The Muscular System

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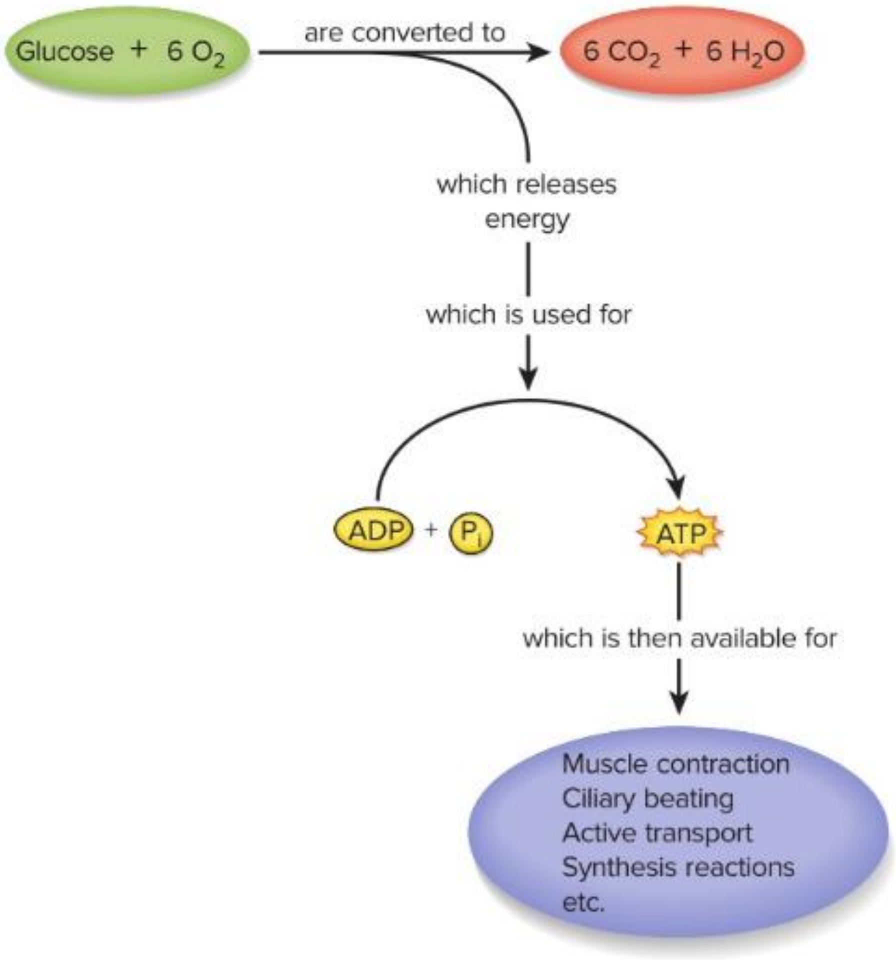
PART III

Two main pathways of ATP synthesis

- **anaerobic fermentation**
  - enables cells to produce ATP in the absence of oxygen
  - yields little ATP and toxic lactic acid, a major factor in muscle fatigue

- **aerobic respiration**
  - produces far more ATP
  - less toxic end products (CO_2 and water)
  - requires a continual supply of oxygen



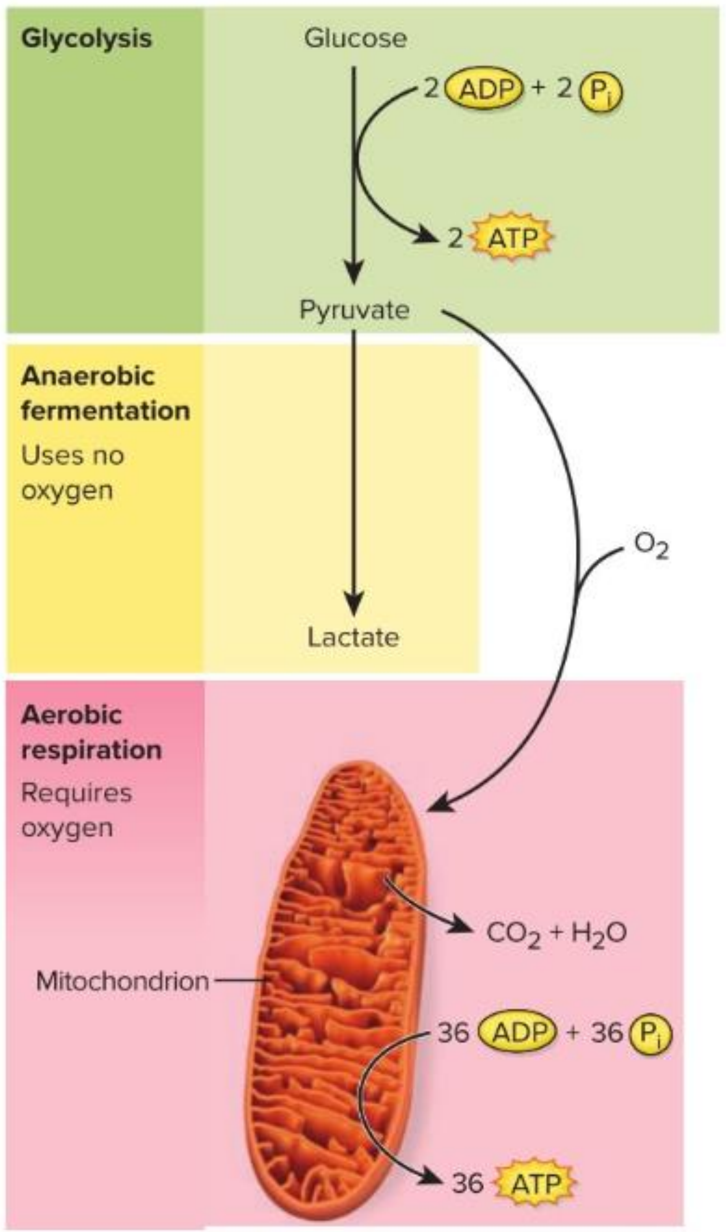


FIGURE 2.30 The Source and Uses of ATP.

Modes of ATP Synthesis During Exercise

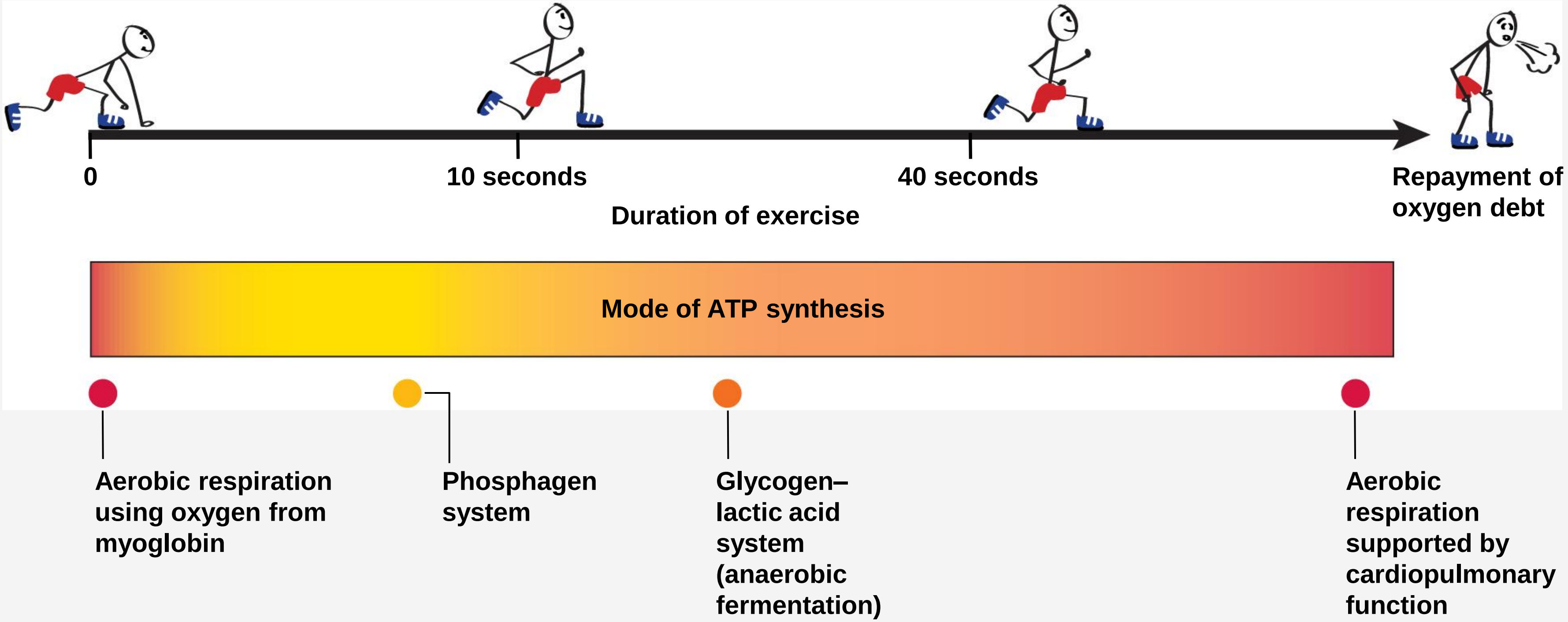
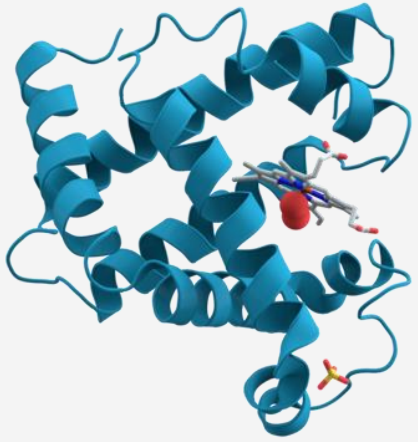


Figure 11.18

- In a short, intense exercise such as a 100 m dash, the myoglobin in a muscle fiber supplies oxygen for a limited amount of aerobic respiration at the outset, but this oxygen supply is quickly depleted.

Myoglobin is an iron- and oxygen-binding protein found in the muscle tissue. Not presented in the blood, heavy weight.

In case of **prolonged compression syndrome** myoglobin yield to blood and clogs the renal tubules



Immediate Energy Needs

- two enzyme systems control these **phosphate transfers**
  - **myokinase** – transfers P_i from one ADP to another converting the latter to ATP
  - **creatine kinase** – obtains P_i from a phosphate-storage molecule creatine phosphate (CP)
    - fast-acting system that helps maintain the ATP level while other ATP-generating mechanisms are being activated

- **phosphagen system** – ATP and CP collectively
  - provides nearly all energy used for short bursts of intense activity
    - one minute of brisk walking
    - 6 seconds of sprinting or fast swimming
    - important in activities requiring brief but maximum effort
      - football, baseball, and weight lifting

Immediate Energy Needs

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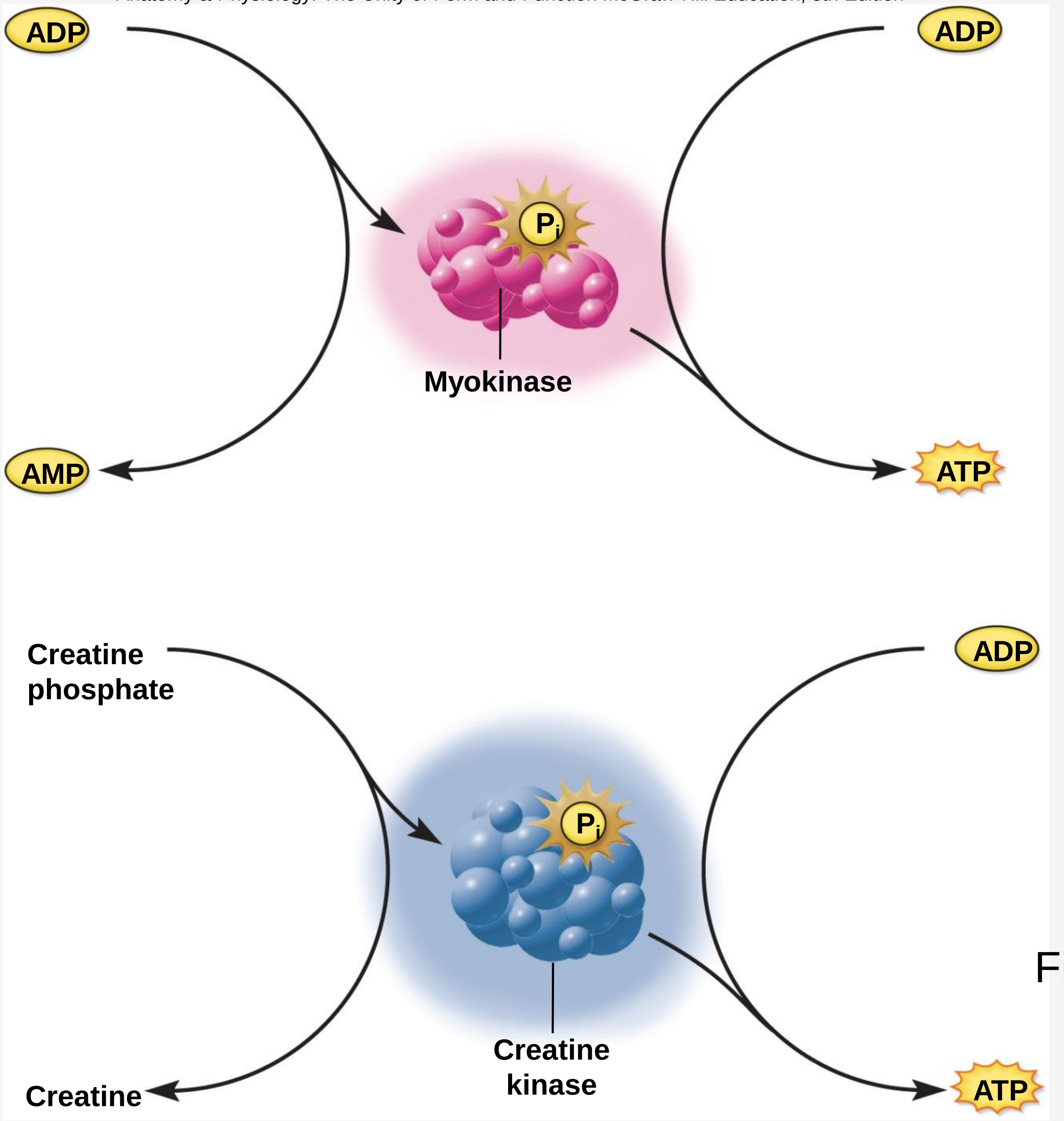

Figure 11.19

Short-Term Energy Needs

- as the phosphagen system is exhausted
- muscles shift to **anaerobic fermentation**
  - muscles obtain glucose from blood and their own stored glycogen
  - in the absence of oxygen, **glycolysis** can generate a net gain **of 2 ATP** for every glucose molecule consumed
  - converts glucose (pyruvate) to lactic acid
- **glycogen-lactic acid system** – the pathway from glycogen to lactic acid
- produces enough ATP for **30 – 40 seconds** of maximum activity

Long-Term Energy Needs

- after 40 seconds or so, the respiratory and cardiovascular systems “catch up” and deliver oxygen to the muscles fast enough for aerobic respiration to meet most of the ATP demands
- aerobic respiration produces 36 ATP per glucose
  - efficient means of meeting the ATP demands of prolonged exercise
  - one’s rate of **oxygen consumption** rises for 3 to 4 minutes and levels off to a steady state in which aerobic ATP production keeps pace with demand
  - then, as glucose and glycogen are depleted, fatty acids become the more significant fuel.

Fatigue

- **muscle fatigue** - progressive weakness and loss of contractility from prolonged use of the muscles
  - repeated squeezing of rubber ball
  - holding text book out level to the floor

- **causes** of muscle fatigue
  - ATP synthesis declines as glycogen is consumed
  - ATP shortage slows down the Na^+ - K^+ pumps
    - compromises their ability to maintain the resting membrane potential and excitability of the muscle fibers
  - lactic acid lowers pH of sarcoplasm
    - inhibits enzymes involved in contraction, ATP synthesis, and other aspects of muscle function
  - release of K^+ with each action potential causes the accumulation of extracellular K^+
    - hyperpolarizes the cell and makes the muscle fiber less excitable
  - motor nerve fibers use up their ACh
    - less capable of stimulating muscle fibers – **junctional fatigue**
  - central nervous system, where all motor commands originate, fatigues by unknown processes, so there is less signal output to the skeletal muscles

Endurance

- **endurance** – the ability to maintain high-intensity exercise for more than 4 to 5 minutes
  - determined in large part by one's **maximum oxygen uptake** (VO_2max)
  - **maximum oxygen uptake** – the point at which the rate of oxygen consumption reaches a plateau and does not increase further with an added workload
    - proportional to body size
    - peaks at around age 20
    - usually greater in males than females
    - can be twice as great in trained endurance athletes as in untrained person
      - results in twice the ATP production

Oxygen Debt

- heavy breathing continues after strenuous exercise
  - **excess post-exercise oxygen consumption (EPOC)** – the difference between the resting rate of oxygen consumption and the elevated rate following exercise.
  - typically about 11 liters extra is needed after strenuous exercise
  - repaying the **oxygen debt**

- needed for the following purposes:
  - **replace oxygen reserves** depleted in the first minute of exercise
    - oxygen bound to myoglobin and blood hemoglobin, oxygen dissolved in blood plasma and other extracellular fluid, and oxygen in the air in the lungs
  - **replenishing the phosphagen system**
    - synthesizing ATP and using some of it to donate the phosphate groups back to creatine until resting levels of ATP and CP are restored
  - **oxidizing lactic acid**
    - 80% of lactic acid produced by muscles enter bloodstream
    - reconverted to pyruvic acid in the kidneys, cardiac muscle, and especially the liver
    - liver converts most of the pyruvic acid back to glucose to replenish the glycogen stores of the muscle.
  - **serving the elevated metabolic rate**
    - occurs while the body temperature remains elevated by exercise and consumes more oxygen

Beating Muscle Fatigue

- taking **oral creatine** increases level of creatine phosphate in muscle tissue and increases speed of ATP regeneration
  - useful in burst type exercises – weight-lifting
  - risks are not well known
    - muscle cramping, electrolyte imbalances, dehydration, water retention, stroke
    - kidney disease from overloading kidney with metabolite creatinine

- **carbohydrate loading** – dietary regimen
  - packs extra glycogen into muscle cells
  - extra glycogen is hydrophilic and adds 2.7 g water/ g glycogen
    - athletes feel sense of heaviness outweighs benefits of extra available glycogen

Physiological Classes of Muscle Fibers

- **slow oxidative (SO)**, **slow-twitch**, **red**, or **type I fibers**
  - abundant mitochondria, myoglobin and capillaries - deep red color
    - adapted for aerobic respiration and fatigue resistance
      - relative long twitch lasting about 100 msec
      - soleus of calf and postural muscles of the back

- **fast glycolytic (FG), fast-twitch**, **white**, or **type II fibers**
  - fibers are well adapted for quick responses, but not for fatigue resistance
  - rich in enzymes of phosphagen and glycogen-lactic acid systems generate lactic acid causing fatigue
  - poor in mitochondria, myoglobin, and blood capillaries which gives pale appearance
    - SR releases & reabsorbs Ca^{+2} quickly so contractions are quicker (7.5 msec/twitch)
      - extrinsic eye muscles, gastrocnemius and biceps brachii

- ratio of different fiber types have genetic predisposition – born sprinter
  - muscles differ in fiber types - gastrocnemius is predominantly FG for quick movements (jumping)
  - soleus is predominantly SO used for endurance (jogging)

FG and SO Muscle Fibers

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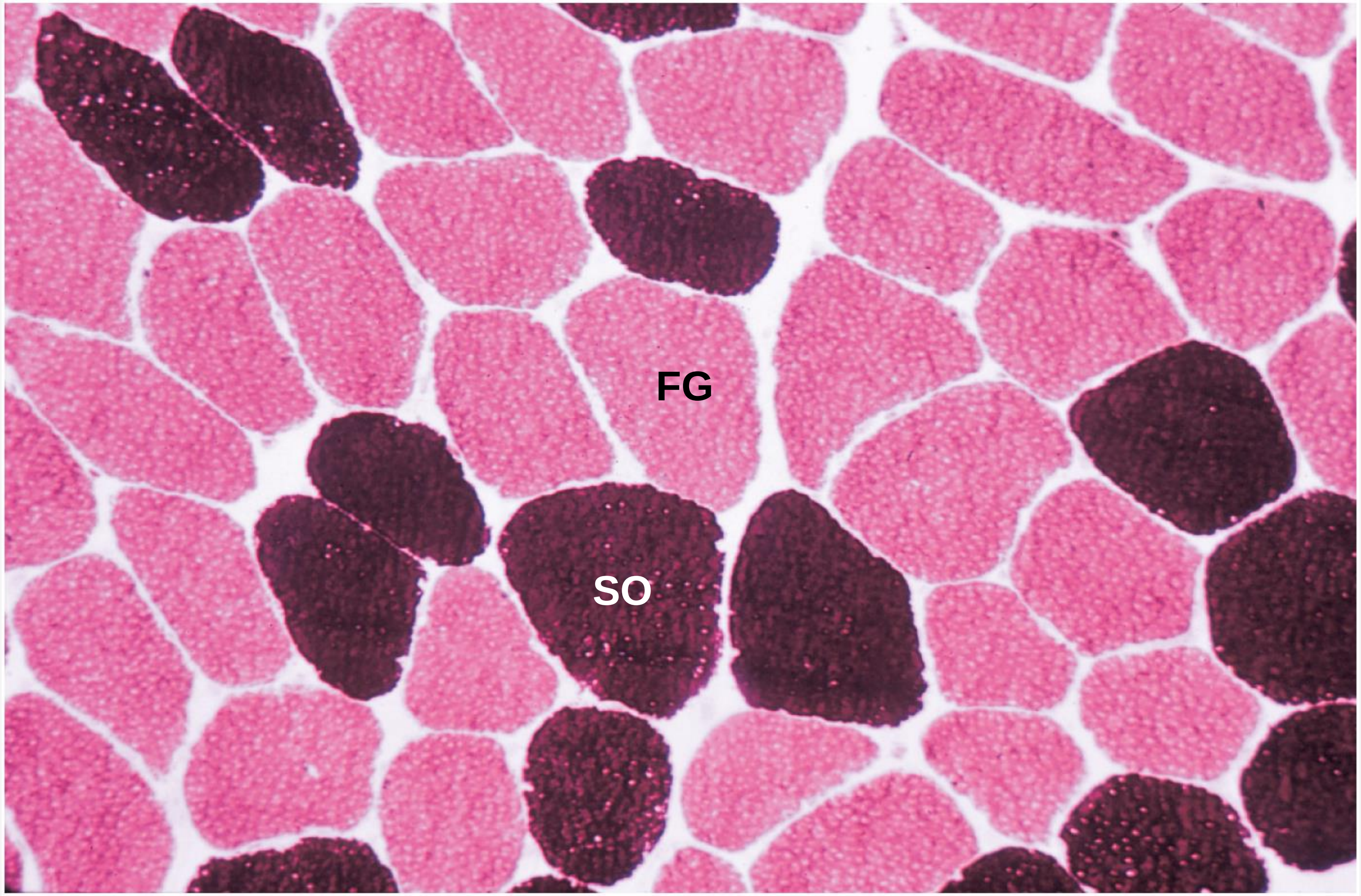

Figure 11.20

Strength and Conditioning

- muscles can generate more tension than the bones and tendons can withstand

- muscular strength depends on:
  - primarily on **muscle size**
    - a muscle can exert a tension of 3 or 4 kg / cm^2 of cross-sectional area
  - **fascicle arrangement**
    - pennate are stronger than parallel, and parallel stronger than circular
  - **size of motor units**
    - larger the motor unit the stronger the contraction
  - **multiple motor unit summation** – **recruitment**
    - when stronger contraction is required, the nervous system activates more motor units
  - **temporal summation**
    - nerve impulses usually arrive at a muscle in a series of closely spaced action potentials
    - the greater the frequency of stimulation, the more strongly a muscle contracts
  - **length – tension relationship**
    - a muscle resting at optimal length is prepared to contract more forcefully than a muscle that is excessively contracted or stretched
  - **fatigue**
    - fatigued muscles contract more weakly than rested muscles

Strength and Conditioning

- **resistance training** (weight lifting)
  - contraction of a muscles against a load that resist movement
  - a few minutes of resistance exercise a few times a week is enough to stimulate muscle growth
  - growth is from cellular enlargement
  - muscle fibers synthesize more myofilaments and myofibrils and grow thicker

- **endurance training** (aerobic exercise)
  - improves fatigue resistant muscles
  - slow twitch fibers produce more mitochondria, glycogen, and acquire a greater density of blood capillaries
  - improves skeletal strength
  - increases the red blood cell count and oxygen transport capacity of the blood
  - enhances the function of the cardiovascular, respiratory, and nervous systems

PART IV

LEARNING OUTCOMES

- ***name and locate the muscles of the abdominal wall, back, and pelvic floor***
- ***identify the attachments, action, and innervation of these muscles.***

Muscles of the Anterior Abdominal Wall

- four pairs of sheetlike muscles
  - *external abdominal oblique*
  - *internal abdominal oblique*
  - *transverse abdominal*
  - *rectus abdominis [**rectus = straight**]*
- strengthen abdominal wall

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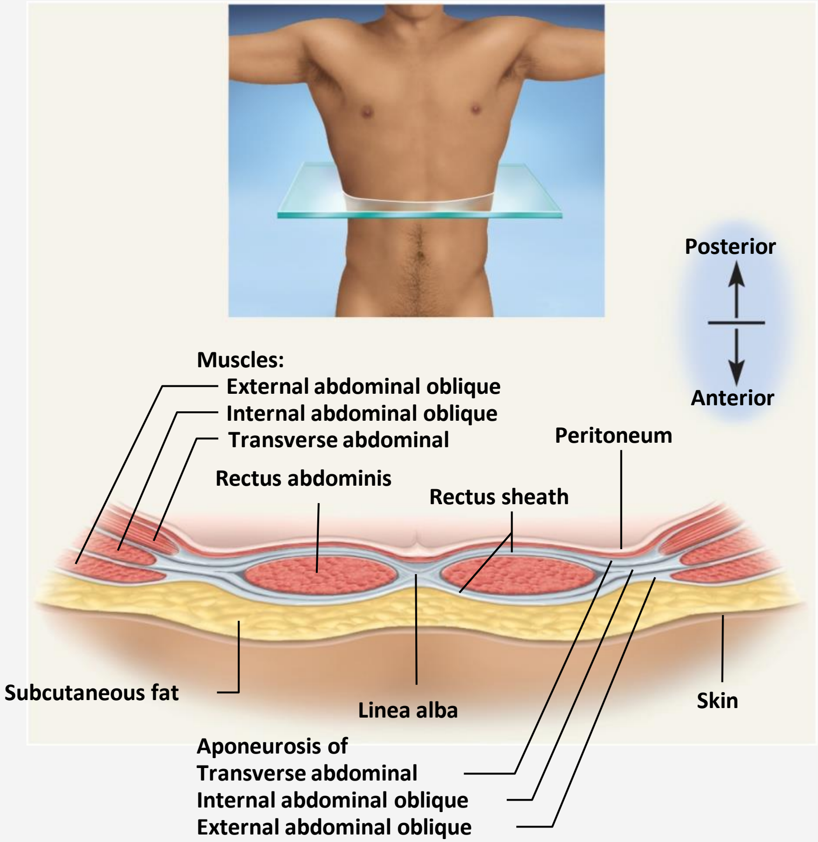

Figure 10.14

Muscles of the Anterior Abdominal Wall

- Three layers of muscle enclose the lumbar region and extend about halfway across the anterior abdomen.
- The most **superficial layer** is the ***external abdominal oblique***. Its fibers pass downward and anteriorly. The **next deeper layer** is the ***internal abdominal oblique****,* whose fibers pass upward and anteriorly, roughly perpendicular to those of the external oblique. The **deepest layer** is the ***transverse abdominal*** *(transversus abdominis),* with horizontal fibers. Anteriorly, a pair of **vertical *rectus abdominis*** muscles extends from **sternum to pubis**. These are divided into segments by three transverse tendinous intersections, giving them an appearance that body builders nickname the "six pack."

Lateral Abdominal Muscles

External abdominal oblique

Internal abdominal oblique

Transverse abdominis

external abdominal oblique

- most superficial of lateral abdominal muscles
- supports abdominal viscera against pull of gravity
- stabilizes vertebral column during heavy lifting
- maintains posture
- compresses abdominal organs
- aids in forced expiration
- rotation at waist

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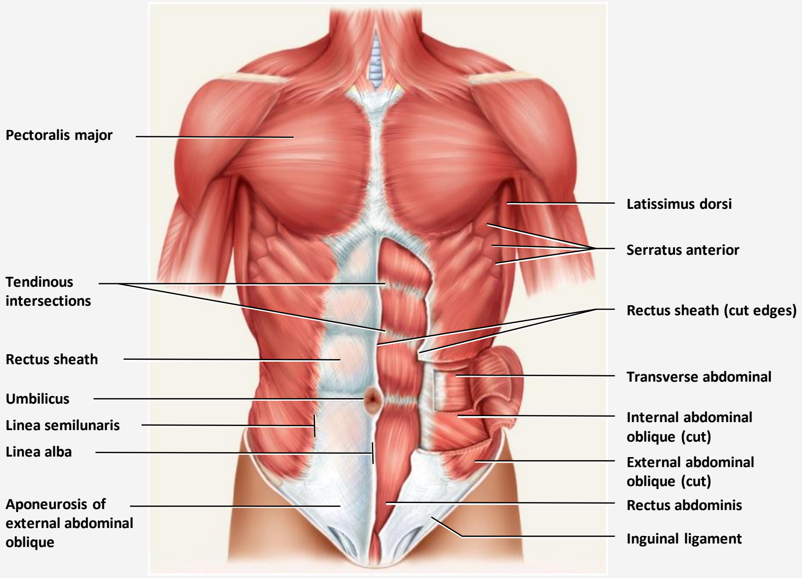

(a) Superficial

Figure 10.15a

internal abdominal oblique

- intermediate layer of lateral abdominal muscles
- unilateral contraction causes ipsilateral rotation of waist
- **aponeurosis** – tendons of oblique and transverse muscles
  –broad, fibrous sheets

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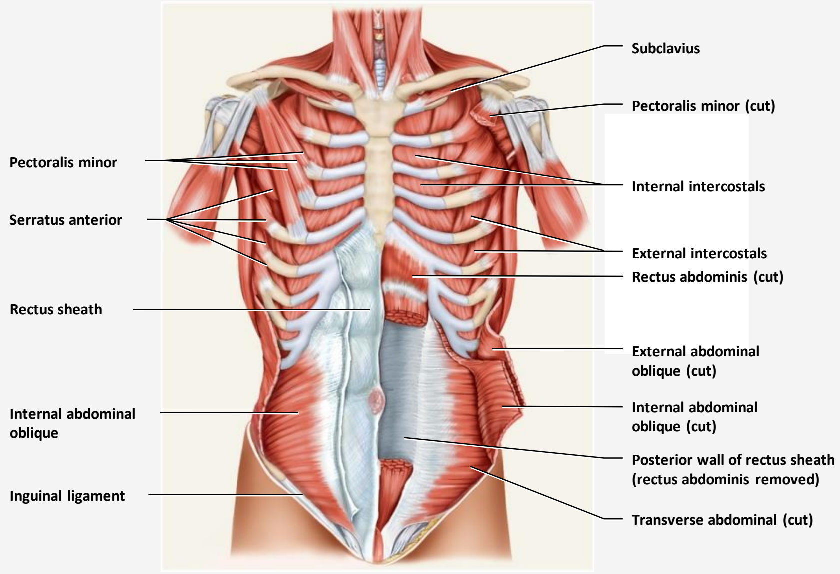

(b) Deep

Figure 10.15b

Internal abdominal oblique & Transversus abdominis

transverse abdominal

- deepest of lateral abdominal muscles
- horizontal fibers
- compresses abdominal contents
- contributes to movements of vertebral column

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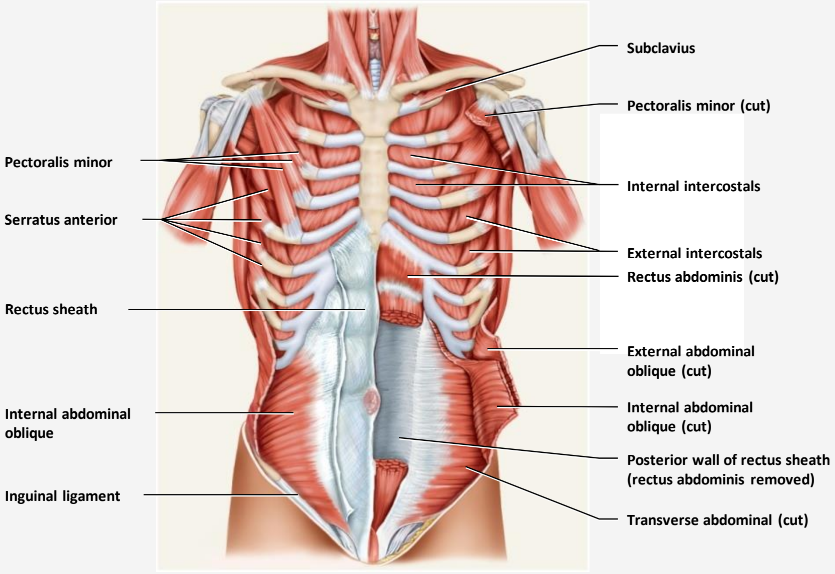

(b) Deep

Figure 10.15b

rectus abdominis

- flexes lumbar region of vertebral column
- produces forward bending at the waist
- extends from sternum to pubis
- **rectus sheath** encloses muscle
- three transverse **tendinous intersections** divide rectus abdominis into segments – “six pack”

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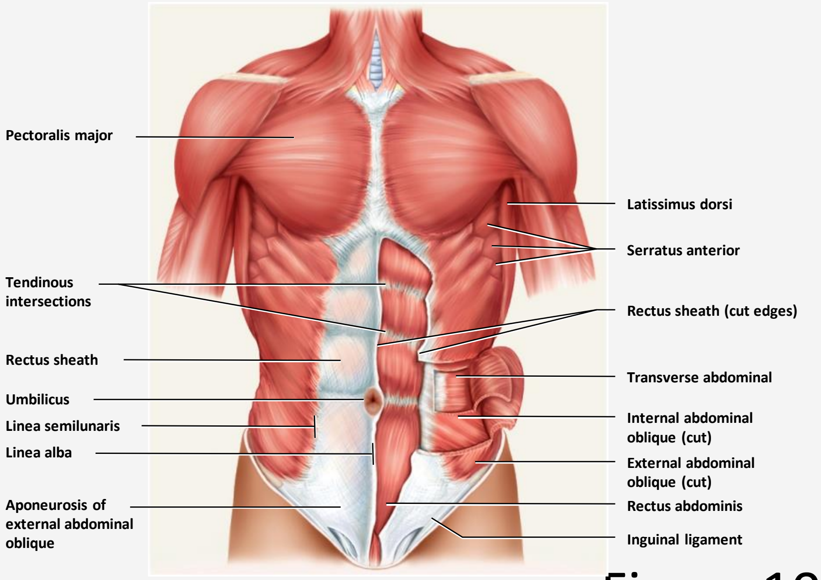


(a) Superficial

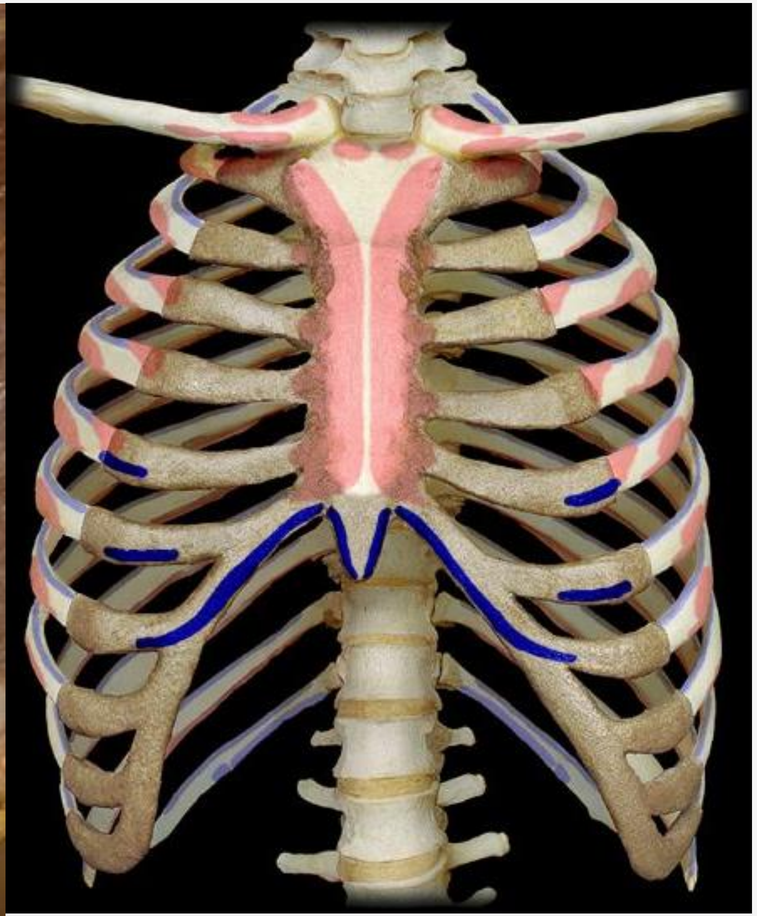
Figure 10.15a

Rectus abdominis

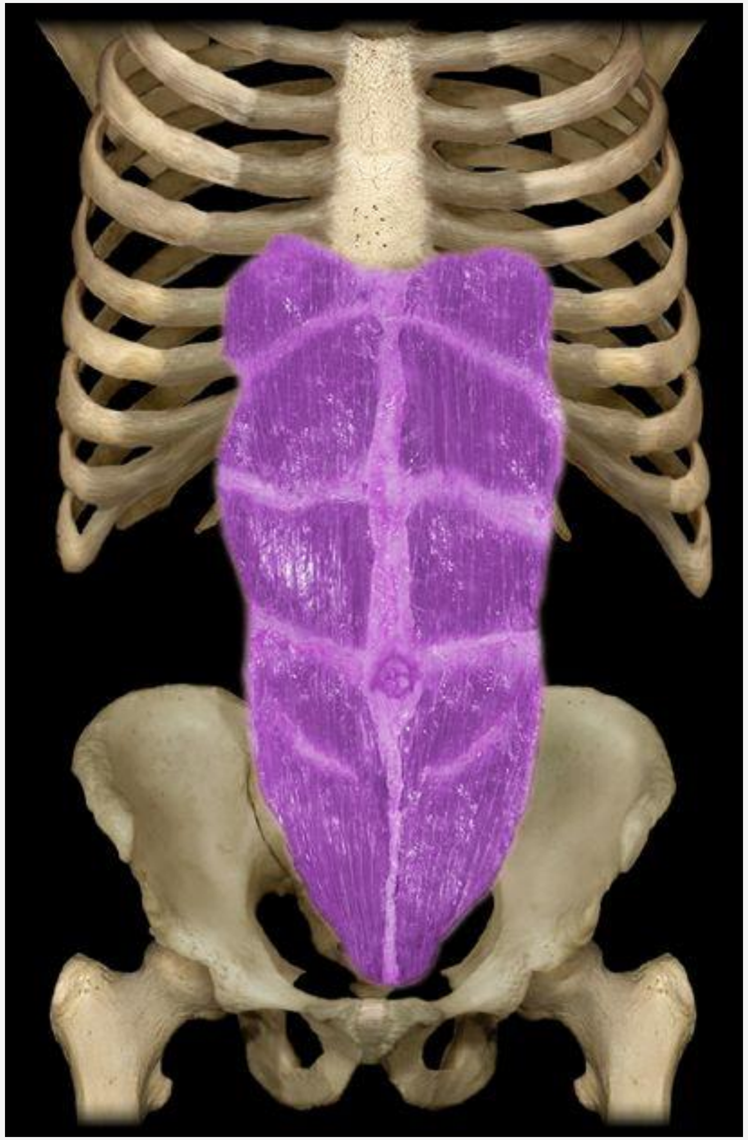
tendinous intersections

linea alba

insertions



Rectus abdominis



Muscles of the Pelvic Floor

- The floor of the pelvic cavity is formed mainly by an extensive muscle called the *levator ani*.[***levator* = that which elevates; *ani* = of the anus**]
- Inferior to this is the **perineum [PERR-ih-NEE-um]**, a diamond-shaped area between the thighs bordered by four **bony landmarks**: <u>the pubic symphysis anteriorly, the coccyx posteriorly, and the ischial tuberosities laterally</u>. The pelvic floor and perineum are penetrated by the anal canal, urethra, and vagina. The anterior half of the perineum is the **urogenital triangle** and the posterior half is the **anal triangle** (fig. 10.20b). These are especially important **landmarks in obstetrics**.

