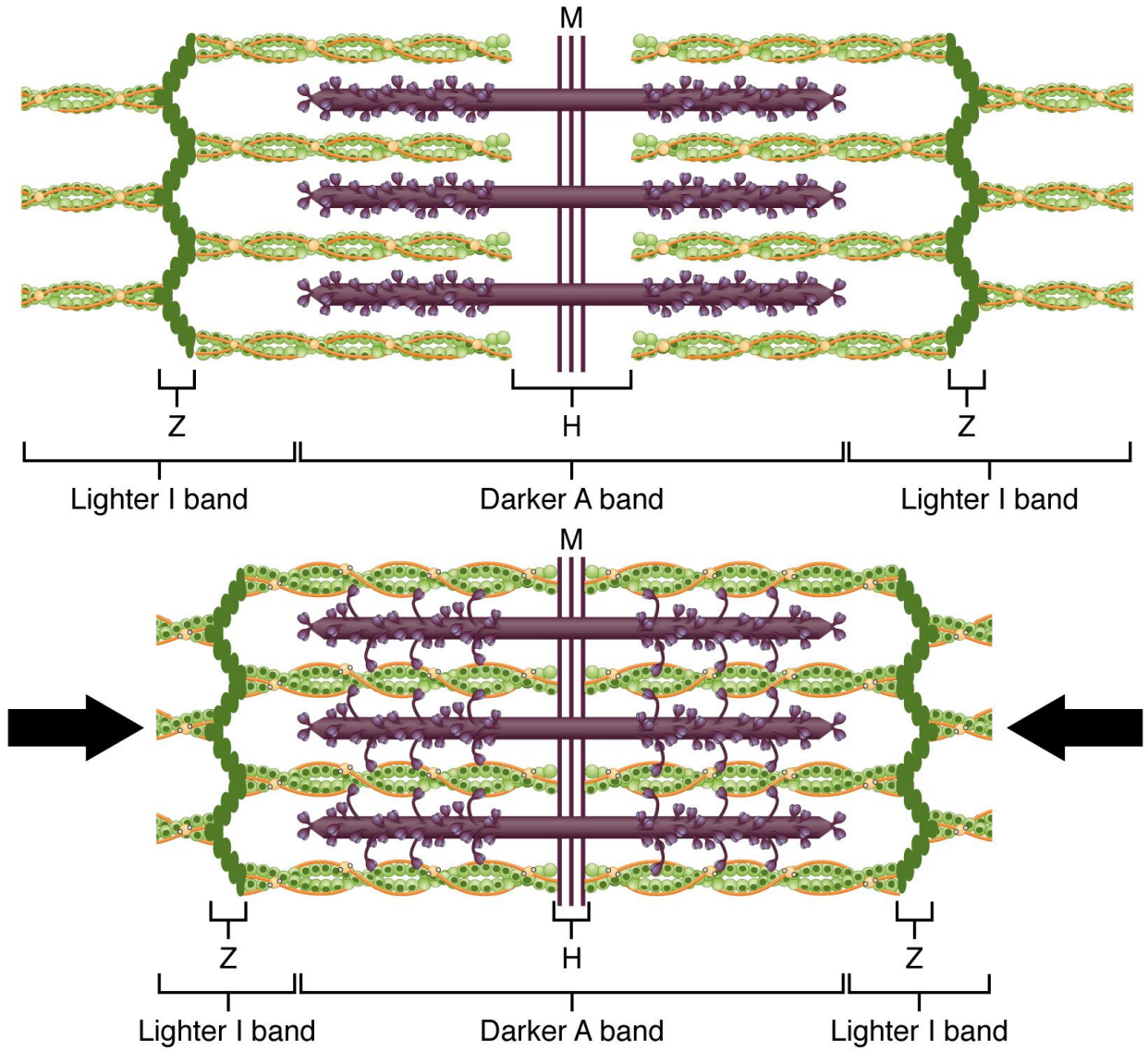
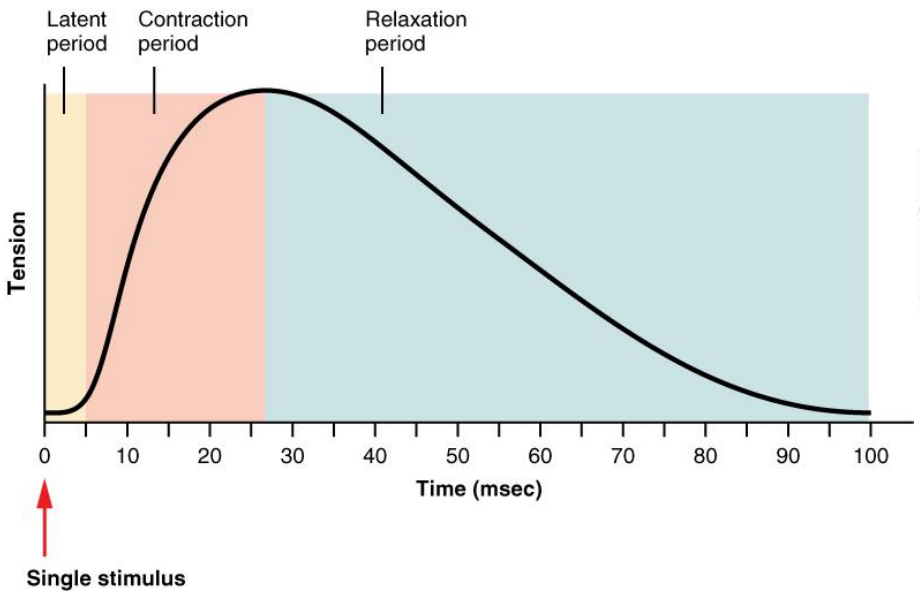
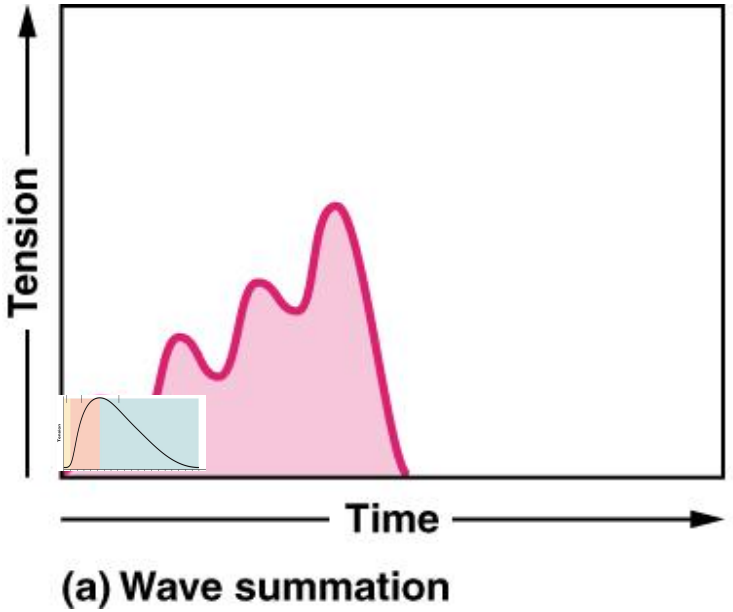


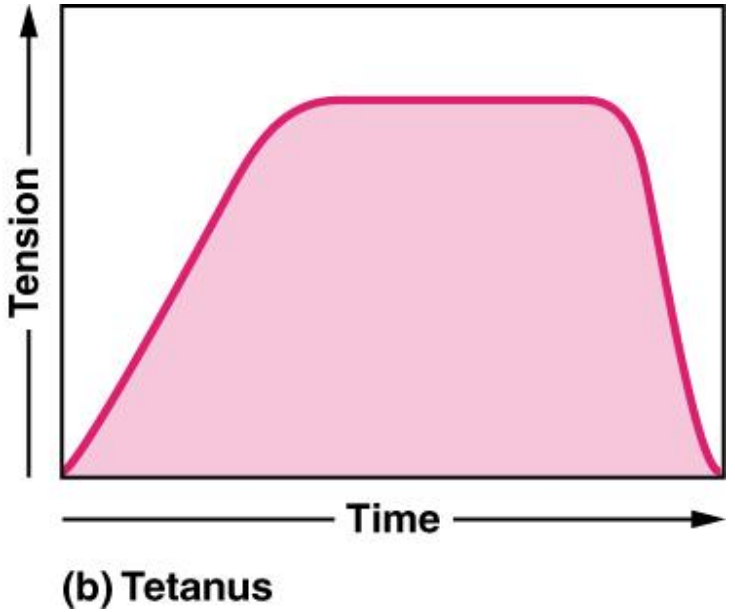
Figure 10.10 **The Sliding Filament Model of Muscle** by Openstax College

Stimulation: Frequency of Motor Neuron Stimulation





(a) Wave summation



(b) Tetanus

Muscle Twitch

- smallest contraction
- single cycle

Summation

twitches must be added together

Incomplete tetanus

motor units take turns

Complete tetanus

- muscle never relaxes
- achieved in a lab setting

Figure 10.15 and Figure 10.16 **Myogram, Wave Summation, and Tetanus** by Openstax College

Major Muscles: Head and Face

Orbicularis Oculi

Buccinator

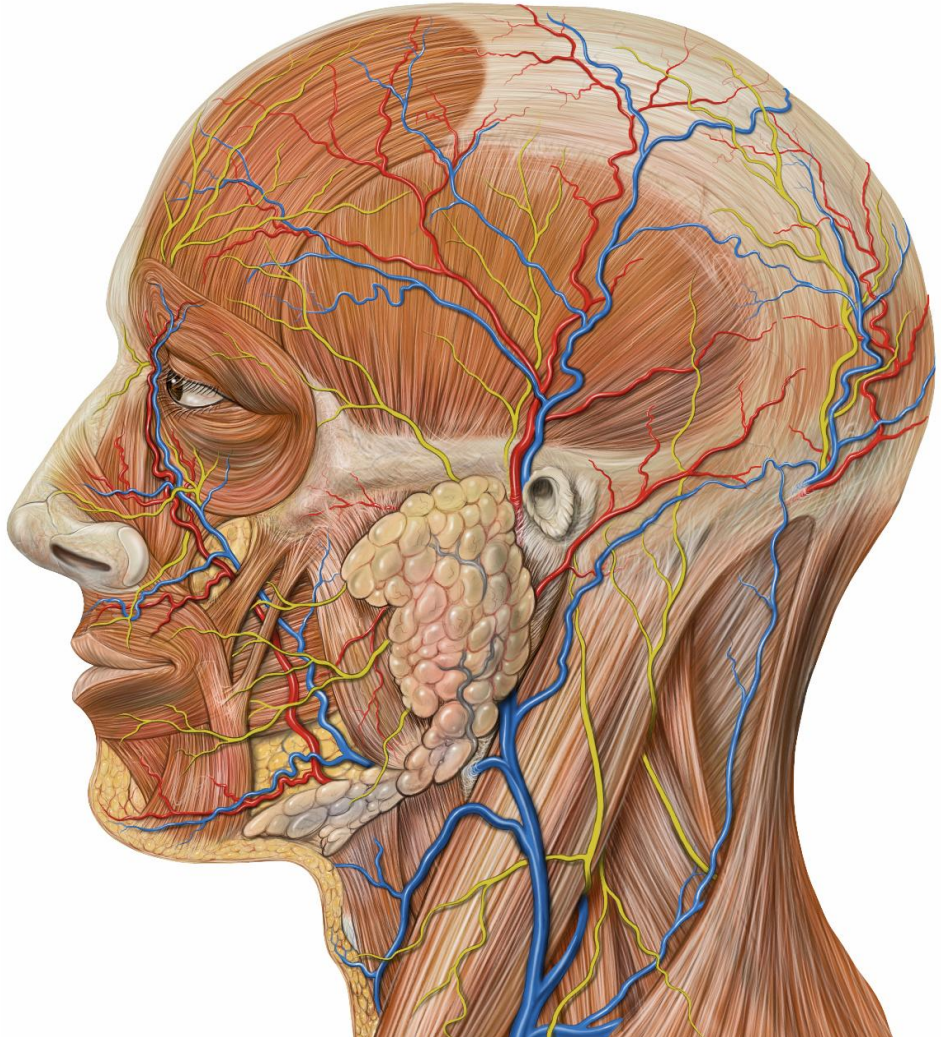
Orbicularis Oris

Sternocleidomastoid

Frontalis

Temporalis

Occipitalis

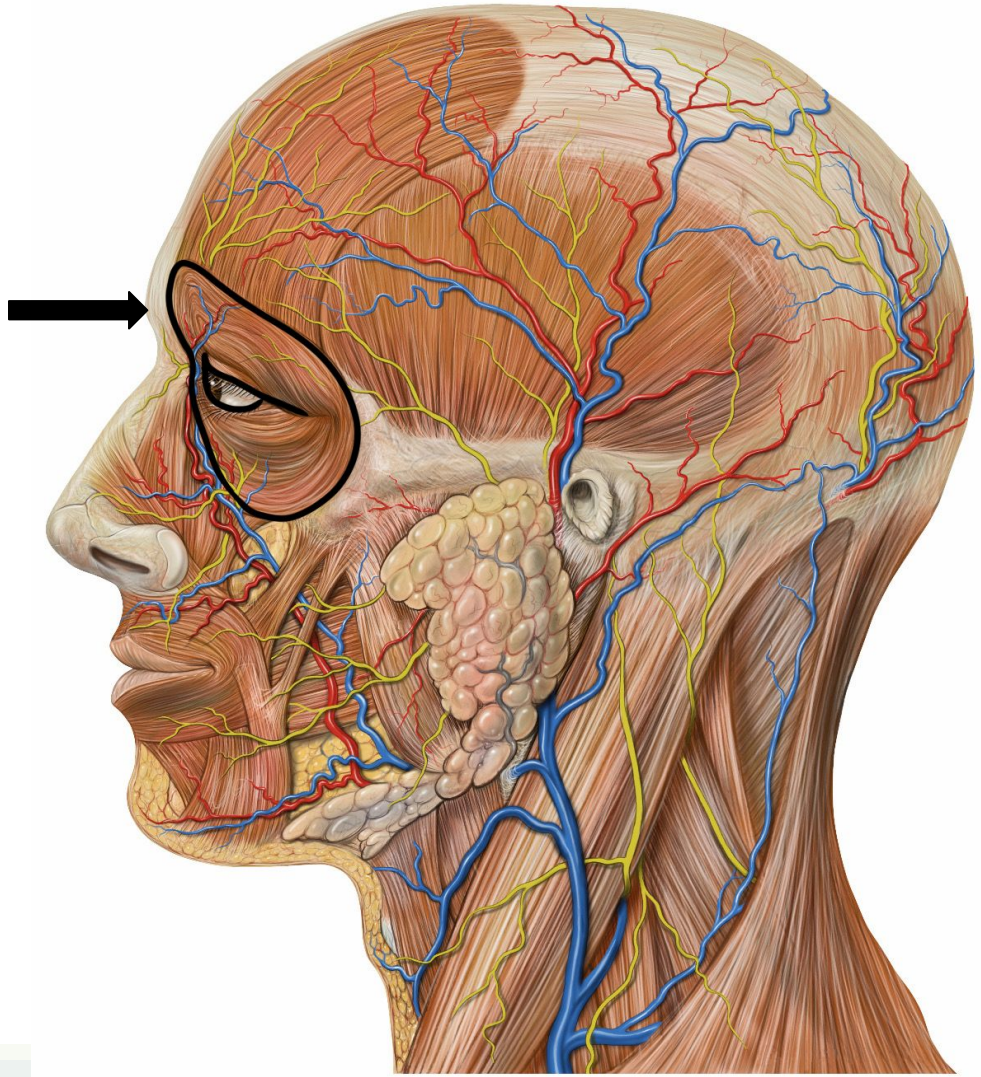


Head and Face: Orbicularis Oculi

Orbicularis Oculi

Functions:

- close eyelids
- drain tears by compressing lacrimal sac
- squint and frown

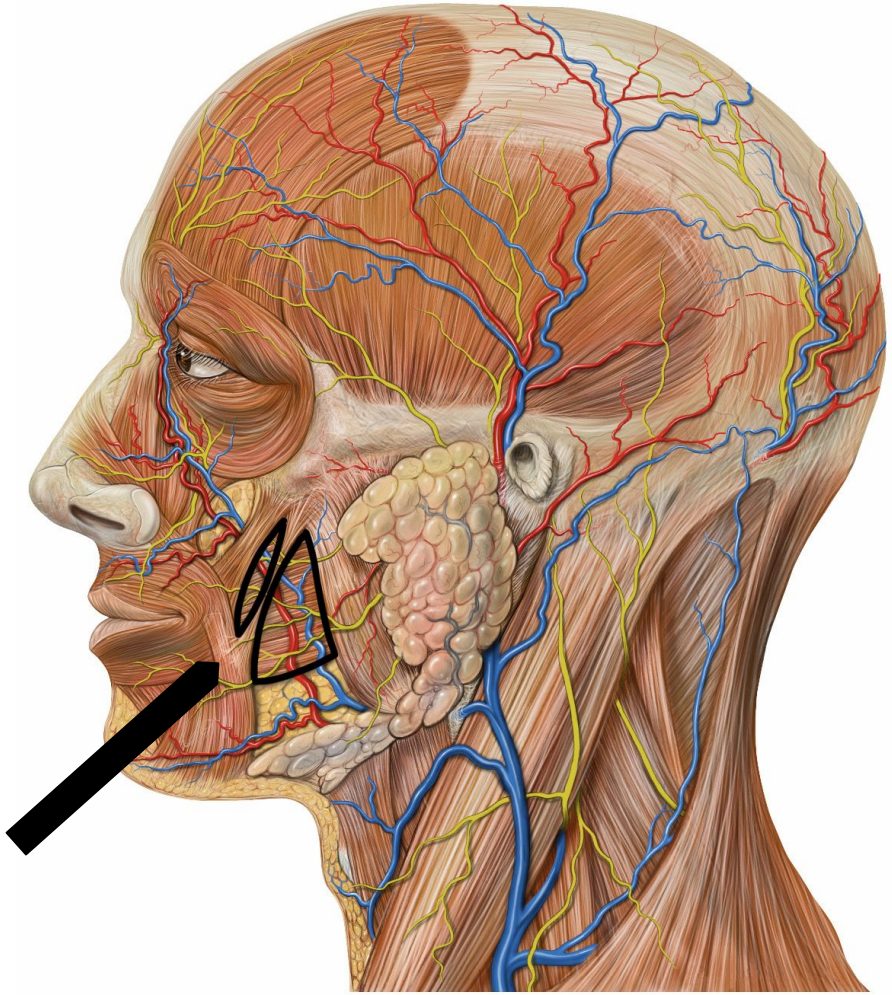


Head and Face: Buccinator

Buccinator

Functions:

- compress cheek against teeth for chewing so that food doesn't accumulate in cheek
- blowing air as if playing a clarinet or saxophone
- whistling
- speech sounds that require wider mouth opening

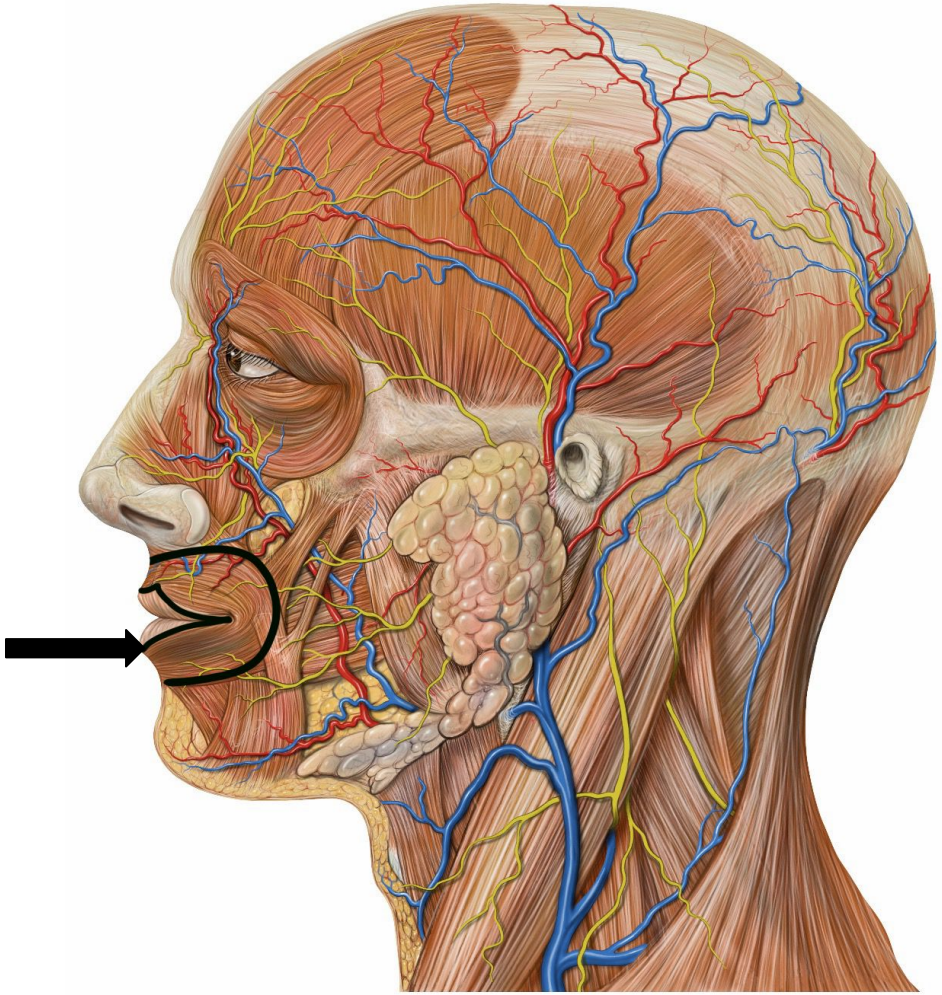


Head and Face: Orbicularis Oris

Orbicularis Oris

Functions:

- close lips
- pucker lips
- press lips together or sneer
- maintain seal of mouth so that saliva doesn't drip

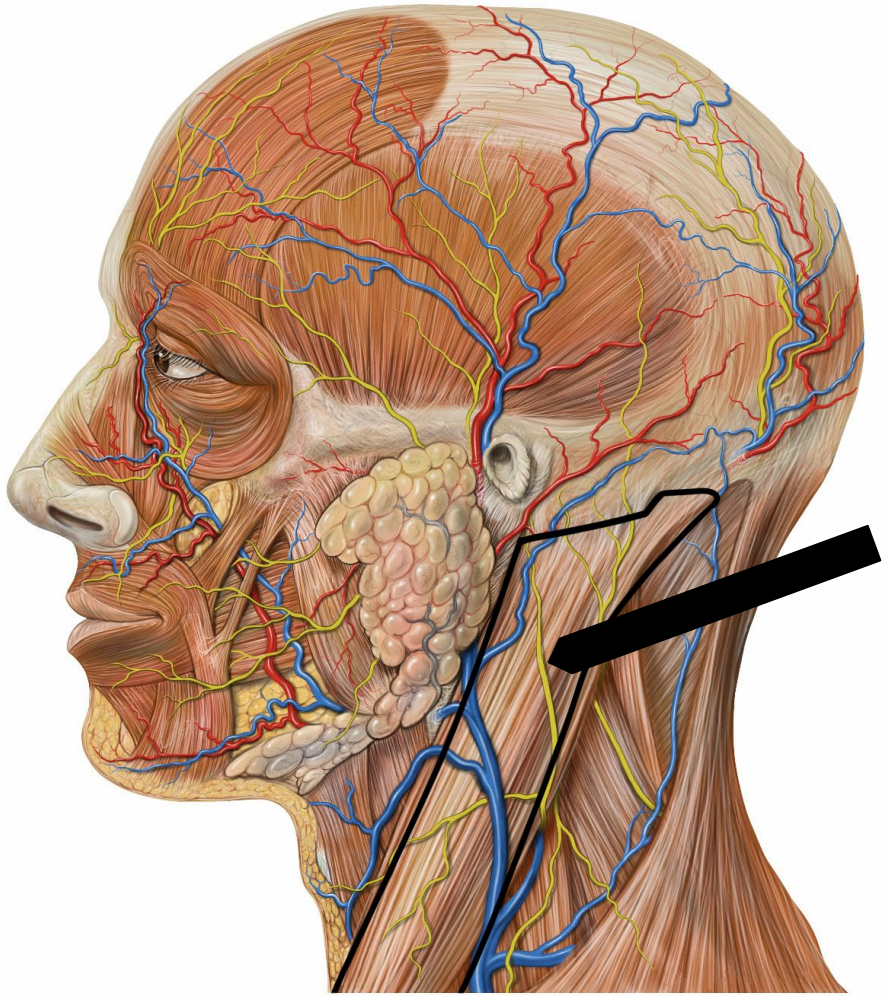


Head and Face: Sternocleidomastoid

Sternocleidomastoid

Functions:

- bilaterally flex neck bringing head forward
- unilaterally tilt and turn head

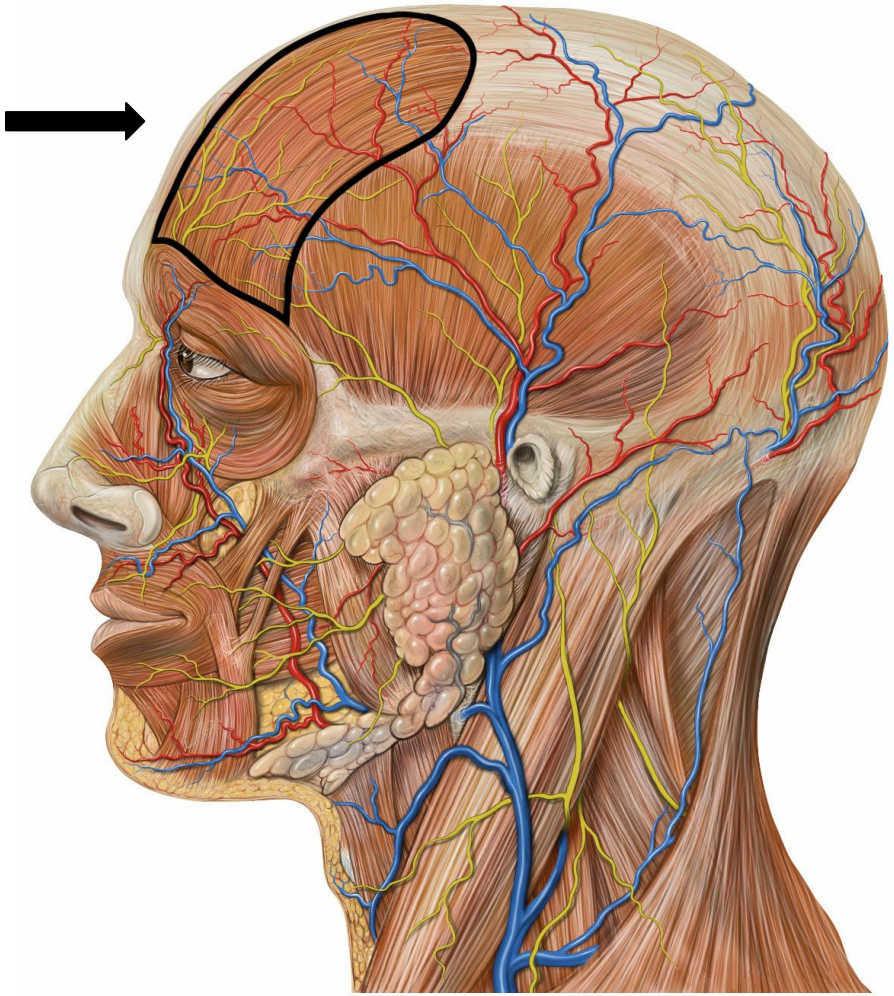


Head and Face: Frontalis

Frontalis

Functions:

- elevate eyebrows
- wrinkle forehead

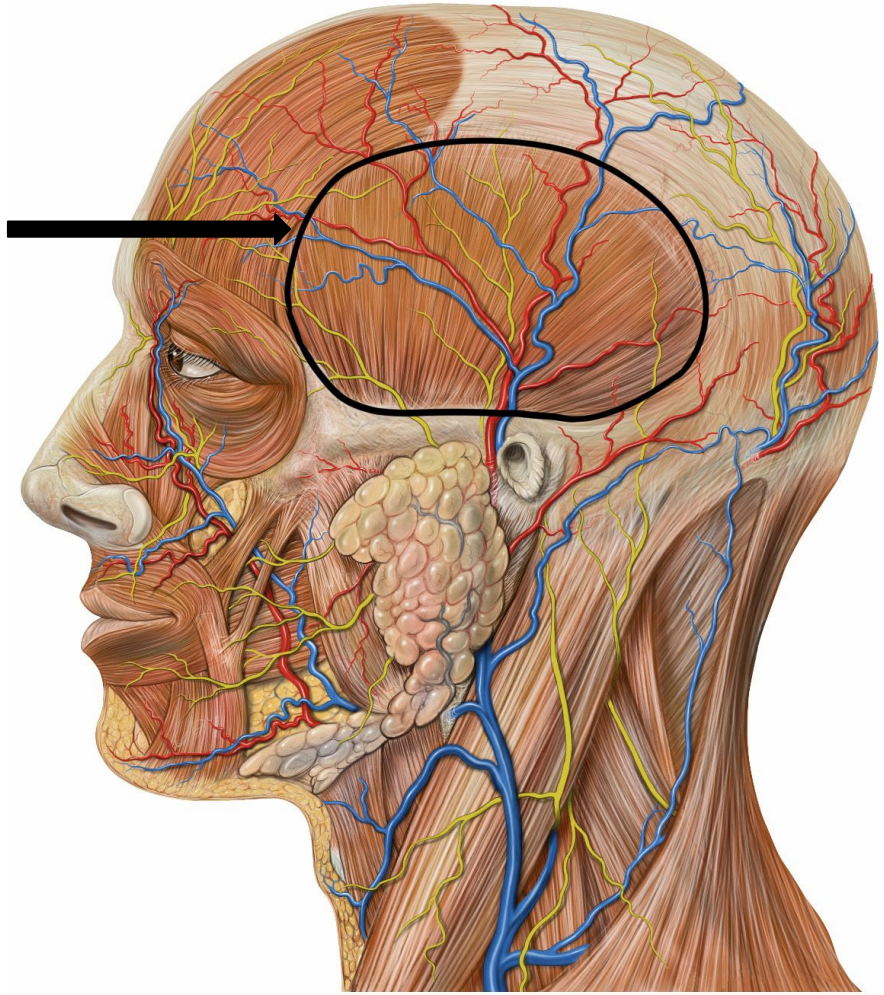


Head and Face: Temporalis

Temporalis

Functions:

- chew
- move jaw side to side

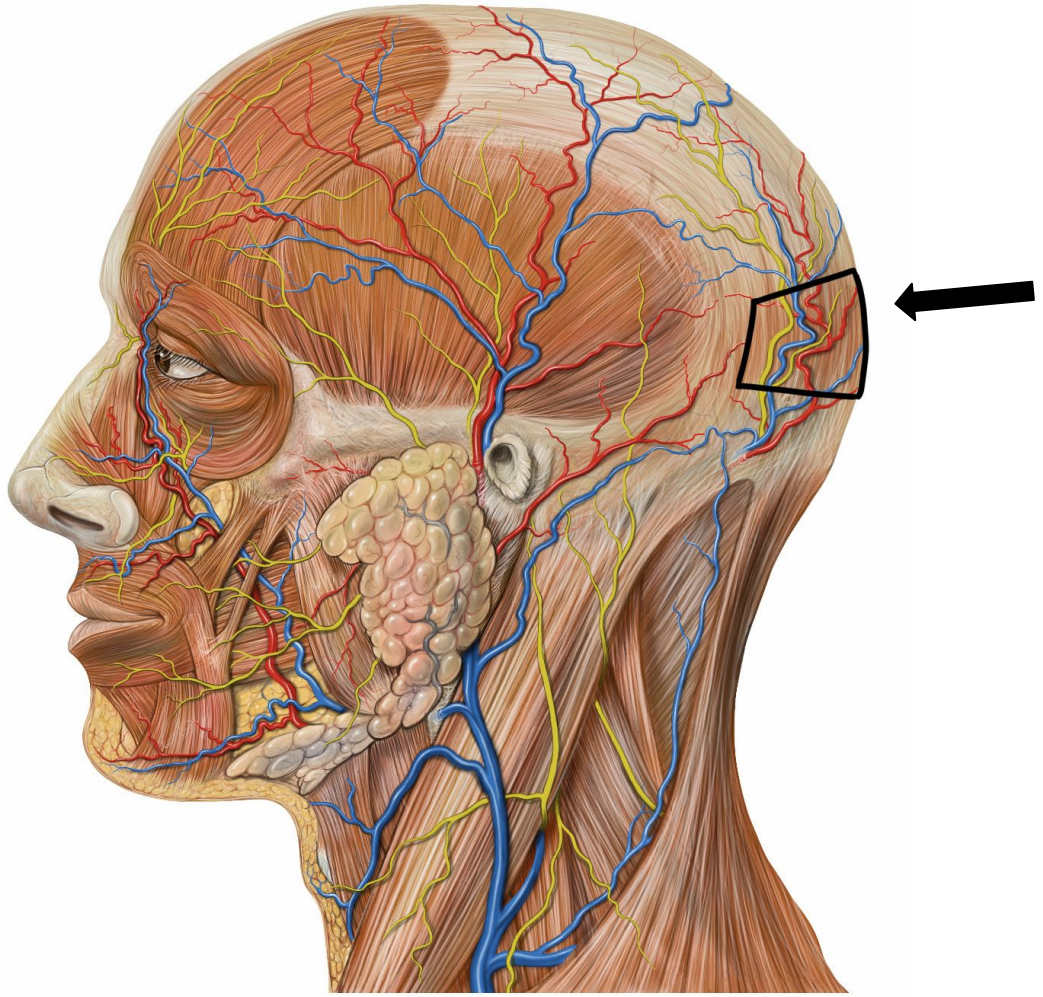


Head and Face: Occipitalis

Occipitalis

Functions:

- pull scalp posteriorly

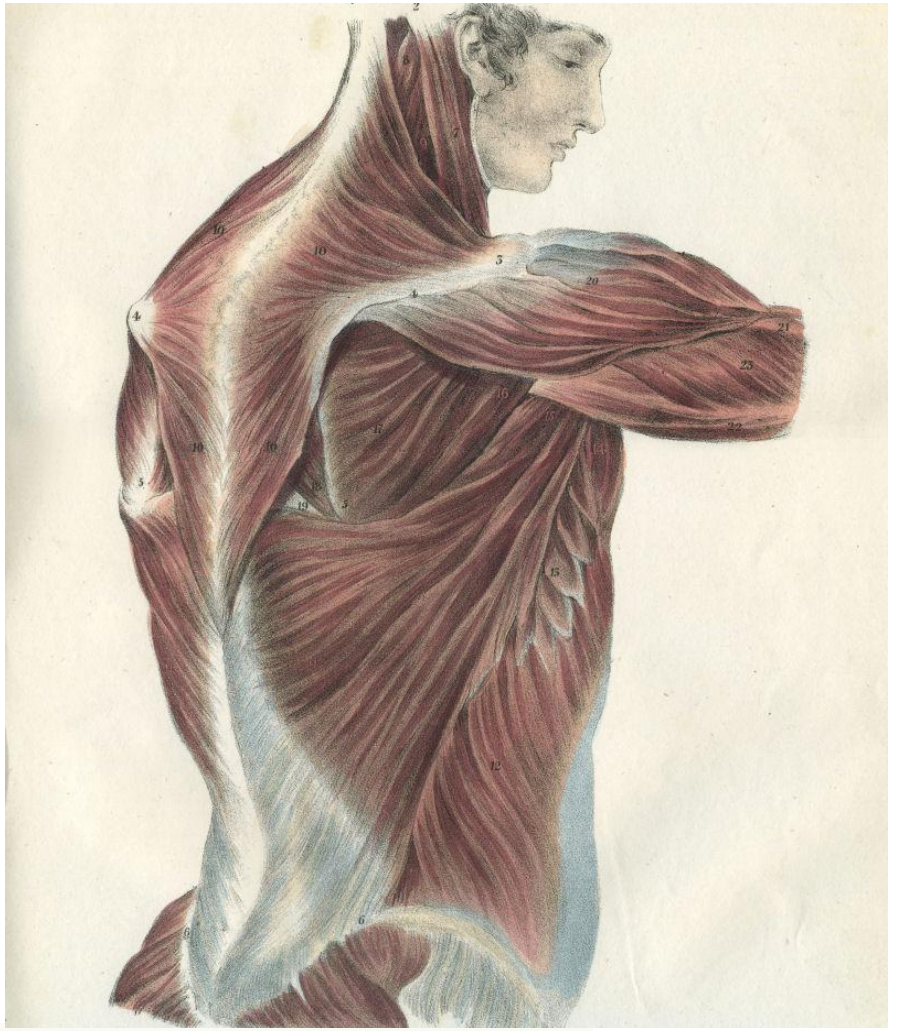


Major Muscles: Back

Trapezius

Latissimus Dorsi

Deltoid



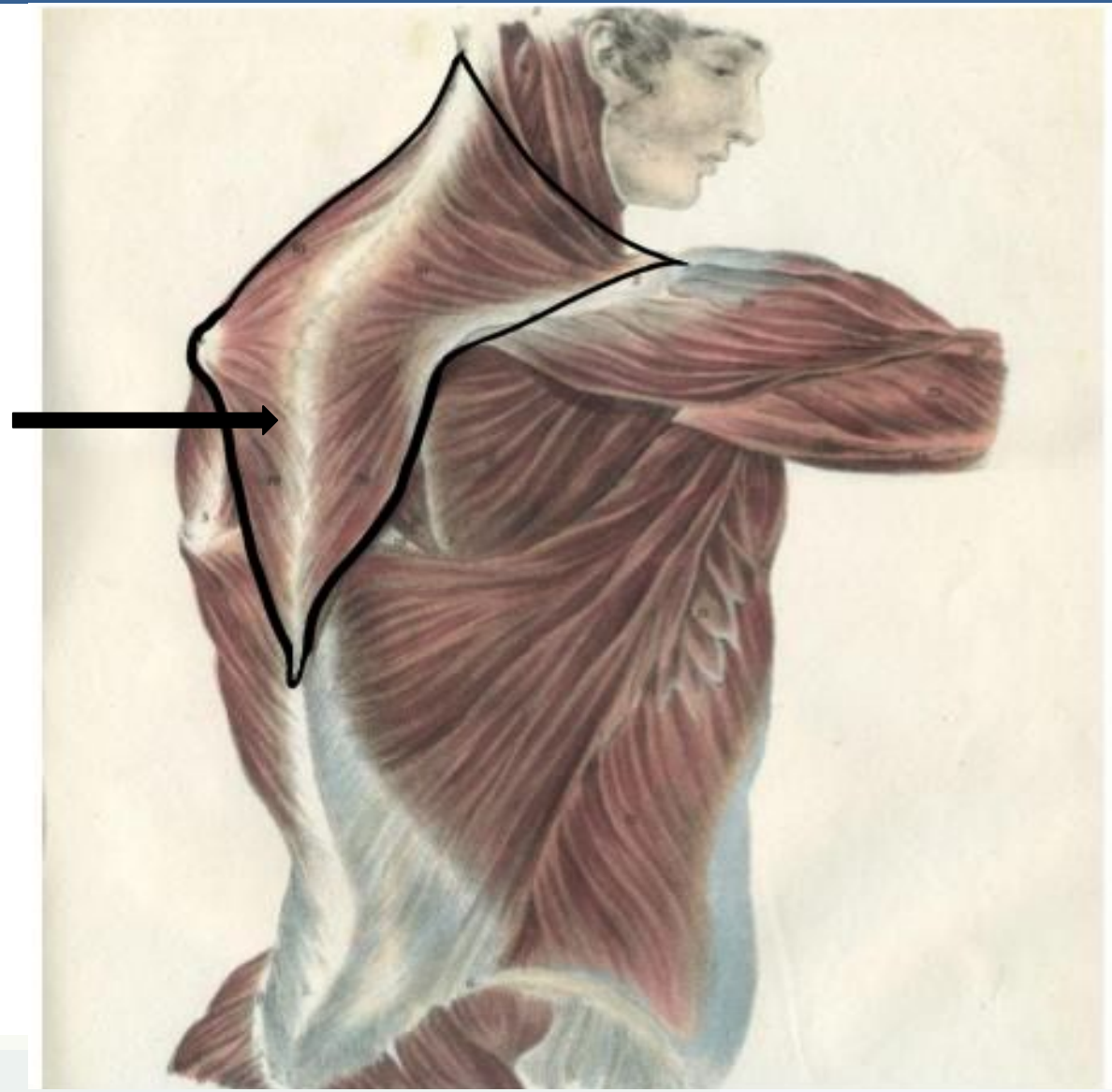
Series of Anatomical Plates Muscles Plate 21 by Jones Quain, M.D., Public domain, via Wikimedia Commons

Back: Trapezius

Trapezius

Functions:

- elevate shoulder
- rotate shoulder
- retract shoulder

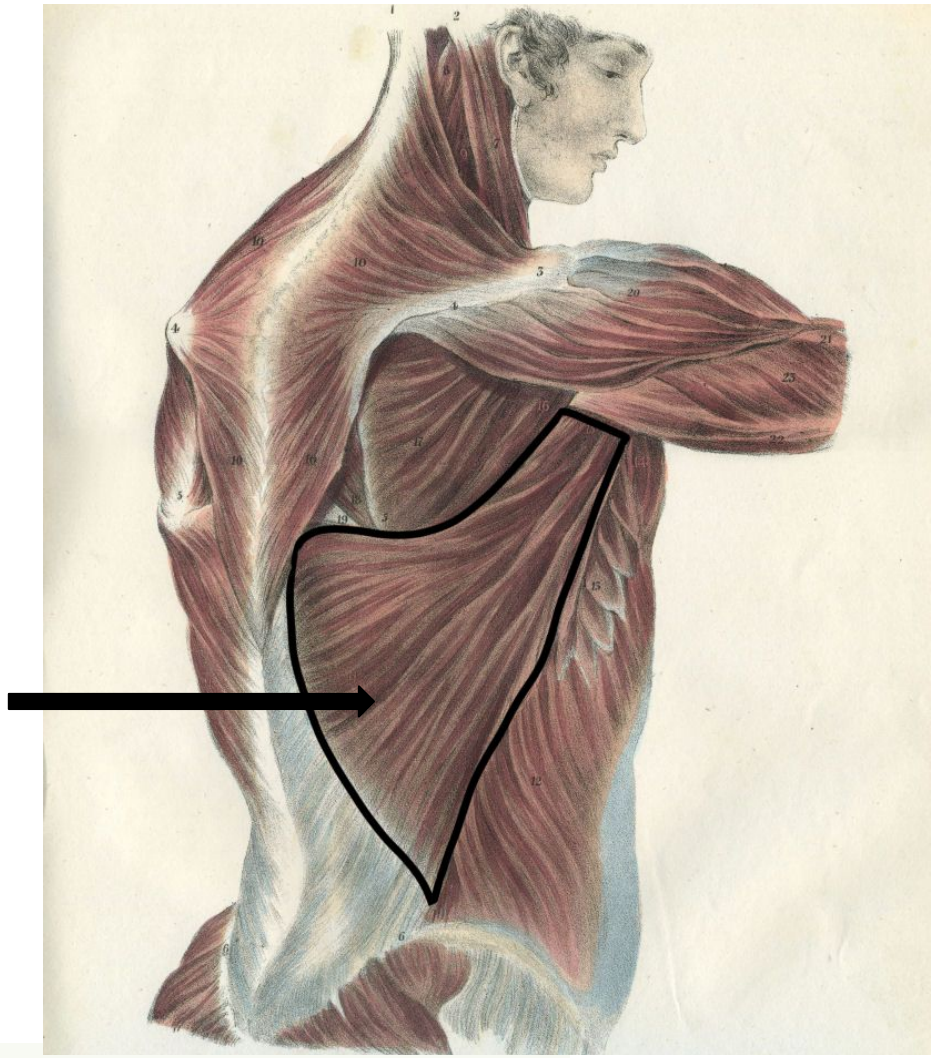


Back: Latissimus Dorsi

Latissimus Dorsi

Functions:

- adduct shoulder
- internally rotate shoulder
- extend shoulder

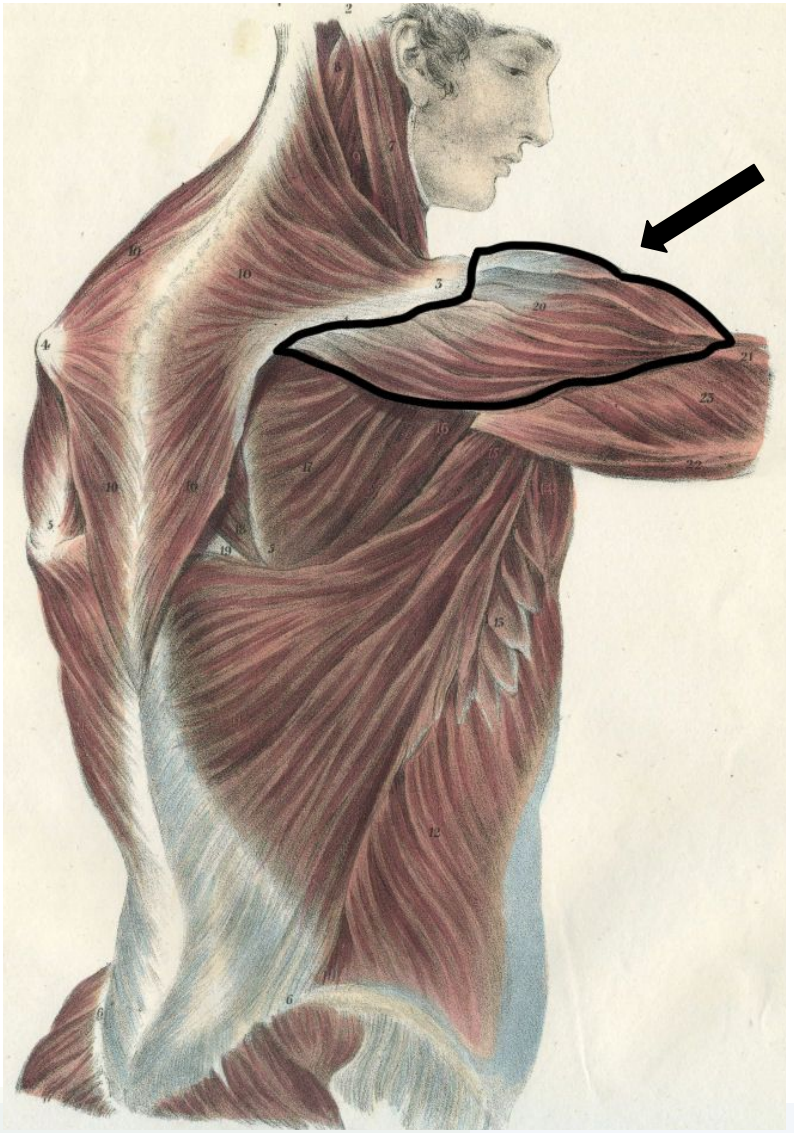


Back: Deltoid

Deltoid

Functions:

- abduct arm
- flex arm forward
- extend arm backward
- rotates arm
- stabilize shoulder



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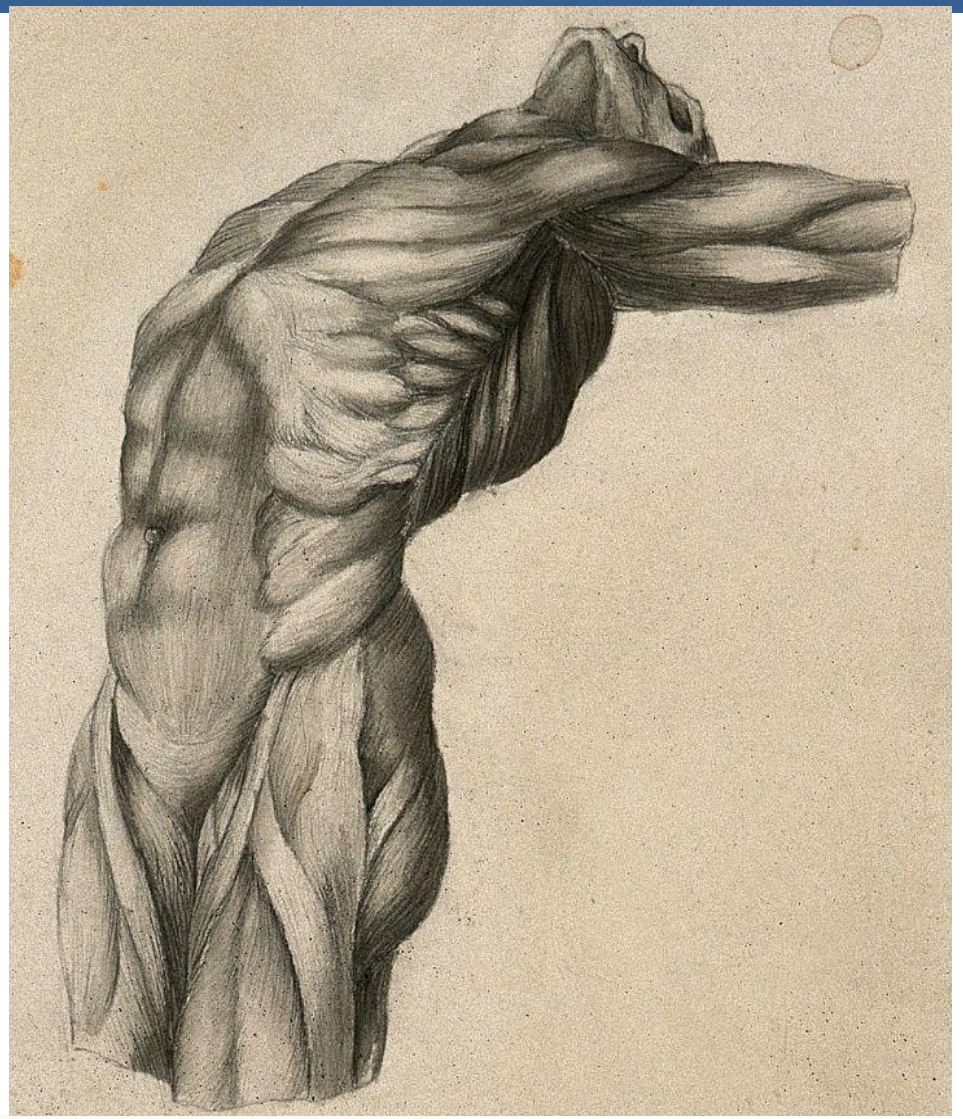
Major Muscles: Torso

Pectoralis Major

External Oblique

Rectus Abdominis

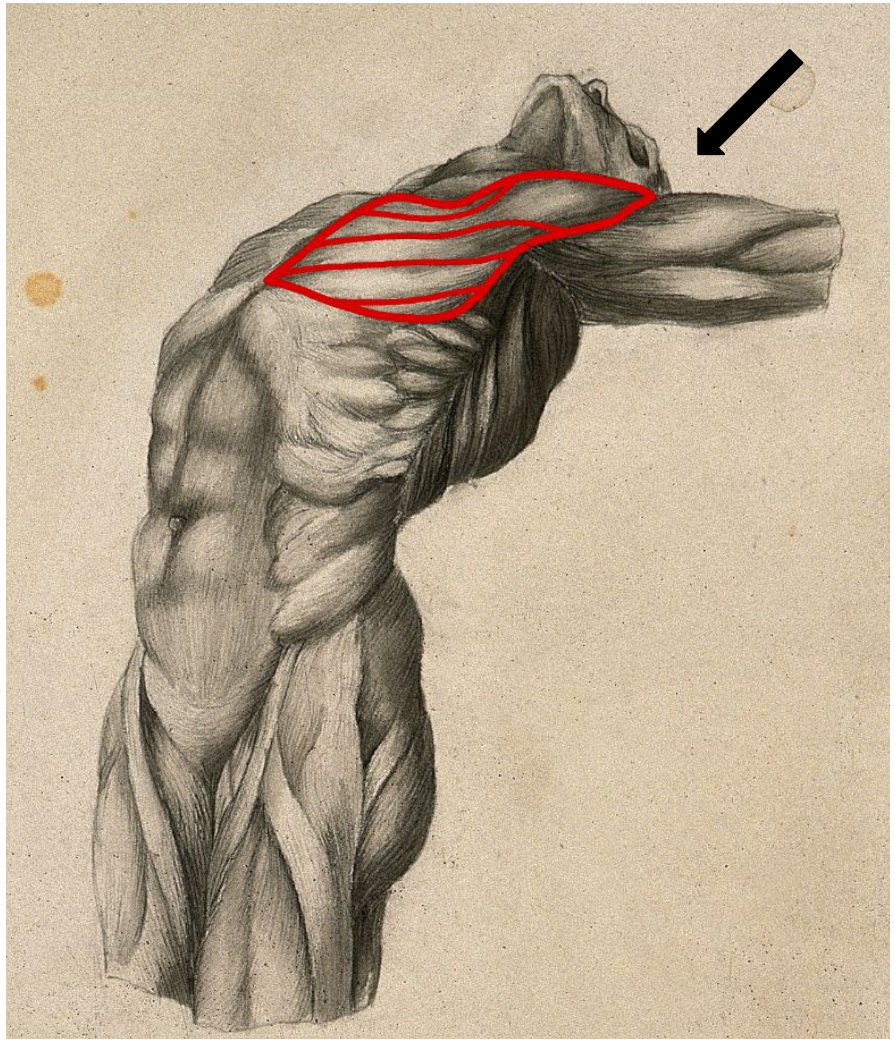


Torso: Pectoralis Major

Pectoralis Major

Functions:

- adduct arm
- internally rotate arm
- flex arm at shoulder
- assist in breathing

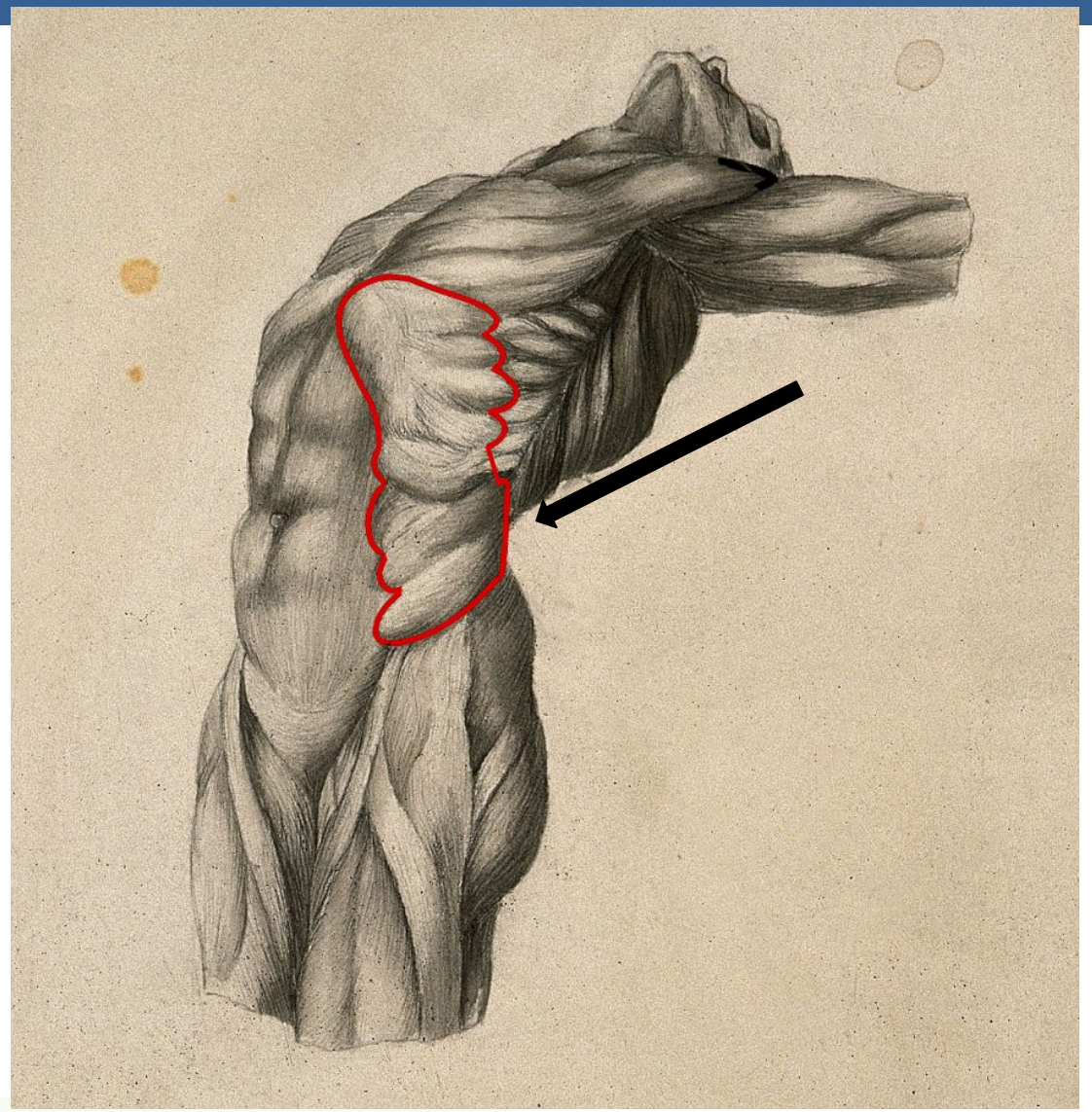


Torso: External Oblique

External Oblique

Functions:

- trunk flexion
- lateral flexion
- trunk rotation
- forced expiration

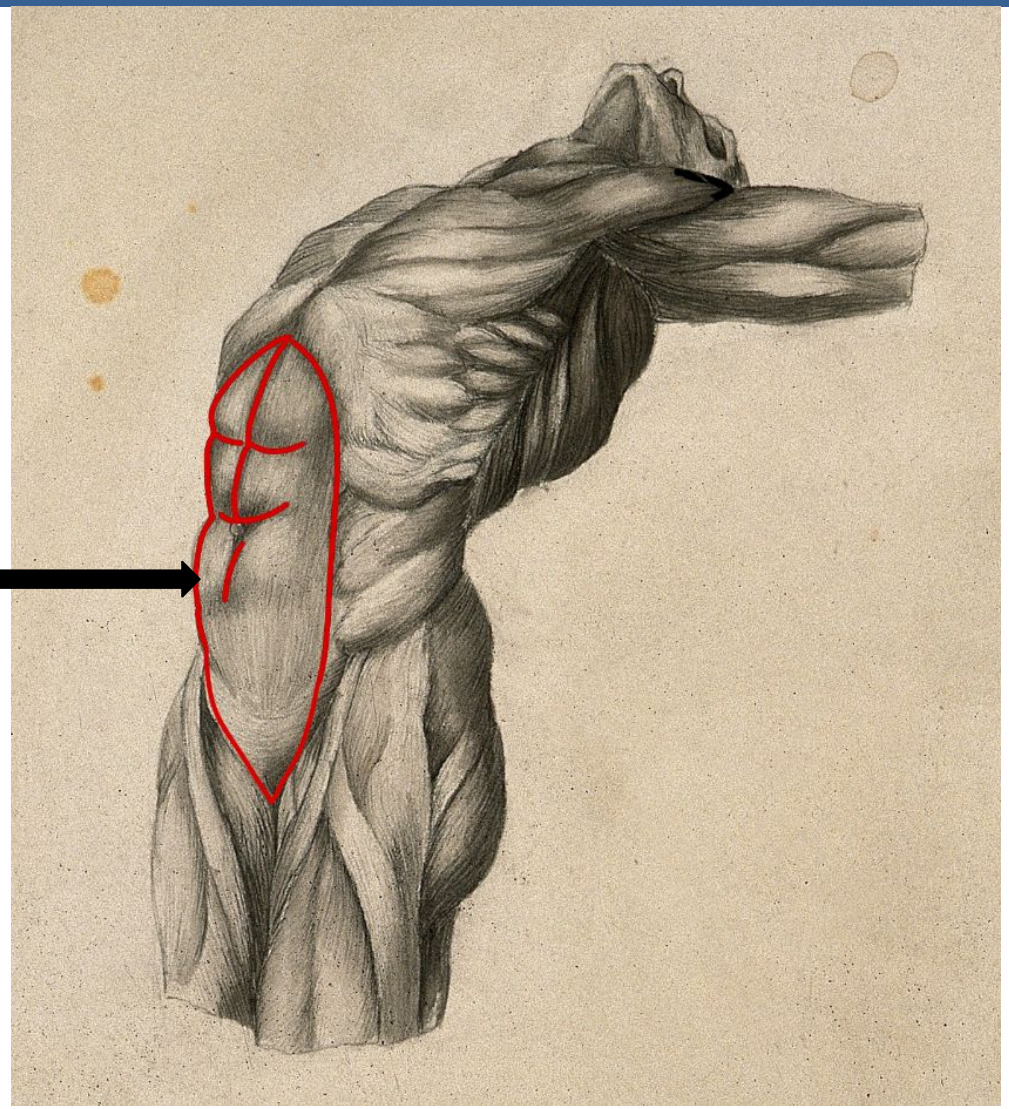


Torso: Rectus Abdominis

Rectus Abdominis

Functions:

- trunk flexion
- tense abdominal muscles
- stability
- increase intraabdominal pressure as in bowel movements