Muscles of the Pelvic Floor

- The urogenital triangle is divided into two muscle compartments separated by a strong fibrous **perineal membrane.**
- The muscle compartment between this membrane and the skin is called **superficial perineal space,** and the compartment between the perineal membrane and levator ani is the **deep perineal space.**
- We will examine these structures beginning inferiorly, just beneath the skin, and progressing superiorly to the pelvic floor.

Muscles of the Pelvic Floor

- three layers of muscles and fasciae that span pelvic outlet
  - penetrated by anal canal, urethra, and vagina

- **perineum** – diamond-shaped region between the thighs
  - bordered by four bony landmarks
    - **pubic symphysis** anteriorly
    - **coccyx** posteriorly
    - **ischial tuberosities** laterally
  - **urogenital triangle** – anterior half of perineum
  - **anal triangle** – posterior half of perineum

Muscles of the Pelvic Floor

- three layers or compartments of the perineum
  - **superficial perineal space** – three muscles
    - *ischiocavernosus[**ischio = ischium of hip bone; cavernosus = corpus cavernosum of the penis or clitoris**],*
    - *bulbospongiosus[**bulbo = bulb of the penis; spongiosus = corpus spongiosum of the penis**],*
    - *superficial transverse peritoneal*

Muscles of the Pelvic Floor

- three layers or compartments of the perineum
  - **middle compartment** - spanned by urogenital diaphragm
    - composed of a fibrous membrane and two or three muscles
    - *deep transverse perineal muscle,*
    - *external urethral*
    - *anal sphincters*
    - *compressor urethrae* in females only
  - **pelvic diaphragm** – deepest layer consists of two muscle pairs
    - *levator ani and coccygeus*

Muscles of the Pelvic Floor

- **pelvic diaphragm** – is deep to the foregoing structures and is composed mainly of the right and left *levator ani muscles*.
- **The levator ani spans most of the pelvic outlet and forms the floor of the lesser (true) pelvis.** It is divided into three portions that are sometimes regarded as separate muscles**—**
- **the *ischiococcygeus* (or *coccygeus*),**
- ***iliococcygeus,***
- ***pubococcygeus*.**
- **The left and right levator ani muscles converge on the *anococcygeal ligament,* through which they are indirectly anchored to the coccyx.**

Superficial Perineal Space

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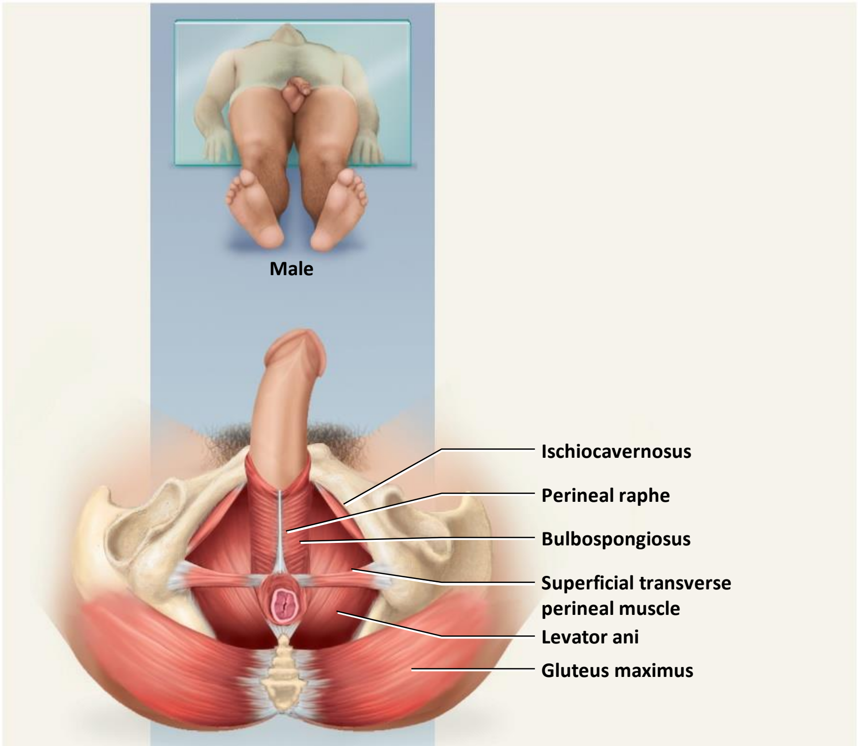
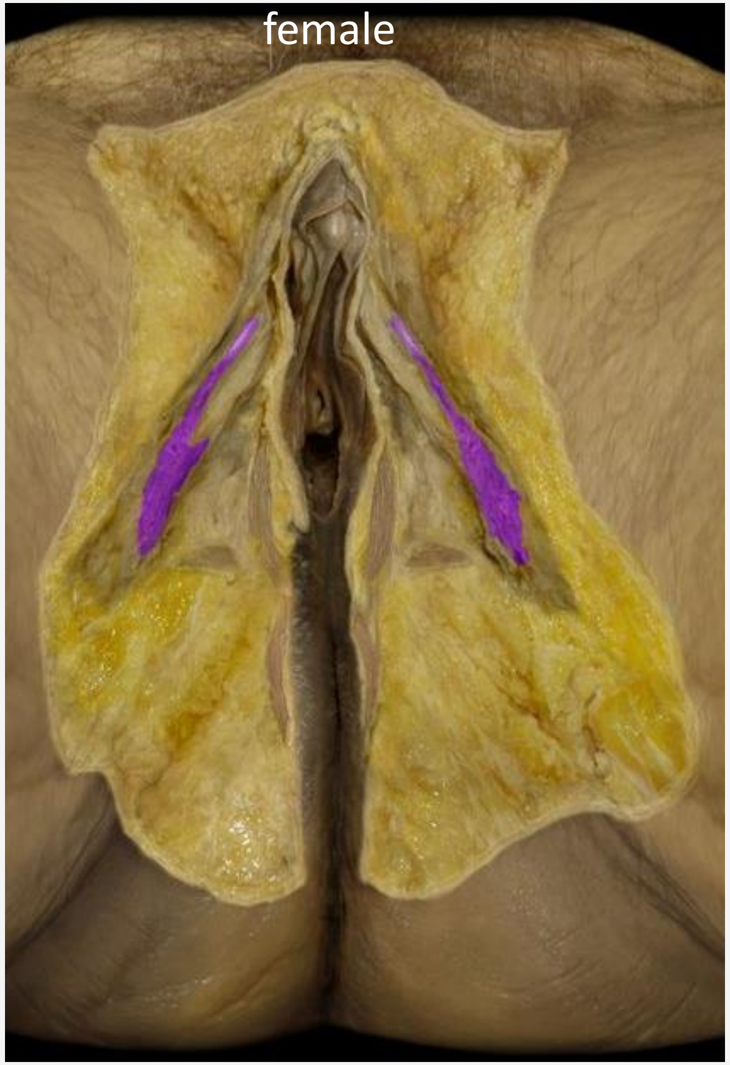


(a) Superficial perineal space, inferior view

Figure 10.20a

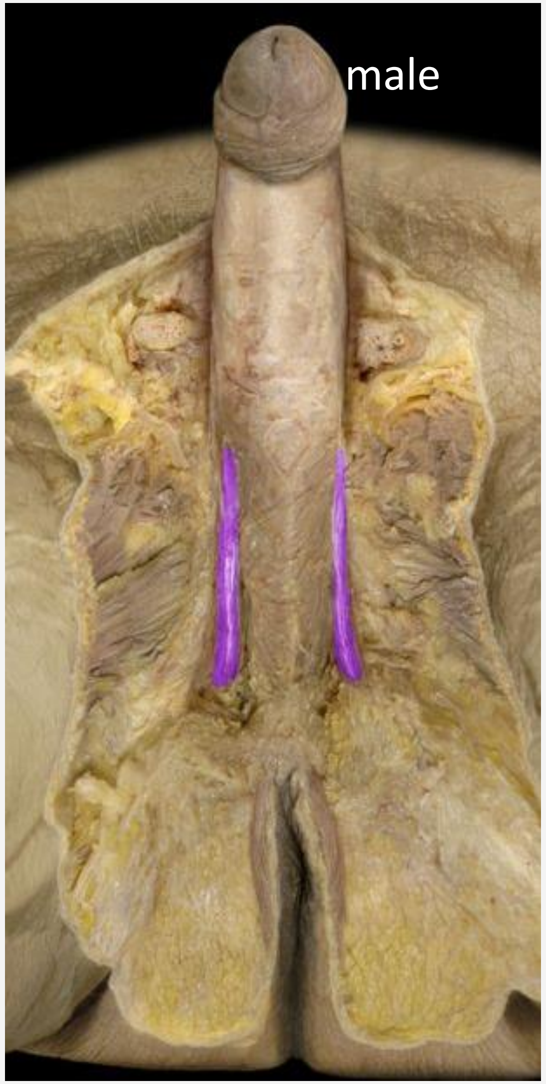
- three muscles found just deep to the skin
- *ischiocavernosus* – maintains erection
- *bulbospongiosus* – aids in erection, expels remaining urine
- *superficial transverse perineal* – not always present

Muscles of the Pelvic Floor
Ischiocavernosus

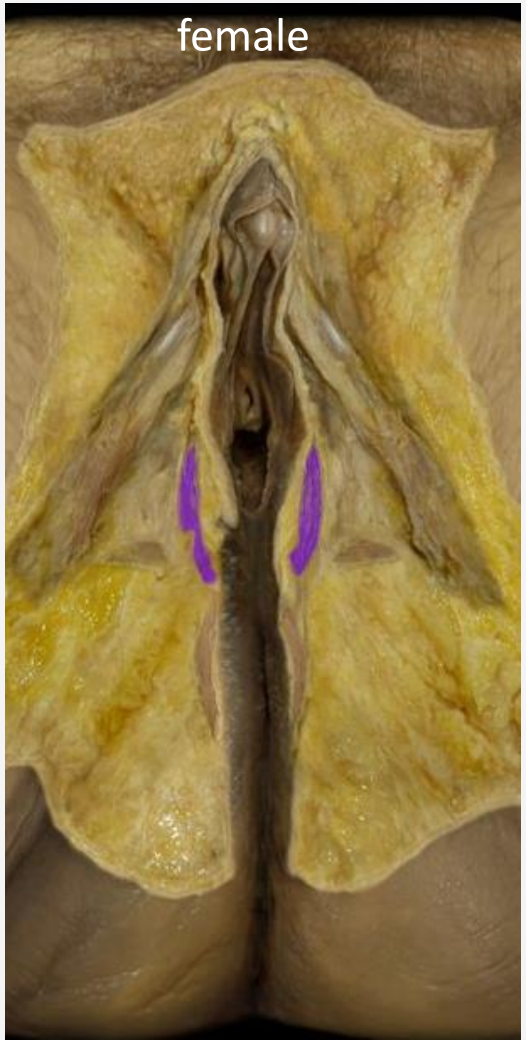


compresses erectile tissue

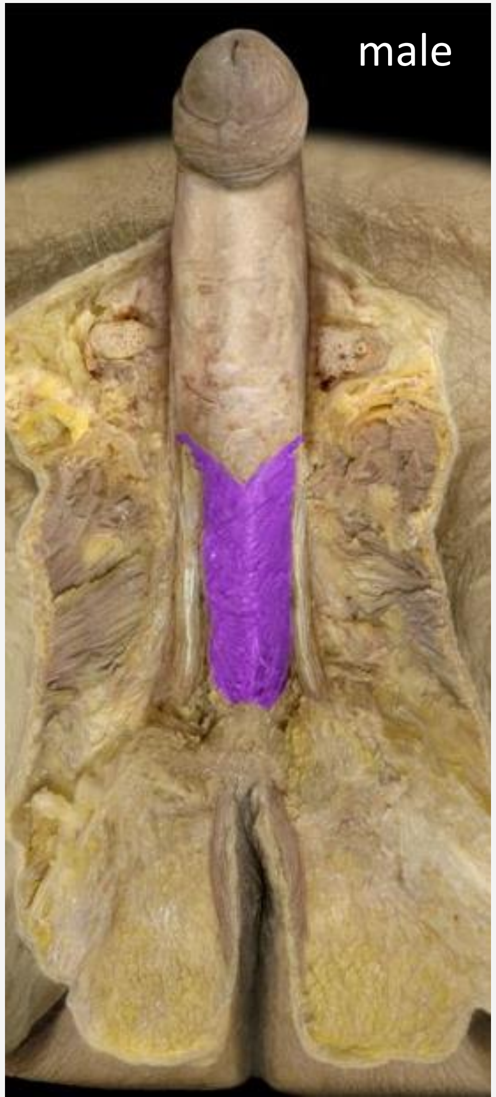
helps maintain erection of clitoris & penis



Muscles of the Pelvic Floor
Bulbospongiosus



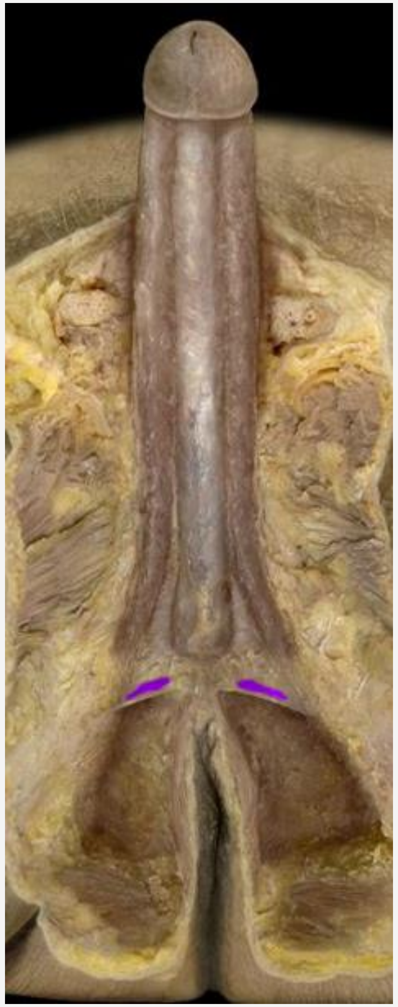
compresses erectile tissue around vaginal orifice and compresses erectile tissue at base of penis



Muscles of the Pelvic Floor
Superficial transverse perineal

female

male



Muscles of Middle Compartment

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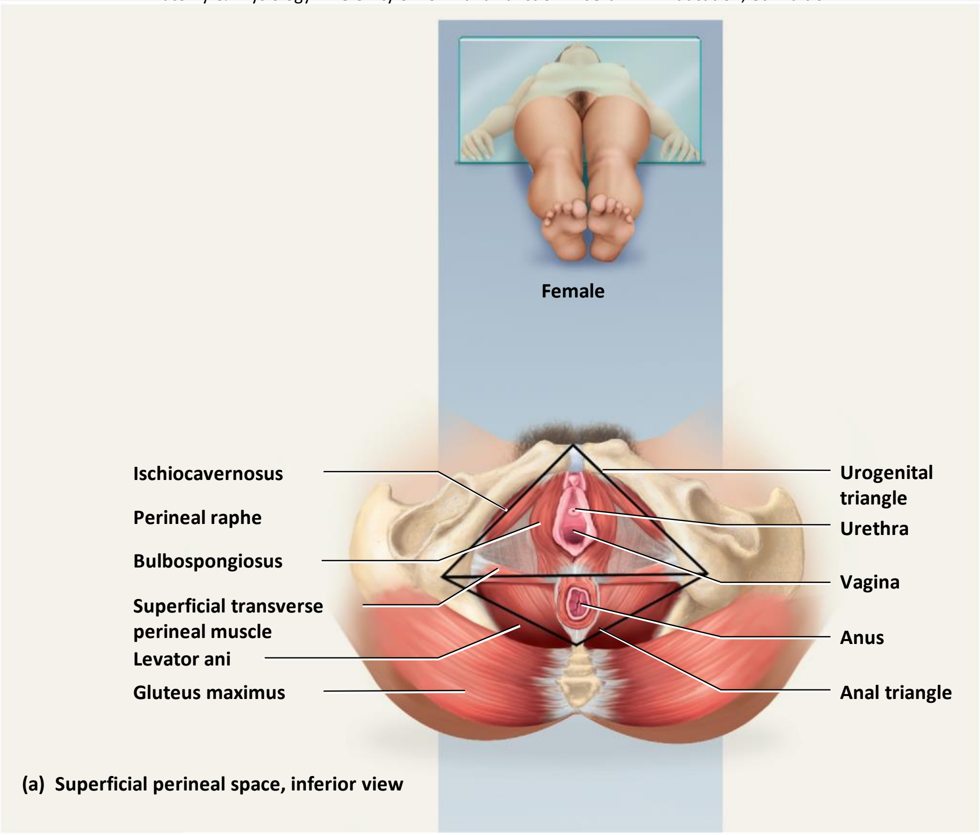


(a) Superficial perineal space, inferior view

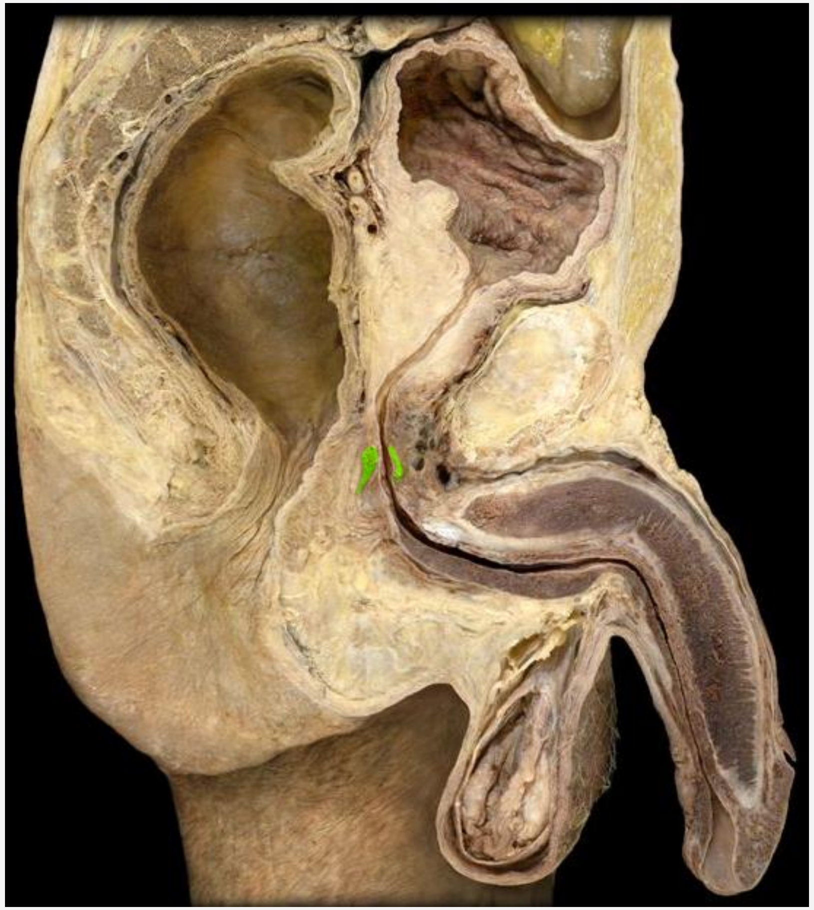
Figure 10.20b

- middle layer of pelvic floor contains *urogenital diaphragm* and *external urethral* and *anal sphincters*

Muscles of the Pelvic Floor
External urethral sphincter

female

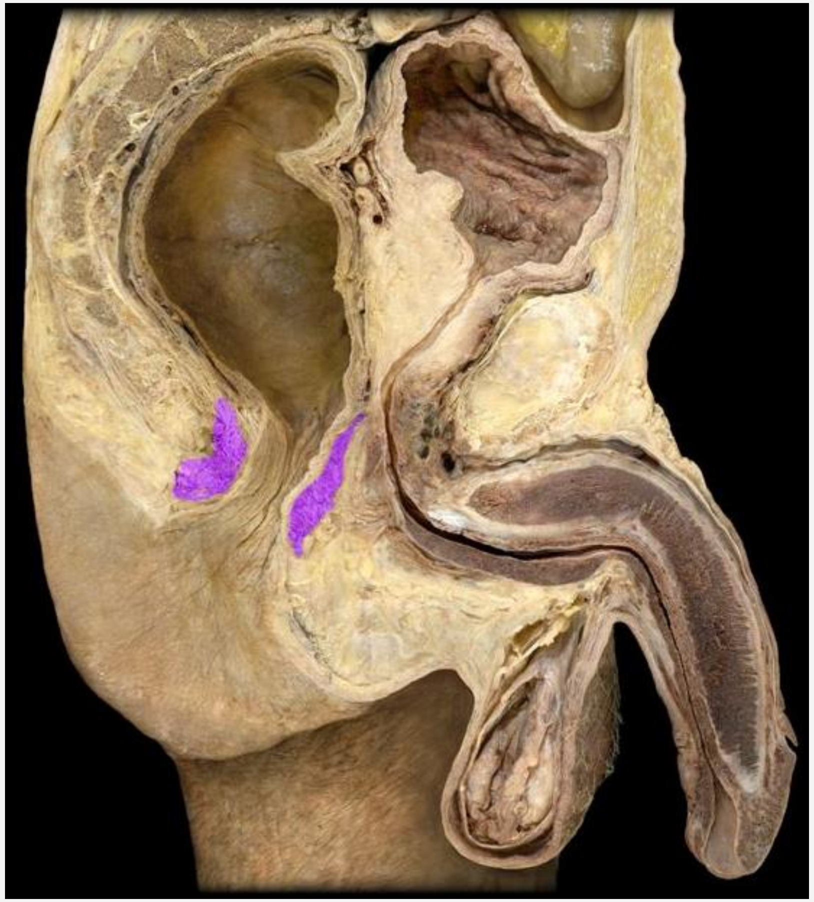
male



Muscles of the Pelvic Floor
External anal sphincter

female

male



Muscles of Pelvic Diaphragm

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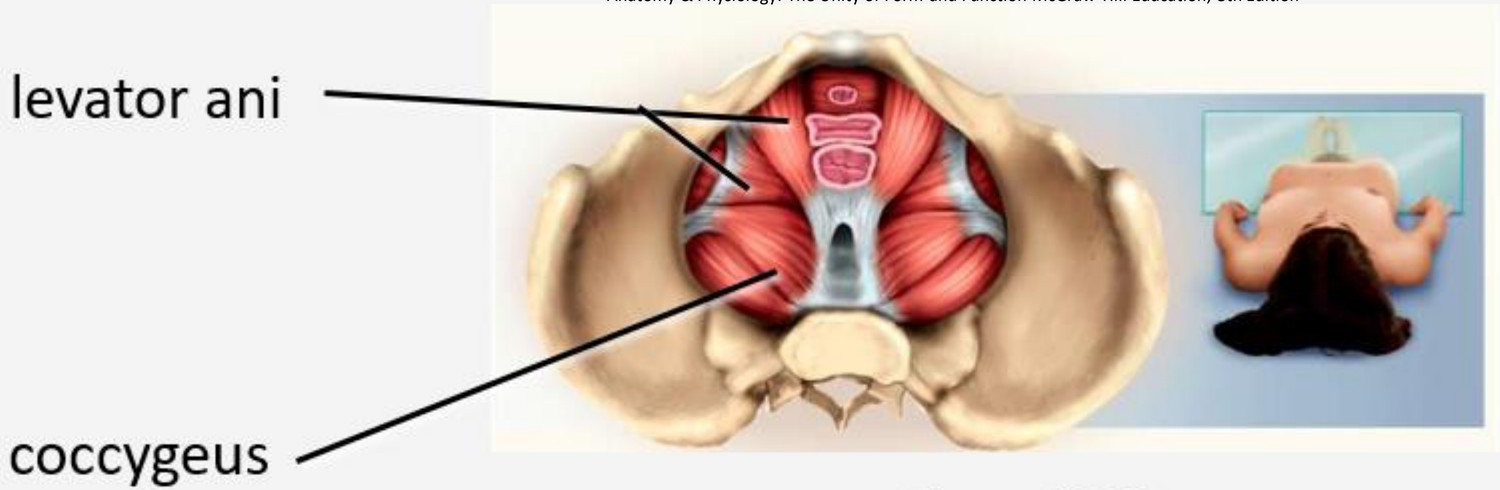
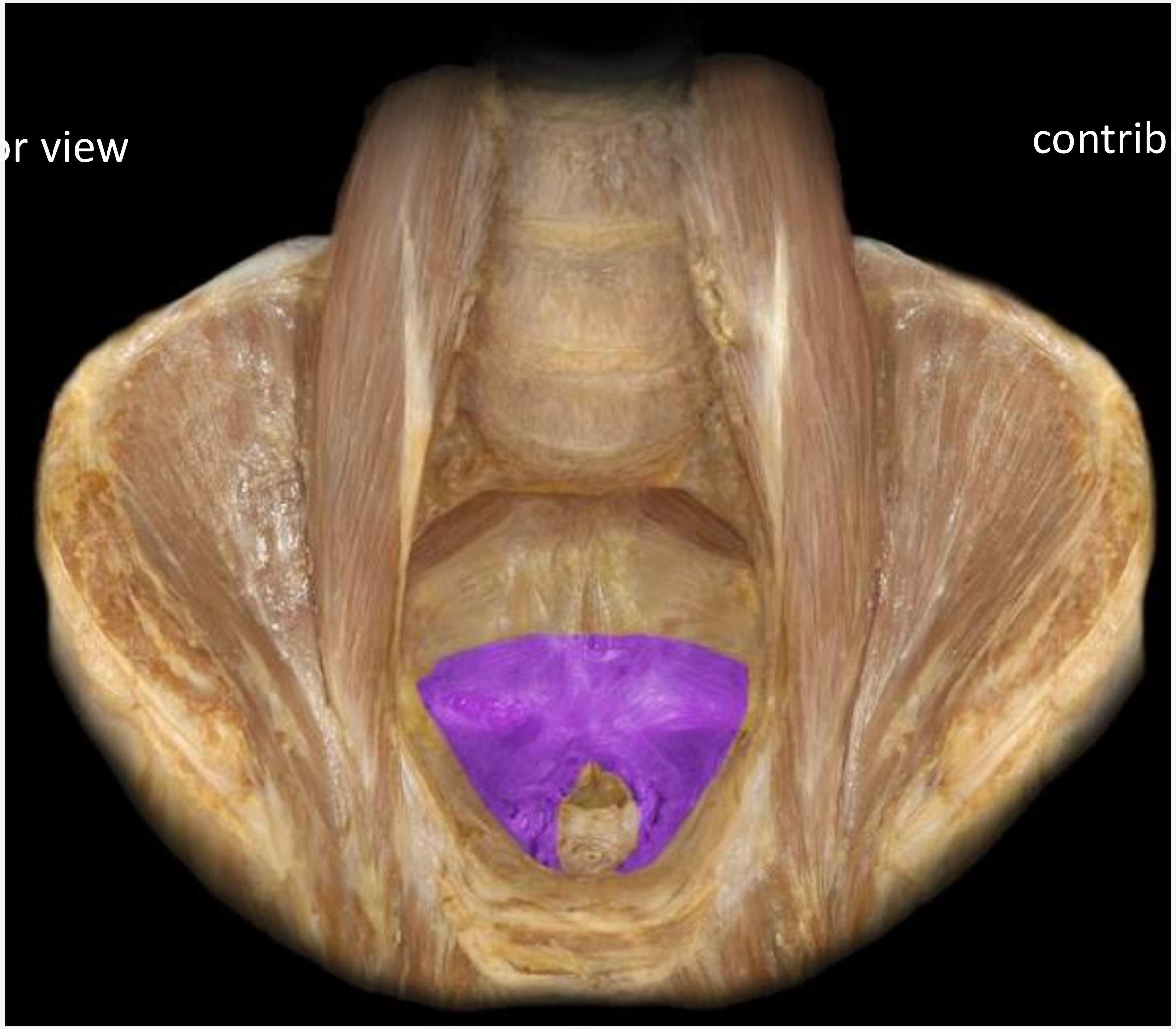


Figure 10.20c

- deepest compartment of the perineum
- pelvic diaphragm – two muscle pairs
  - *levator ani* - supports viscera and defecation
  - *coccygeus* - supports and elevates pelvic floor

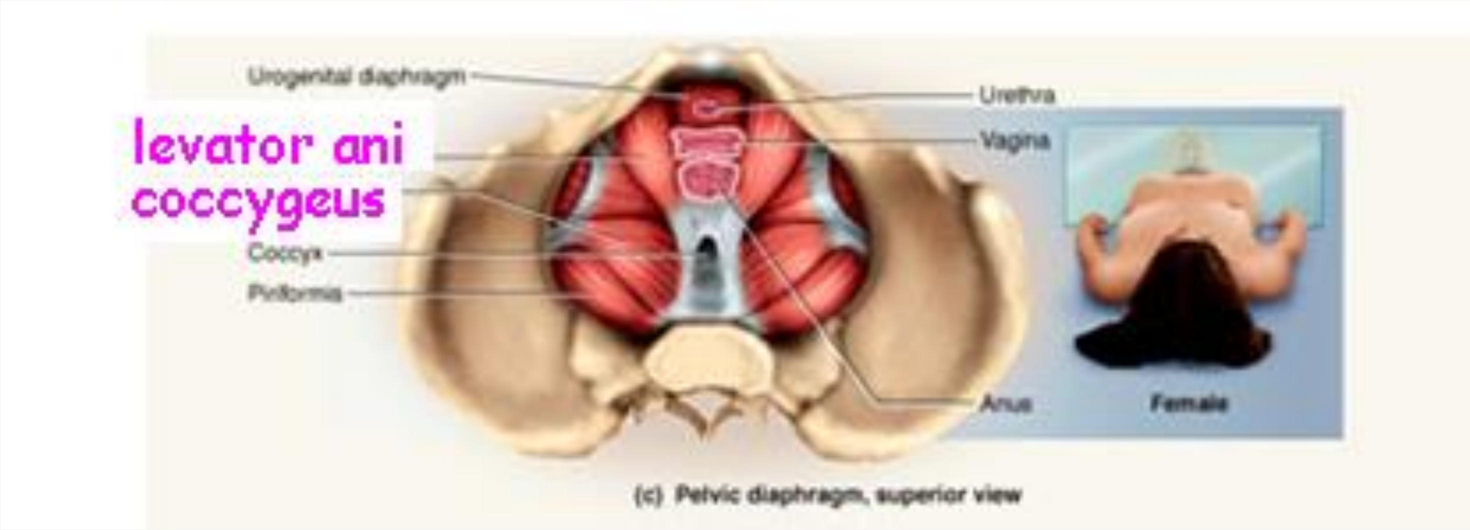
Muscles of the Pelvic Floor
Levator ani



Muscles of the Pelvic Floor
Coccygeus

superior view

contributes to pelvic floor



DEEPER INSIGHT 10.3

CLINICAL APPLICATION

Hernias

A hernia is any condition in which the viscera protrude through a weak point in the muscular wall of the abdominopelvic cavity. The most common type to require treatment is an *inguinal hernia* (fig. 10.21).

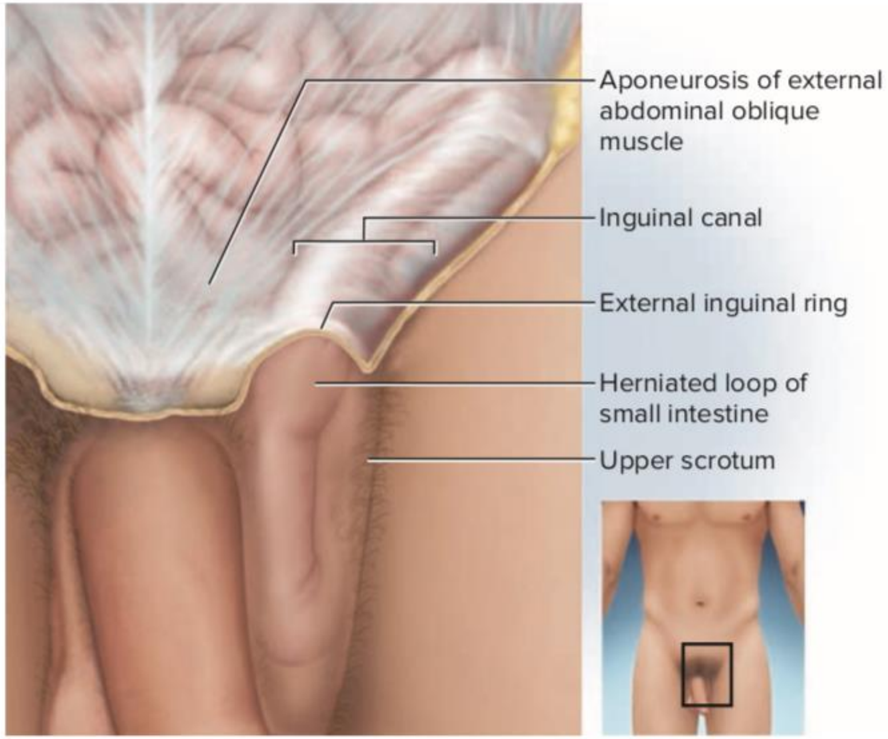


FIGURE 10.21 Inguinal Hernia. A loop of small intestine has protruded through the inguinal canal into a space beneath the skin.

DEEPER INSIGHT 10.3

CLINICAL APPLICATION

Hernias

A In the male fetus, each testis descends from the pelvic cavity into the scrotum by way of a passage called the *inguinal canal* through the muscles of the groin. This canal remains a weak point in the pelvic floor, especially in infants and children. When pressure rises in the abdominal cavity, it can force part of the intestine or bladder into this canal or even into the scrotum. This also sometimes occurs in men who hold their breath while lifting heavy weights.

DEEPER INSIGHT 10.3

CLINICAL APPLICATION

Hernias

When the diaphragm and abdominal muscles contract, pressure in the abdominal cavity can soar to 1,500 pounds per square inch—more than 100 times the normal pressure and quite sufficient to produce an inguinal hernia, or "rupture." Inguinal hernias rarely occur in women.

DEEPER INSIGHT 10.3

CLINICAL APPLICATION

Hernias

Two other sites of hernia are the diaphragm and navel. A *hiatal hernia* is a condition in which part of the stomach protrudes through the diaphragm into the thoracic cavity. This is most common in overweight people over 40. It may cause heartburn due to the regurgitation of stomach acid into the esophagus, but most cases go undetected. In an *umbilical hernia,* abdominal viscera protrude through the navel.

Hernias

- **hernia** – any condition in which the viscera protrudes through a weak point in the muscular wall of the abdominopelvic cavity
- **inguinal hernia**
  – most common type of hernia (rare in women)
  – viscera enter inguinal canal or even the scrotum
- **hiatal hernia**
  – stomach protrudes through diaphragm into thorax
  – overweight people over 40
- **umbilical hernia**
  – viscera protrude through the navel

LEARNING OUTCOMES

- how pulmonary ventilation affects abdominal pressure and vice versa
- Pulmonary ventilation is when the movement of air depends on pressure change so if the pressure is too much, the movement of air will stop

LEARNING OUTCOMES

- **Alice works out at a fitness center three times a week doing weight lifting and abdominal crunches. Martha prefers to sit on the sofa eating potato chips and watching TV. Both become pregnant. Other things being equal, give one reason related to table 10.5 why Alice may have an easier time with her childbirth than Martha will.**

Muscles of Back

- Muscles of the back primarily **extend, rotate,** and laterally flex the **vertebral column**.
- The most prominent **superficial** back muscles are the **latissimus dorsi** [***latissimus* = broadest; *dorsi* = of the back**] and **trapezius[*trapez* = table, trapezoid],** they are concerned with upper limb movements
- Deep to these are the ***serratus posterior superior* and *inferior*** . They extend from the vertebrae to the ribs. They aid in deep breathing and are further discussed in "The Respiratory Muscles."