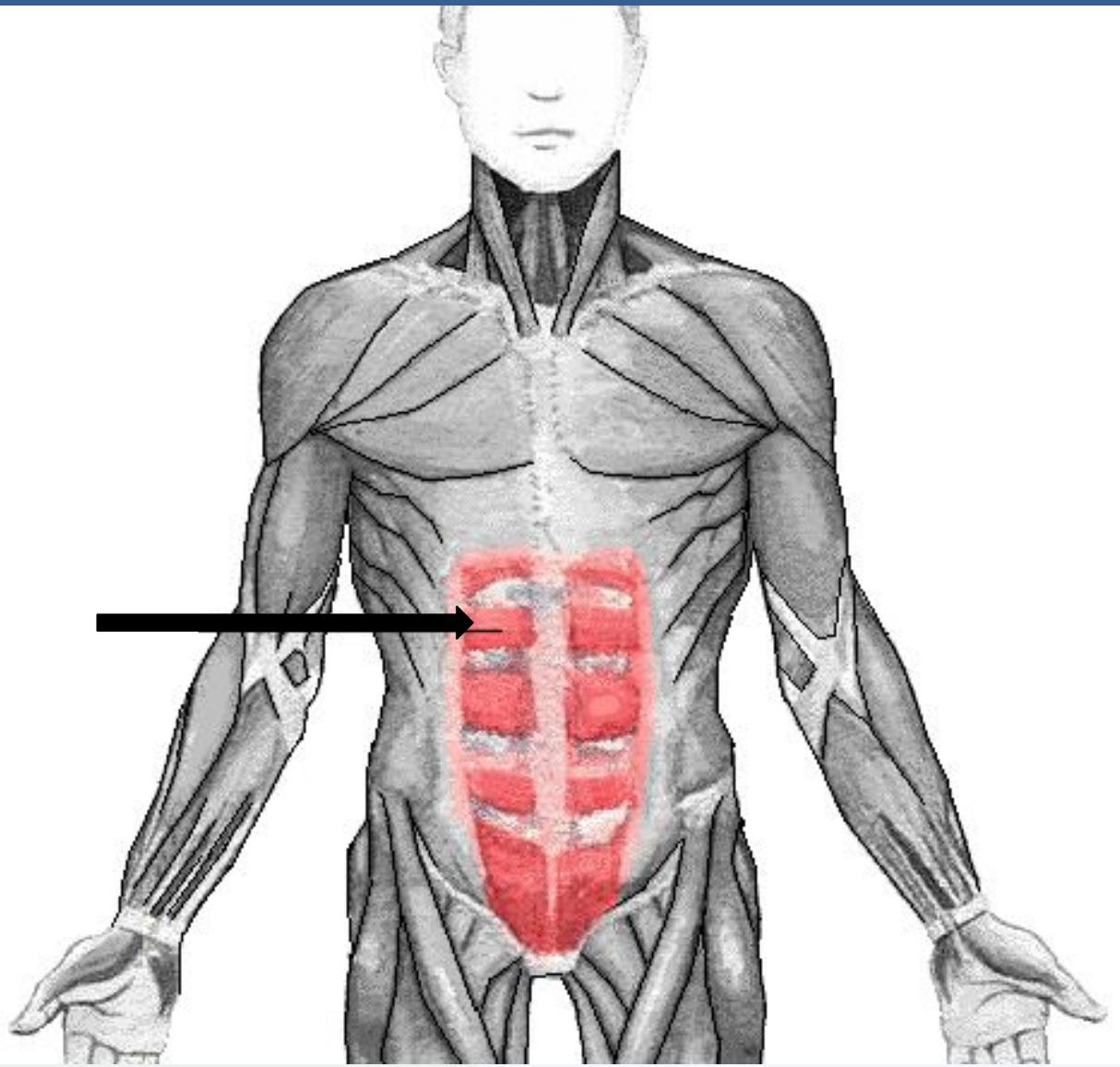


Torso: Rectus Abdominis anterior view

Rectus Abdominis

Functions:

- trunk flexion
- tense abdominal muscles
- stability
- increase intraabdominal pressure as in bowel movements



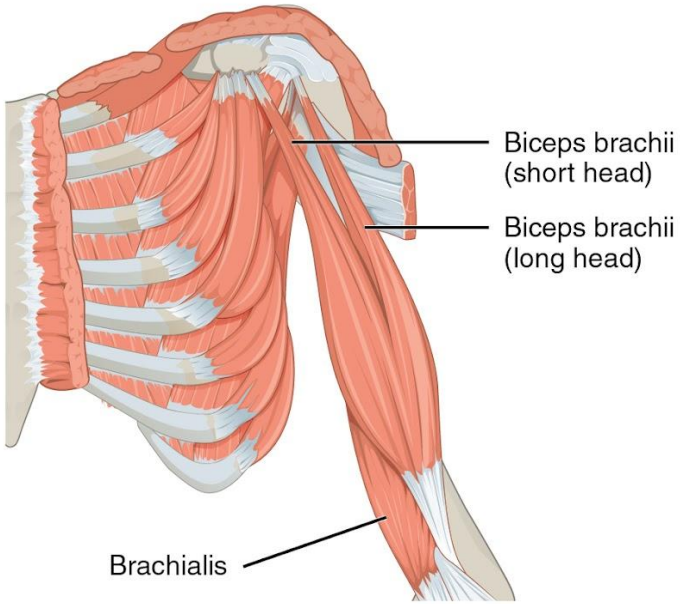
Rectus Abdominis by Nikai, CC BY-SA 3.0, via Wikimedia Commons

Major Muscles: Upper Arm

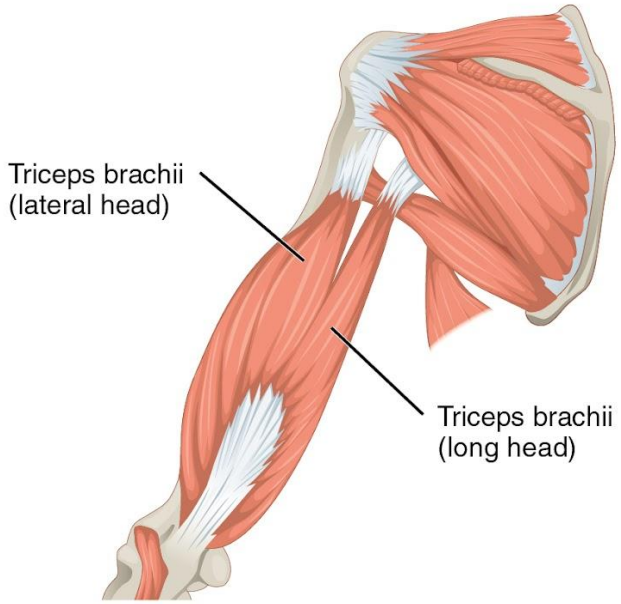
Biceps Brachii

Triceps Brachii

Brachioradialis



Left upper arm muscles (anterior lateral view)



Left upper arm muscles (posterior view)

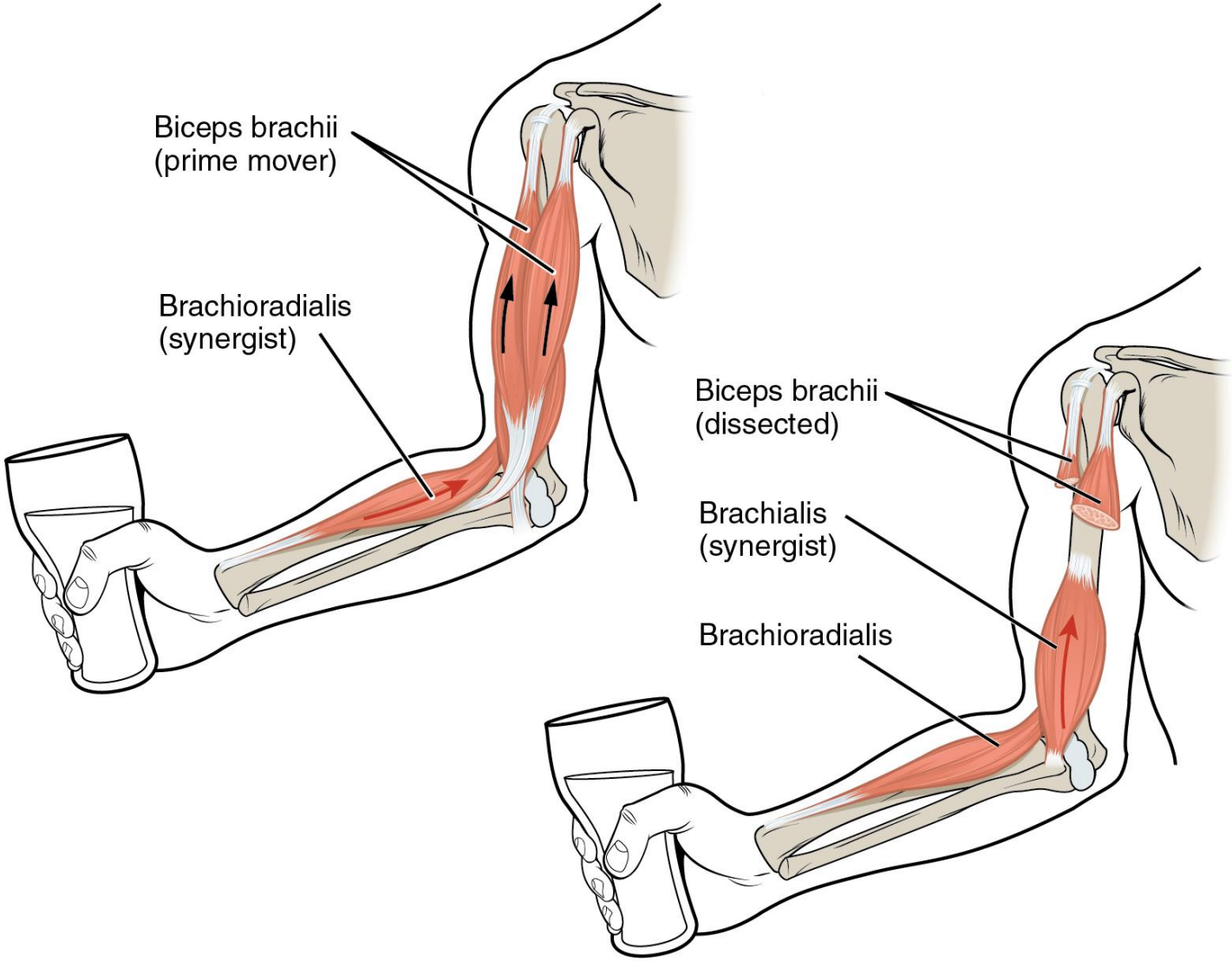
Figure 11.25 **Muscles That Move the Forearm** by Openstax College

Upper Arm: Biceps Brachii

Biceps Brachii

Functions:

- elbow flexion
- rotates forearm
- shoulder flexion
- stabilizes shoulder

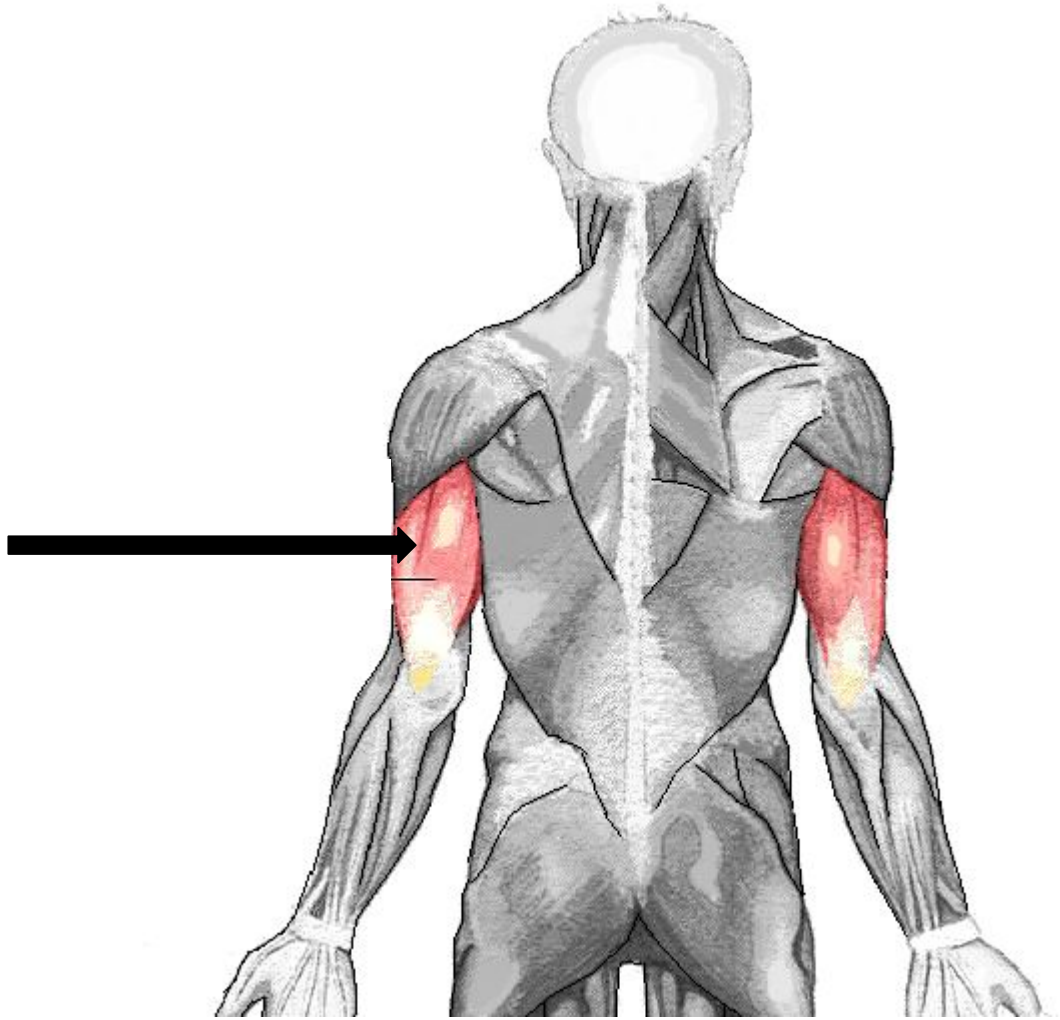


Upper Arm: Triceps Brachii

Triceps Brachii

Functions:

- elbow extension
- brings arm closer to body (adduction)
- stabilizes shoulder
- stabilizes elbow

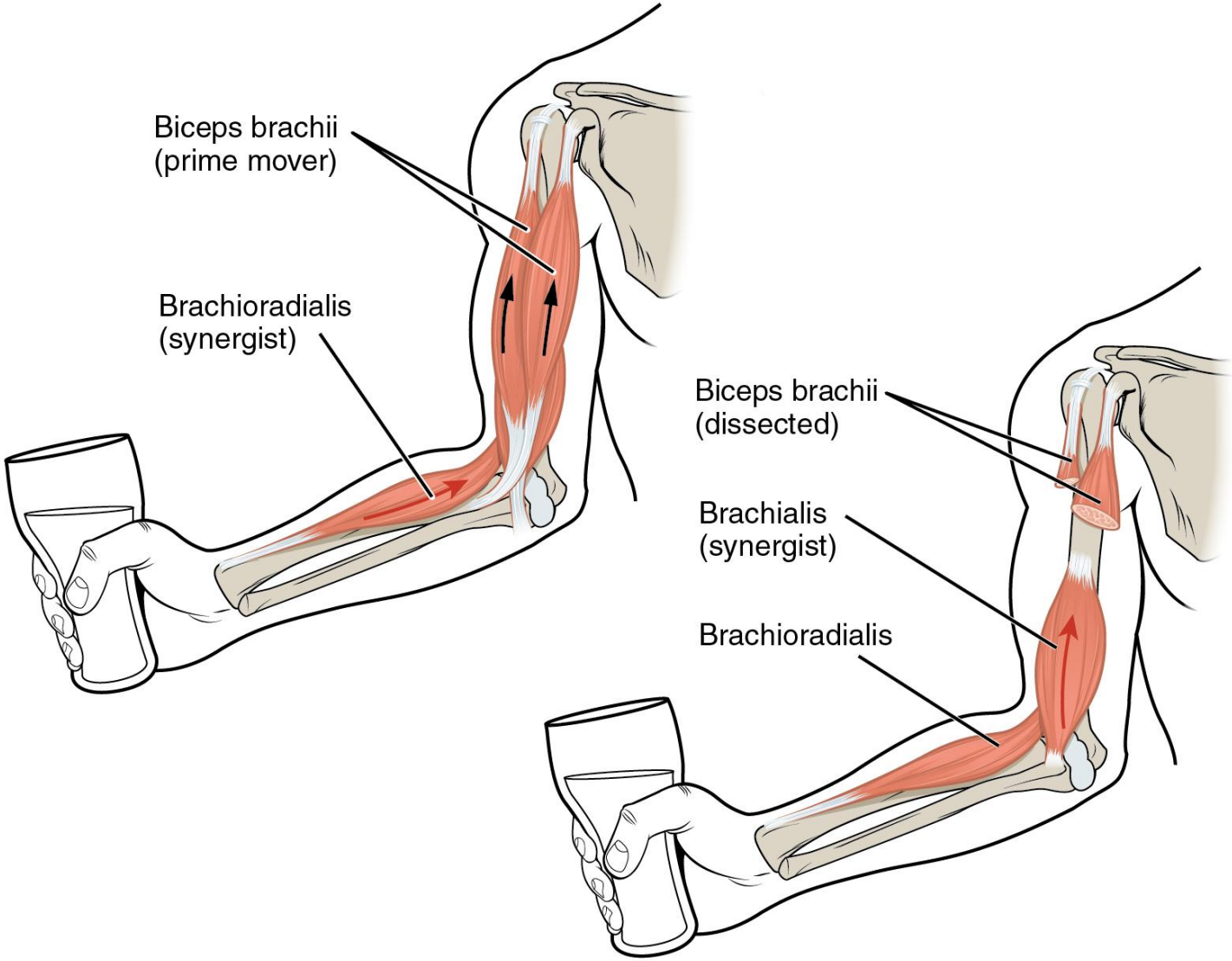


Arm: Brachioradialis

Brachioradialis

Functions:

- flexes elbow
- rotates forearm



Major Muscles: Forearm

Supinator

Pronator Teres

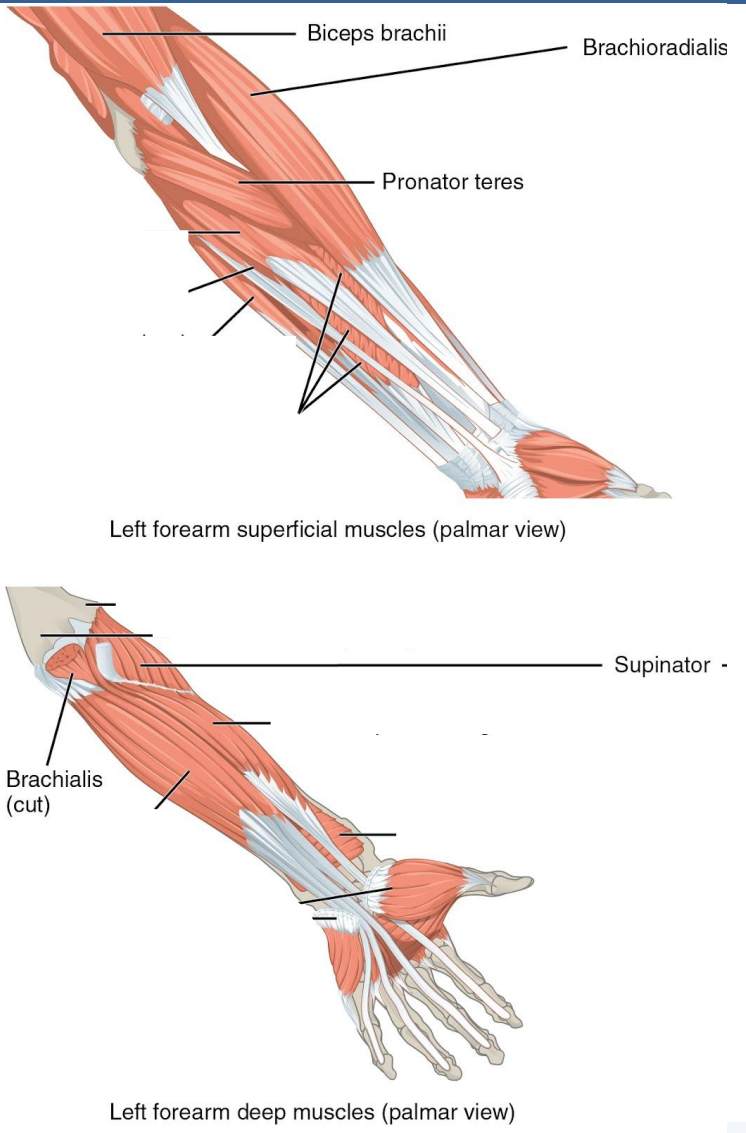


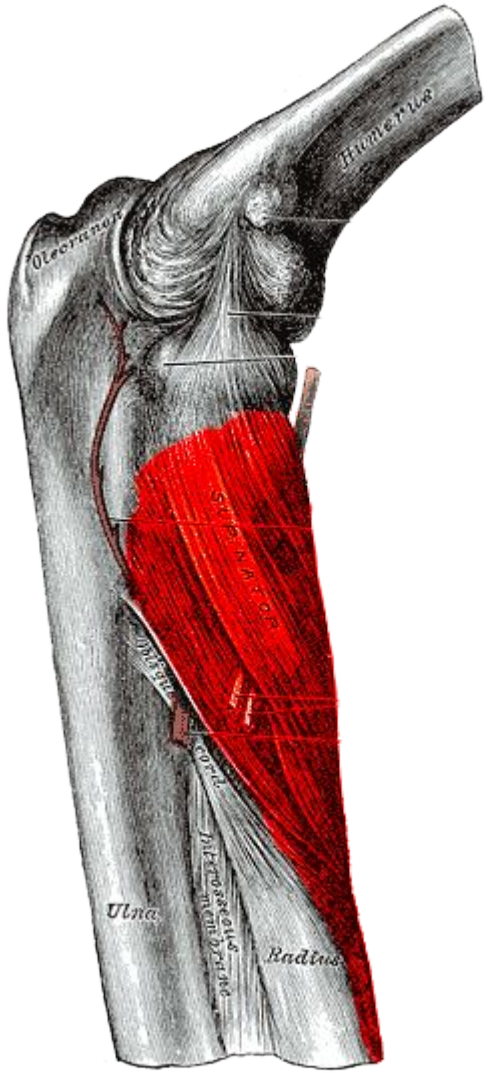
Figure 11.25 **Muscles That Move the Forearm** by Openstax College

Forearm: Supinator

Supinator in **red**

Functions:

- supinates forearm
  - palms face anteriorly
  - like you carry soup



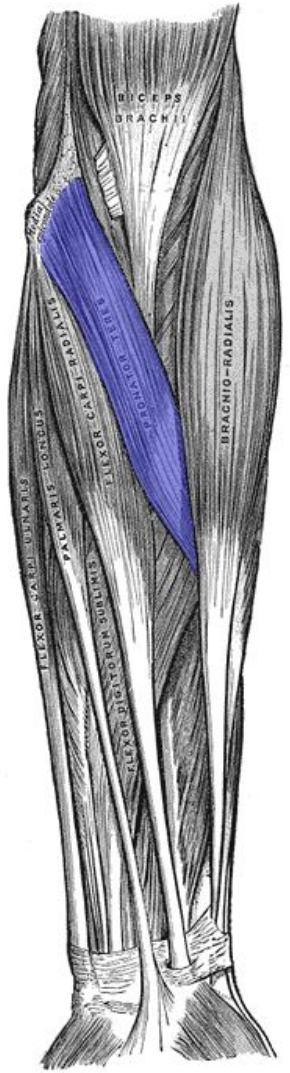
Supinator By Henry Vandyke Carter, Public Domain, via Wikimedia Commons

Forearm: Pronator Teres

Pronator Teres in **violet**

Functions:

- pronates forearm
  - palms face posteriorly

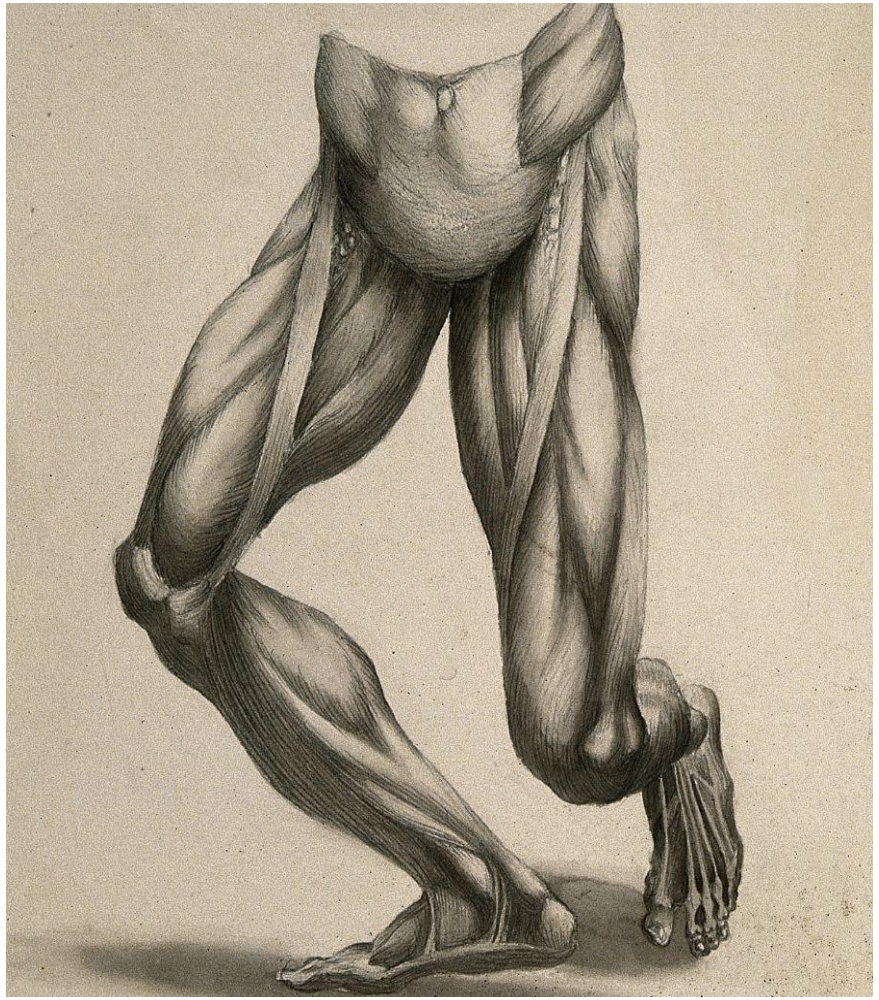


Pronator Teres By Selket, Public Domain, via Wikimedia Commons

Major Muscles: Upper Leg anterior

Quadriceps femoris:

- Rectus femoris
- Vastus lateralis
- Vastus medialis
- Vastus intermedius



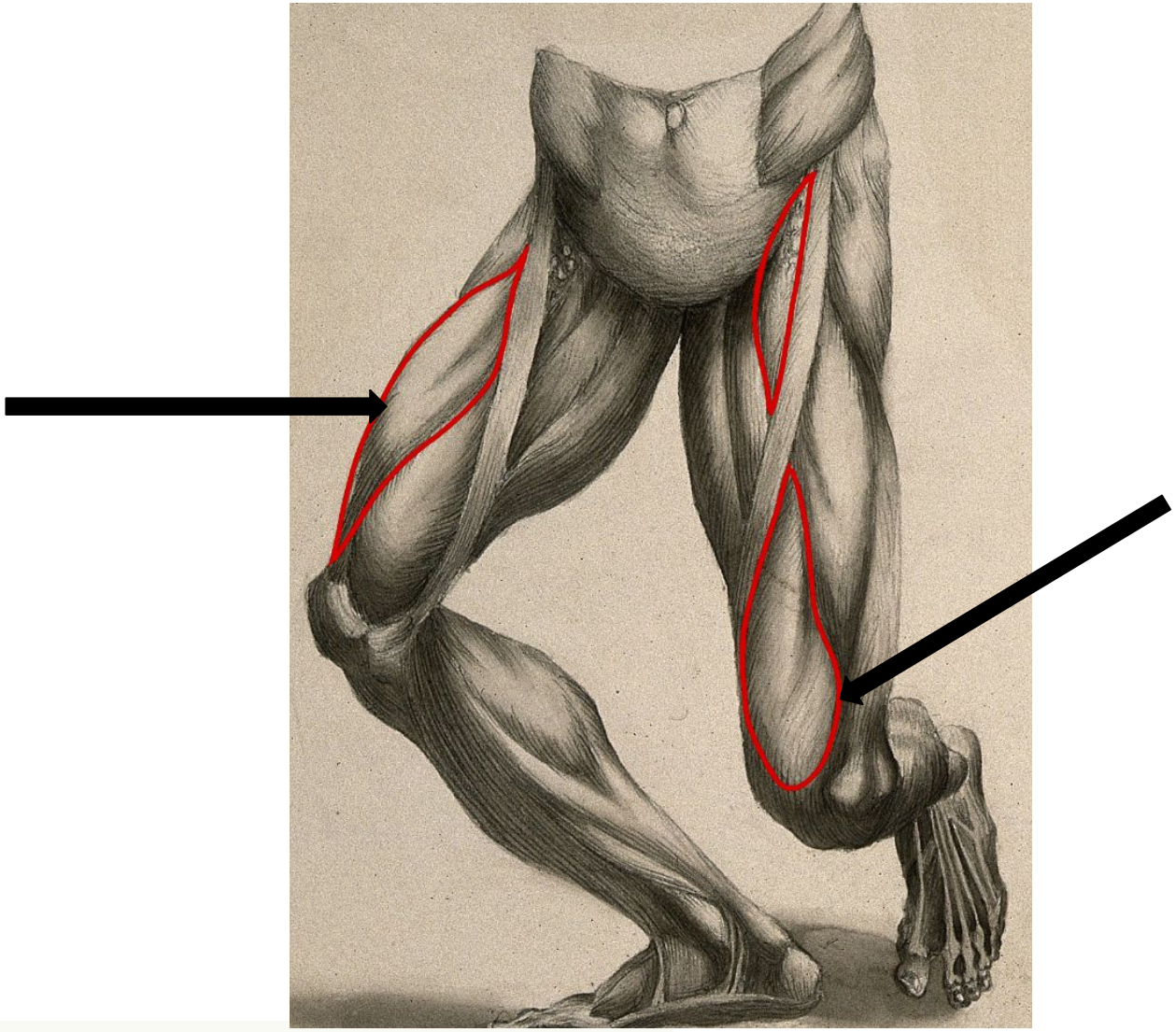
Quads: Rectus Femoris

Quadriceps femoris:

- Rectus femoris

Functions:

- hip flexion
- knee extension



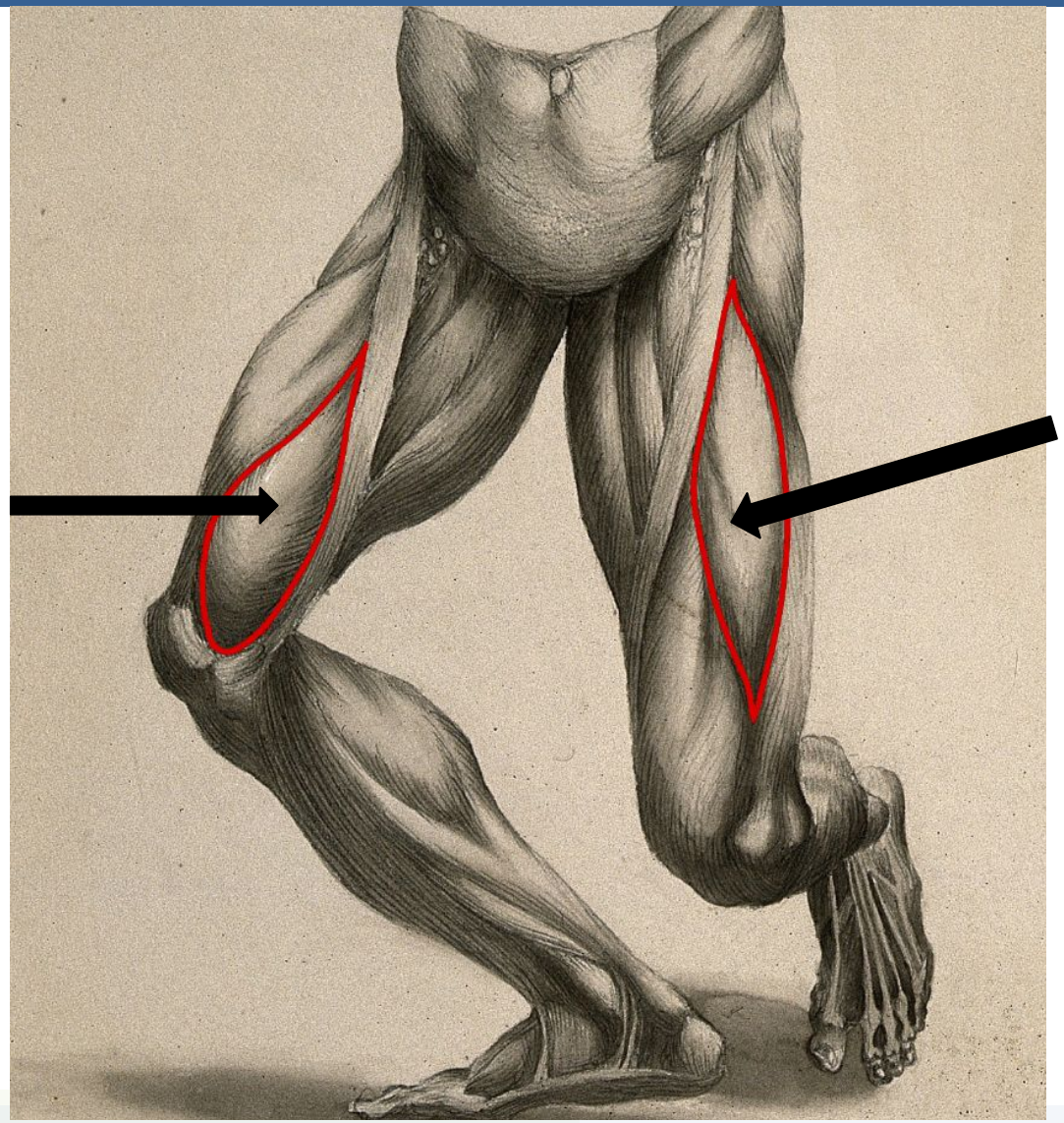
Quads: Vastus Lateralis and Vastus Medialis

Quadriceps femoris:

- Vastus Lateralis
- Vastus Medialis

Functions:

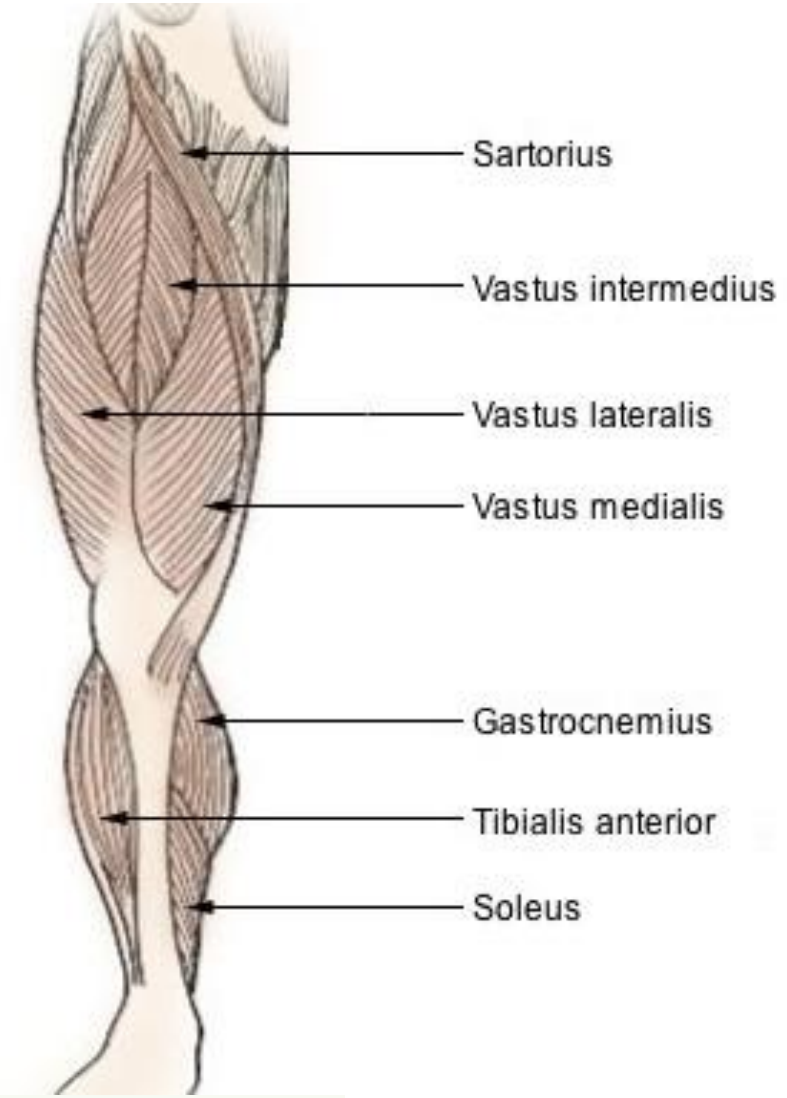
- knee extension



Quads: Vastus Intermedius

Quadriceps femoris:

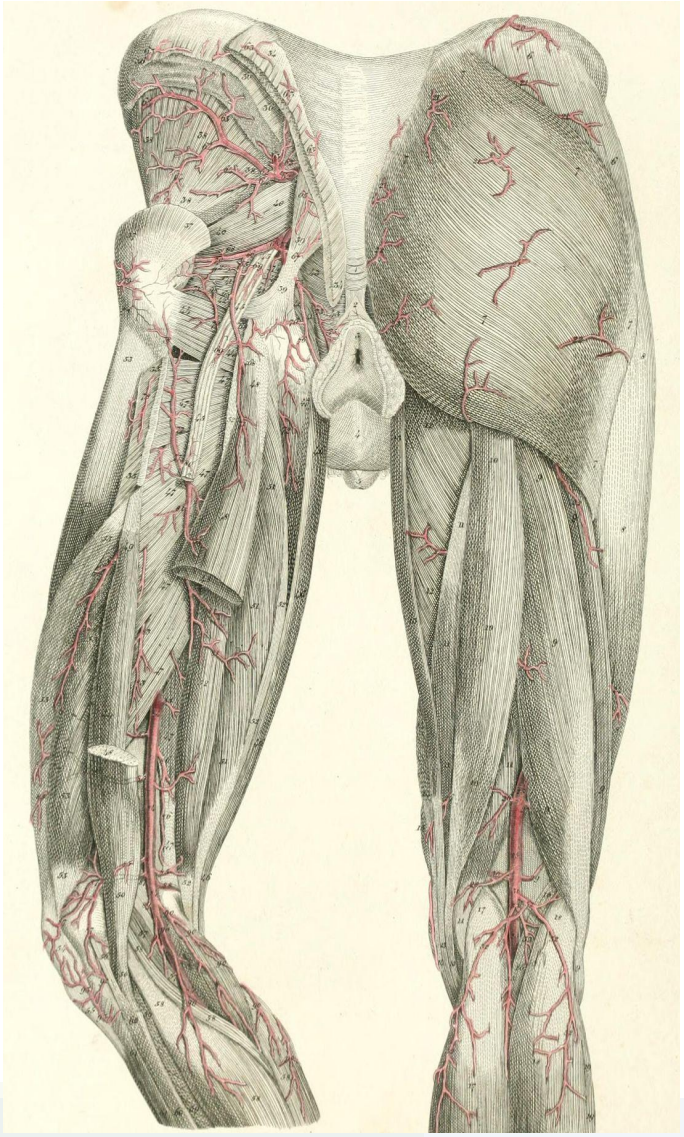
- Vastus intermedius
  - must remove rectus femoris to view the vastus intermedius
  - knee extension



Major Muscles of the human body: Upper Leg posterior

Biceps femoris

Gluteus Maximus



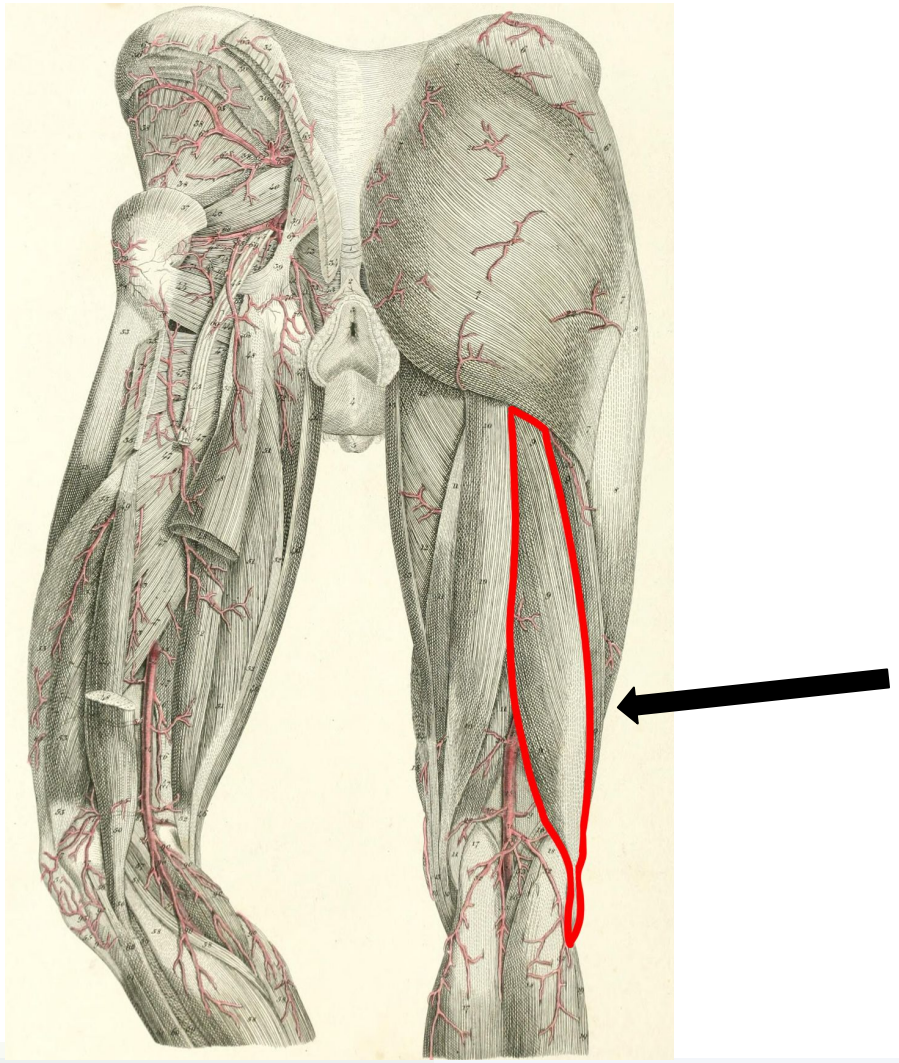
Plates of the arteries of the Human Body Internet Archive Book Images, No restrictions, via Wikimedia Commons

Upper Leg posterior: Biceps Femoris

Biceps femoris

Functions:

- hip extension
- lateral rotation of tibia

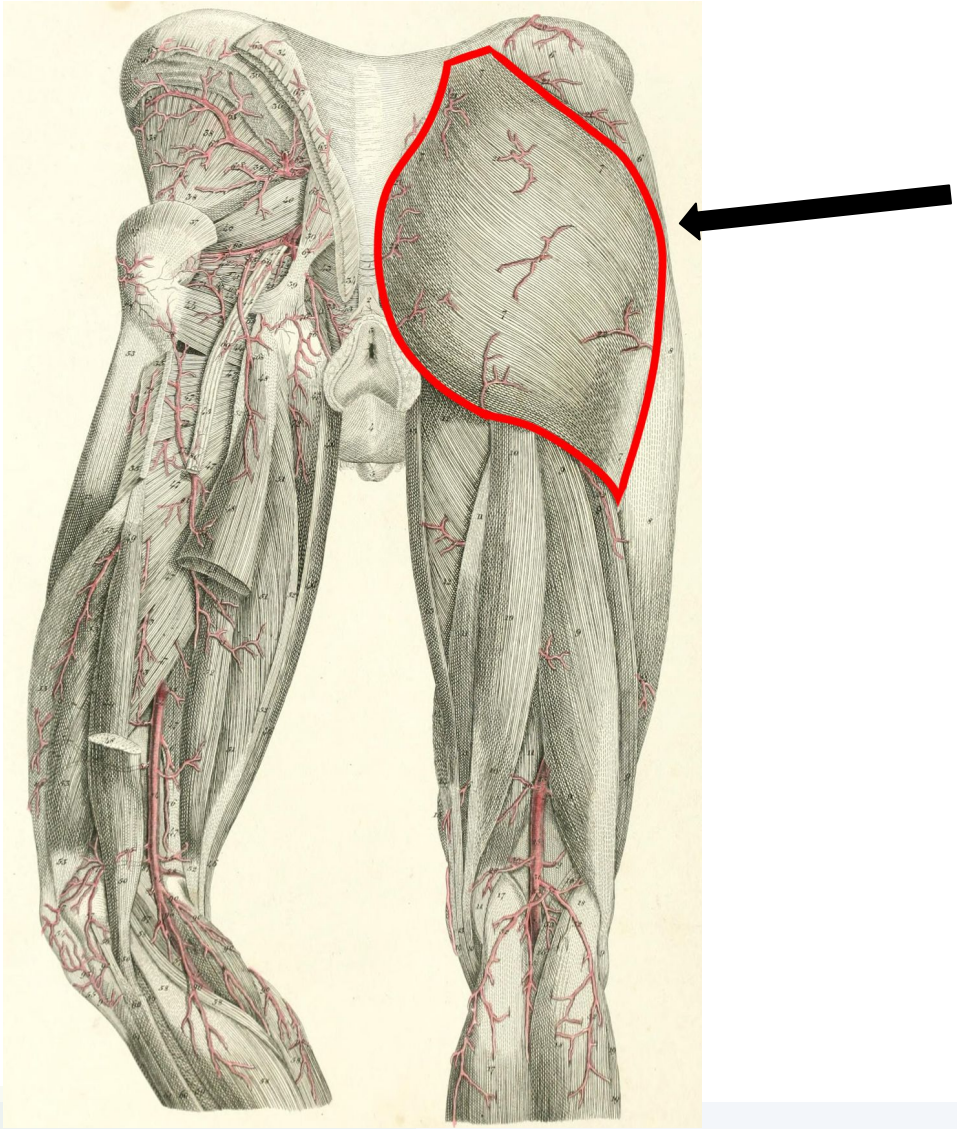


Upper Leg posterior: Gluteus Maximus

Gluteus Maximus

Functions:

- hip extension
- external rotation
- core stability
- pelvic stabilization
- walking & running
- sitting & standing