Superficial Muscles of Back

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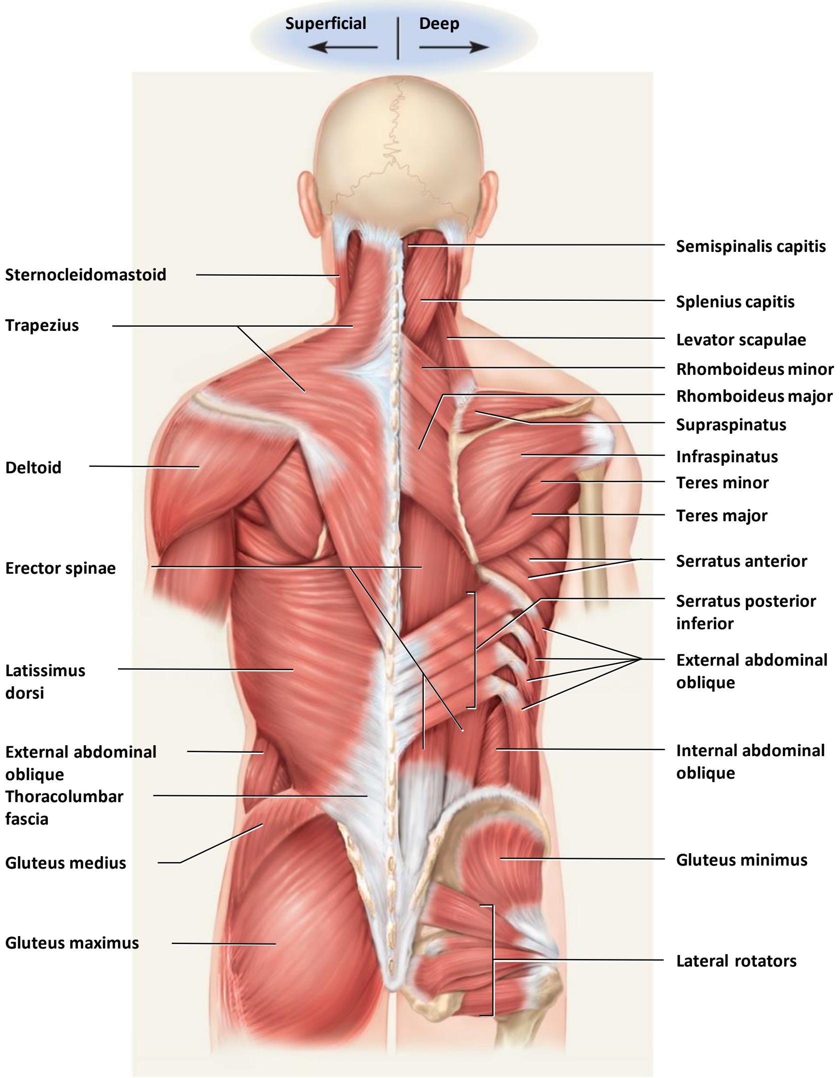
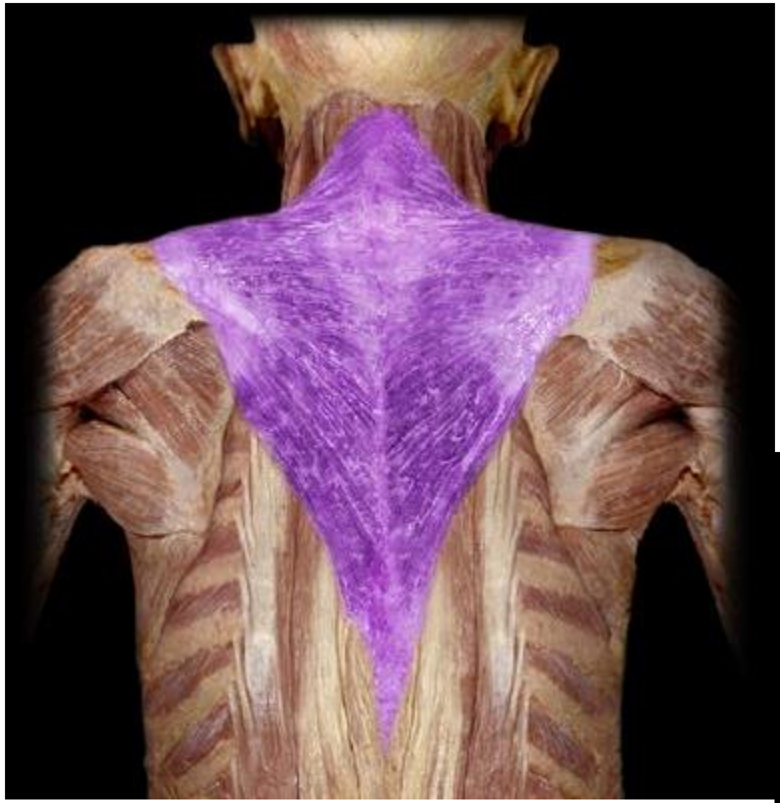


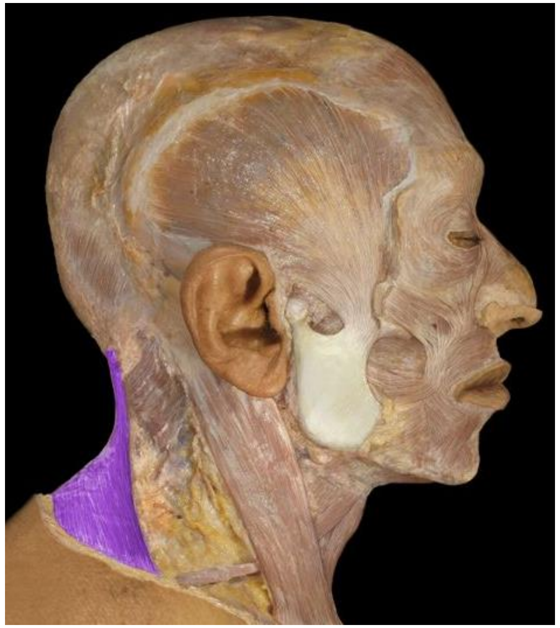
Figure 10.17

extend, rotate, and laterally flex vertebral column

upper limb movement

Superficial Back Muscles – Trapezius





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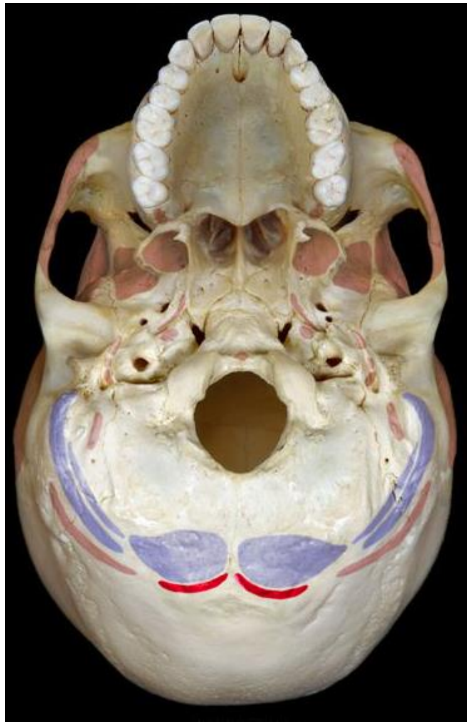

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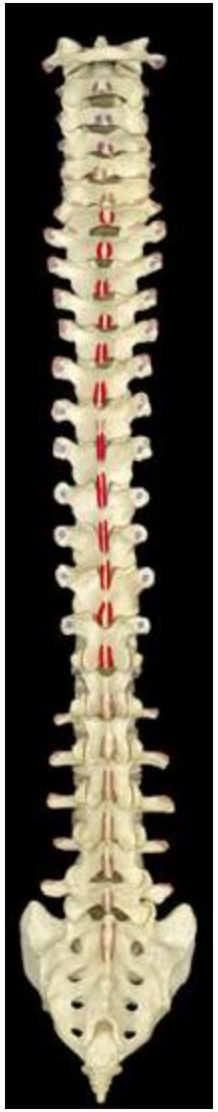
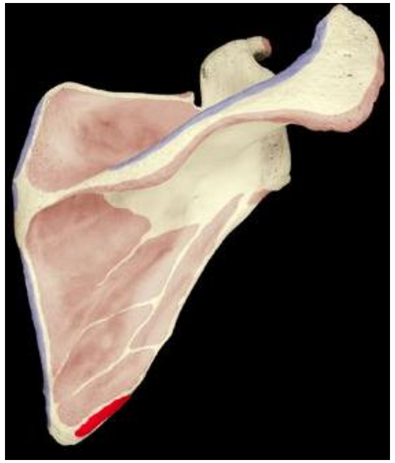


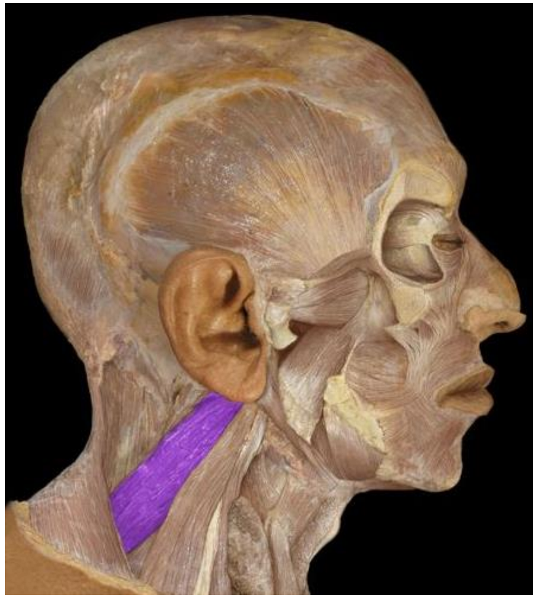
Superficial Back Muscles – Latissimus dorsi

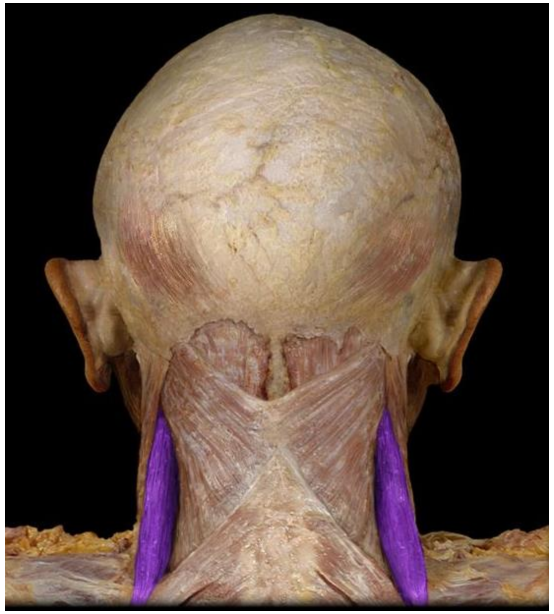


origins

insertion

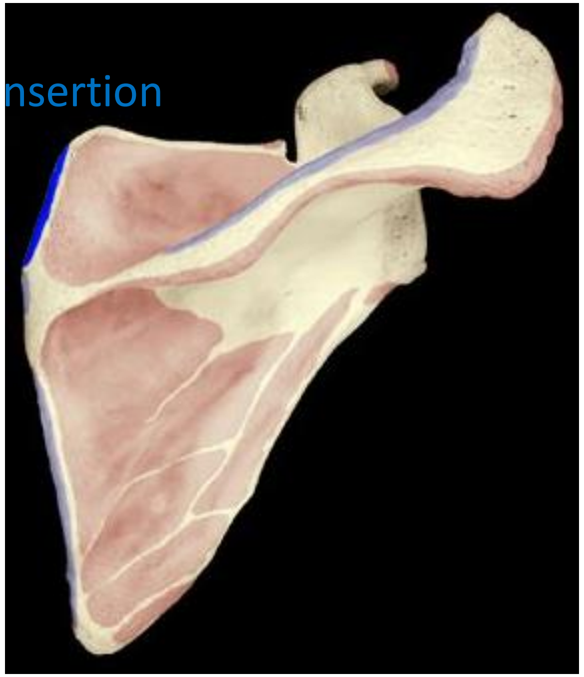
Superficial Back Muscles – Levator scapulae



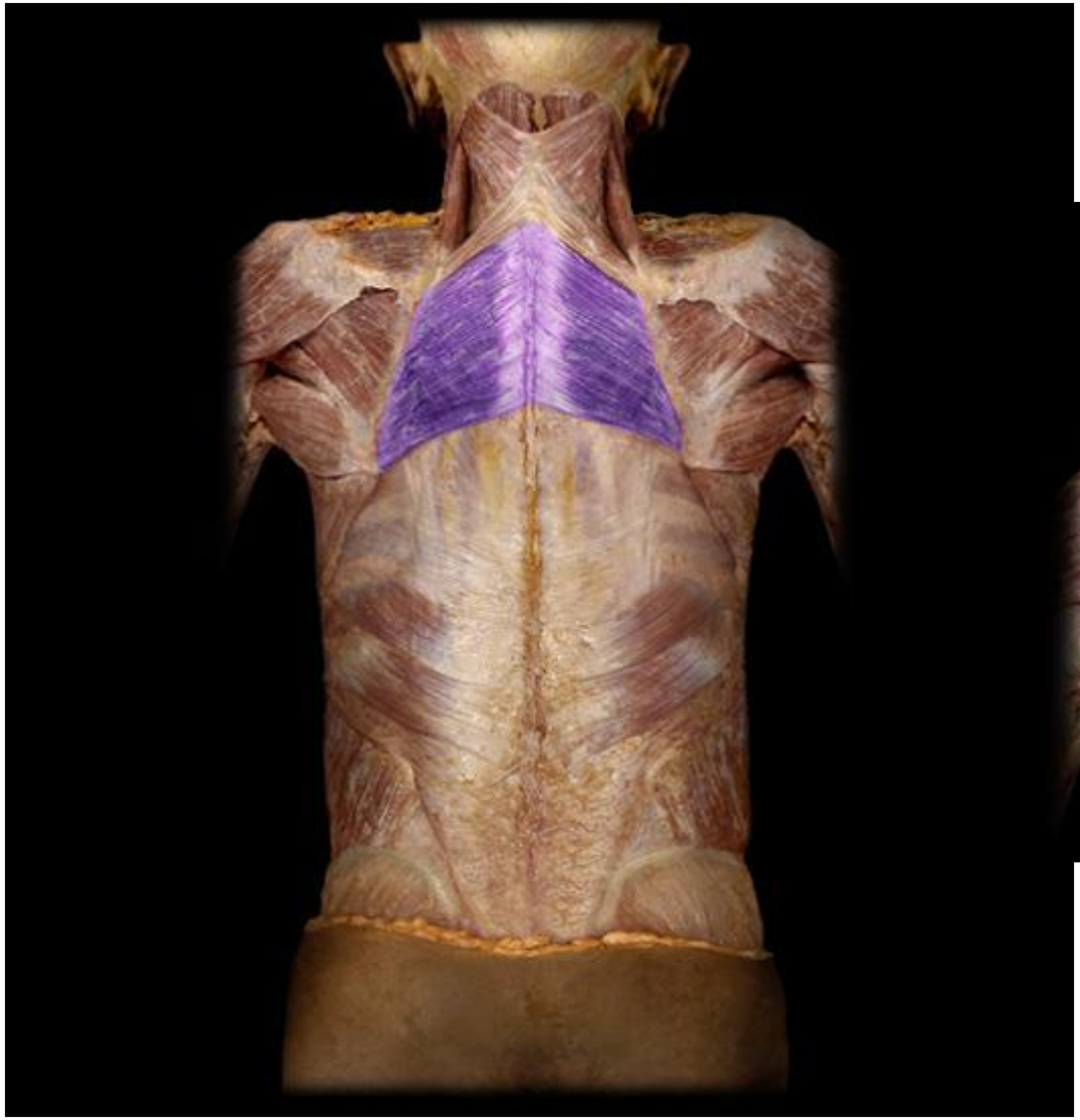


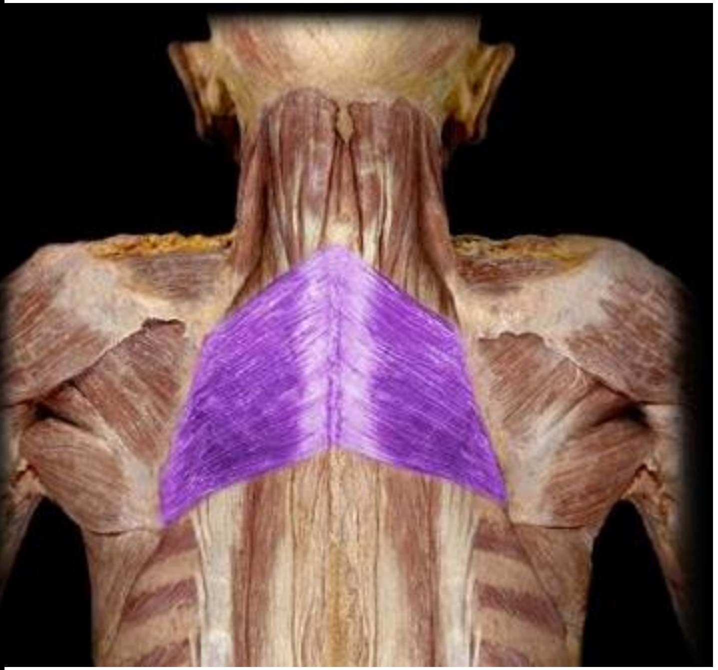
origin

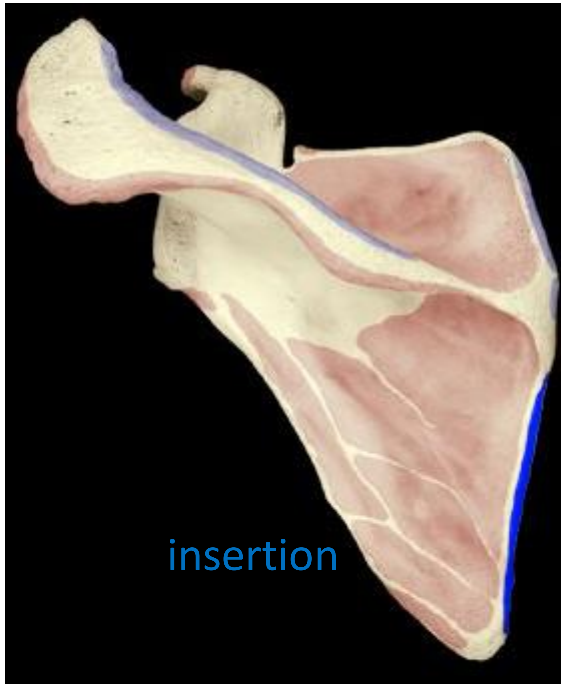
insertion

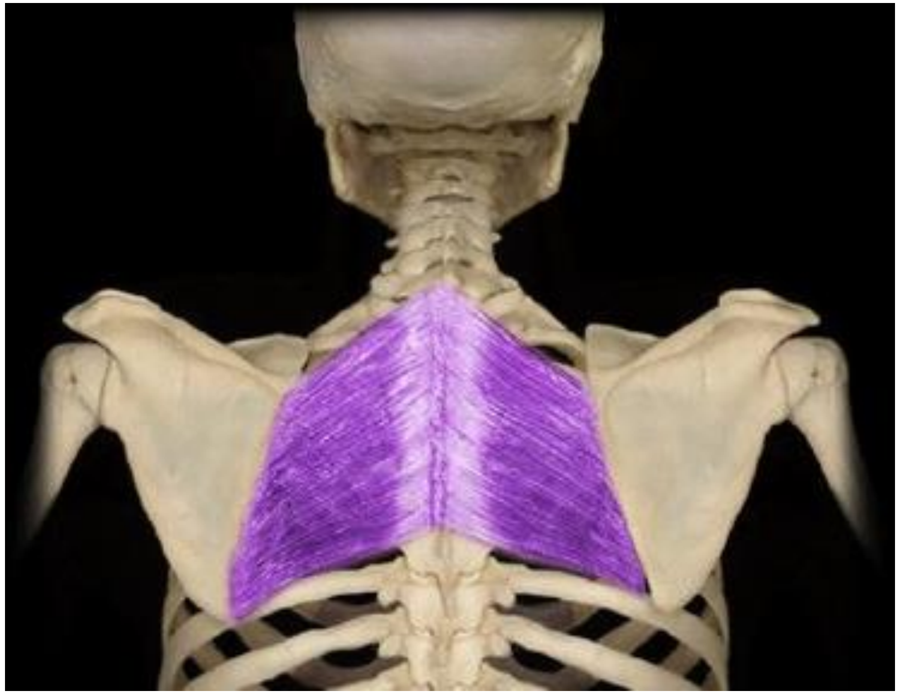


Superficial Back Muscles – Rhomboideous major



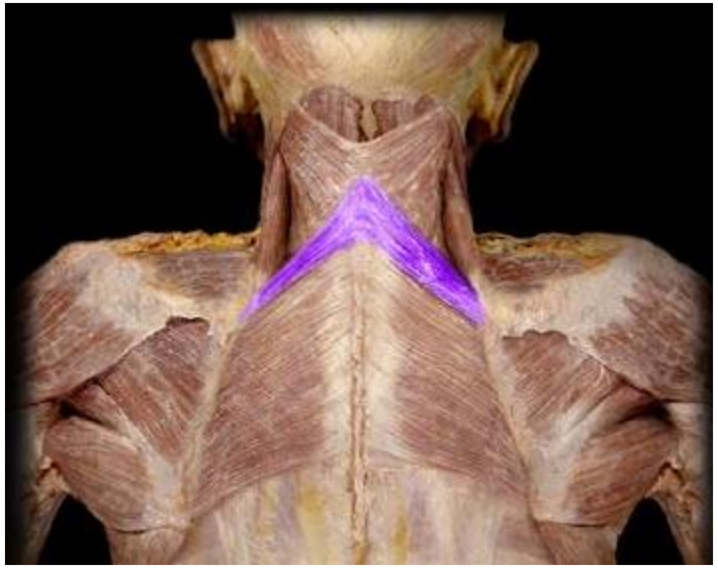


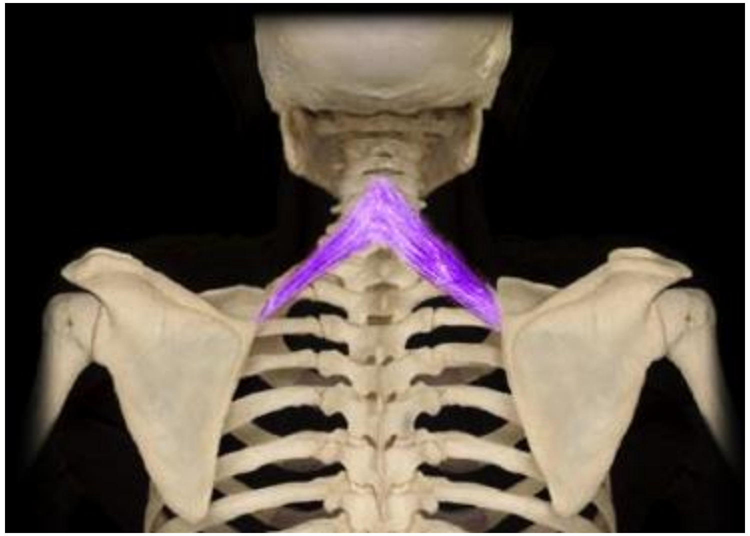


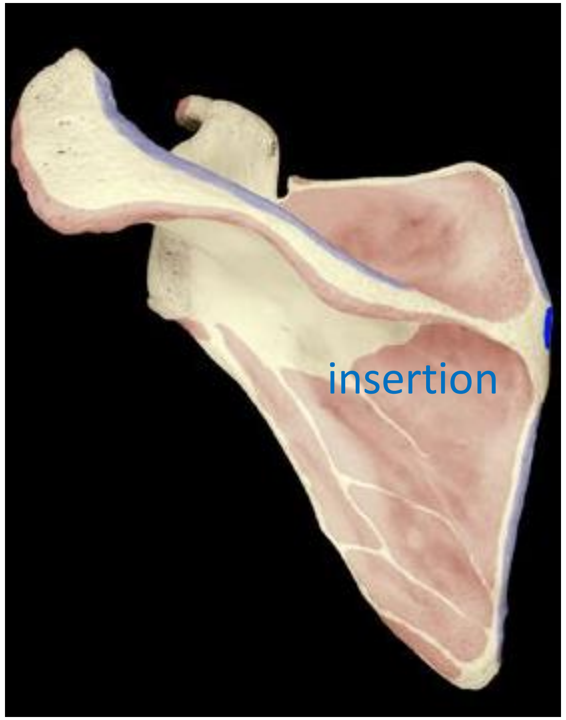


origin

Superficial Back Muscles – Rhomboideous minor



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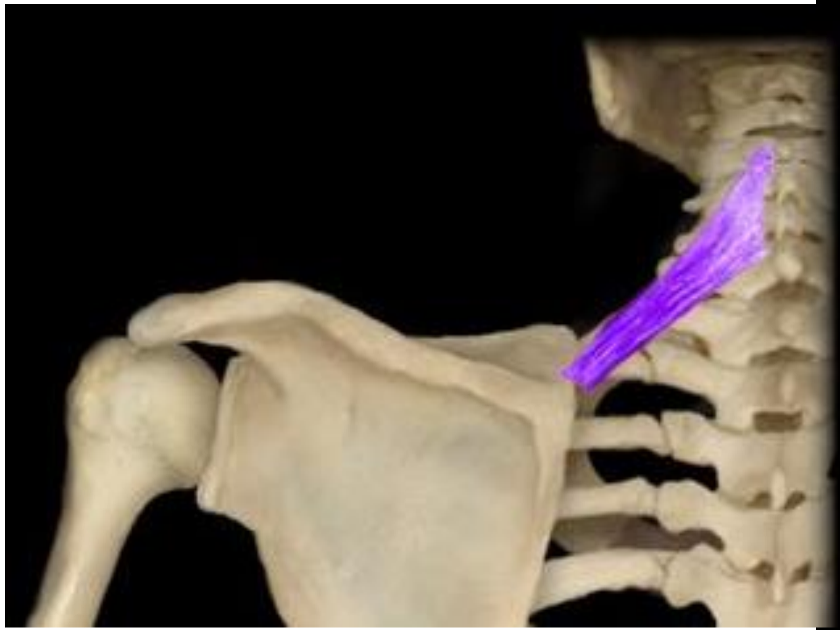
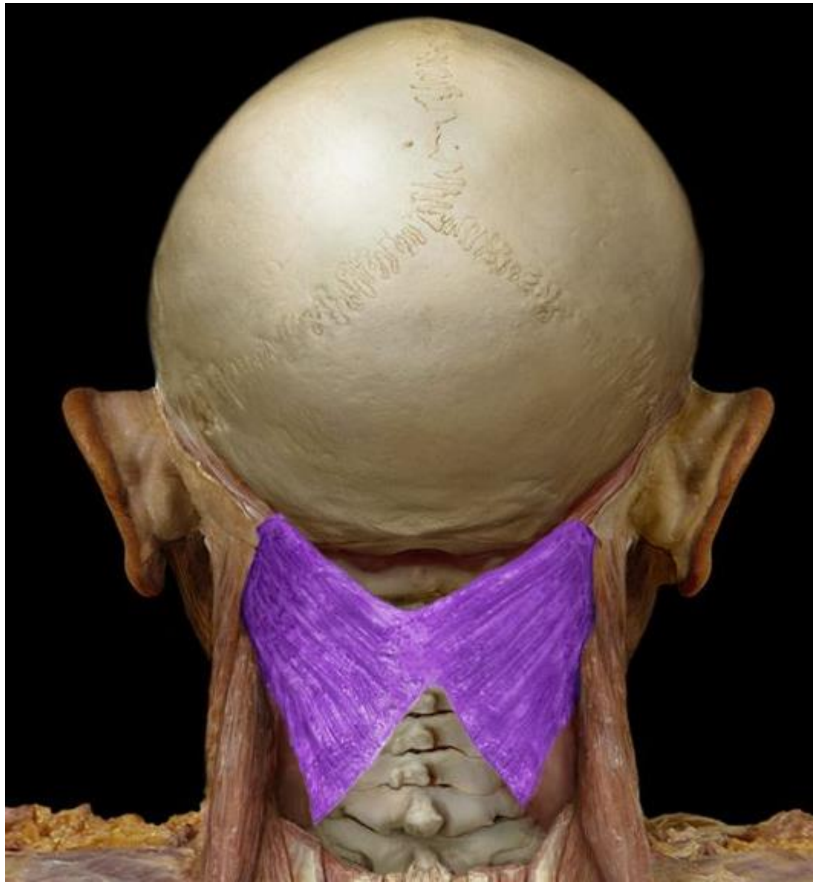



origin

Superficial Back Muscles – Splenius capitis

insertion



origin

Intermediate Back Muscle
Serratus posterior superior & inferior

Muscles of Back

- Deep to these is a prominent muscle, the **erector spinae,** which runs vertically for the entire length of the back **from the cranium to the sacrum.** It is a thick muscle, easily palpated on each side of the vertebral column in the lumbar region.
- As it ascends, it divides in the upper lumbar region into three parallel columns. The **most lateral** of these is the **iliocostalis,** which from inferior to superior is divided into the ***iliocostalis lumborum*, *iliocostalis thoracis*, and *iliocostalis cervicis*** (lumbar, thoracic, and cervical regions).
- The next medial column is the **longissimus**, divided from inferior to superior into the ***longissimus thoracis*, *longissimus cervicis***, and ***longissimus capitis*** (thoracic, cervical, and cephalic regions).
- The most medial column is the **spinalis,** divided into ***spinalis thoracis*, *spinalis cervicis*, and *spinalis capitis*.**
- The functions of all three columns are sufficiently similar that we will treat them collectively as the **erector spinae.**

Deep Muscles of the Back

- ***erector spinae***
  - ***iliocostalis, longissimus, spinalis***
  - from cranium to sacrum
  - extension and lateral flexion of vertebral column
- ***semispinalis thoracis***
  - extension and contralateral rotation of vertebral column
- ***quadratus lumborum*** *[quadrat = four-sided; lumborum = of the lumbar region]*
  - aids respiration
  - ipsilateral flexion of lumbar vertebral column
- ***multifidus****[multi = many; fid = branched, sectioned]*
  - stabilizes adjacent vertebrae
  - maintains posture

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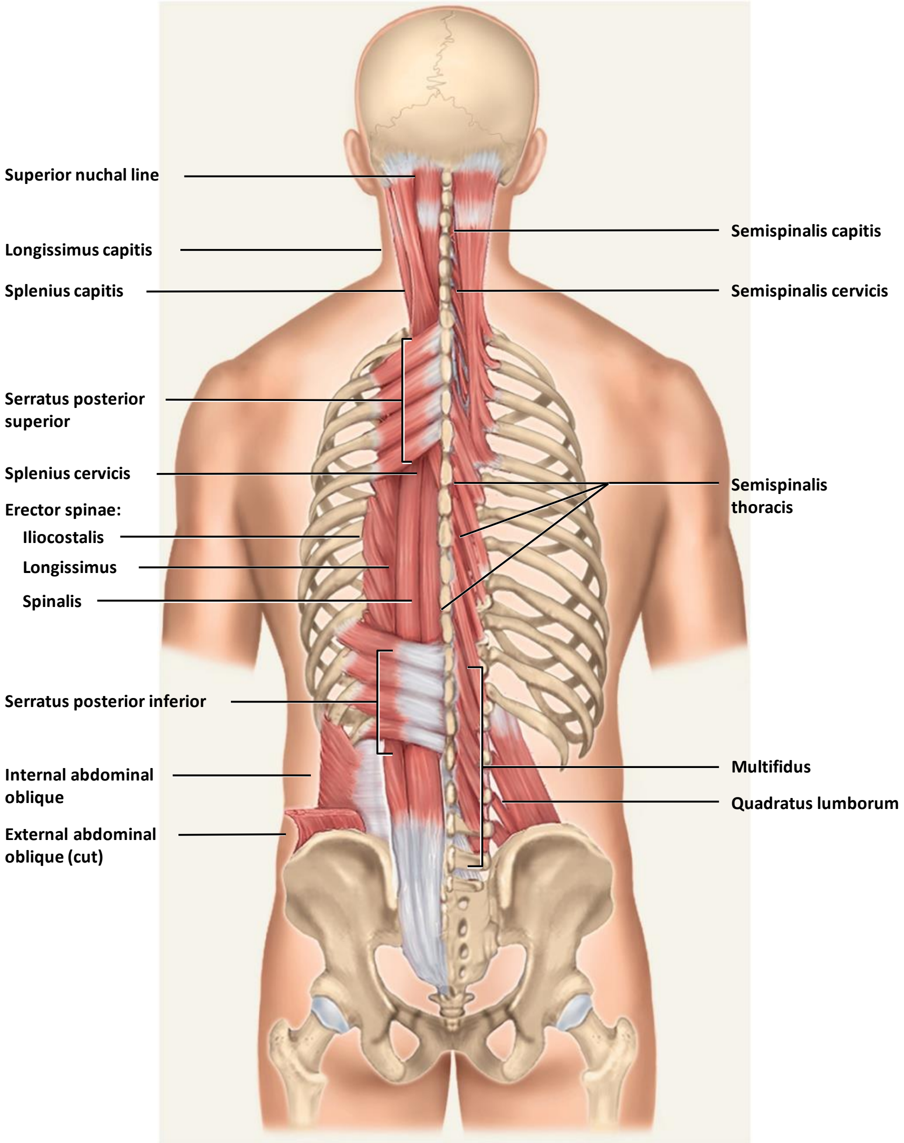
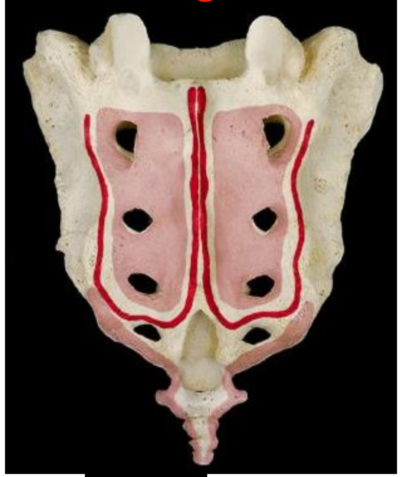


Figure 10.18

Deep Back Muscles – Erector spinae

insertion

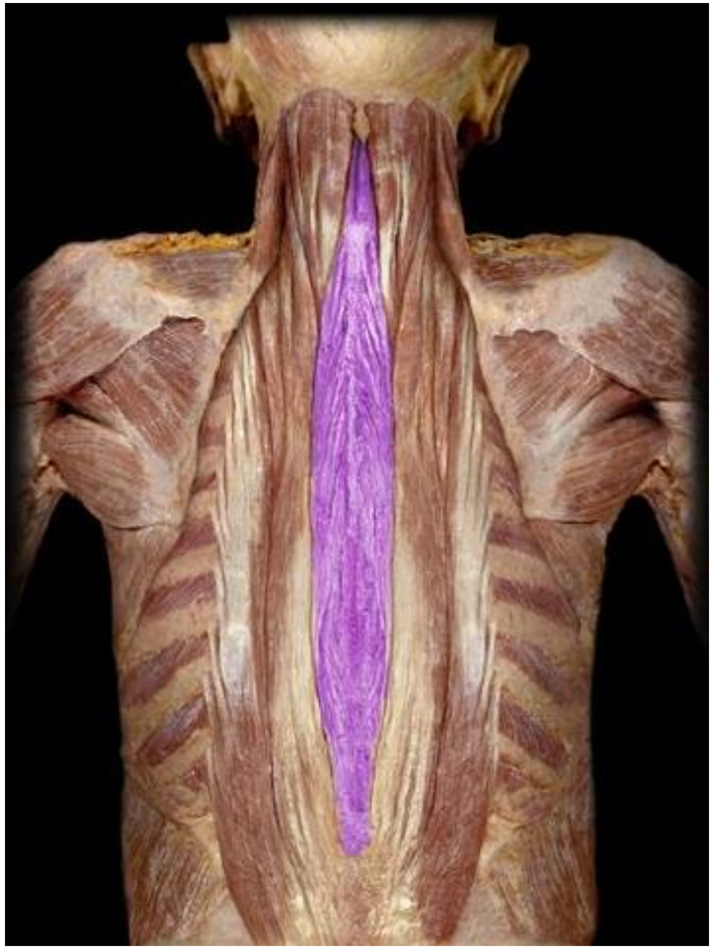
origin



Deep Back Muscles – Iliocostalis of Erector spinae

origin

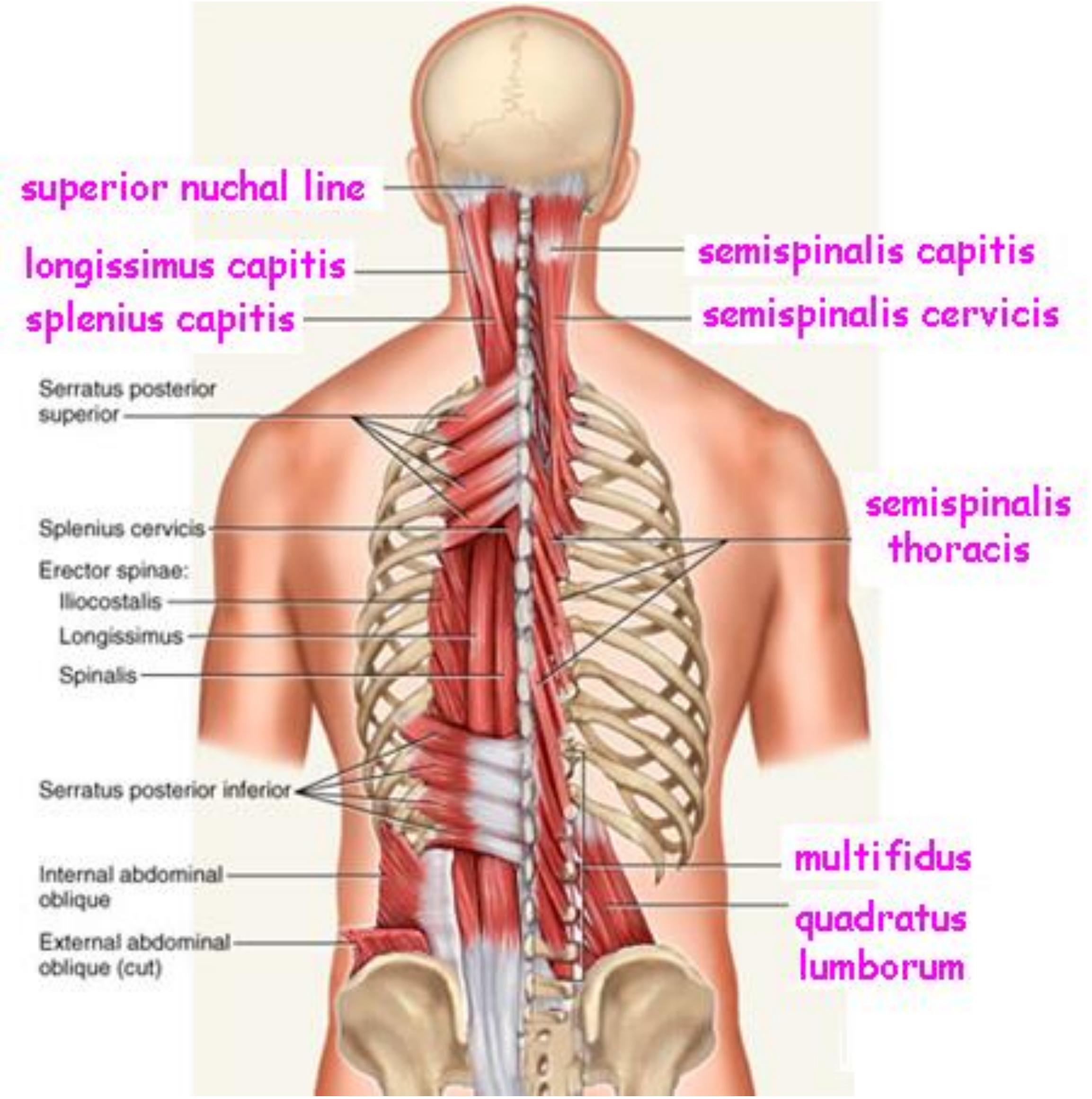
insertion



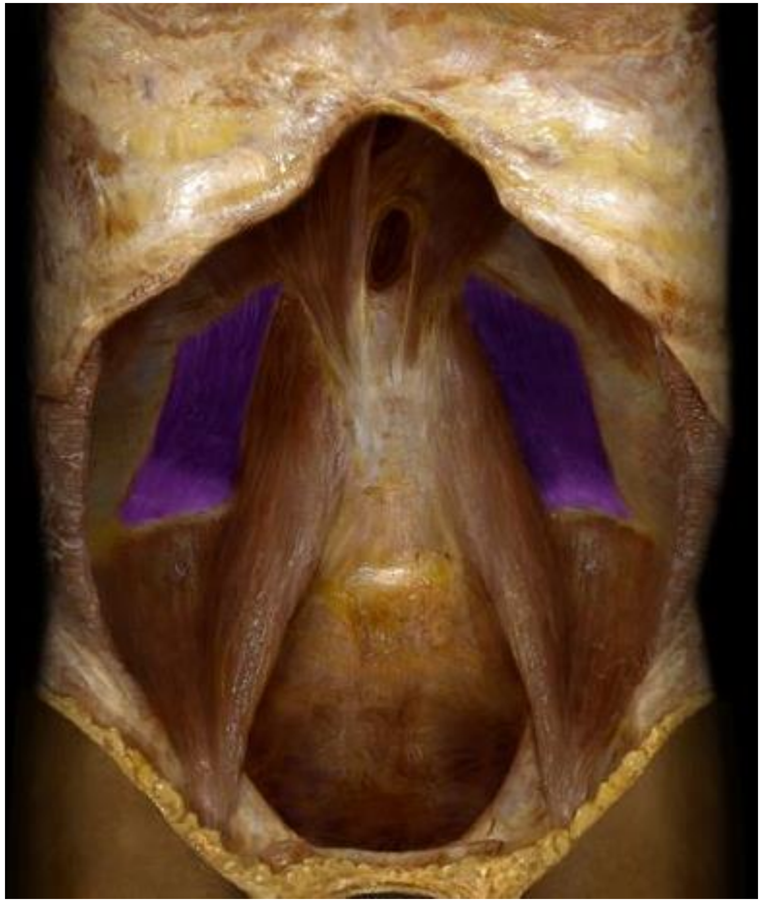

origin

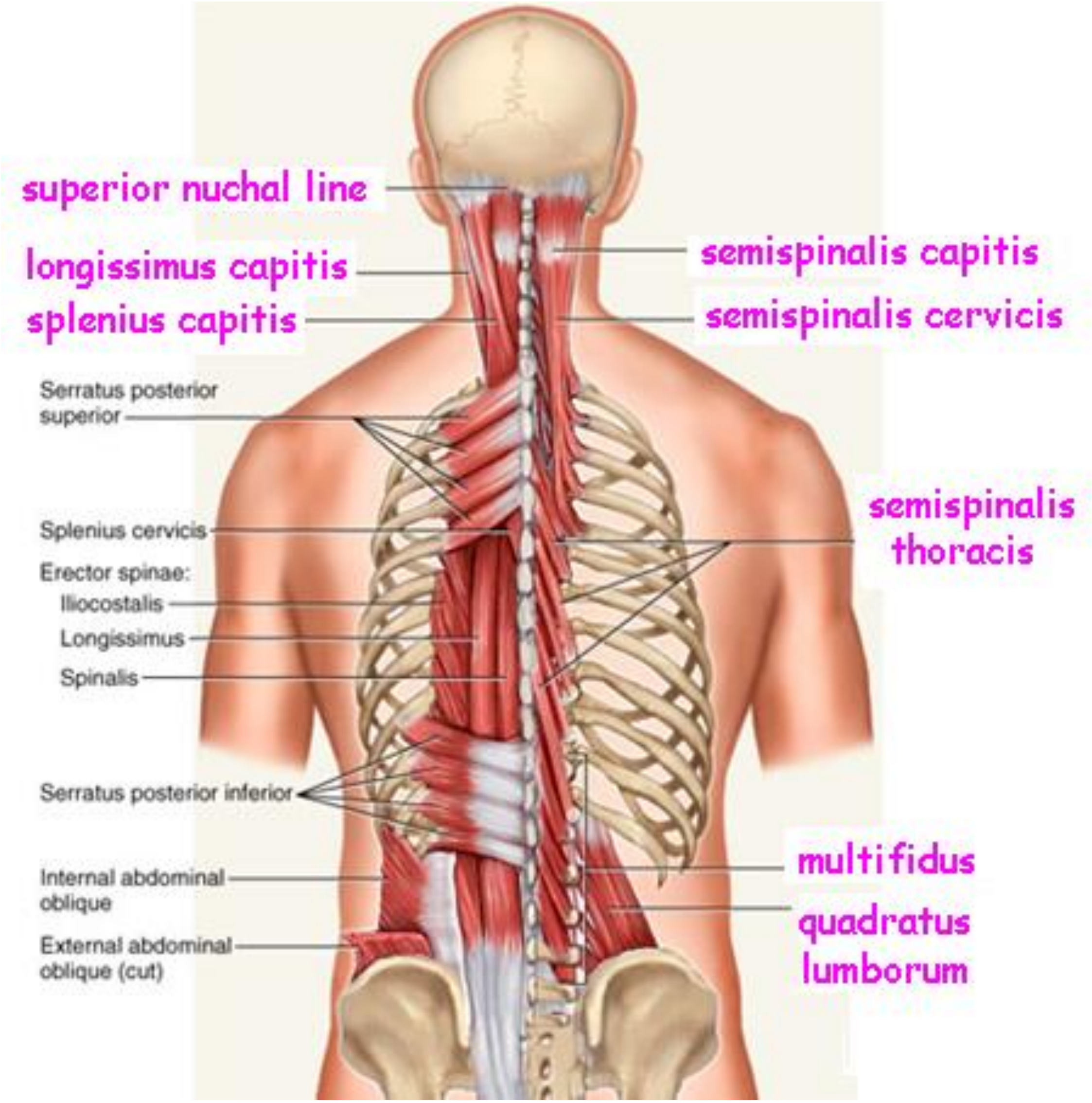

insertion

Deep Back Muscles – Semispinalis thoracis



Deep Back Muscles – Quadratus lumborum

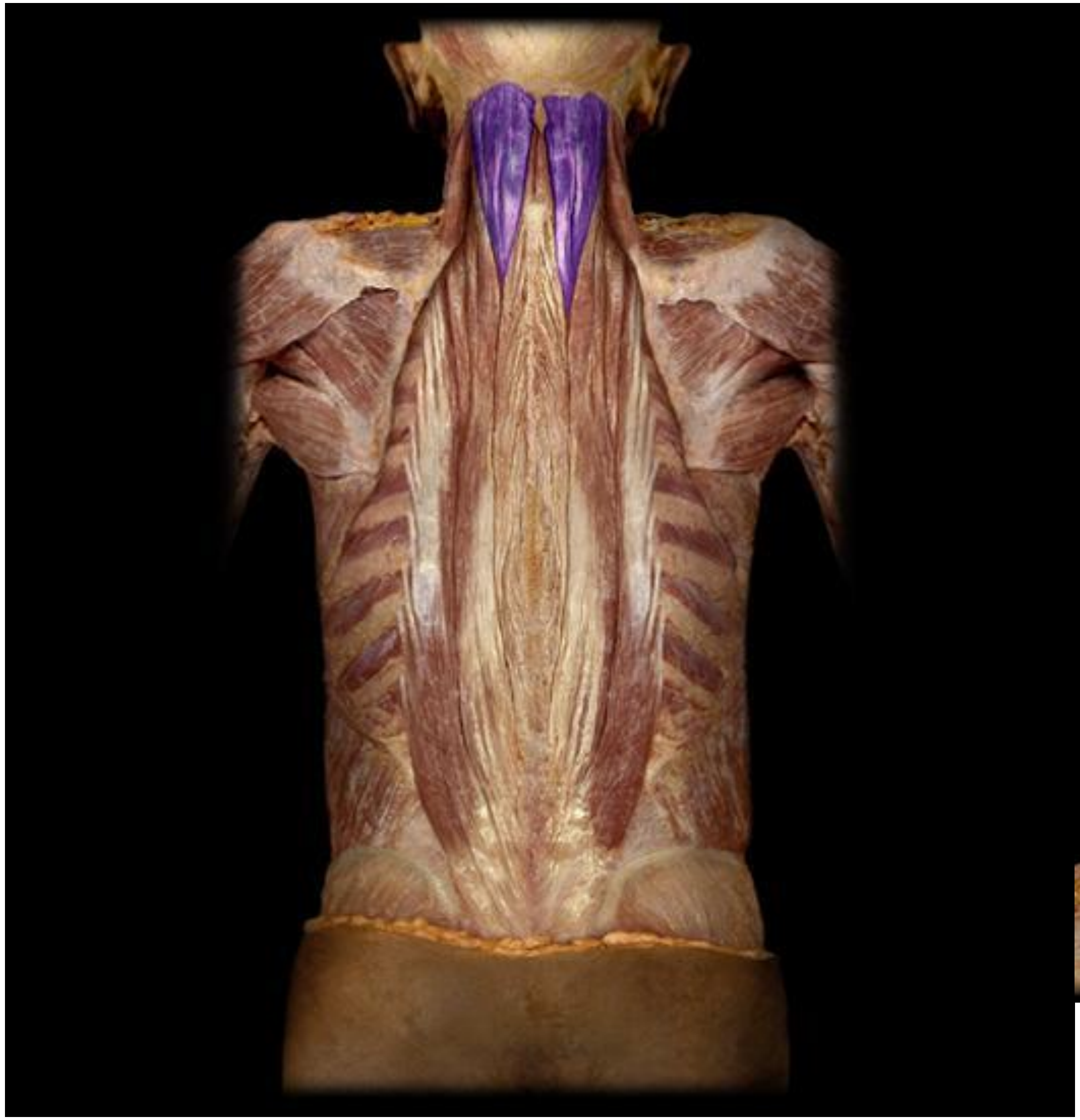


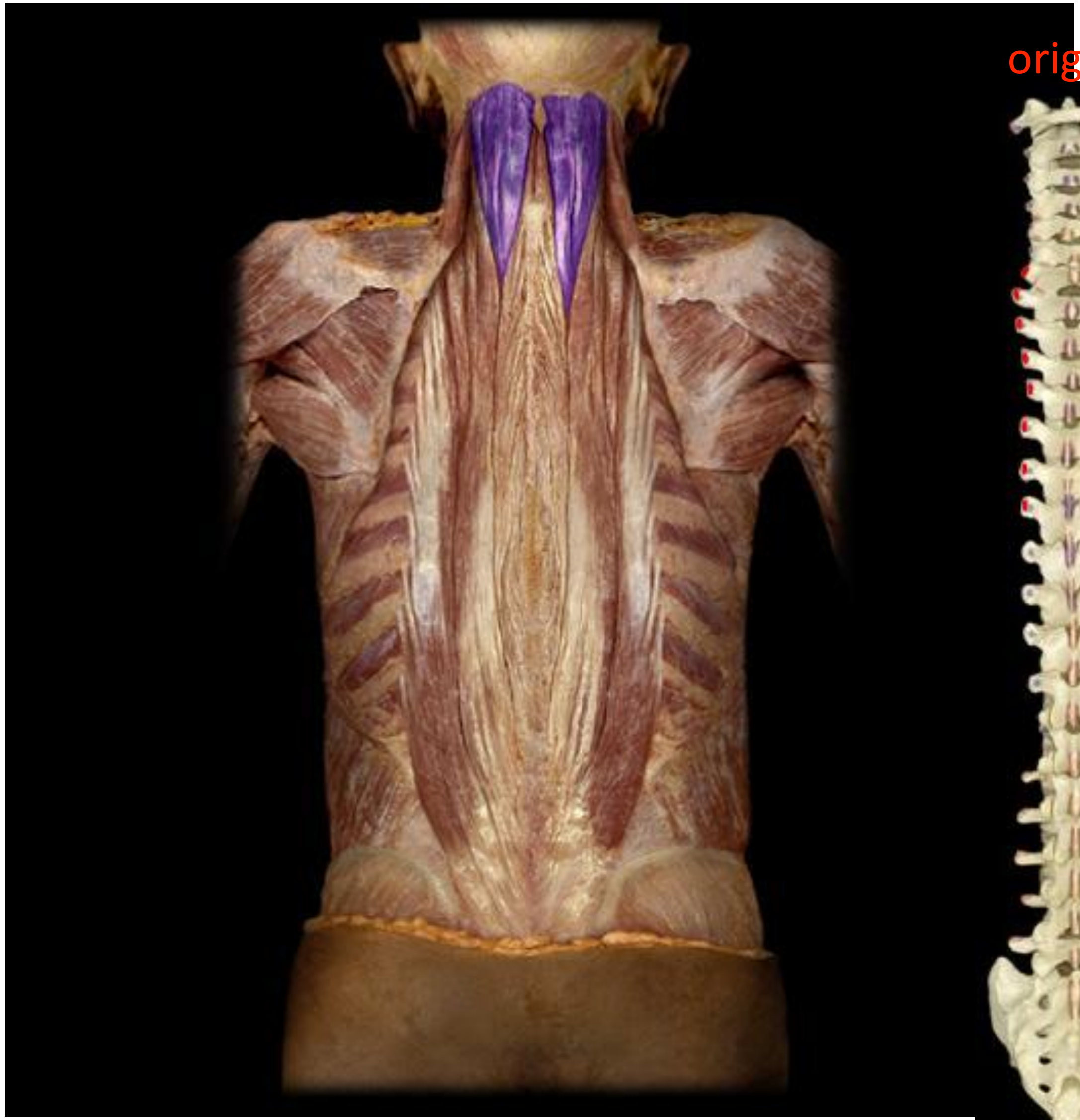


origin
sacrum
vertebrae

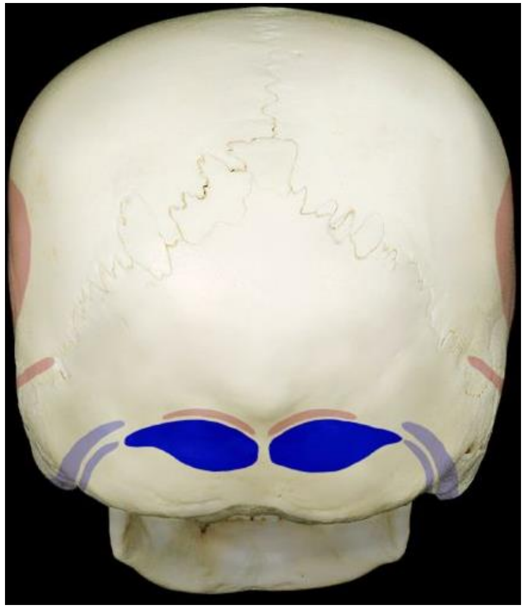
insertion
all vertebrae
spinous processes

Deep Back Muscles – Semispinalis capitis





origin



insertion

DEEPER INSIGHT 10.2

CLINICAL APPLICATION

Heavy Lifting and Back Injuries

When you are fully bent over forward, as in touching your toes, the erector spinae is fully stretched. Because of the *length–tension relationship*, muscles that are stretched to such extremes cannot contract very effectively. Standing up from such a position is therefore initiated by the hamstring muscles on the back of the thigh and the gluteus maximus of the buttocks. The erector spinae joins in the action when it is partially contracted.

DEEPER INSIGHT 10.2

CLINICAL APPLICATION

Heavy Lifting and Back Injuries

Standing too suddenly or improperly lifting a heavy weight, however, can strain the erector spinae, cause painful muscle spasms, tear tendons and ligaments of the lower back, and rupture intervertebral discs. The lumbar muscles are adapted for maintaining posture, not for lifting. This is why it is important, in heavy lifting, to crouch and use the powerful extensor muscles of the thighs and buttocks to lift the load.

Apply what you know

- ❑ **Name a major superficial muscle and two major deep muscles of the back**

LEARNING OUTCOMES

As a result of the lesson you will be able to:

- ***name and locate the muscles of respiration and explain how they affect airflow and abdominal pressure***
- ***identify the attachments, action, and innervation of these muscles.***
- ***Explain what a motor unit is and how it relates to muscle contraction; name and locate the muscles that produce facial expressions***
- ***Describe the structure of the junction where a nerve fiber meets a muscle fiber;***
- ***Explain why a cell has an electrical charge difference across its plasma membrane and, in general terms, how this relates to muscle contraction.***

Before we go on

- ❑ **Why are the muscles of the face different from typical skeletal muscle**

Before we go on

- Most skeletal muscles create movement by actions on the skeleton.
- Facial muscles are different in that they create facial movements and expressions by pulling on the skin—no bone movements are involved

Muscles of the Trunk

- **three functional groups**
  - **muscles of respiration**
  - **muscles that support abdominal wall and pelvic floor**
  - **movement of vertebral column**

Muscles of Respiration

- breathing requires the use of muscles enclosing thoracic cavity
- **inspiration** – air intake
- **expiration** – expelling air

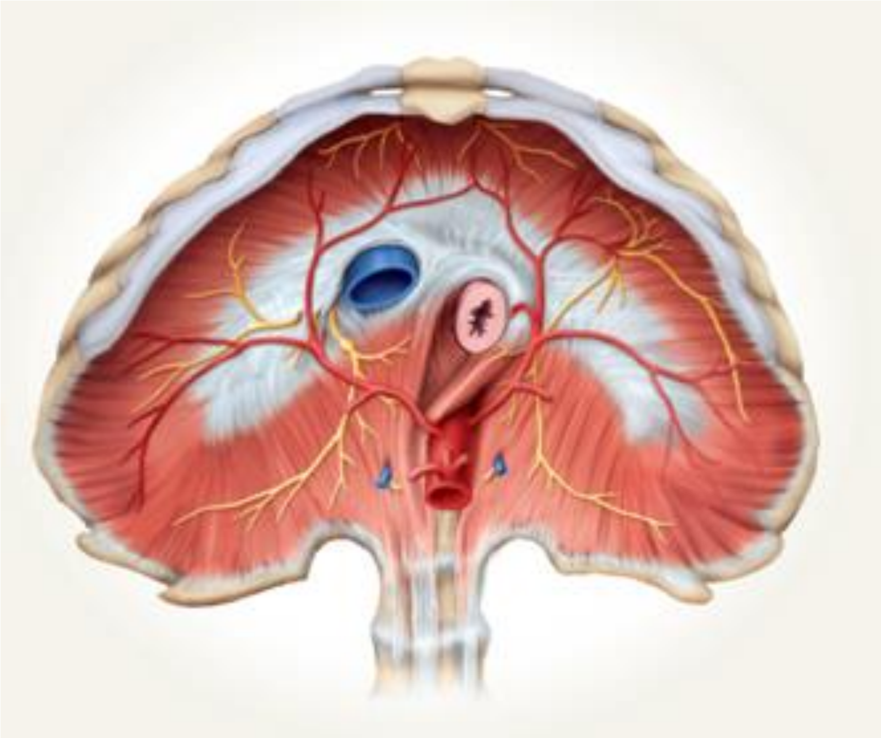
Muscles of Respiration

- **Muscles of Respiration**
  - *diaphragm* ***[dia = across; phragm = partition]***
  - *external intercostal* ***[inter = between; costa = rib]***
  - *internal intercostal*
  - *innermost intercostal muscles*

- other muscles of chest and abdomen that contribute to breathing
  - ***sternocleidomastoid, scalenes*** of neck
  - ***pectoralis major*** and ***serratus anterior*** of chest
  - ***latissimus dorsi*** of back
  - *abdominal muscles* – ***internal and external obliques***, and ***transverse abdominis***
  - some ***anal muscles***

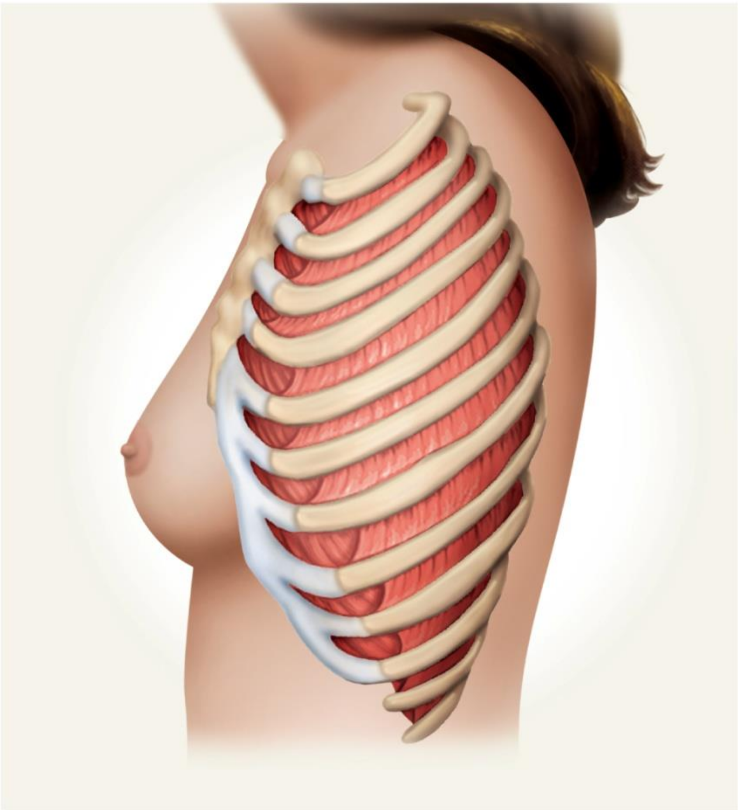
Muscles of Respiration

Diaphragm



Phrenic Nerve

Intercostals



Intercostal Nerves

Diaphragm

- The ***diaphragm*** is a muscular dome between the thoracic and abdominal cavities, bulging upward against the base of the lungs. It has openings for passage of the esophagus, major blood and lymphatic vessels, and nerves between the two cavities.
- Its fibers converge from the margins toward a fibrous central tendon.
- When the diaphragm **contracts,** it flattens slightly and enlarges the thoracic cavity, causing air intake ***(inspiration)****;* when it **relaxes**, it rises and shrinks the thoracic cavity, expelling air *(expiration)*.

Muscles of Respiration - D*iaphragm*

- **muscular dome between thoracic and abdominal cavities**
- muscle fascicles extend to a fibrous **central tendon**
- **contraction flattens diaphragm**
  - enlarges thoracic cavity (inspiration)
- in **relaxation** of diaphragm it rises
  - shrinks the thoracic cavity (expiration)

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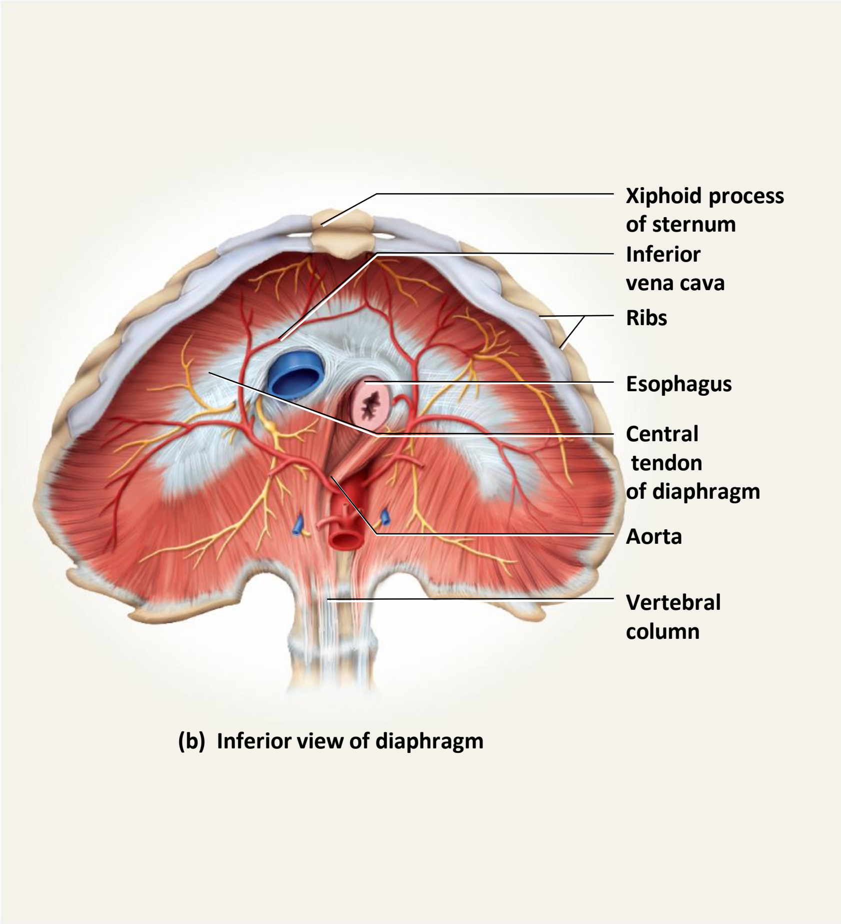
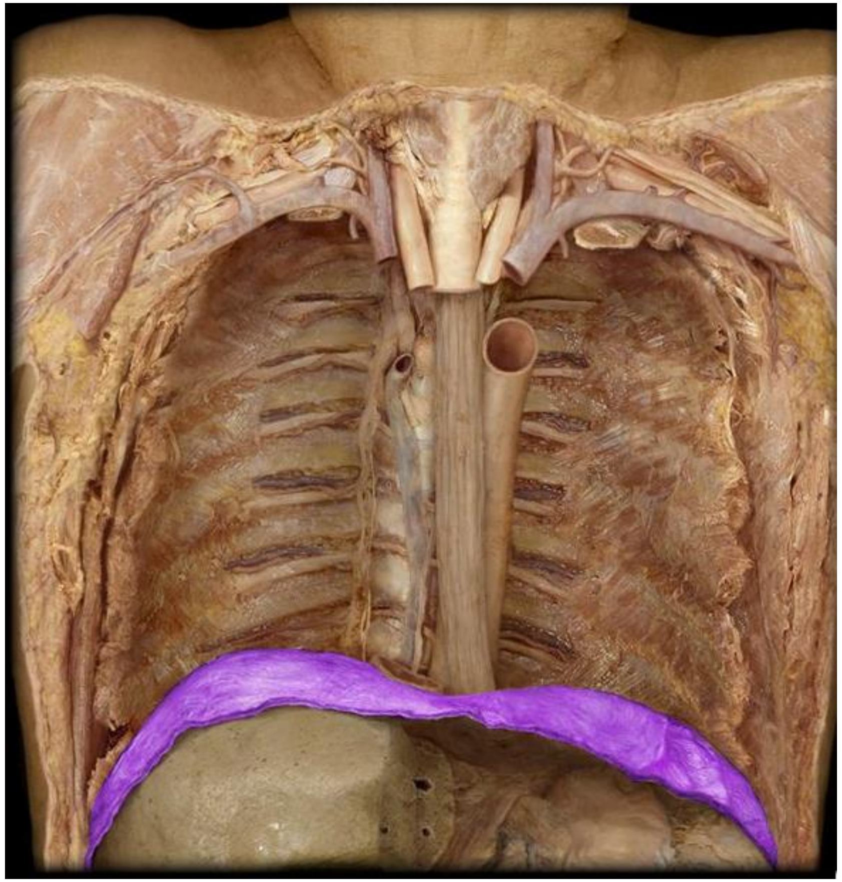
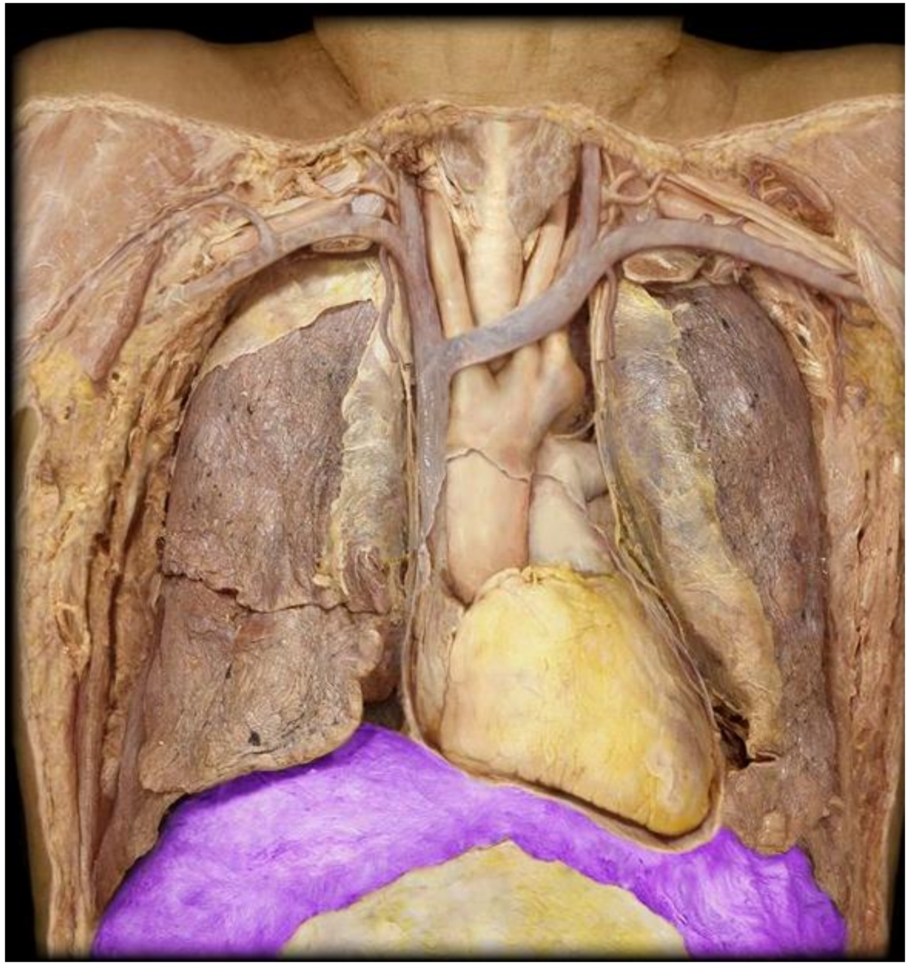


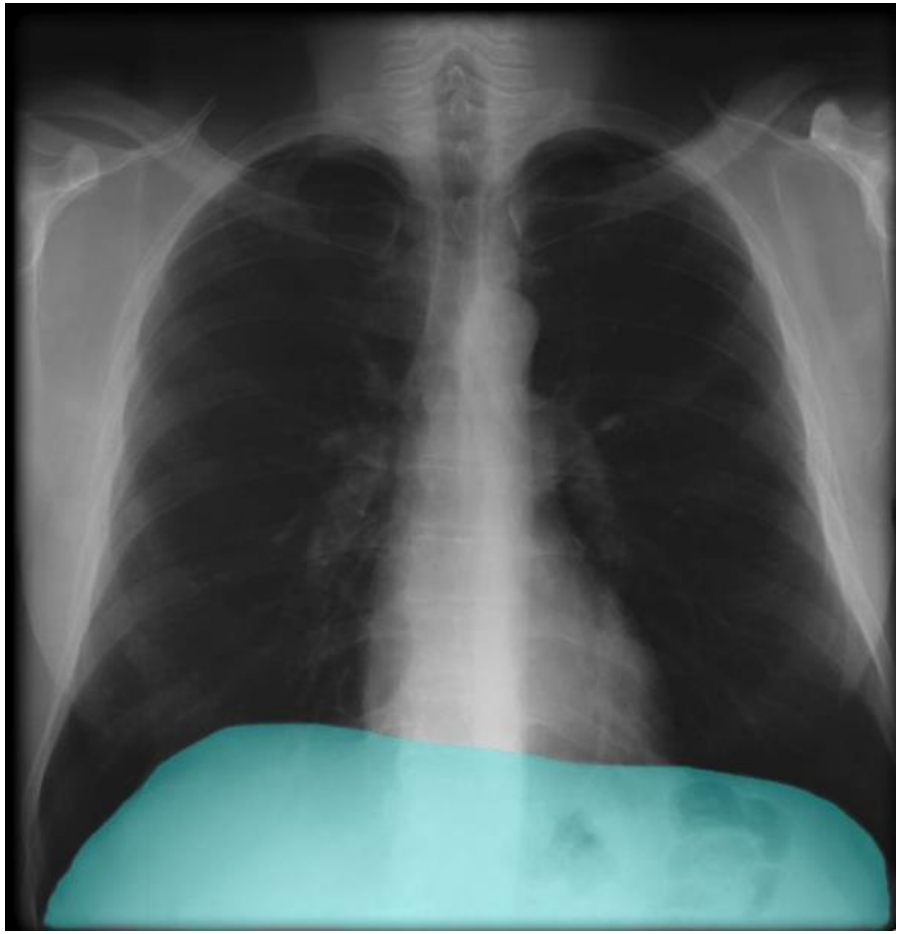
Figure 10.13b

Diaphragm



Diaphragm





Muscles of Respiration - *intercostals*

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- *external intercostals*
  - elevates ribs
  - expand thoracic cavity
  - create partial vacuum causing inflow of air
- *internal intercostals*
  - depresses and retracts ribs
  - compresses thoracic cavity
  - expelling air
- *innermost intercostals*
  - same action as internal intercostals

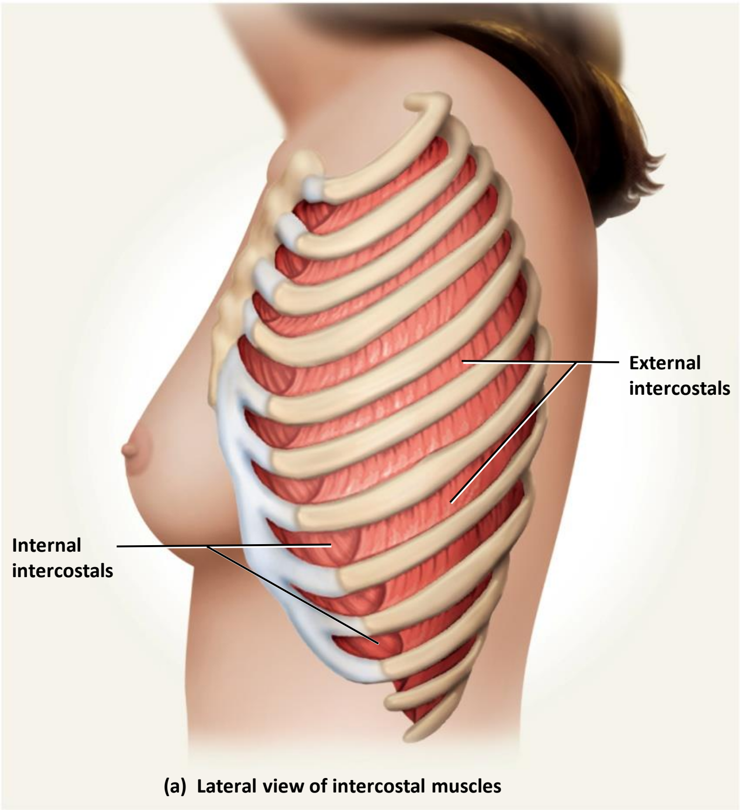
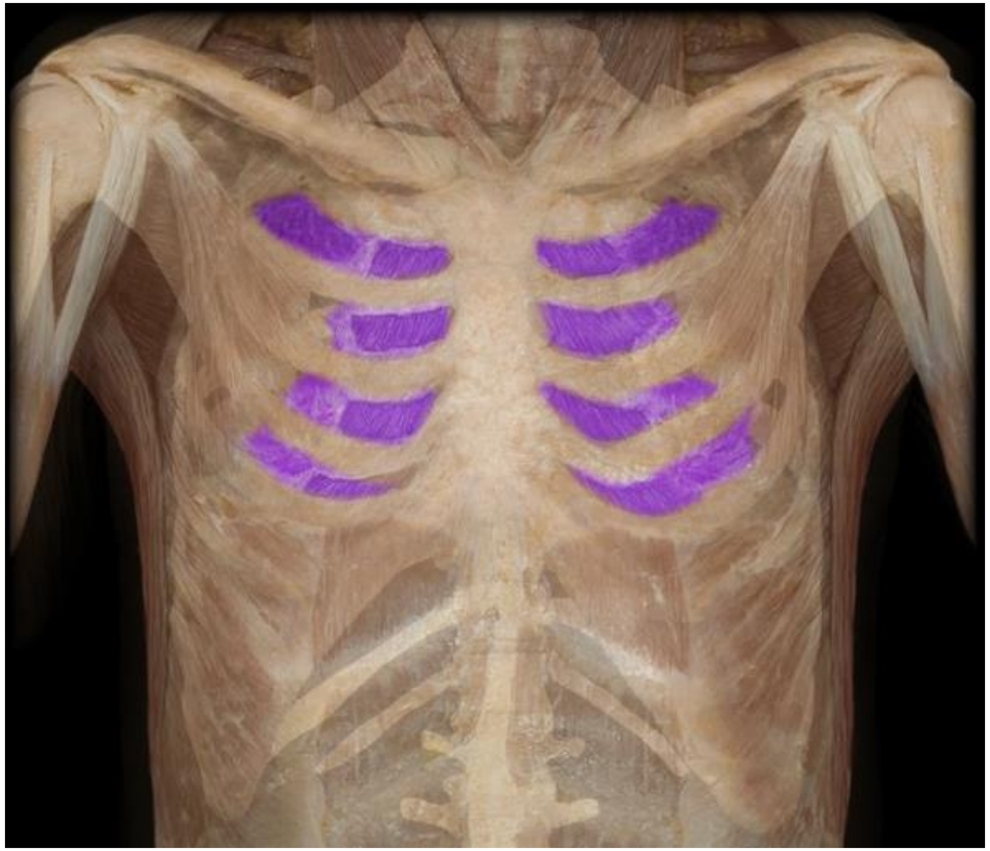