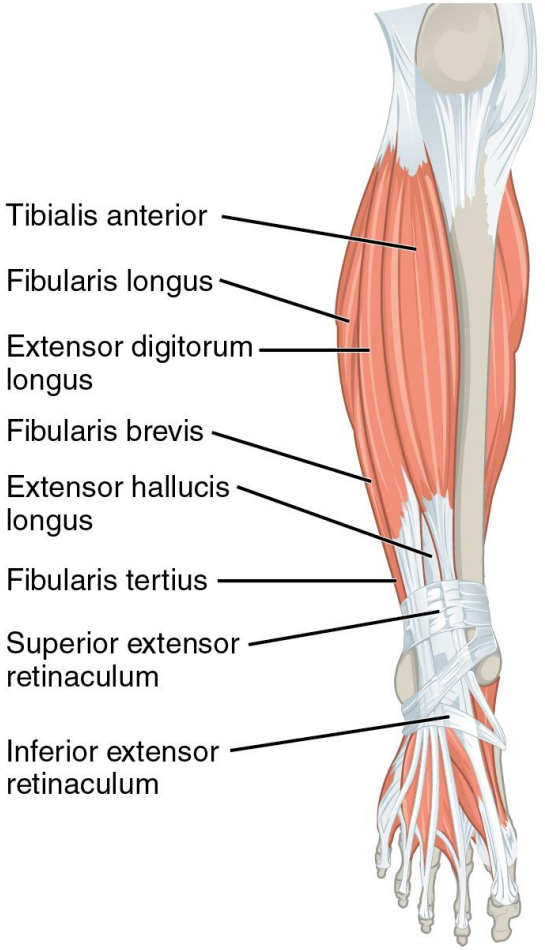


Major Muscles: Lower Leg

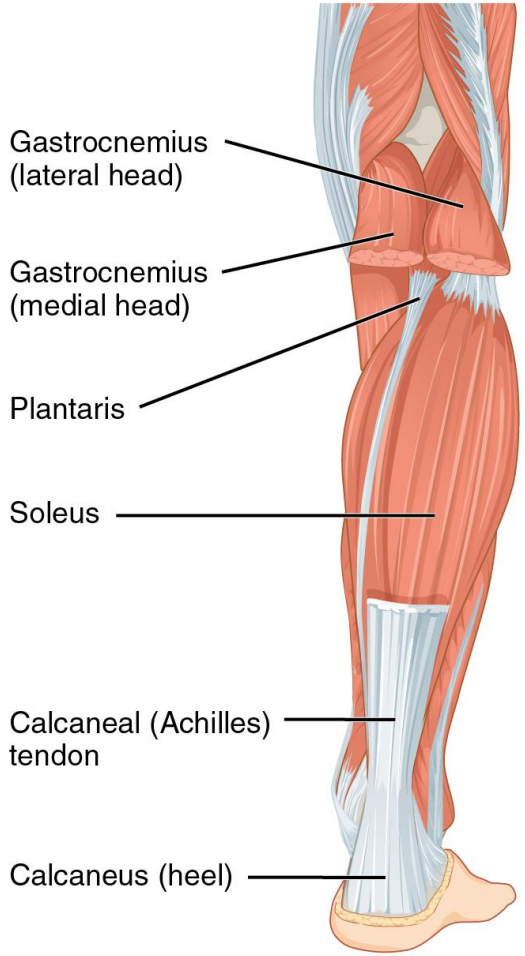
Tibialis Anterior

Gastrocnemius

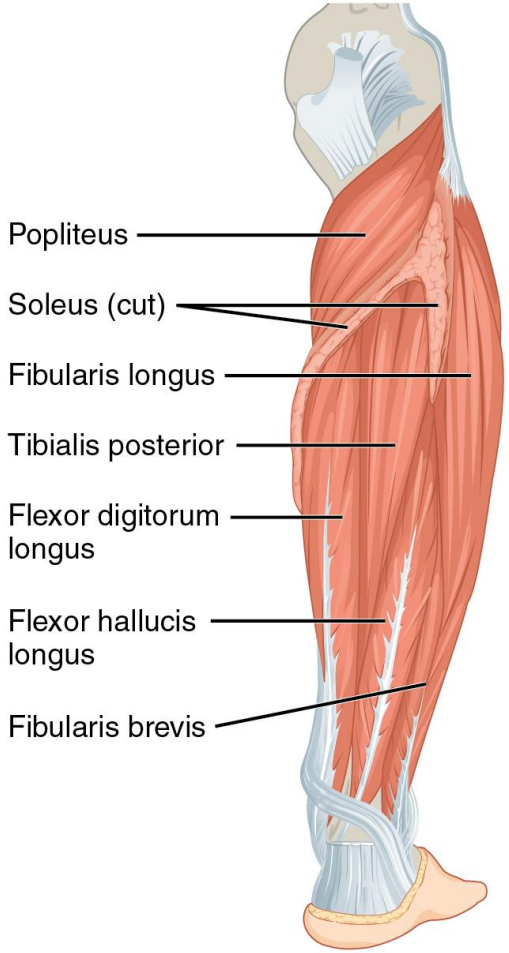
Soleus



Superficial muscles of the right lower leg (anterior view)



Superficial muscles of the right lower leg (posterior view)



Deep muscles of the right lower leg (posterior view)

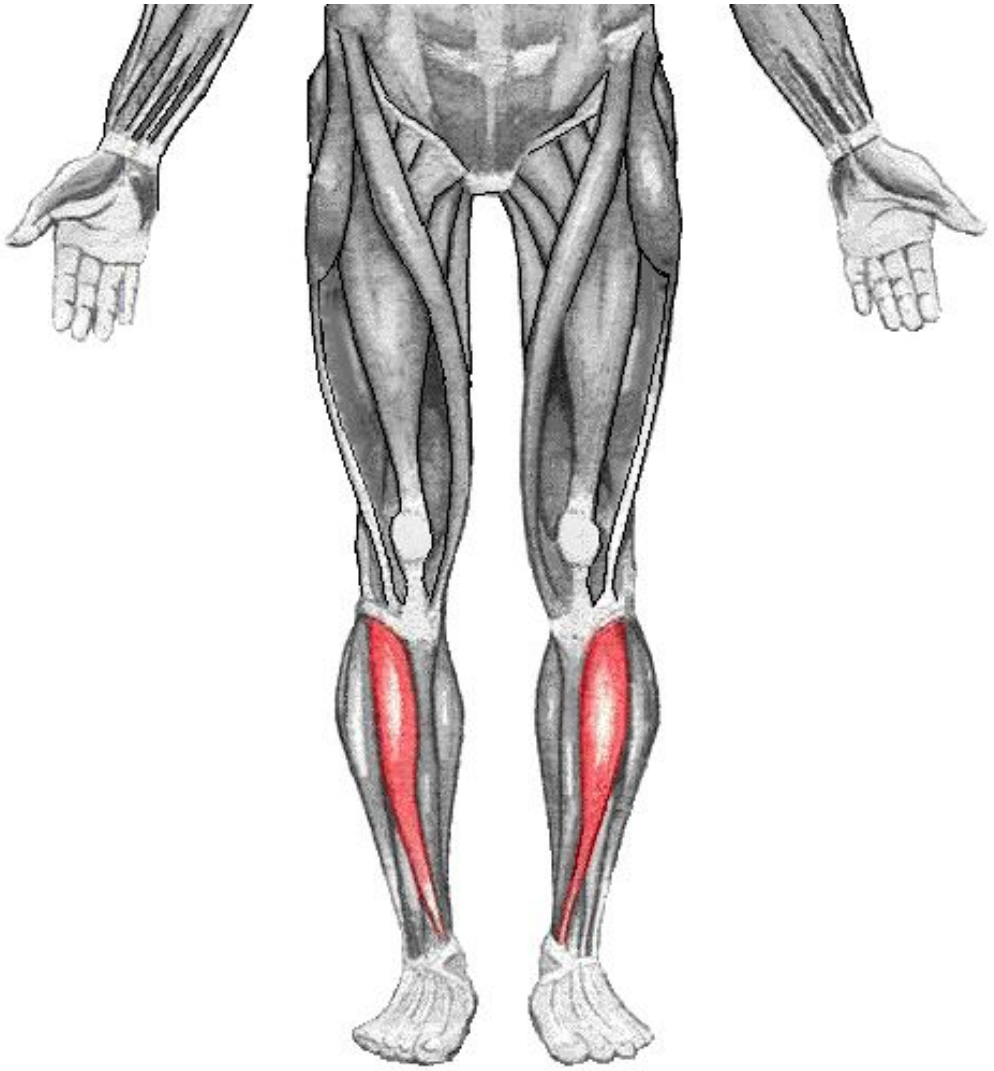
Figure 11.32 Muscles of the Lower Leg by Openstax College

Lower Leg: Tibialis Anterior

Tibialis Anterior

Function:

- dorsiflexion
  - standing on one's heels

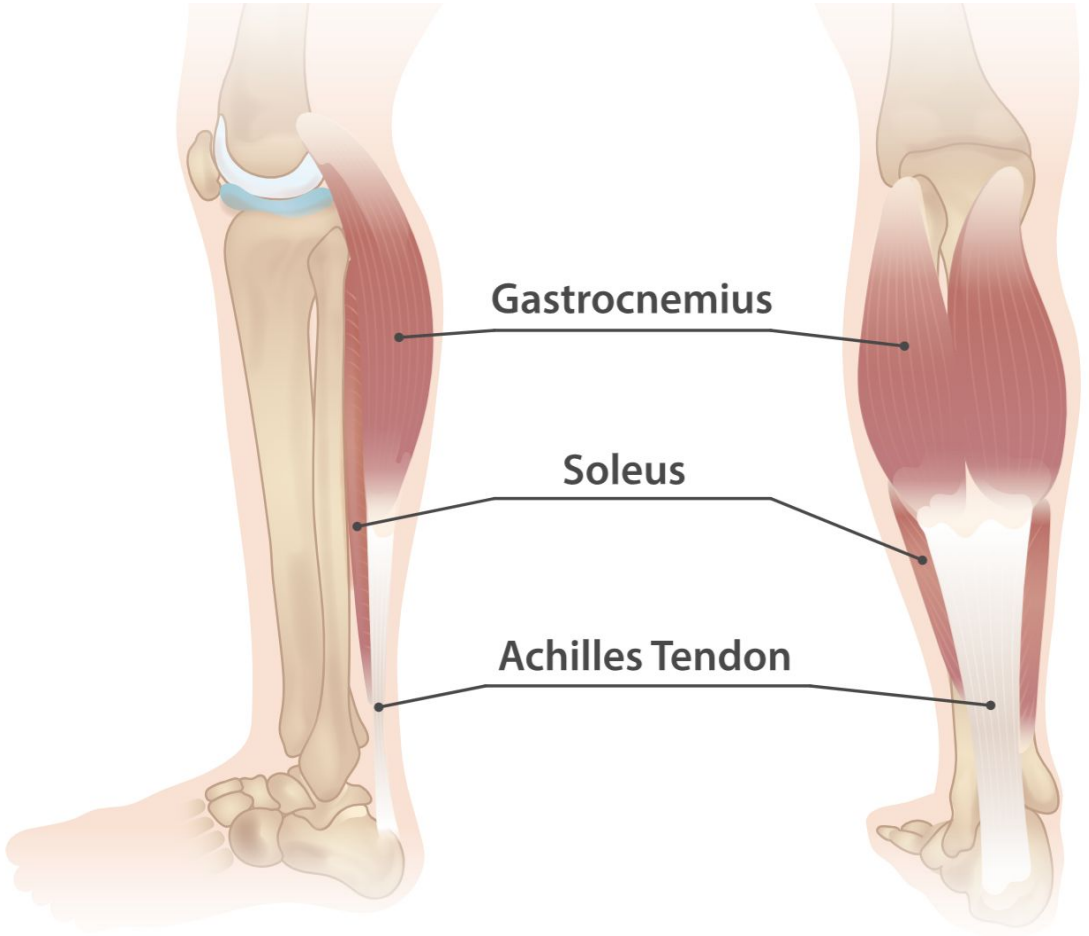


Lower Leg: Gastrocnemius

Gastrocnemius

Function:

- plantar flexion
  - standing on one's toes



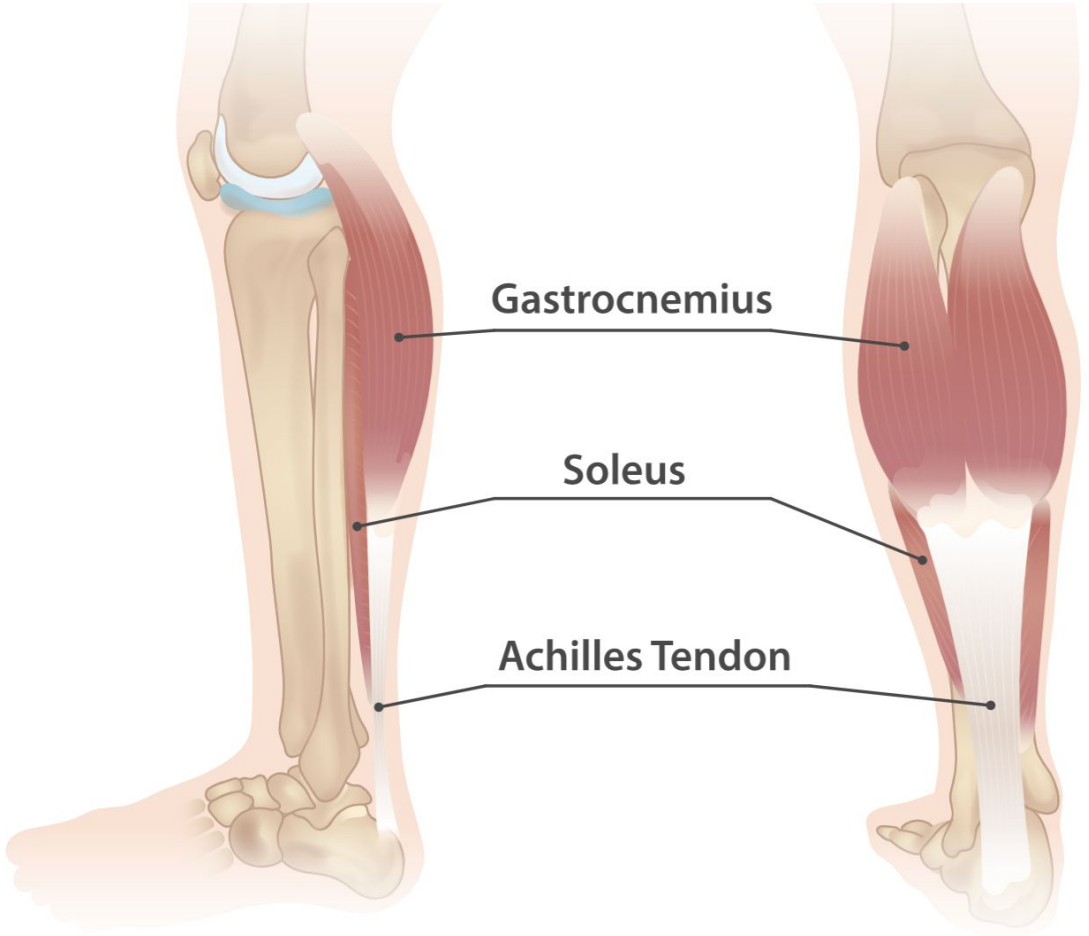
Lower Leg Muscles by InjuryMap, CC BY-SA 4.0, via Wikimedia Commons

Lower Leg: Soleus

Soleus

Function:

- plantar flexion
  - standing on one's toes



Lower Leg Muscles by InjuryMap, CC BY-SA 4.0, via Wikimedia Commons

Lesson 3: Muscle Contraction Summary

Summary:

Describe the sequence of events from neuronal stimulation that lead to muscle contraction, control its strength and duration, and allow cessation.

Describe how the frequency of action potentials from a motor neuron affects tension produced in the skeletal muscle.

Identify the major muscles by anatomical name.