Figure 10.13a

External intercostals



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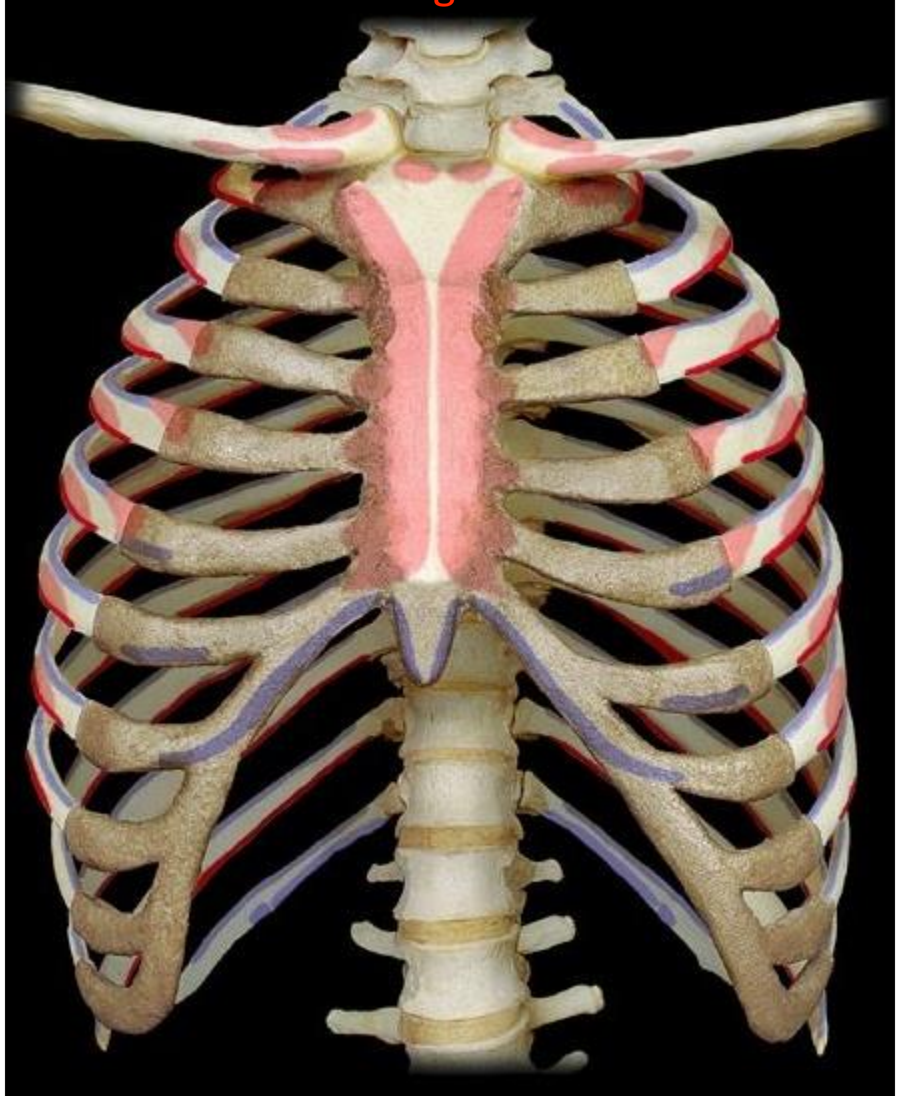
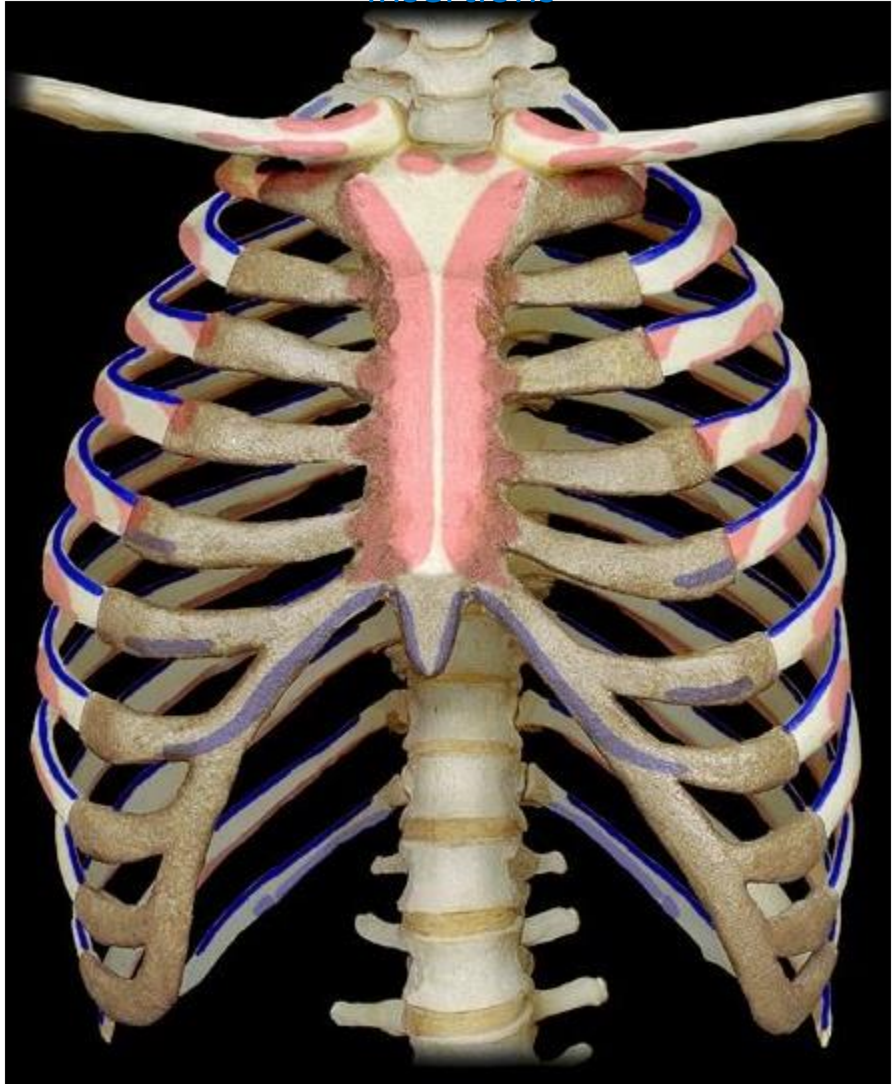
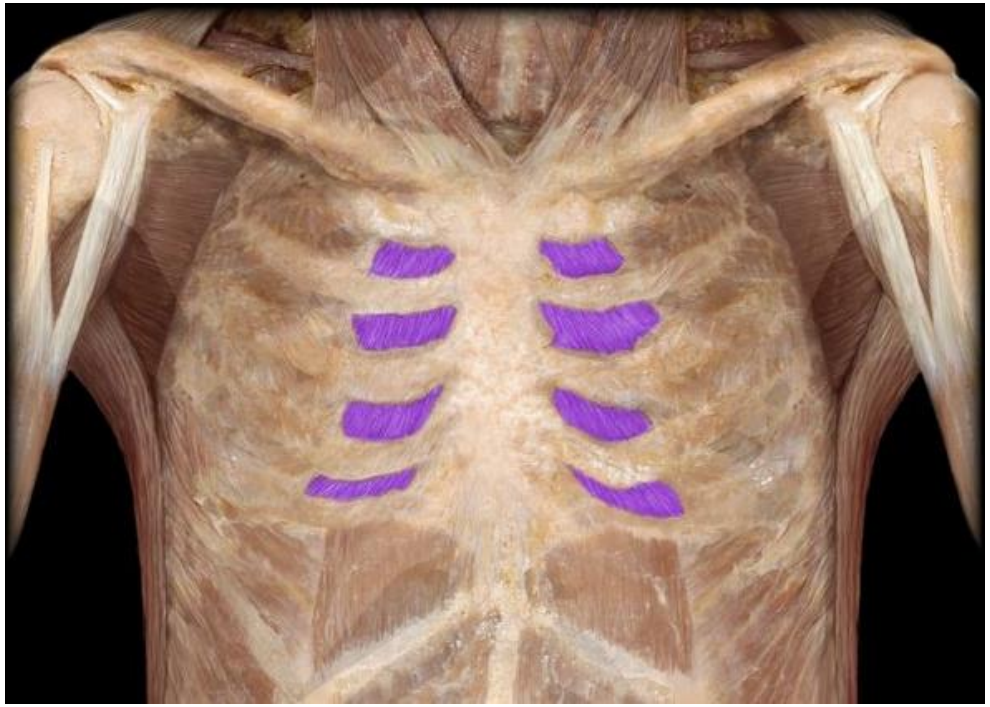


insertions



Internal intercostals



Apply what you know

- ❑ **Which muscles are used more often, the external intercostals or internal intercostals? Explain.**

Apply what you know

- ❑ **The intercostal muscles are used more often. They are attached between the ribs and are important in manipulating the width of the rib cage**

Apply what you know

- ❑ **Read the following material and define the terms highlighted in boldface**

DEEPER INSIGHT 11.1

CLINICAL APPLICATION

Neuromuscular Toxins and Paralysis

Toxins that interfere with synaptic function can paralyze the muscles. Organophosphate pesticides such as malathion, for example, are *cholinesterase inhibitors* that bind to AChE and prevent it from degrading ACh. Depending on the dose, this can prolong the action of ACh and produce *spastic paralysis*, a state in which the muscles contract and cannot relax; clinically, this is called a *cholinergic crisis.* Another example of spastic paralysis is *tetanus (lockjaw)*, caused by the toxin of a soil bac- terium, *Clostridium tetani.* In the spinal cord, a neurotransmitter called glycine normally stops motor neurons from producing unwanted muscle contractions. The tetanus toxin blocks glycine release and thus causes overstimulation and spastic paralysis of the muscles.

DEEPER INSIGHT 11.1

CLINICAL APPLICATION

Neuromuscular Toxins and Paralysis

***Flaccid paralysis*, by contrast, is a state in which the muscles are limp and cannot contract. It poses a threat of death by suffocation if it affects the respiratory muscles. Among the causes of flaccid paralysis are poisons such as curare (cue-RAH-ree), which competes with ACh for receptor sites but does not stimulate the muscle. Curare is extracted from certain plants and used by some South American natives to poison blowgun darts. It has been used to treat muscle spasms in some neurological disorders and to relax abdominal muscles for surgery, but other muscle relaxants have now replaced curare for most purposes.**

DEEPER INSIGHT 11.1

CLINICAL APPLICATION

Neuromuscular Toxins and Paralysis

Another cause of flaccid paralysis is *botulism*, a type of food poisoning caused by a neuromuscular toxin secreted by the bacterium *Clostridium botulinum*. Botulinum toxin blocks ACh release. Purified botulinum toxin is marketed as Botox Cosmetic. It is injected in small doses into specific facial muscles. The wrinkles gradually disappear as muscle paralysis sets in over the next few hours. The effect lasts about 4 months until the muscles retighten and the wrinkles return. Botox treatment is the fastest growing cosmetic medical procedure in the United States, with many people going for treatment every few months in their quest for a youthful appearance. It has had some undesirable consequences, however, as it is sometimes administered by unqualified practitioners. Even some qualified physicians use it for treatments not yet approved by the FDA, and some host festive "Botox parties" for treatment of patients in assembly-line fashion.

Muscles Acting on the Foot
Lateral (fibular) Compartment

Fibularis (Peroneus) longus & brevis

origin

tendon

insertion

Muscles Acting on the Foot
Lateral (fibular) Compartment

Fibularis (Peroneus) longus & brevis

Intrinsic Muscles of Foot

- four ventral muscle layers
- support for arches
  - abduct and adduct the toes
  - flex the toes
- one dorsal muscle
  - extensor digitorum brevis extends toes

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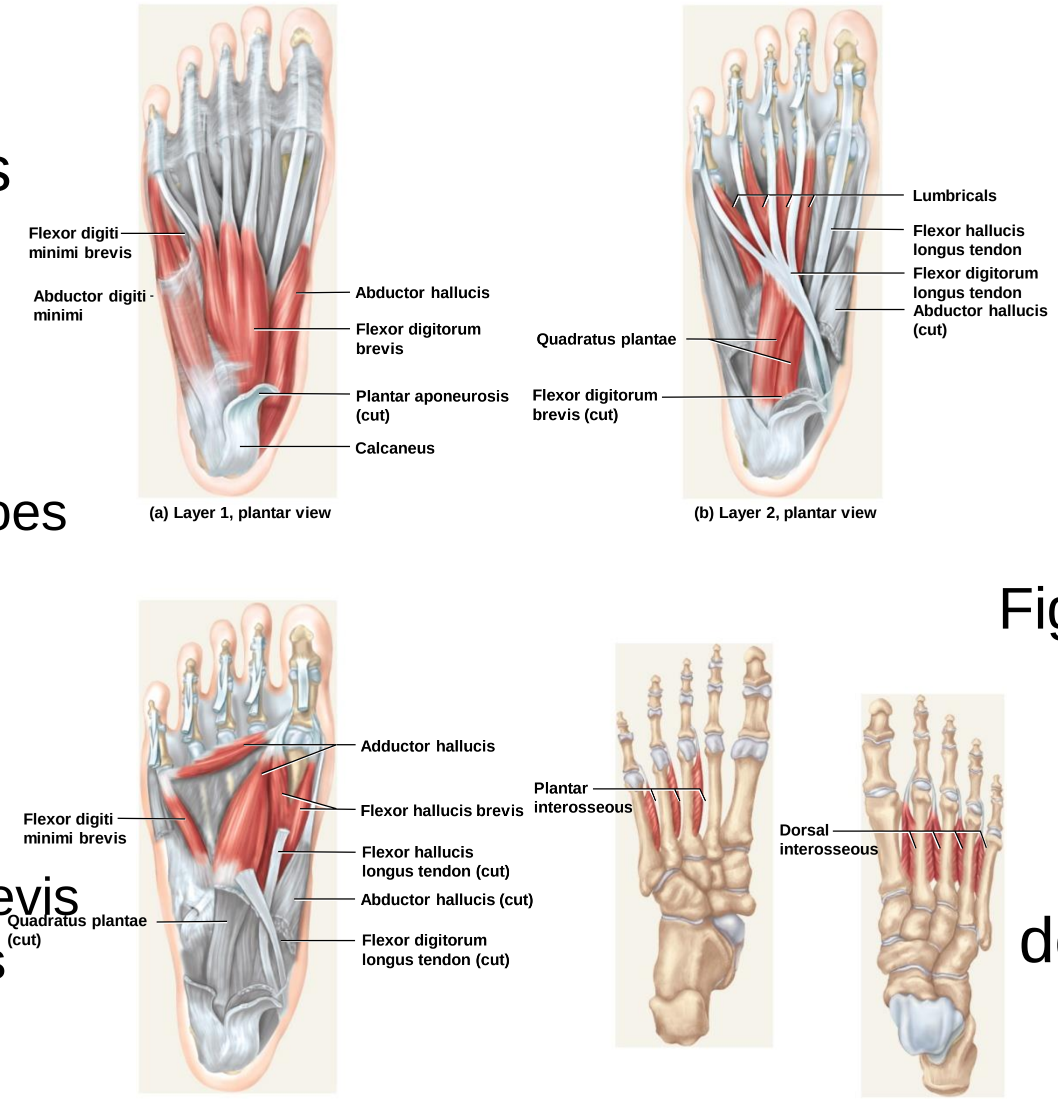


(a) Layer 1, plantar view

(b) Layer 2, plantar view

(c) Layer 3, plantar view

(d) Layer 4, plantar view

(e) Layer 4, dorsal view

Figure 10.43

dorsal view

Intrinsic Muscles of the Foot
Dorsal Aspect
Extensor digitorum brevis

Intrinsic Muscles of the Foot
Ventral Layer 1 – most superficial
Flexor digitorum brevis

origin

insertion

Intrinsic Muscles of the Foot
Ventral Layer 1 – most superficial
Abductor digiti minimi

origin

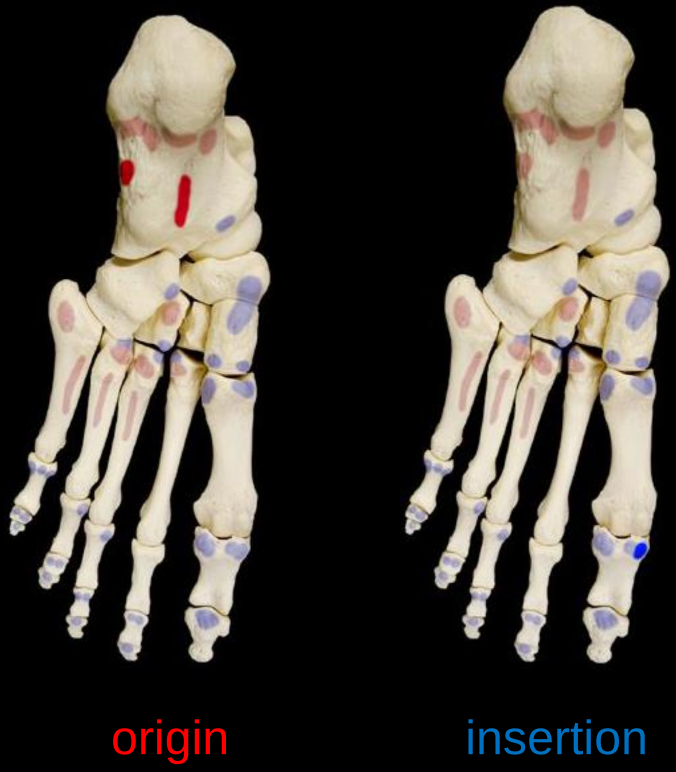
insertion

Intrinsic Muscles of the Foot
Ventral Layer 1 – most superficial
Abductor hallucis

origin

insertion

Intrinsic Muscles of the Foot
Ventral Layer 2
Quadratus plantae



Intrinsic Muscles of the Foot
Ventral Layer 2
Lumbricals

Intrinsic Muscles of the Foot
Ventral Layer 3
Adductor hallucis

Intrinsic Muscles of the Foot
Ventral Layer 3
Flexor digiti minimi brevis

origin

insertion

Intrinsic Muscles of the Foot
Ventral Layer 3
Flexor hallucis brevis

Intrinsic Muscles of the Foot
Ventral Layer 4 - Deepest
Dorsal interosseous (4) muscles

Intrinsic Muscles of the Foot
Ventral Layer 4 - Deepest
Plantar interosseous (3) muscles

origin

insertion

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

- Although the muscular system is subject to fewer diseases than most organ systems, it is particularly vulnerable to injuries resulting from sudden and intense stress placed on muscles and tendons. Each year, thousands of athletes from the high school to professional level sustain some type of injury to their muscles, as do the increasing numbers of people who have taken up running and other forms of physical condi- tioning. Overzealous exertion without proper conditioning and warm-up is frequently the cause. Compartment syndrome is one common sports injury. Others include:

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

- **Baseball finger—**tears in the extensor tendons of the fingers resulting from the impact of a baseball with the extended fingertip.
- **Blocker's arm—**abnormal calcification in the lateral margin of the fore- arm as a result of repeated impact with opposing players.
- **Charley horse—**any painful tear, stiffness, and blood clotting in a muscle. A charley horse of the quadriceps femoris is often caused by football tackles.

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

Pitcher's arm—inflammation at the proximal attachment of the flexor carpi muscles resulting from hard wrist flexion in releasing a baseball.

Pulled groin—strain in the adductor muscles of the thigh; common in gymnasts and dancers who perform splits and high kicks.

Pulled hamstrings—strained hamstring muscles or a partial tear in their tendons, often with a hematoma (blood clot) in the fascia lata. This condition is frequently caused by repetitive kicking (as in foot- ball and soccer) or long, hard running.

Rider's bones—abnormal calcification in the tendons of the adductor muscles of the medial thigh. It results from prolonged abduction of the thighs when riding horses.

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

Rotator cuff injury—a tear in the tendon of any of the SITS (rotator cuff) muscles, most often the tendon of the supraspinatus. Such injuries are caused by strenuous circumduction of the arm, shoul- der dislocation, hard falls or blows to the shoulder, or repetitive use of the arm in a position above horizontal. They are common among baseball pitchers and third basemen, bowlers, swimmers, and weight lifters, and in racquet sports. Recurrent inflammation of a SITS tendon can cause a tendon to degenerate and then to rupture in response to moderate stress. Injury causes pain and makes the shoulder joint unstable and subject to dislocation.

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

Shinsplints—a general term embracing several kinds of injury with pain in the crural region: tendinitis of the tibialis posterior muscle, inflammation of the tibial periosteum, and anterior compartment syndrome. Shinsplints may result from unaccustomed jogging, walking on snowshoes, or any vigorous activity of the legs after a period of relative inactivity.
Tennis elbow—inflammation at the proximal attachment of the extensor carpi muscles on the lateral epicondyle of the humerus. It occurs when these muscles are repeatedly tensed during backhand strokes and then strained by sudden impact with the tennis ball. Any activity that requires rotary movements of the forearm and a firm grip of the hand (for example, using a screwdriver) can cause the symptoms of tennis elbow.

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

Tennis leg—a partial tear in the proximal attachment of the lateral head of the gastrocnemius muscle. It results from repeated strains put on the muscle while supporting the body weight on the toes.

Most athletic injuries can be prevented by proper conditioning. A person who suddenly takes up vigorous exercise may not have sufficient muscle and bone mass to withstand the stresses such exercise entails. These must be developed gradually. Stretching exercises keep ligaments and joint capsules supple and therefore reduce injuries. Warm-up exercises promote more efficient and less injurious musculoskeletal function in several ways. Most of all, moderation is important, as most injuries simply result from overuse of the muscles. “No pain, no gain” is a risky misconception.

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

Muscular injuries can be treated initially with “RICE”: rest, ice, com- pression, and elevation. Rest prevents further injury and allows repair processes to occur; ice reduces swelling; compression with an elastic bandage helps to prevent fluid accumulation and swelling; and eleva- tion of an injured limb promotes drainage of blood from the affected area and limits further swelling. If these measures are not enough, anti-inflammatory drugs may be employed, including corticosteroids as well as aspirin and other nonsteroidal agents. Serious injuries, such as compartment syndrome, require emergency attention by a physician.

Athletic Injuries

- muscles and tendons are vulnerable to sudden and intense stress
- proper conditioning and warm-up needed
- common injuries;
  - compartment syndrome
  - shinsplints
  - pulled hamstrings
  - tennis elbow
  - pulled groin
  - rotator cuff injury
- treat with rest, ice, compression and elevation
- “no pain, no gain” is a dangerous misconception

Compartment Syndrome

- fasciae of arms and legs enclose muscle compartments very snugly
- if a blood vessel in a compartment is damaged, blood and tissue fluid accumulate in the compartment
- fasciae prevent compartment from expanding with increasing pressure
- **compartment syndrome** – mounting pressure on the muscles, nerves and blood vessel triggers a sequence of degenerative events
  - blood flow to compartment is obstructed by pressure
  - if **ischemia** (poor blood flow) persists for more than 2 – 4 hours, nerves begin to die
  - after 6 hours, muscles begin to die
- nerves can regenerate after pressure relieved, but muscle damage is permanent
- myoglobin in urine indicates compartment syndrome
- **treatment** – immobilization of limb and **fasciotomy** – incision to relieve compartment pressure

Muscles Acting on the Foot
Lateral (fibular) Compartment

Fibularis (Peroneus) longus & brevis

origin

tendon

insertion

Intrinsic Muscles of Foot

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- four ventral muscle layers
- support for arches
  - abduct and adduct the toes
  - flex the toes
- one dorsal muscle
  - extensor digitorum brevis extends toes

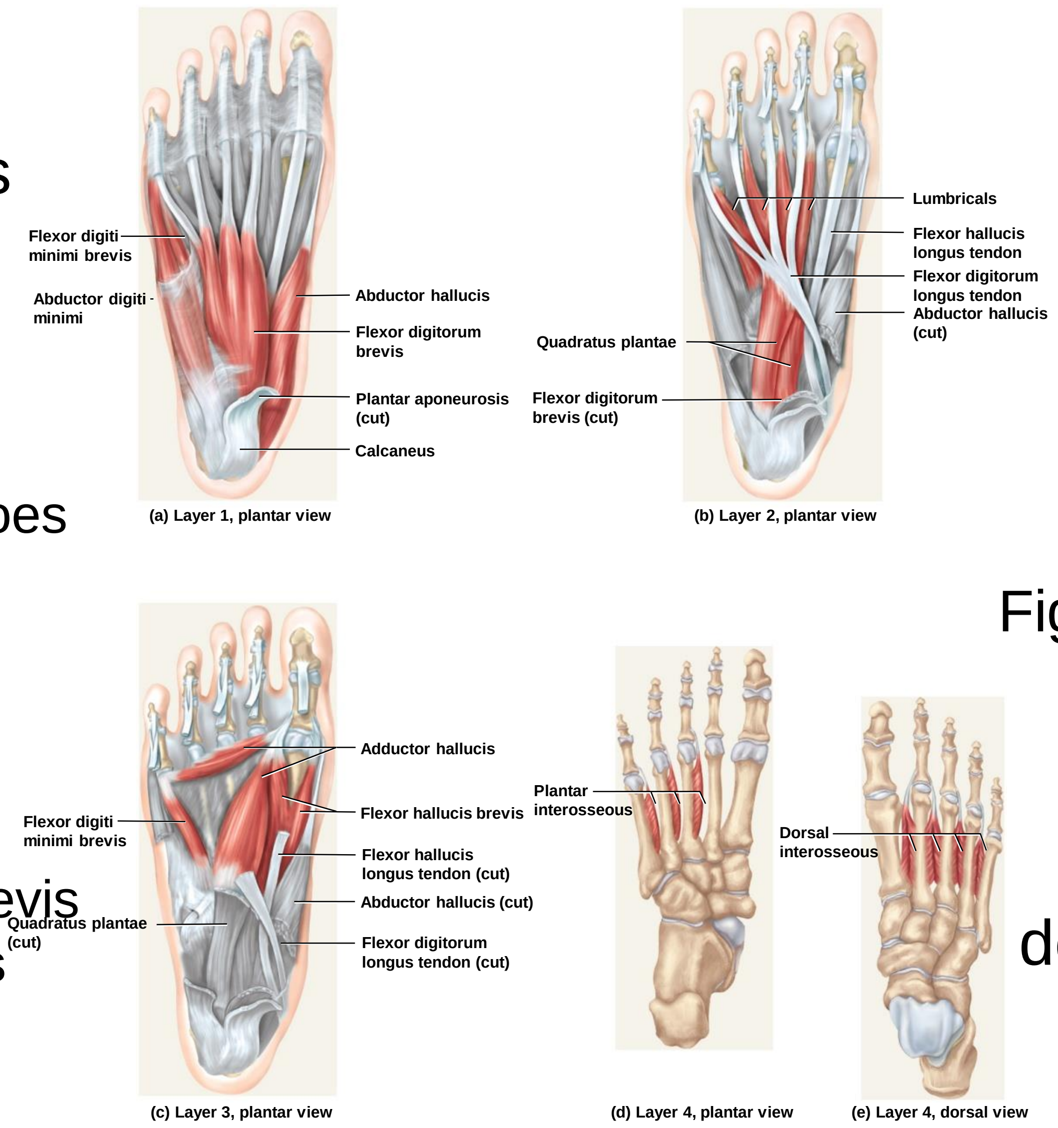


Figure 10.43

dorsal view

Intrinsic Muscles of the Foot
Dorsal Aspect
Extensor digitorum brevis

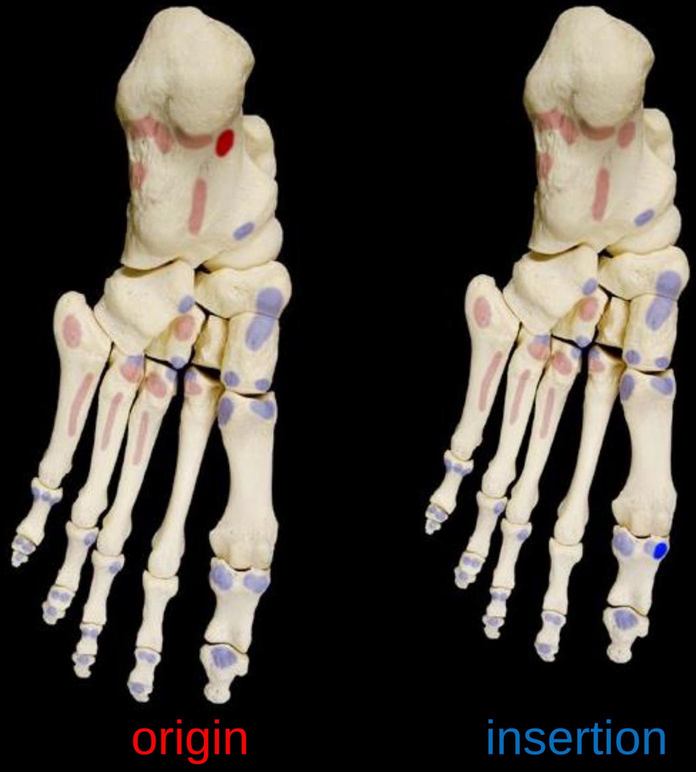
Intrinsic Muscles of the Foot
Ventral Layer 1 – most superficial
Flexor digitorum brevis

origin

insertion

Intrinsic Muscles of the Foot
Ventral Layer 1 – most superficial
Abductor digiti minimi

Intrinsic Muscles of the Foot
Ventral Layer 1 – most superficial
Abductor hallucis



Intrinsic Muscles of the Foot
Ventral Layer 2
Quadratus plantae

origin

insertion

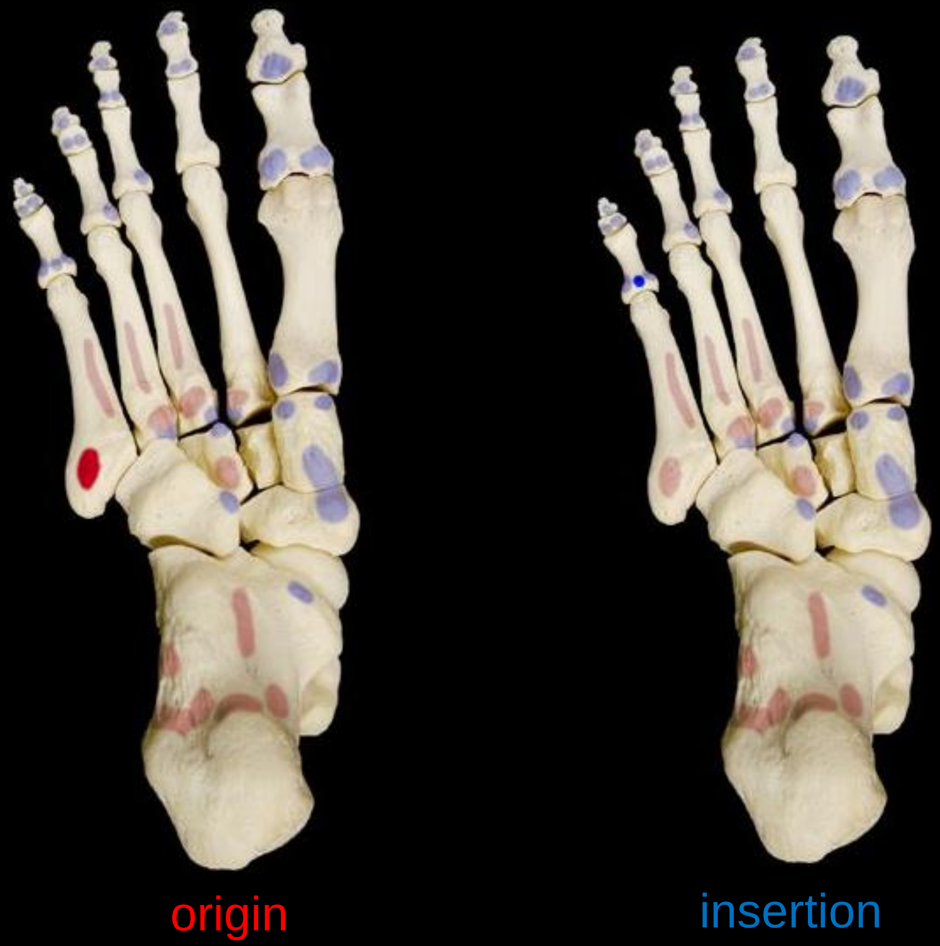
Intrinsic Muscles of the Foot
Ventral Layer 2
Lumbricals

Intrinsic Muscles of the Foot
Ventral Layer 3
Adductor hallucis

origin

insertion

Intrinsic Muscles of the Foot
Ventral Layer 3
Flexor digiti minimi brevis



Intrinsic Muscles of the Foot
Ventral Layer 3
Flexor hallucis brevis

Intrinsic Muscles of the Foot
Ventral Layer 4 - Deepest
Dorsal interosseous (4) muscles

origin

insertion

Intrinsic Muscles of the Foot
Ventral Layer 4 - Deepest
Plantar interosseous (3) muscles

origin

insertion

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

- Although the muscular system is subject to fewer diseases than most organ systems, it is particularly vulnerable to injuries resulting from sudden and intense stress placed on muscles and tendons. Each year, thousands of athletes from the high school to professional level sustain some type of injury to their muscles, as do the increasing numbers of people who have taken up running and other forms of physical condi- tioning. Overzealous exertion without proper conditioning and warm-up is frequently the cause. Compartment syndrome is one common sports injury. Others include:

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

- **Baseball finger—**tears in the extensor tendons of the fingers resulting from the impact of a baseball with the extended fingertip.
- **Blocker's arm—**abnormal calcification in the lateral margin of the fore- arm as a result of repeated impact with opposing players.
- **Charley horse—**any painful tear, stiffness, and blood clotting in a muscle. A charley horse of the quadriceps femoris is often caused by football tackles.

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

Pitcher's arm—inflammation at the proximal attachment of the flexor carpi muscles resulting from hard wrist flexion in releasing a baseball.

Pulled groin—strain in the adductor muscles of the thigh; common in gymnasts and dancers who perform splits and high kicks.

Pulled hamstrings—strained hamstring muscles or a partial tear in their tendons, often with a hematoma (blood clot) in the fascia lata. This condition is frequently caused by repetitive kicking (as in foot- ball and soccer) or long, hard running.

Rider's bones—abnormal calcification in the tendons of the adductor muscles of the medial thigh. It results from prolonged abduction of the thighs when riding horses.

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

Rotator cuff injury—a tear in the tendon of any of the SITS (rotator cuff) muscles, most often the tendon of the supraspinatus. Such injuries are caused by strenuous circumduction of the arm, shoul- der dislocation, hard falls or blows to the shoulder, or repetitive use of the arm in a position above horizontal. They are common among baseball pitchers and third basemen, bowlers, swimmers, and weight lifters, and in racquet sports. Recurrent inflammation of a SITS tendon can cause a tendon to degenerate and then to rupture in response to moderate stress. Injury causes pain and makes the shoulder joint unstable and subject to dislocation.

DEEPER INSIGHT 10.5

CLINICAL APPLICATION

Common Athletic Injuries

Shinsplints—a general term embracing several kinds of injury with pain in the crural region: tendinitis of the tibialis posterior muscle, inflammation of the tibial periosteum, and anterior compartment syndrome. Shinsplints may result from unaccustomed jogging, walking on snowshoes, or any vigorous activity of the legs after a period of relative inactivity. **Tennis elbow—**inflammation at the proximal attachment of the extensor carpi muscles on the lateral epicondyle of the humerus. It occurs when these muscles are repeatedly tensed during backhand strokes and then strained by sudden impact with the tennis ball. Any activity that requires rotary movements of the forearm and a firm grip of the hand (for example, using a screwdriver) can cause the symptoms of tennis elbow.

DEEPER INSIGHT 10.5

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Tennis leg—a partial tear in the proximal attachment of the lateral head of the gastrocnemius muscle. It results from repeated strains put on the muscle while supporting the body weight on the toes.

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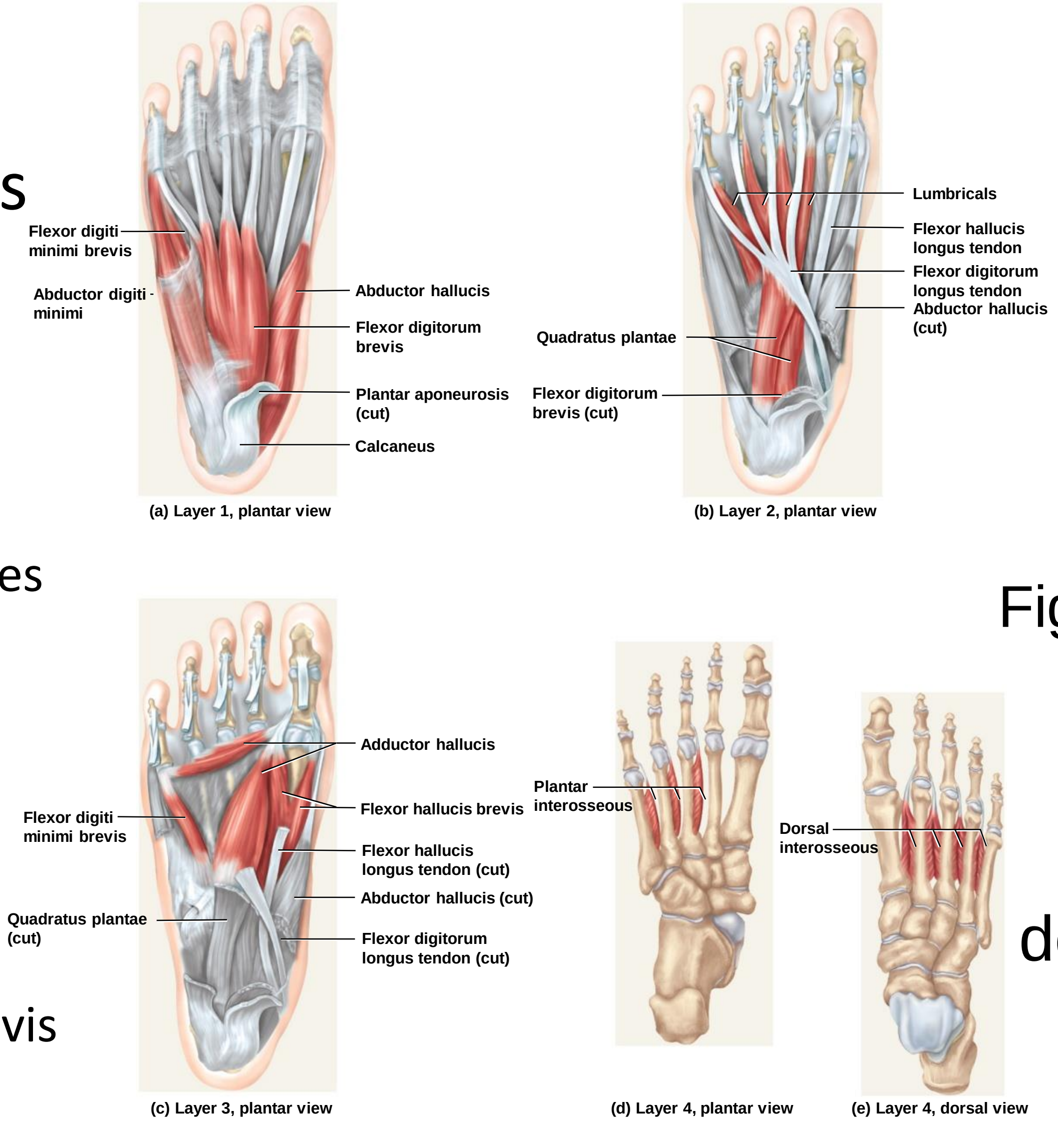

Figure 10.43

dorsal view

origin insertion

origin

insertion

origin

insertion

origin

insertion

origin

insertion

origin

insertion

origin

insertion

origin

insertion

origin

insertion

origin

insertion

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◆ PART II

LEARNING OUTCOMES

As a result of the lesson you will be able to:

- ***name and locate the muscles that produce facial expressions***
- ***name and locate the muscles used for chewing and swallowing;***
- ***name and locate the neck muscles that move the head;***
- ***identify the attachments, action, and innervation of these muscles.***

Muscles of Facial Expression

- muscles that insert in the dermis and subcutaneous tissues
- tense the skin and produce facial expressions
- innervated by facial nerve (CN VII)
- paralysis causes face to sag
- found in scalp, forehead, around the eyes, nose and mouth, and in the neck

Muscles in Facial Expression

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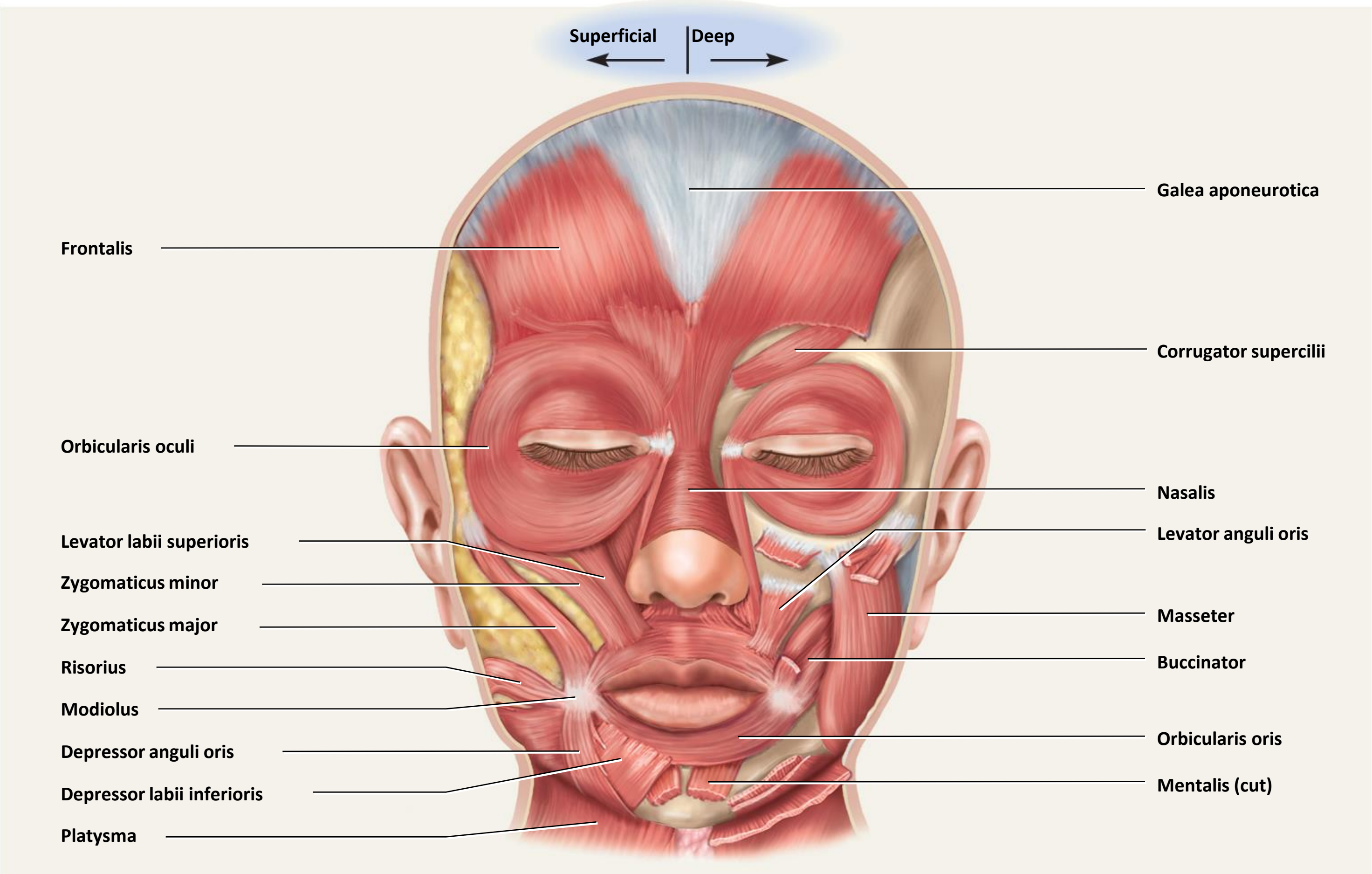

(a) Anterior view

Muscles in Facial Expression

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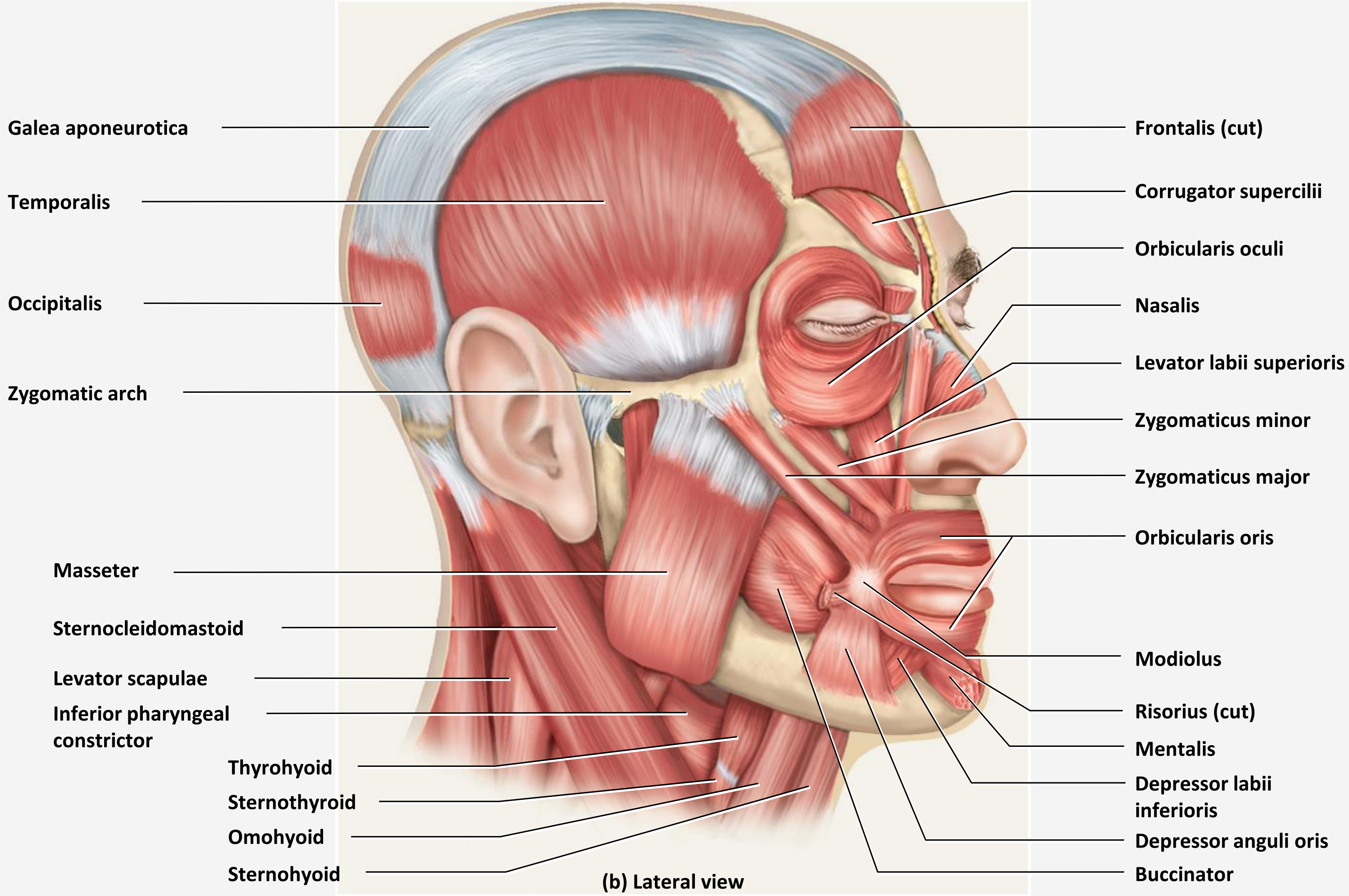


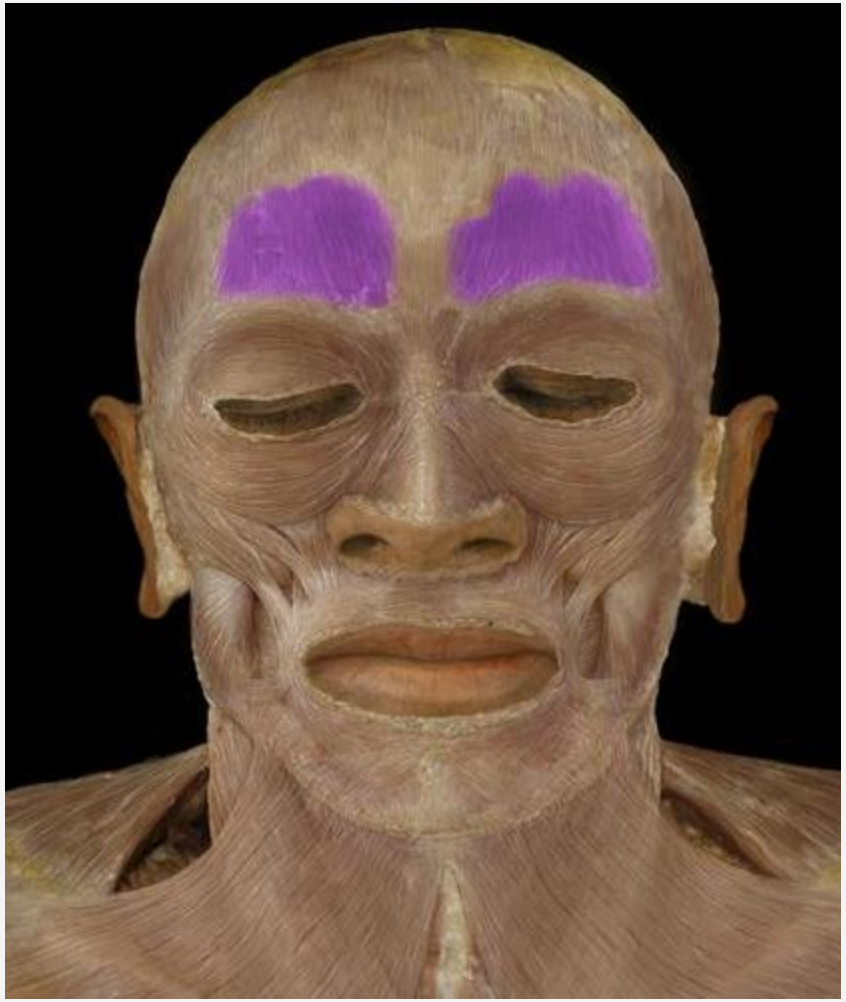
(b) Lateral view

Figure 10.7b

Muscles of Facial Expression

- **The Scalp.**
- The *occipitofrontalis* overlies the dome of the cranium.
- It is divided into the *frontalis* of the forehead and *occipitalis* at the rear of the head, **named for the frontal and occipital bones underlying them**.
- They are connected to each other by a broad aponeurosis, the **galea aponeurotica**[14]
- (*galea* = helmet; *apo* = above; *neuro* = nervous system, brain).

Frontalis



Occipitalis

origin

Muscles in Facial Expression

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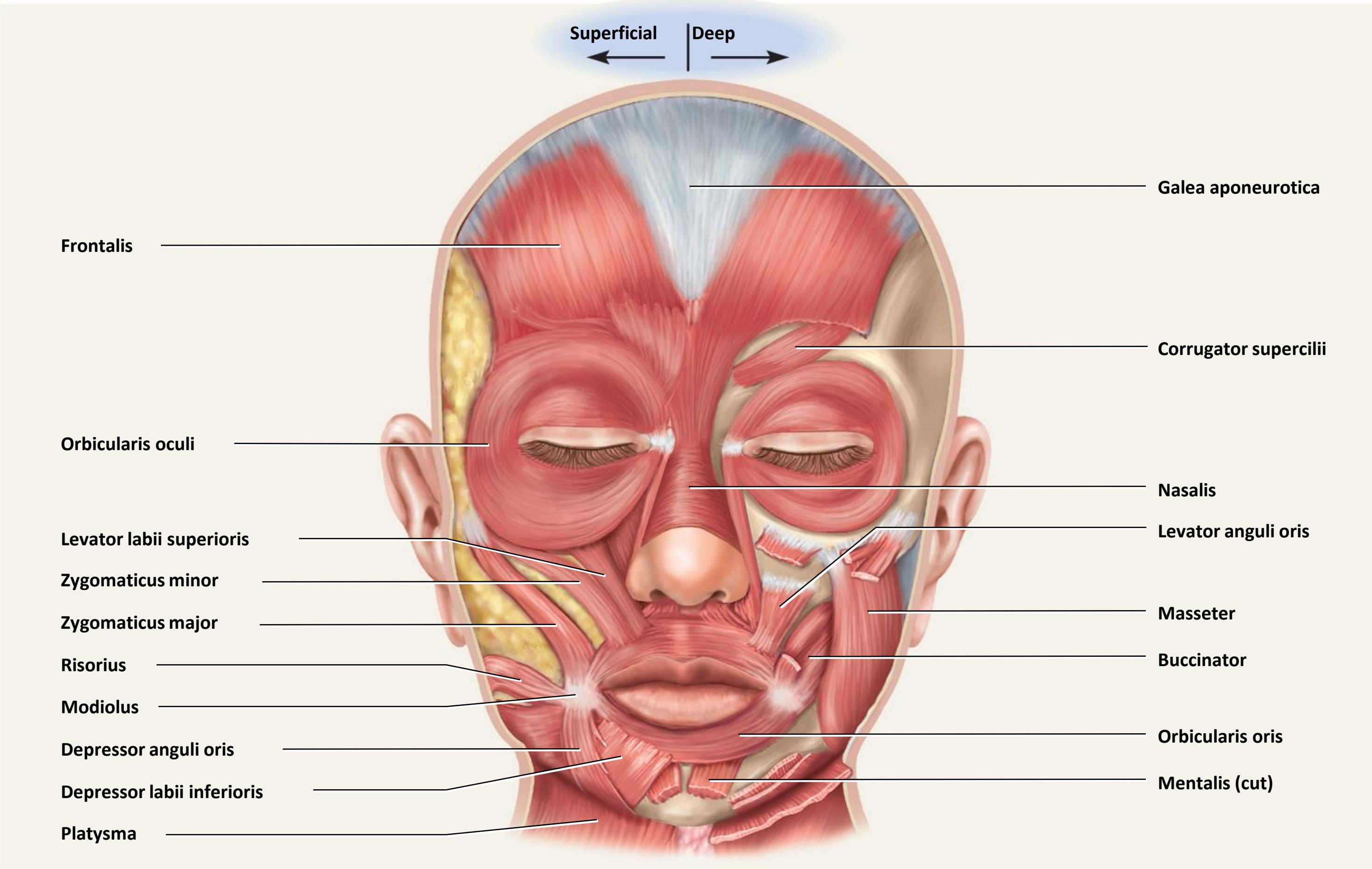

(a) Anterior view

Muscles in Facial Expression

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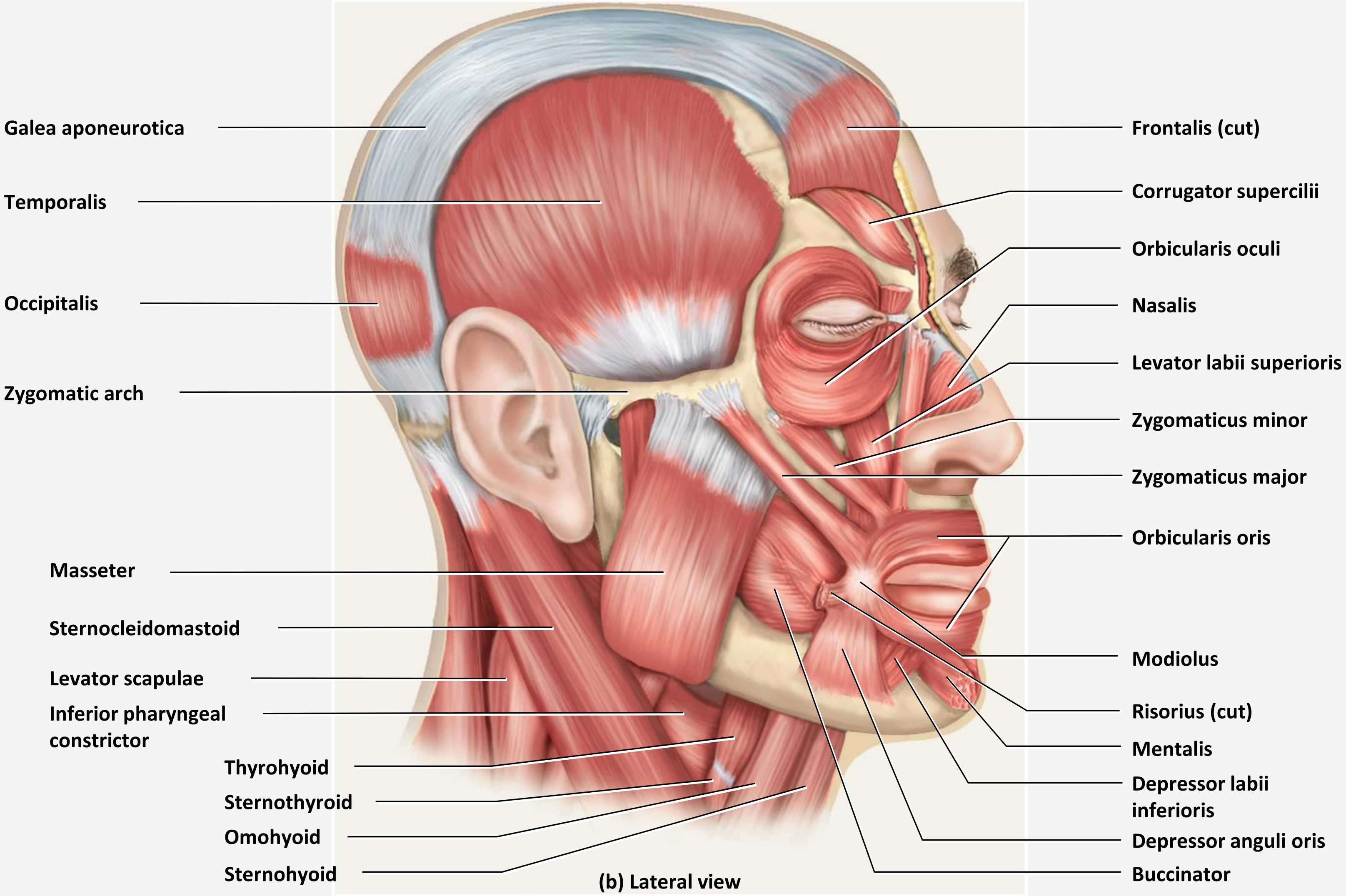


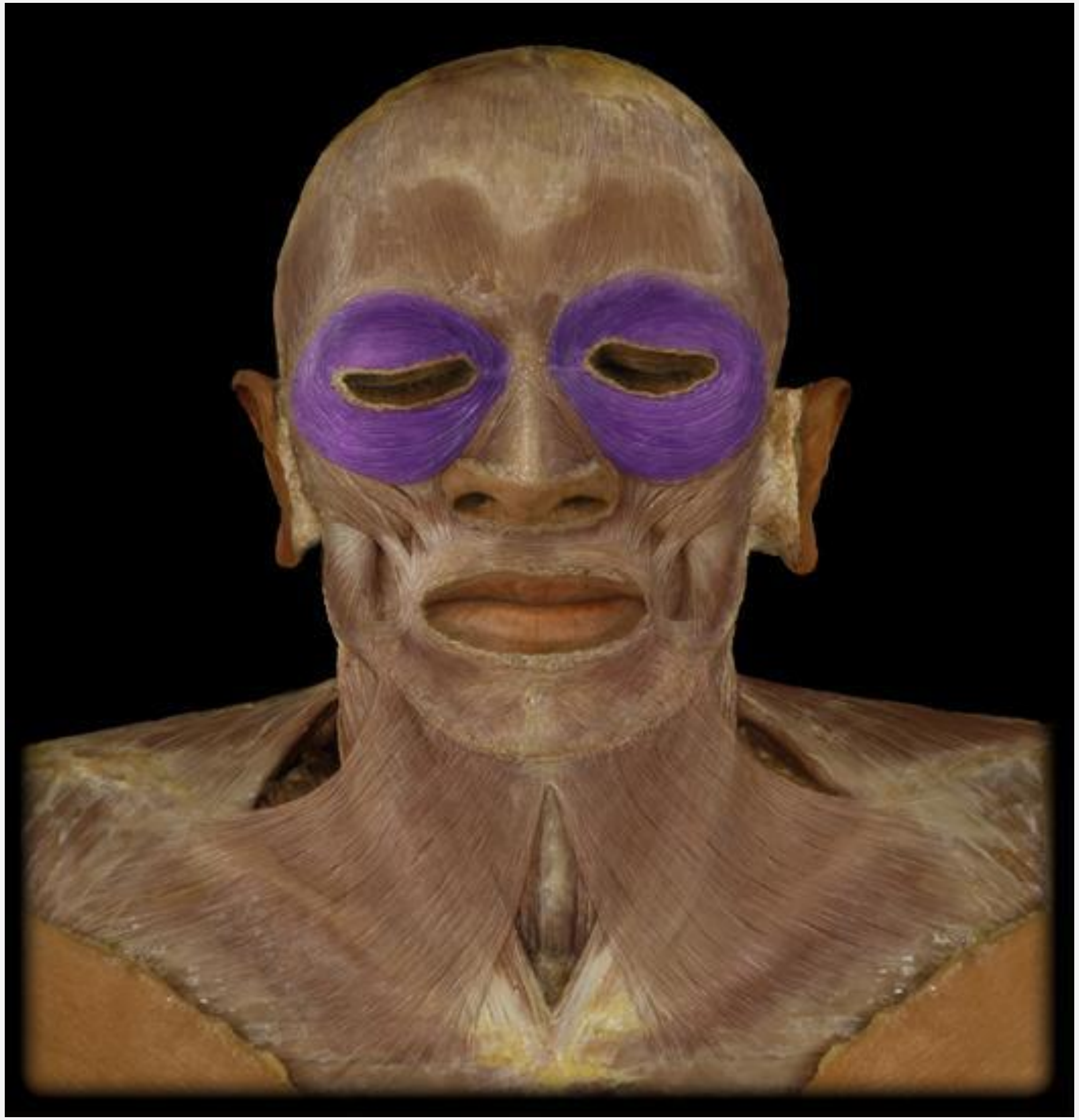
(b) Lateral view

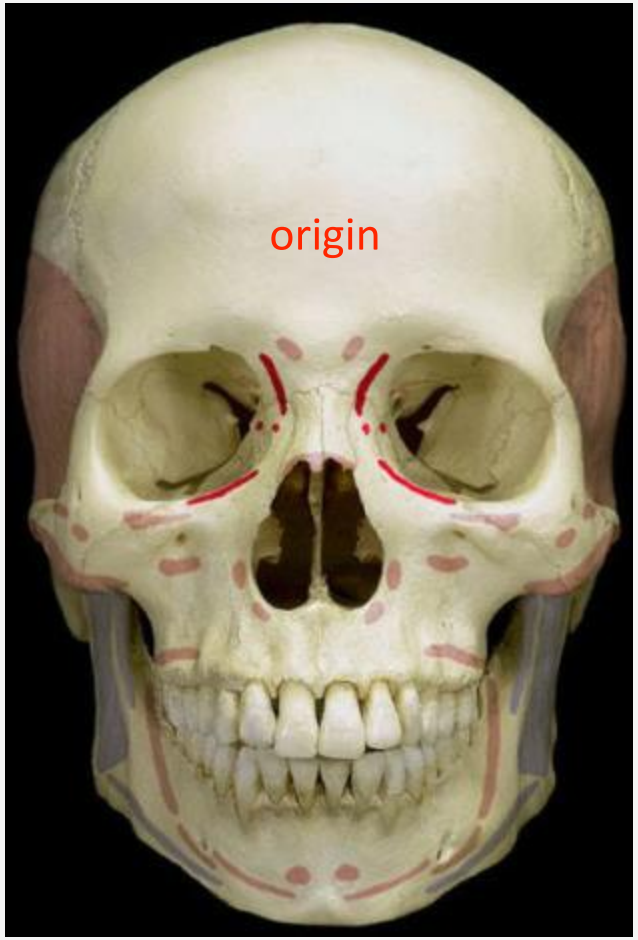
Figure 10.7b

Muscles of Facial Expression

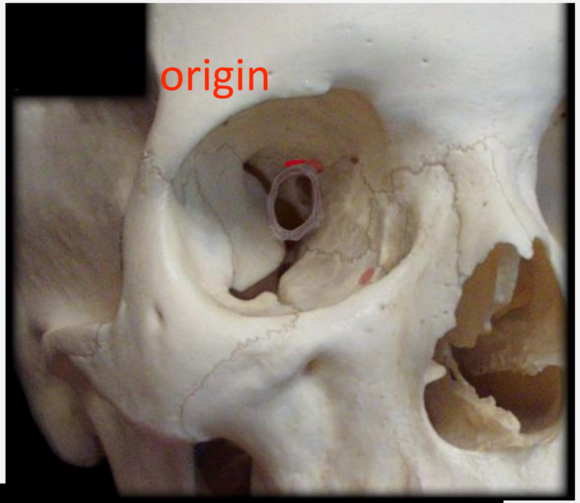
- **The Orbital and Nasal Regions.**
- The *orbicularis oculi (**orb** **= circle; ocul** **= eye**)*is a sphincter of the eyelid that encircles and closes the eye.
- The *levator palpebrae superioris(**levator*** **= that which raises; *palpebr* = eyelid; *superior* = upper** *)* lies deep to the orbicularis oculi, in the eyelid and orbit (see fig. 16.24a), and opens the eye. Other muscles in this group move the eyelids and skin of the forehead and dilate the nostrils.
-

Orbicularis oculi





Levator palpebrae superioris



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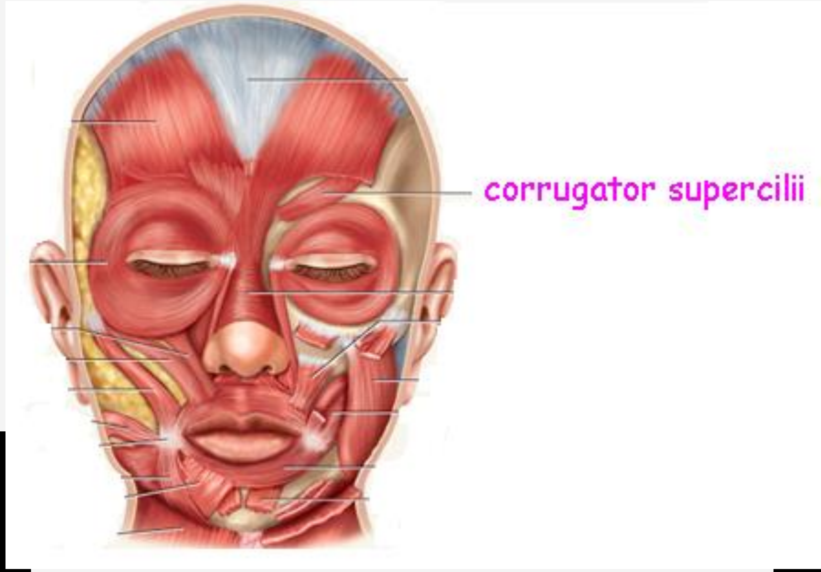
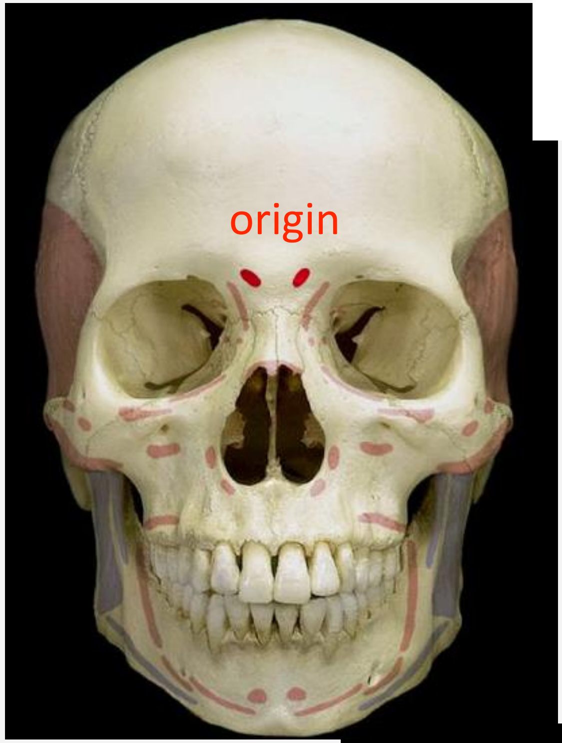
Muscles of Facial Expression

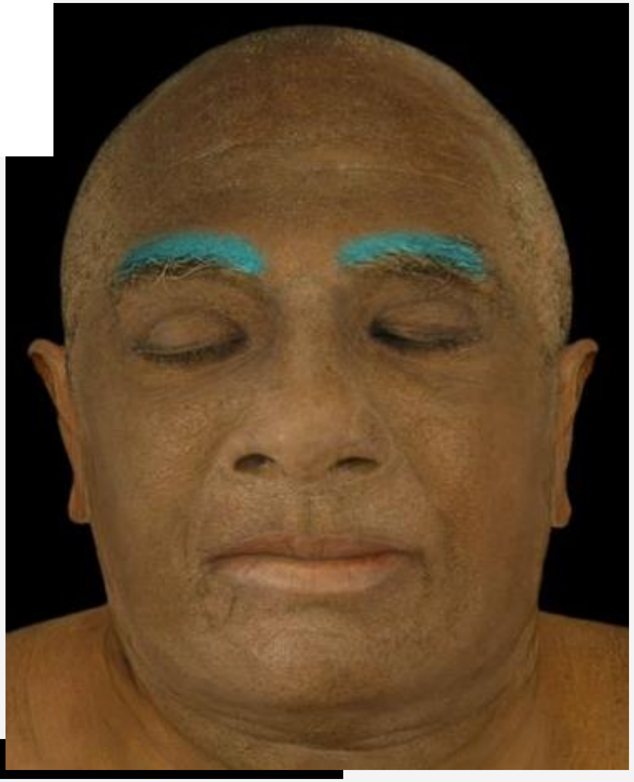
- **The Orbital and Nasal Regions.**
- The Corrugator supercilii *(**corrug*** **= wrinkle;** ***supercilii*** **= of the eyebrow** *) d*raws eyebrows medially and downward in frowning and concentration; reduces glare of bright sunlight .
- Nasalis (***nas*** **= of the nose**).Widens nostrils; narrows internal air passage between vestibule and nasal cavity
-

Corrugator supercilii

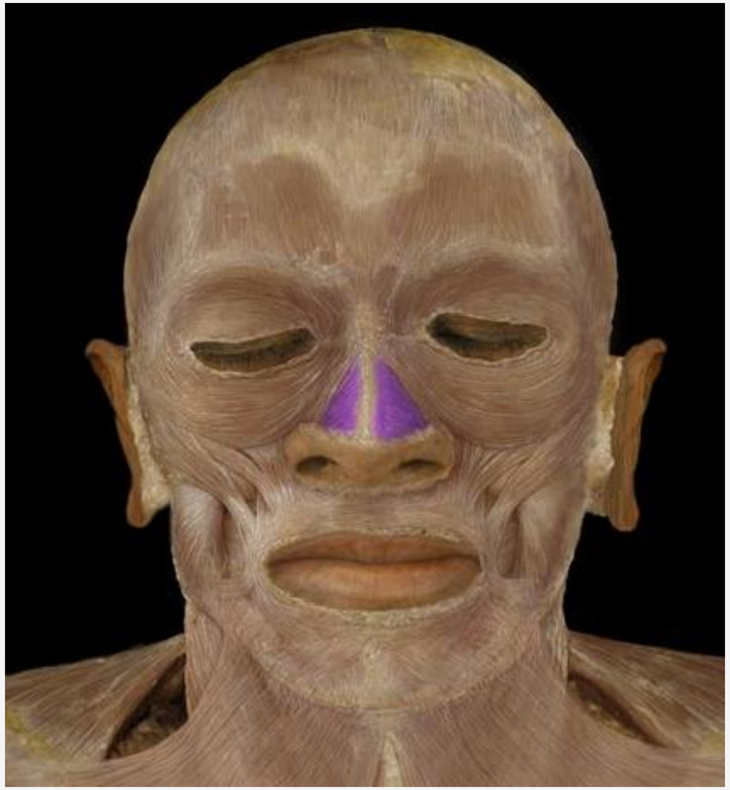


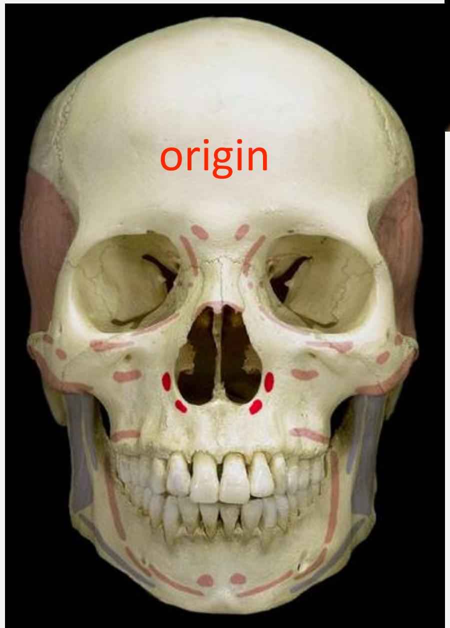


insertion
Skin of Eyebrow



Nasalis

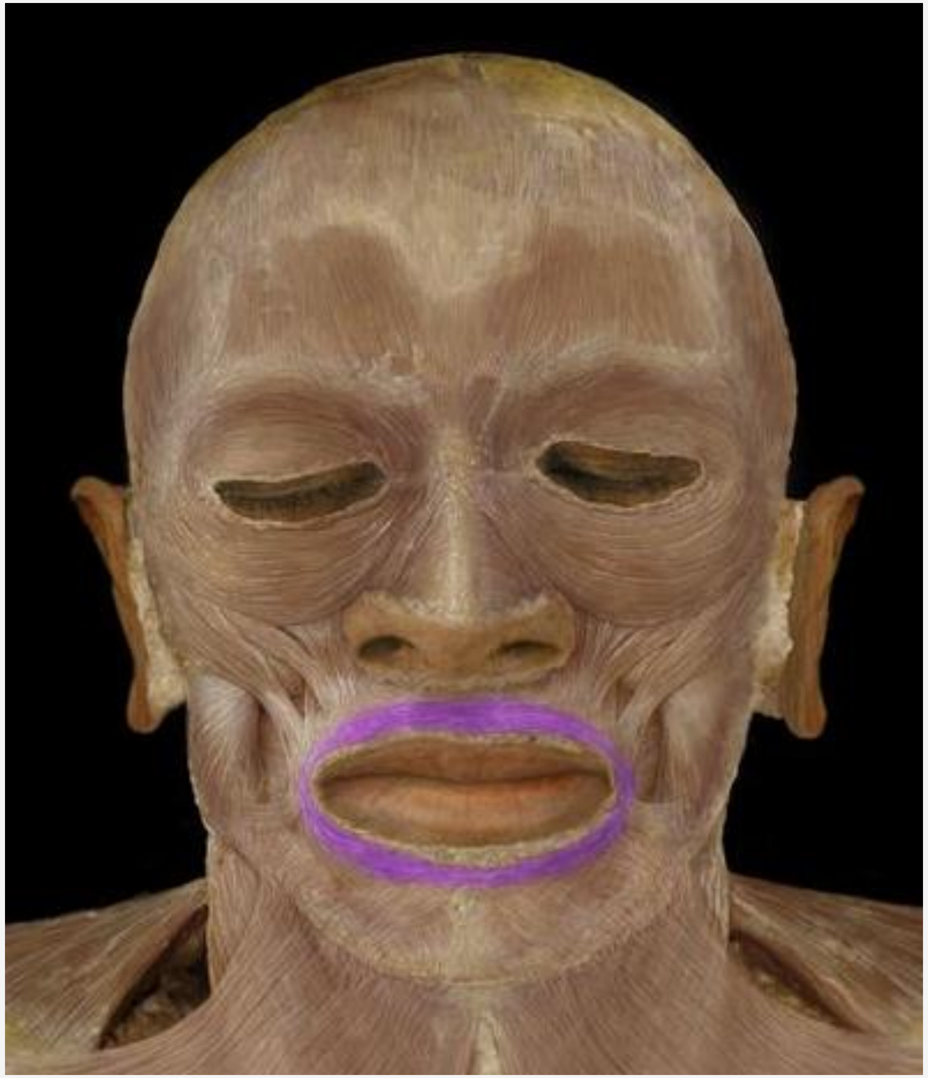




Muscles of Facial Expression

- **The Oral Region.**
- The mouth is the most expressive part of the face, and lip movements are necessary for intelligible speech; thus, it is not surprising that the muscles here are especially diverse.
- The *orbicularis oris*(***orb*** **= circle;** ***oris*** **= of the mouth**) is a complex of muscles in the lips that encircles the mouth; until recently it was misinterpreted as a sphincter, or circular muscle, but it is actually composed of four independent quadrants that interlace and give only an appearance of circularity.

Orbicularis oris

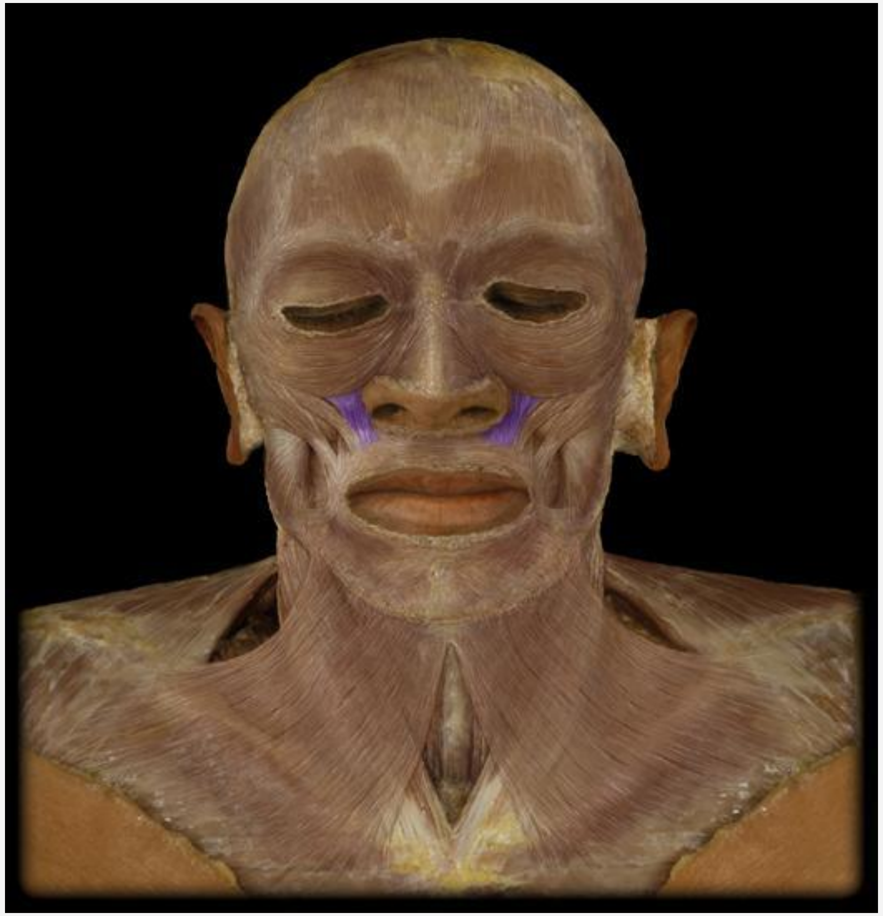


Muscles of Facial Expression

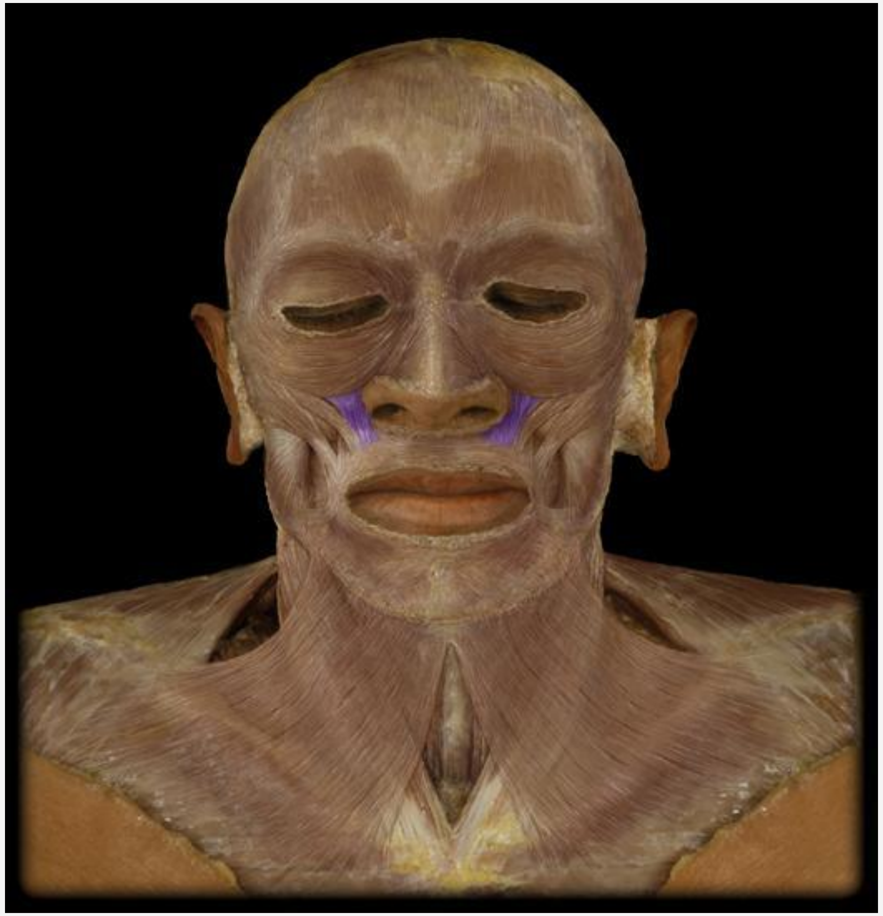
- **The Oral Region.**

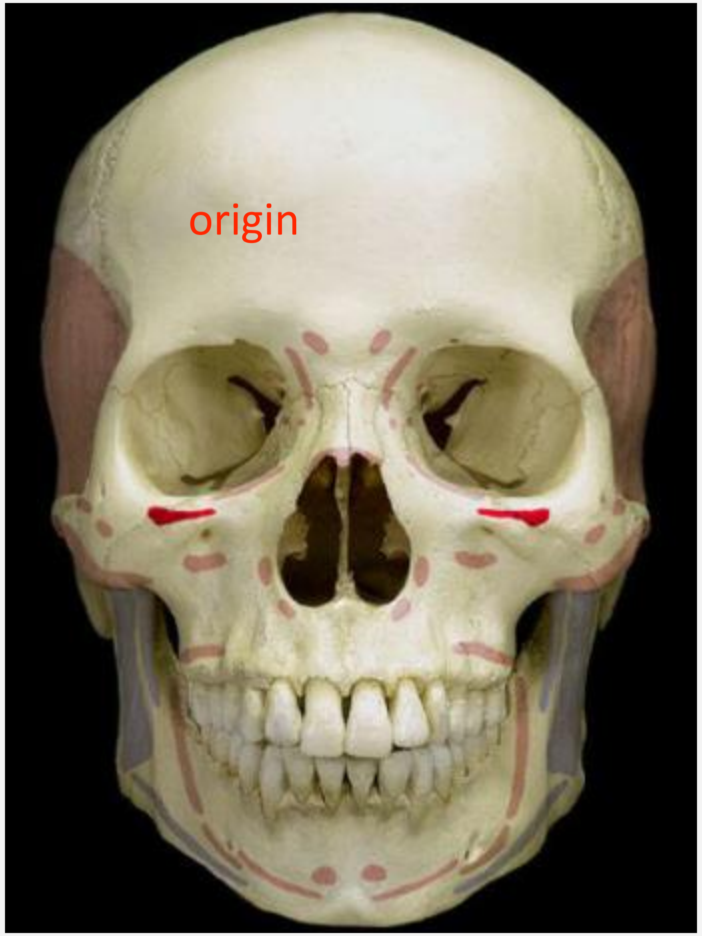
- Levator labii superioris(***levat*** **= to raise;** ***labi*** **= lip;** ***superior*** **= upper**)
- Levator anguli oris (***angul*** **= angle, corner;** ***oris*** **= of the mouth**)
- Zygomaticus (***zygo*** **= join, unite)**
- Zygomaticus minor
- Risorius (***risor*** **= laughter**)
- Depressor anguli oris (***depress*** **= to lower;** ***angul*** **= angle, corner;** ***oris*** **= of the mouth)**
- Depressor labii inferioris (**labi = lip; inferior = lower**)

Levator labii superioris



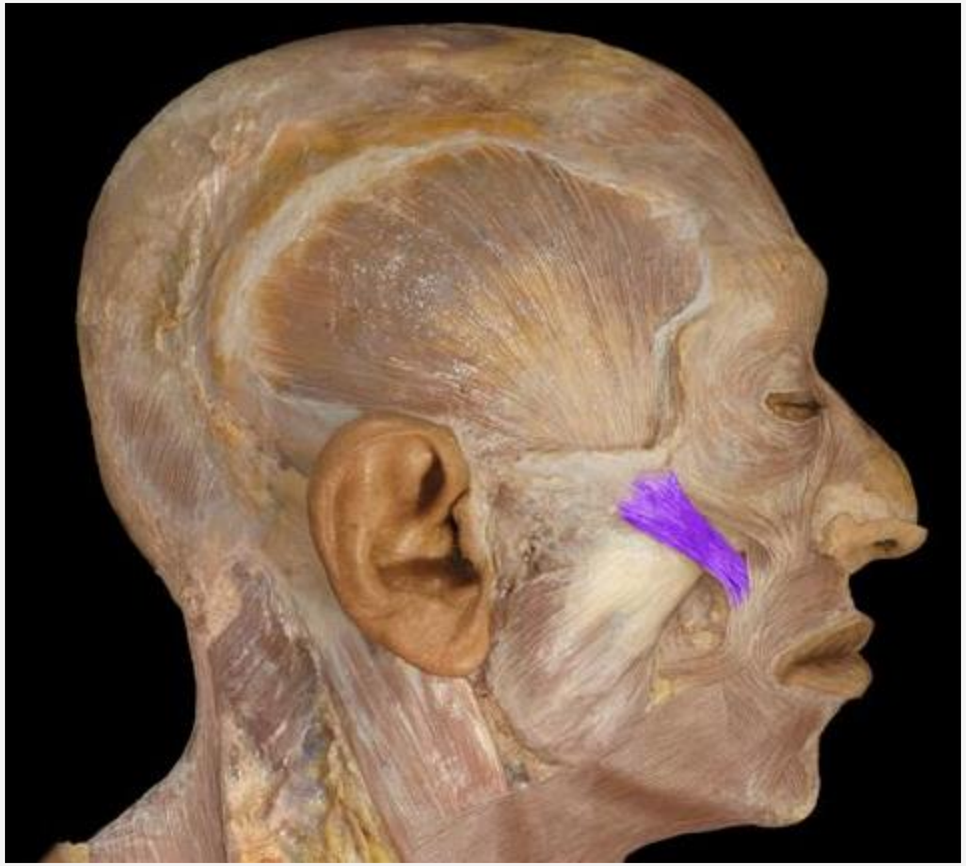
Levator labii superioris

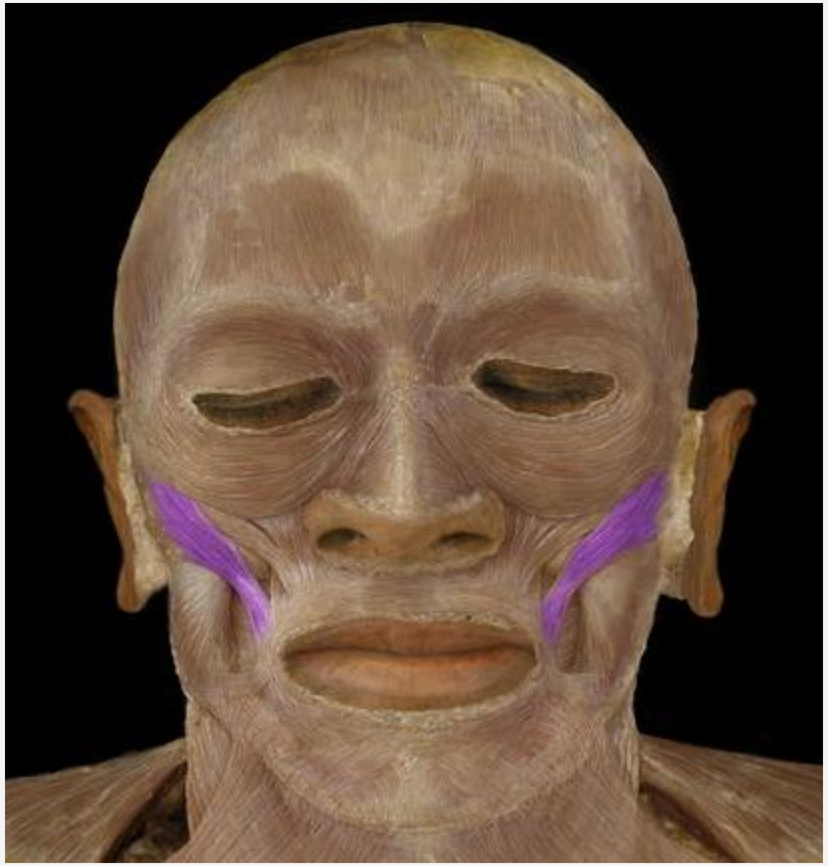




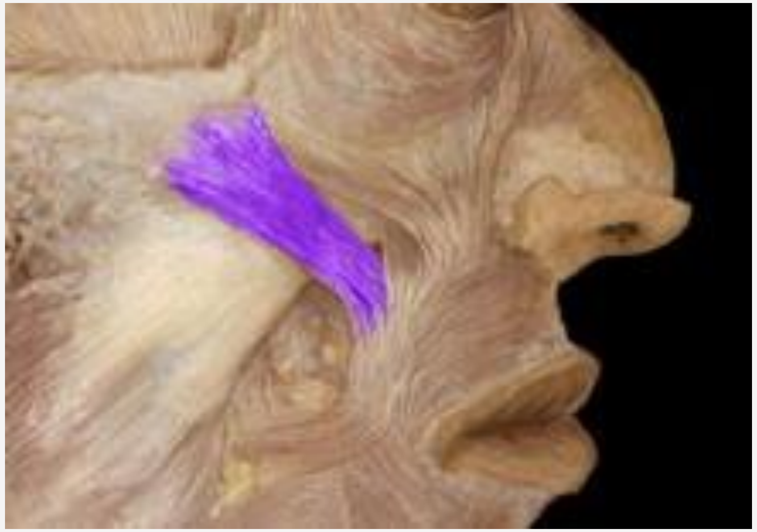
Levator anguli oris

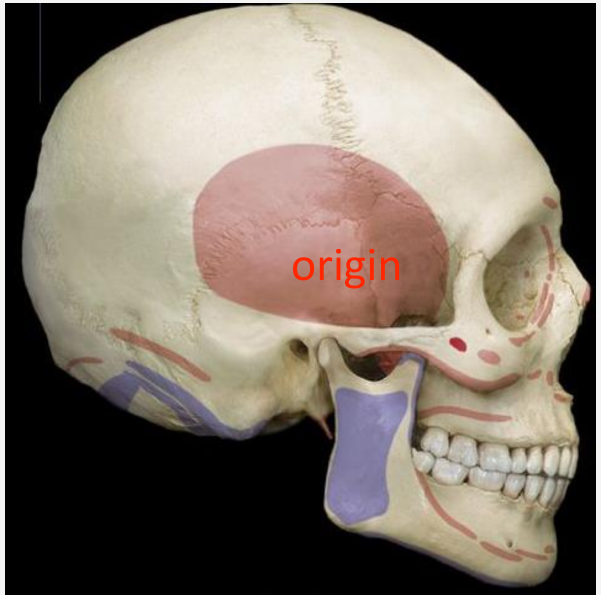
Zygomaticus major



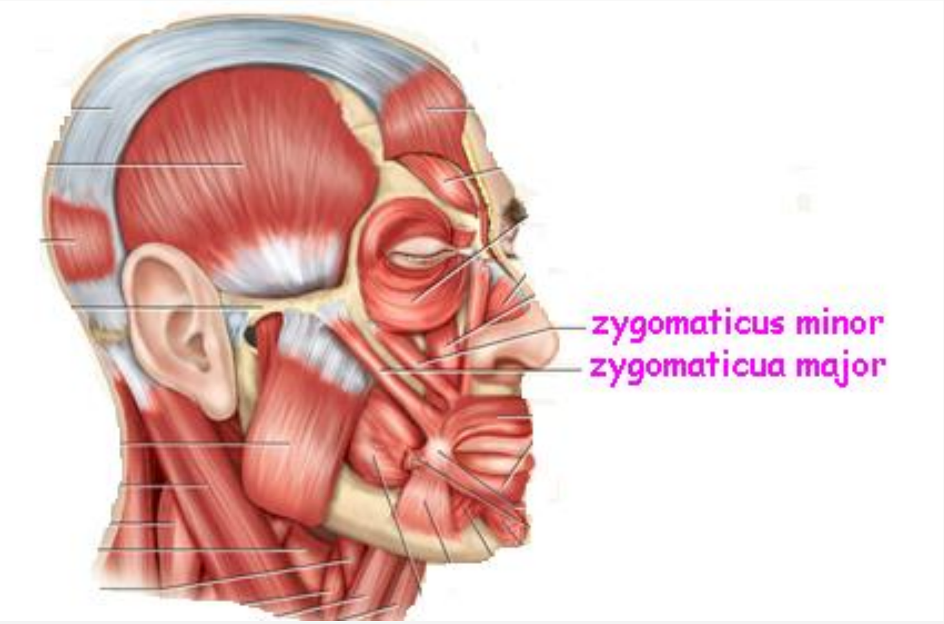


Zygomaticus major



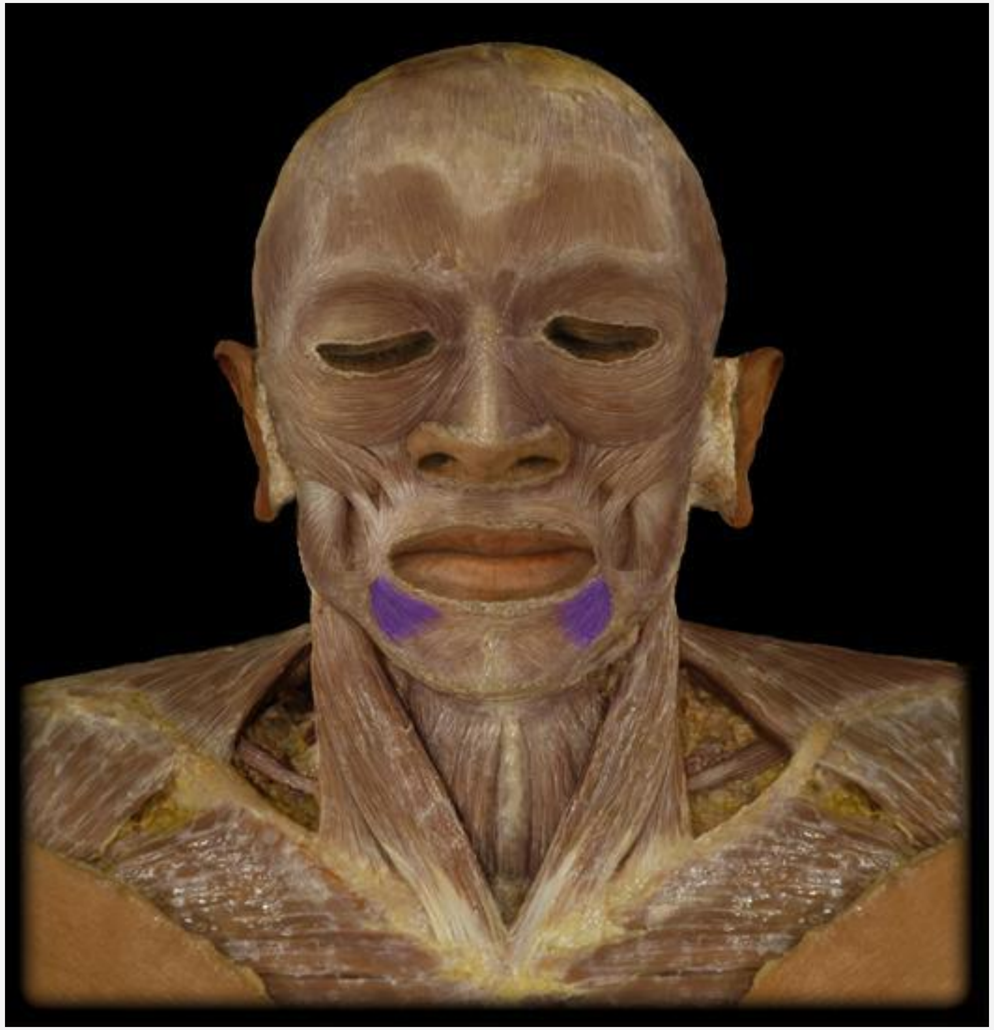


Zygomaticus minor



Risorius

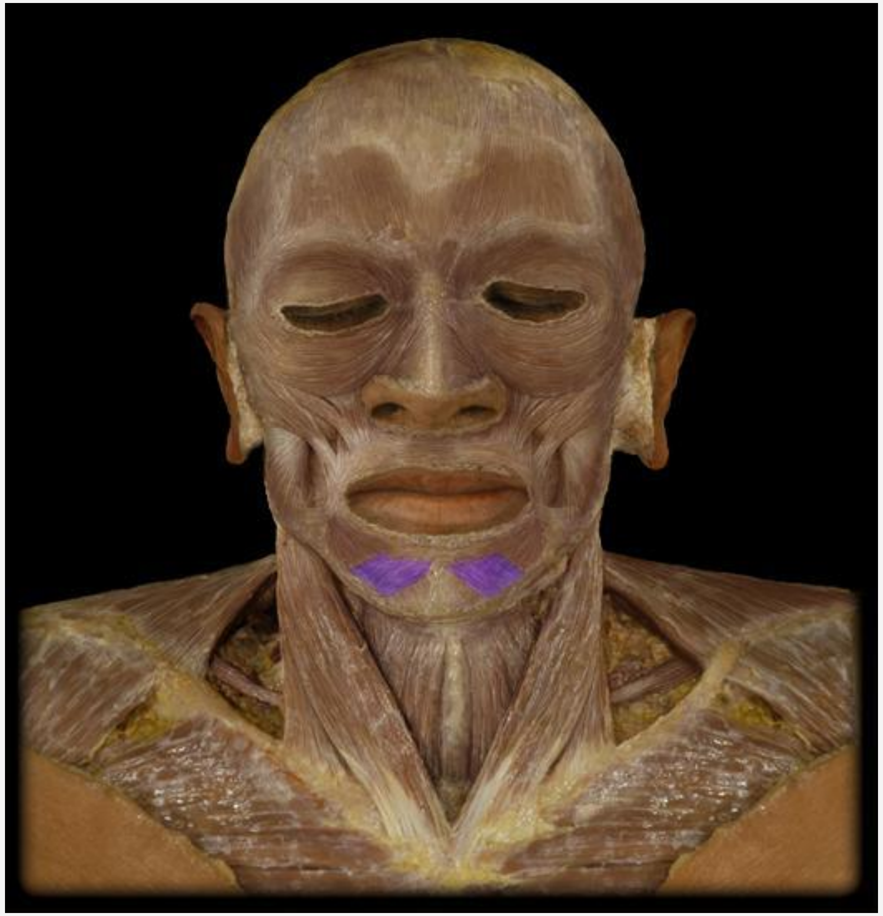
Depressor anguli oris

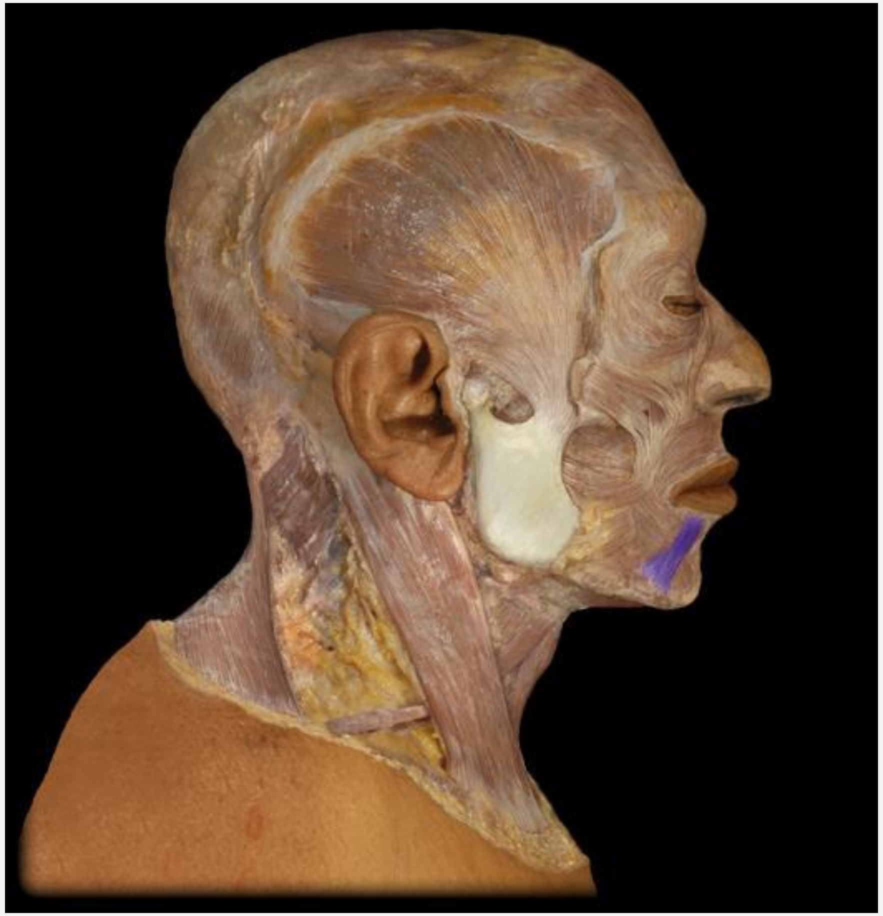


Depressor anguli oris

origin

Depressor labii inferioris





Depressor labii inferioris

origin

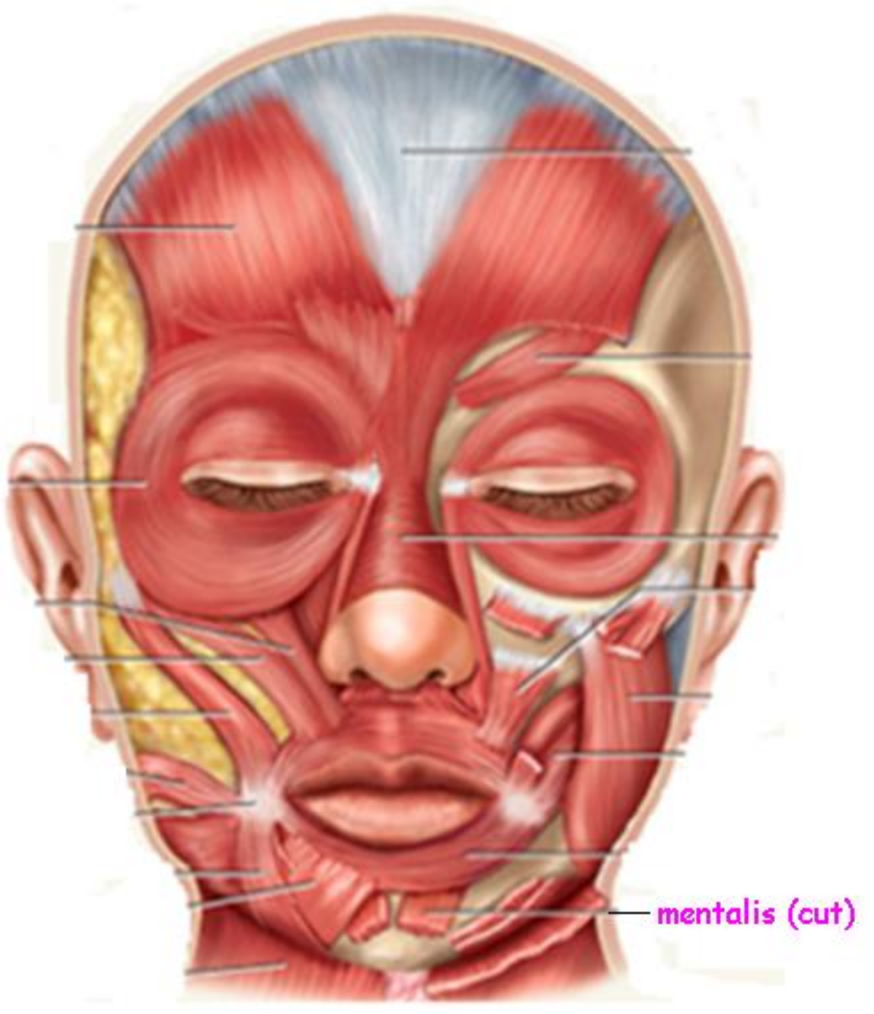
Muscles of Facial Expression

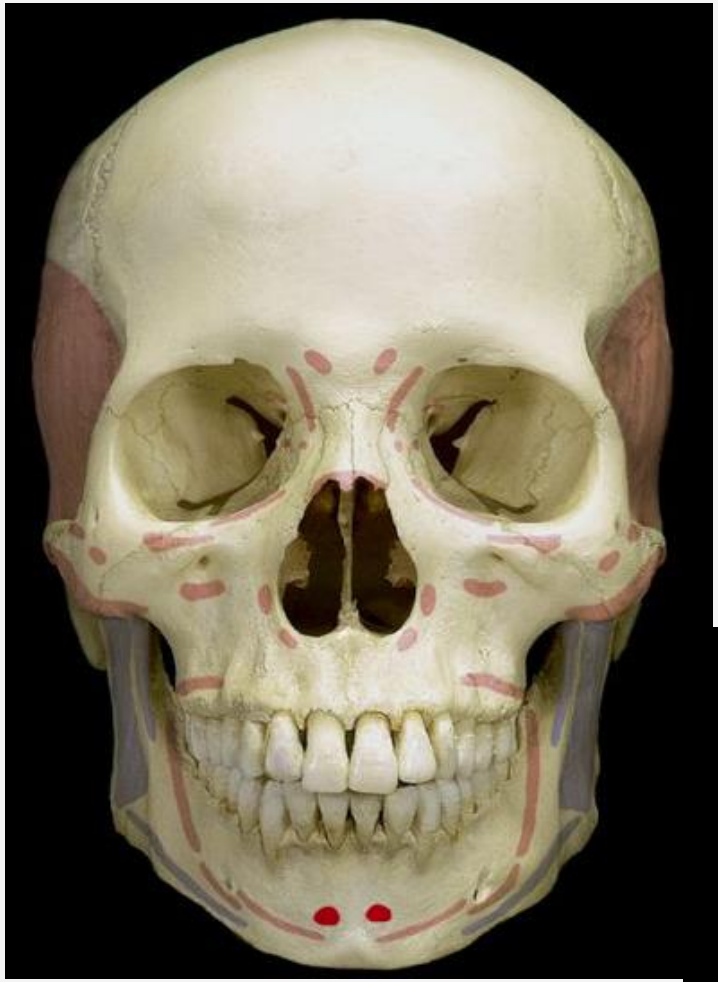
- **The Oral Region.**
- muscles in this region approach the lips from all directions and thus draw the lips or angles (corners) of the mouth upward, laterally, and downward. Some of these arise from a complex cord called the **modiolus**[19] just lateral to each angle of the lips (fig. 10.8b). Named for the hub of a cartwheel, the modiolus is a point of convergence of several muscles of the lower face. You can palpate it by inserting one finger just inside the corner of your lips and pinching the corner between the finger and thumb, feeling for a thick knot of tissue.
-

Muscles of Facial Expression

- **The Mental and Buccal Regions.**
- Adjacent to the oral orifice are the mental region (chin) and buccal region (cheek). In addition to muscles already discussed that act directly on the lower lip, the mental region has a pair of small ***mentalis muscles*** extending from the upper margin of the mandible to the skin of the chin. In some people, these muscles are especially thick and have a visible dimple between them called the *mental cleft* (see fig. 4.18).

Mentalis



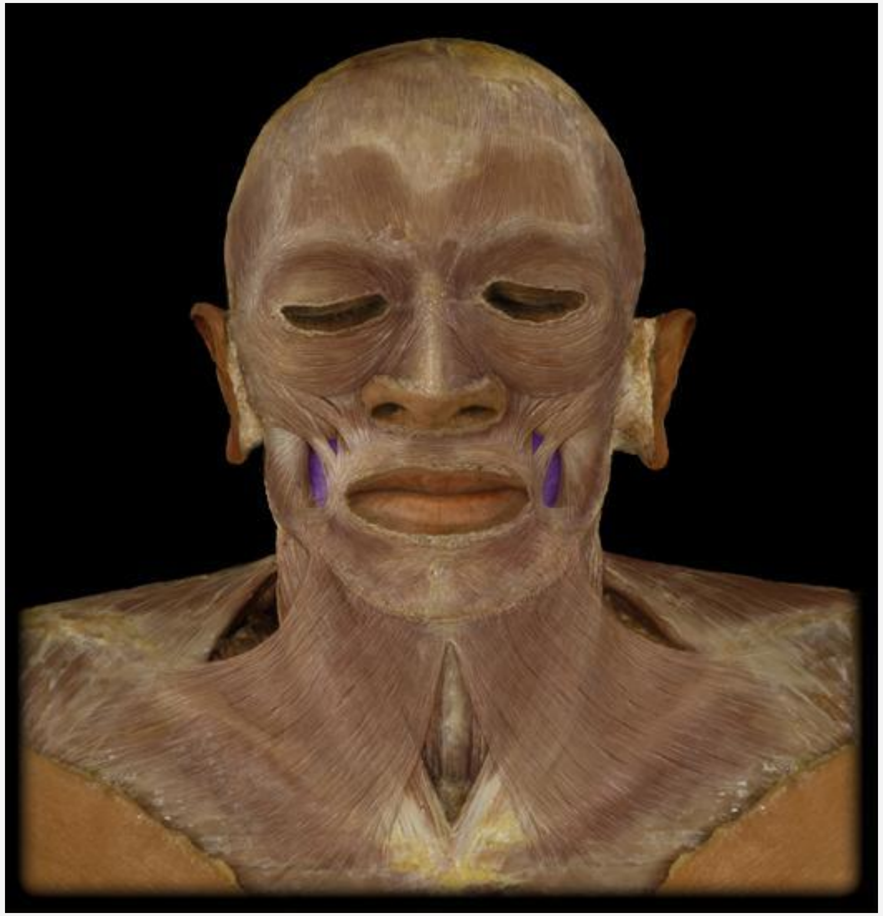


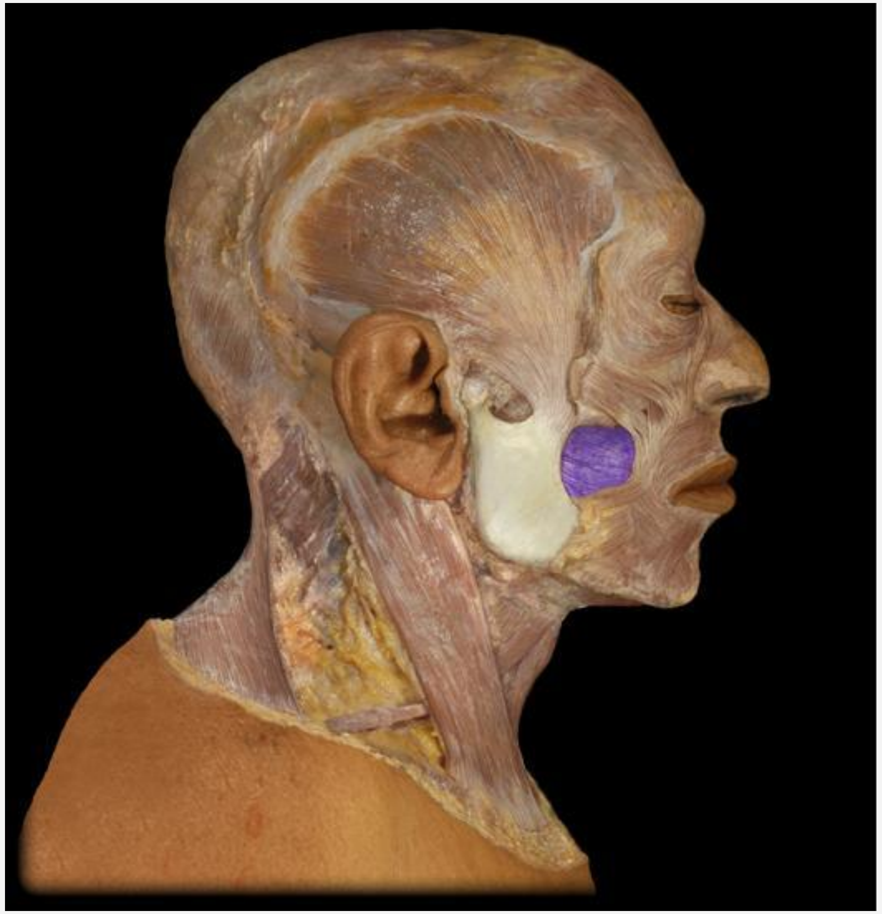
origin

Muscles of Facial Expression

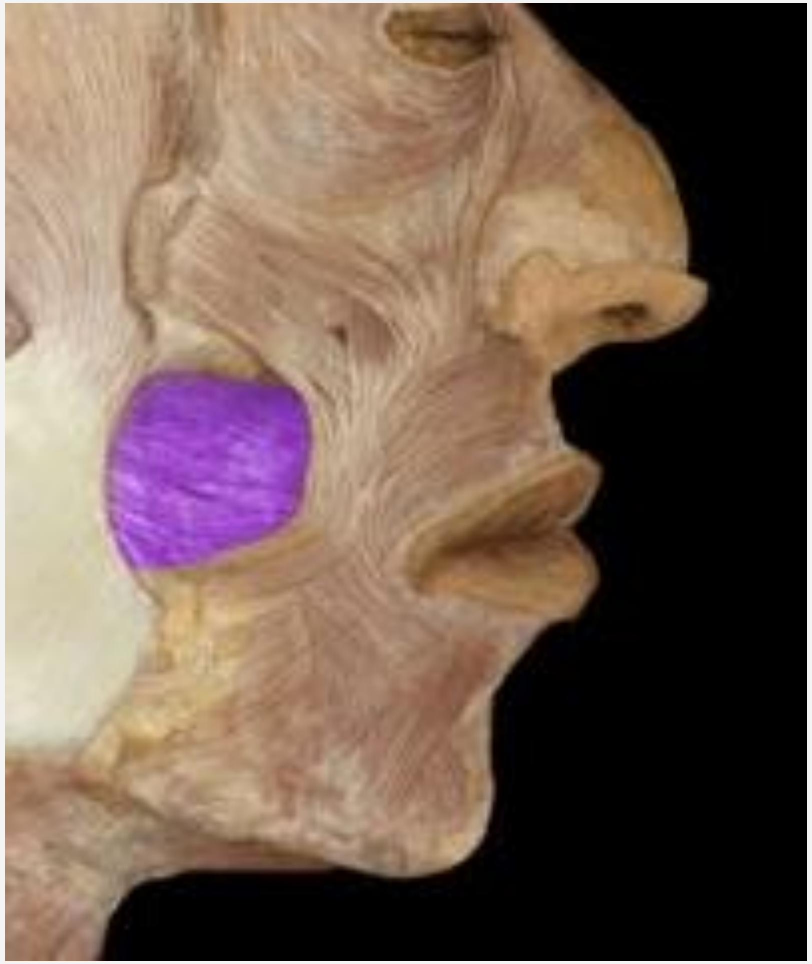
- **The Mental and Buccal Regions.**
- The ***buccinator (****buccinator* = trumpeter ***)*** is the muscle in the cheek. It has multiple functions in chewing, sucking, and blowing.
- If the cheekis inflated with air, compression of the buccinator blows it out. Sucking is achieved by contracting the buccinators to draw the cheeks inward, and then relaxing them. This action is especially important to nursing infants.
- The *platysma* is a thin superficial muscle of the upper chest and lower face. It is relatively unimportant, but when men shave they tend to tense the platysma to make the concavity between the jaw and neck shallower and the skin tauter.

Buccinator





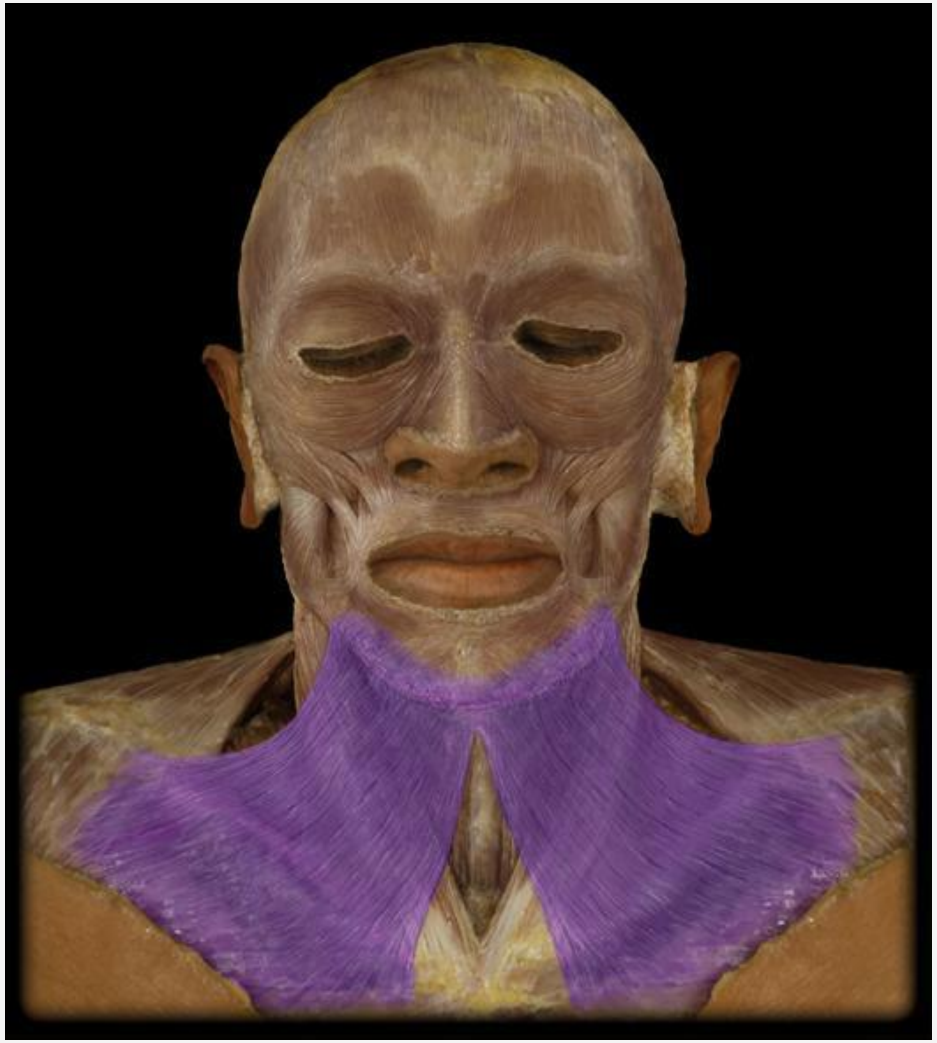
Buccinator



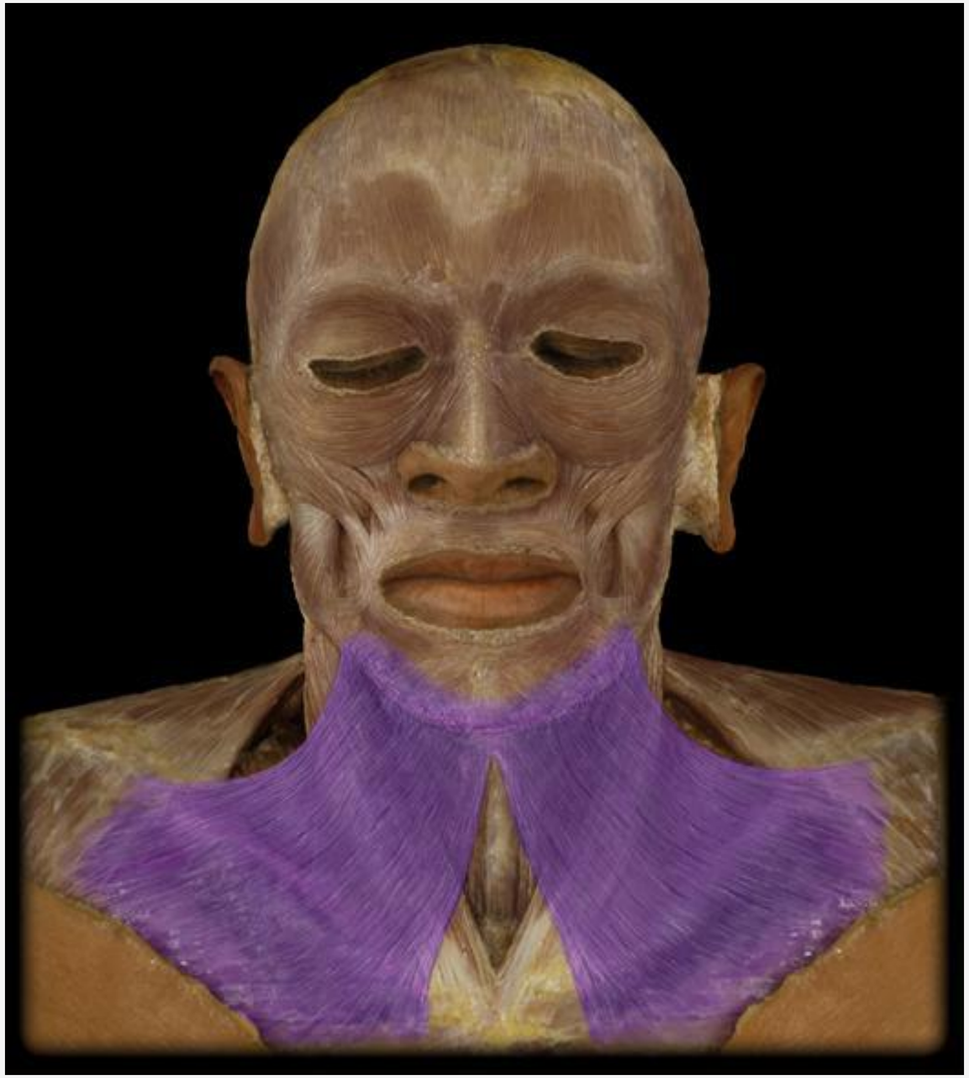
Muscles of Facial Expression

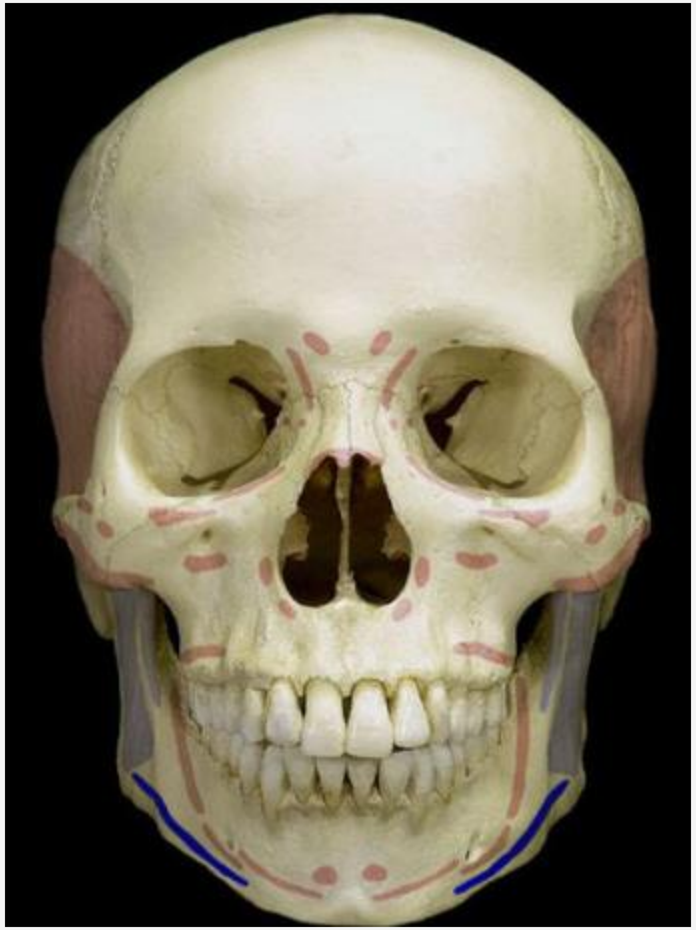
- **The Mental and Buccal Regions.**
- The ***platysma*** (***platy* = flat**) is a thin superficial muscle of the upper chest and lower face.
- It is relatively unimportant, but when men shave they tend to tense the platysma to make the concavity between the jaw and neck shallower and the skin tauter.

Platysma



Platysma



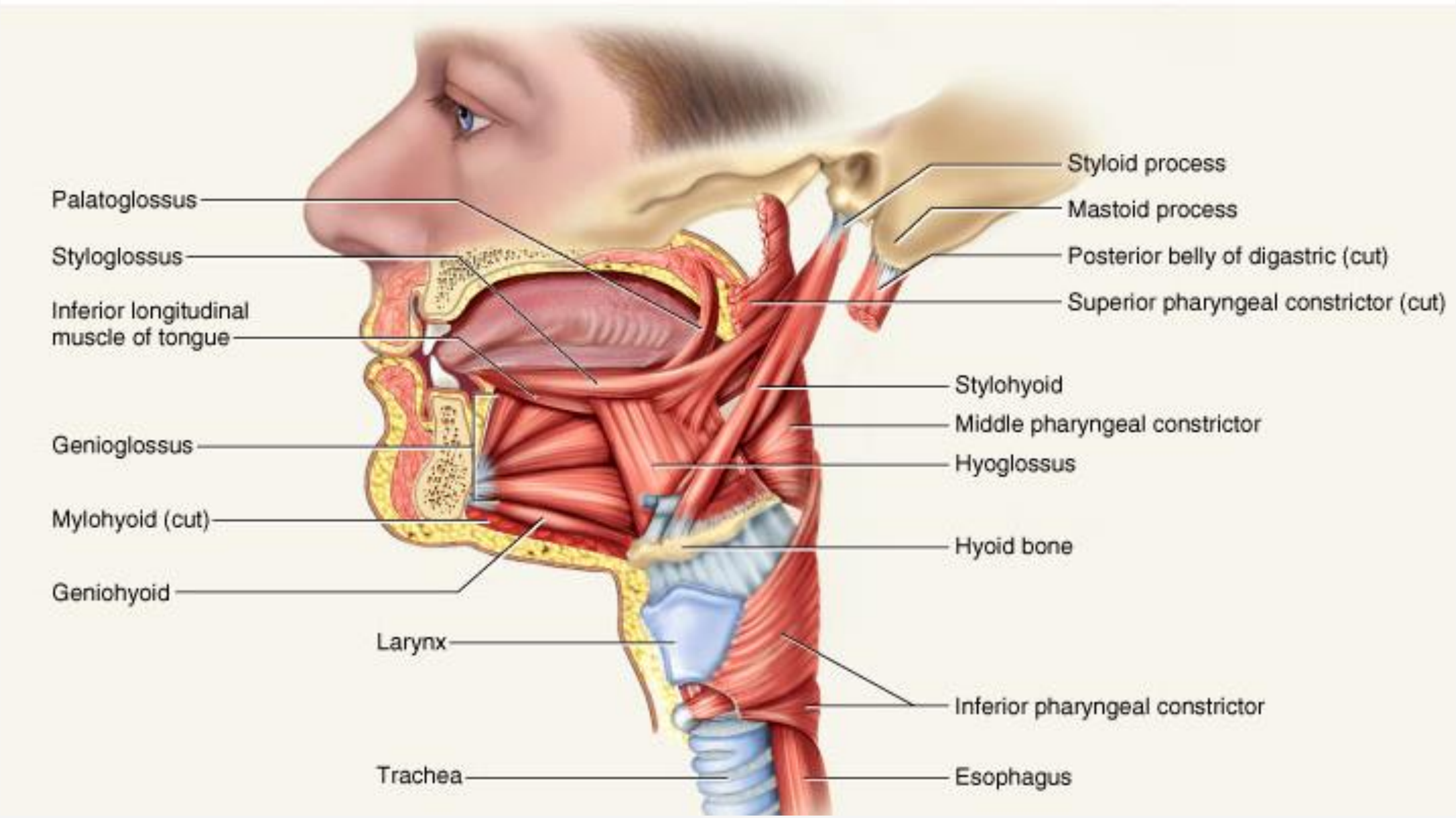


Insertion

Muscles of Chewing and Swallowing

- **extrinsic muscles of the tongue**
  – tongue is very agile organ
  – pushes food between molars for **chewing (mastication)**
  – forces food into the pharynx for **swallowing (deglutition)**
  – crucial importance to speech
- **intrinsic muscles of tongue**
  – vertical, transverse, and longitudinal fascicles

Muscles of the Tongue

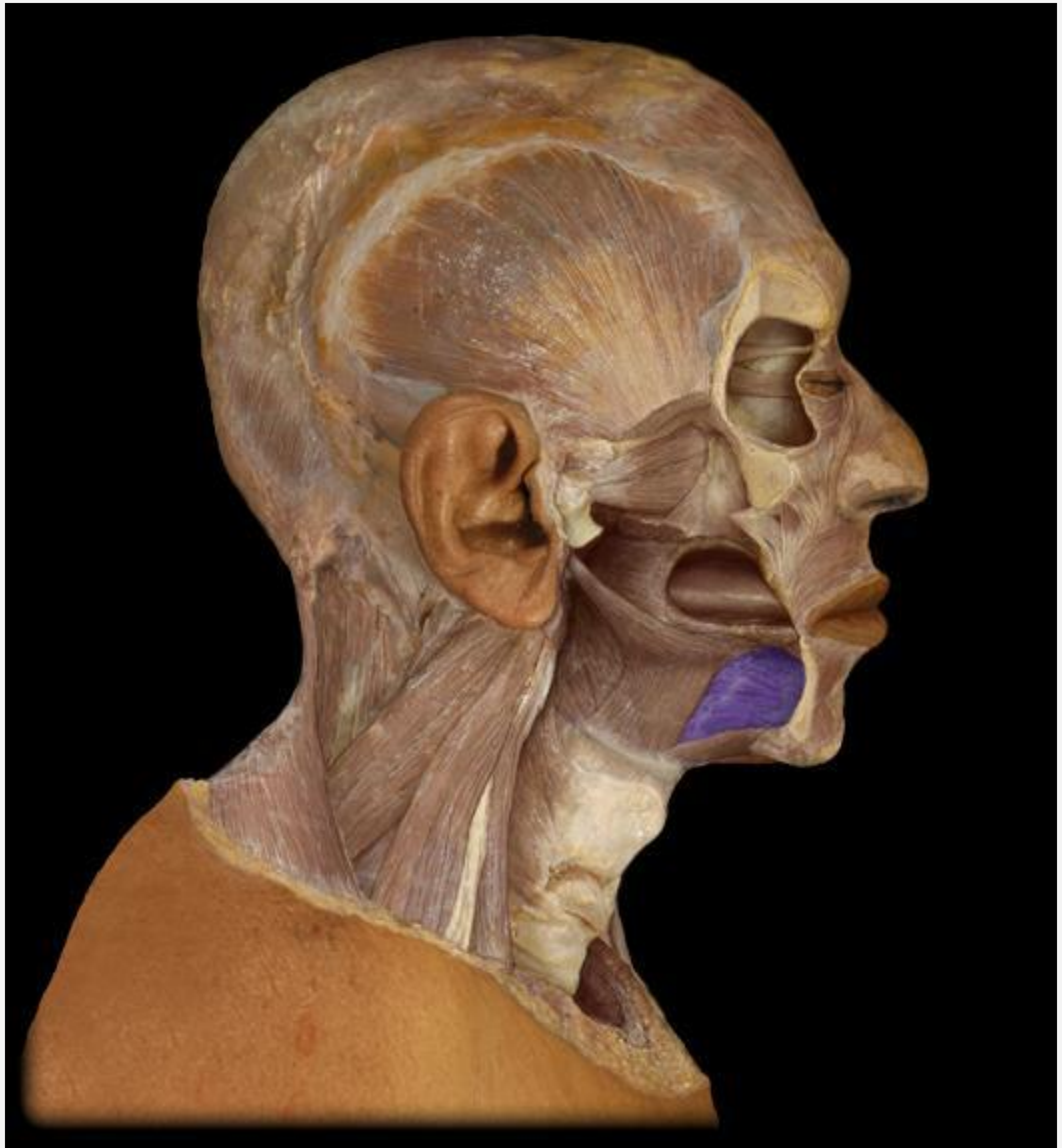


‘glossus’ - tongue

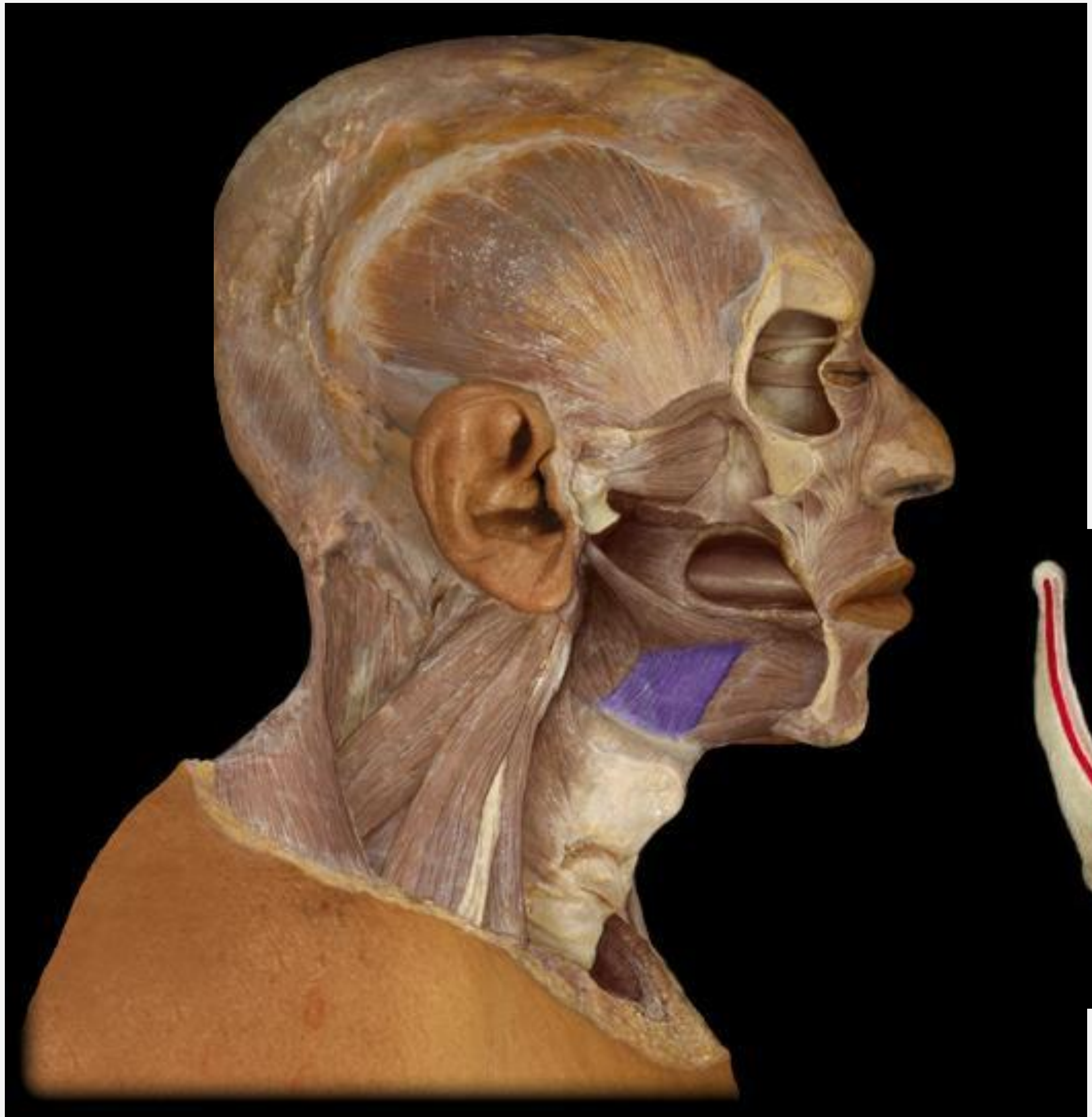
extrinsic muscles of the tongue

- **Genioglossus (*genio* = chin; *gloss* = tongue)**
- **Hyoglossus (*hyo* = hyoid bone; *gloss* = tongue)**
- **Styloglossus (*stylo* = styloid process; *gloss* = tongue)**
- **Palatoglossus (*palato* = palate; *gloss* = tongue)**

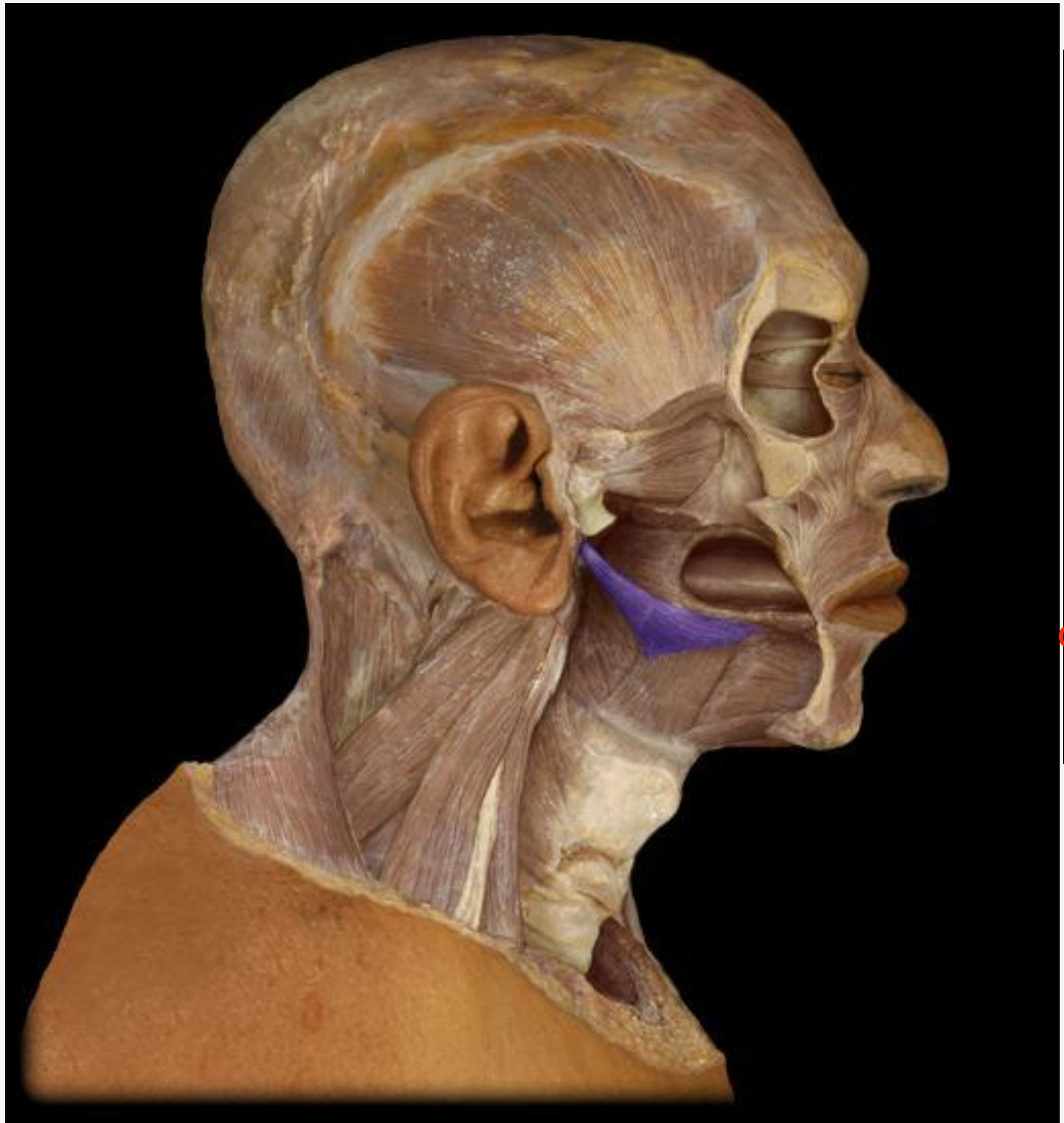
Genioglossus



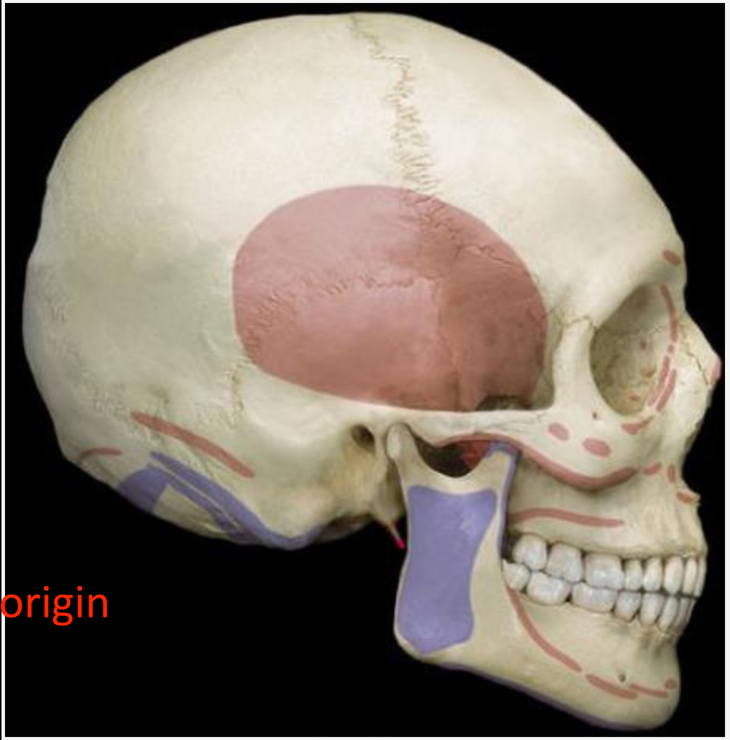
Extrinsic Tongue Muscle Hyoglossus



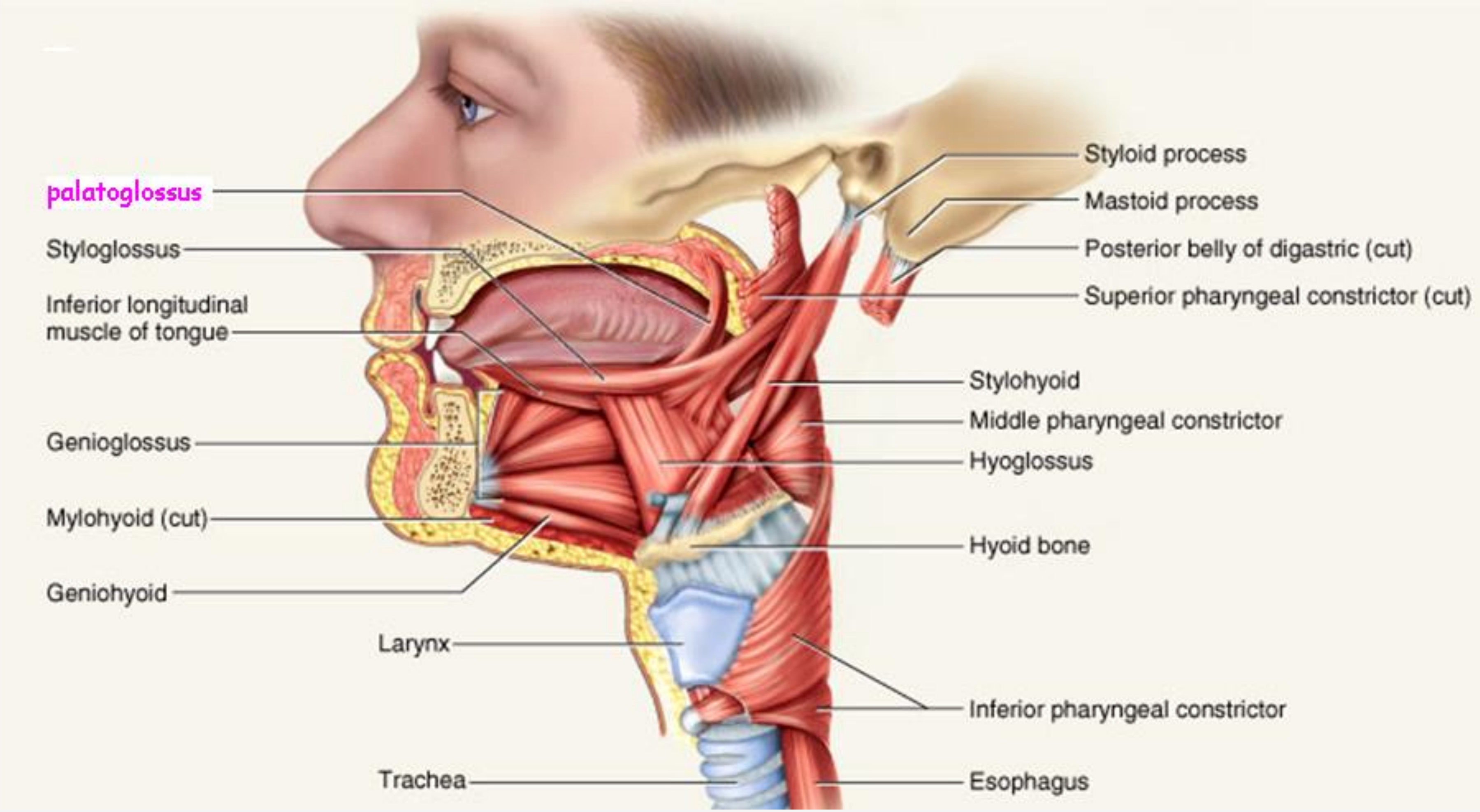
Extrinsic Tongue Muscle Styloglossus



origin



Extrinsic Tongue Muscle Palatoglossus



Muscles of Chewing

- four pairs of muscles produce the biting and chewing movements of the mandible
  - **depression** – to open mouth
  - **elevation** – biting and grinding
  - **protraction** – incisors can cut
  - **retraction** – make rear teeth meet
  - **lateral and medial excursion** – grind food

- *temporalis, masseter, medial pterygoid, lateral pterygoid*

- innervated by **mandibular nerve** which is a branch of the trigeminal (V)

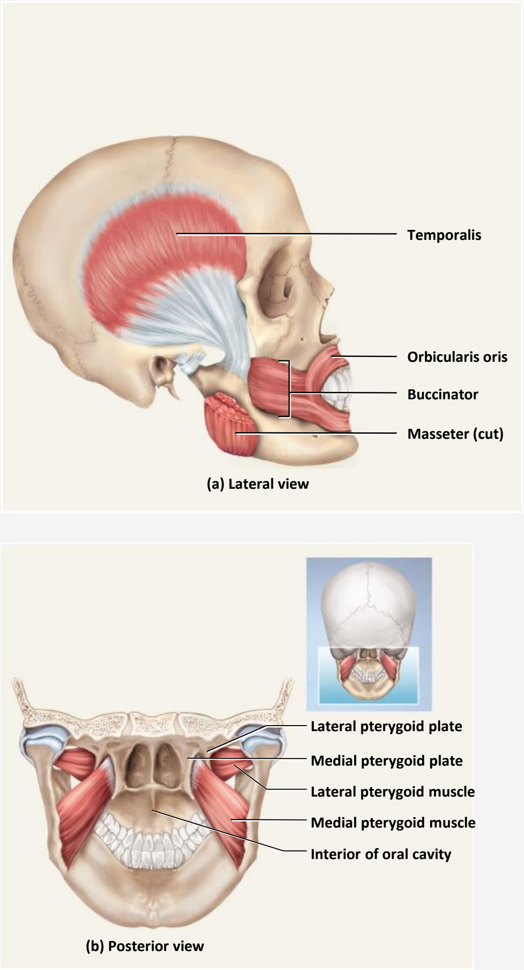
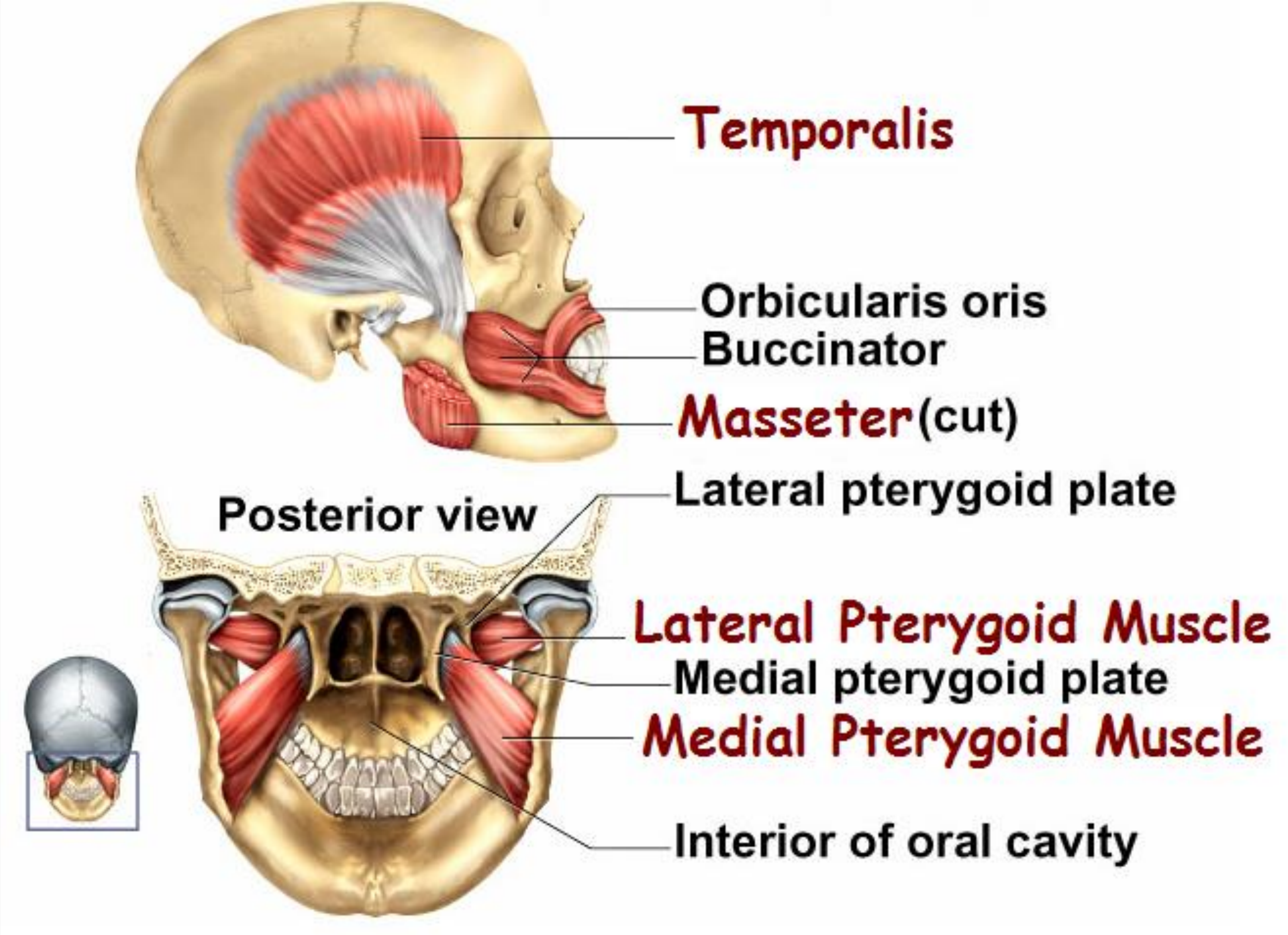
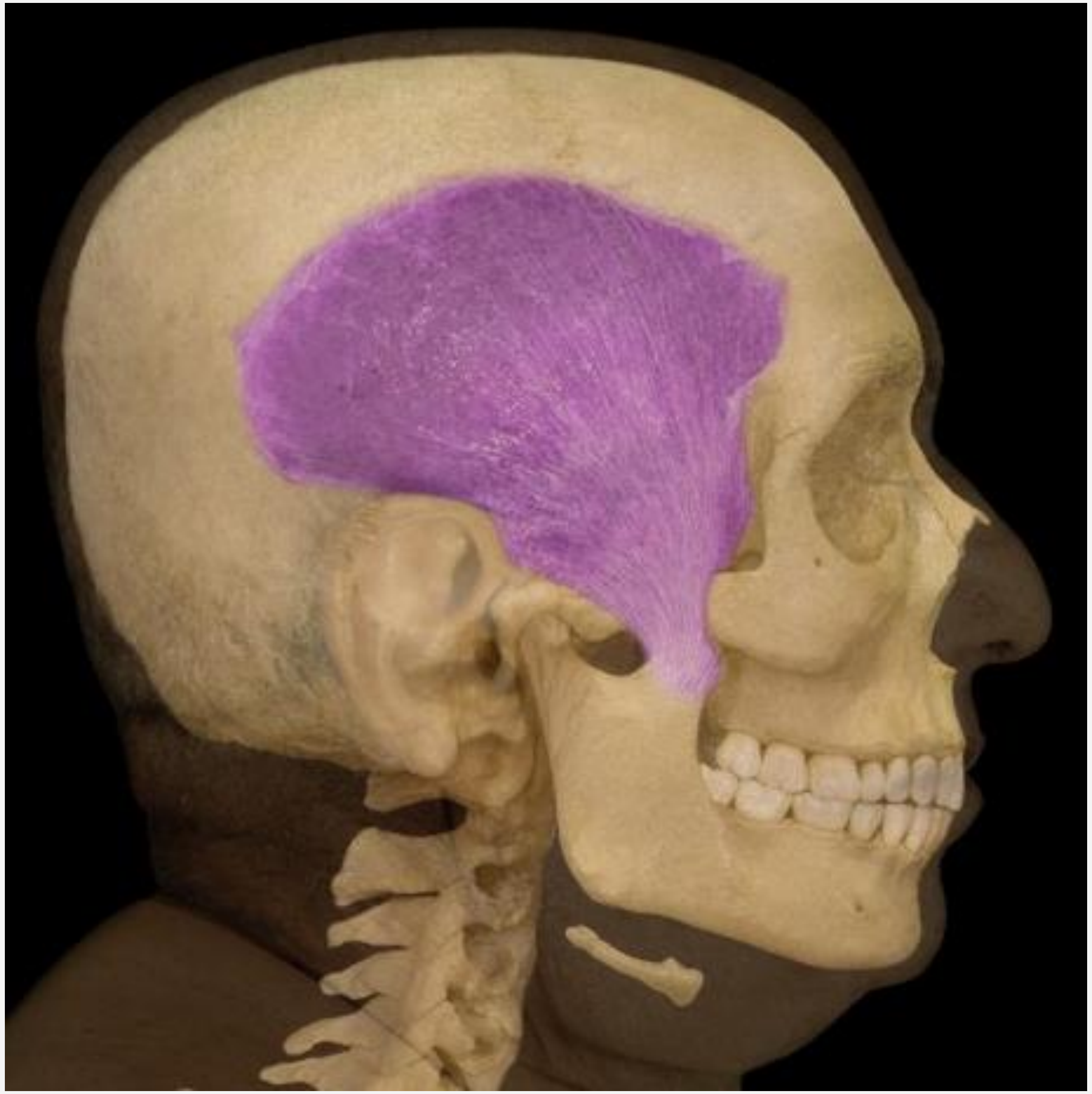


Figure 10.9

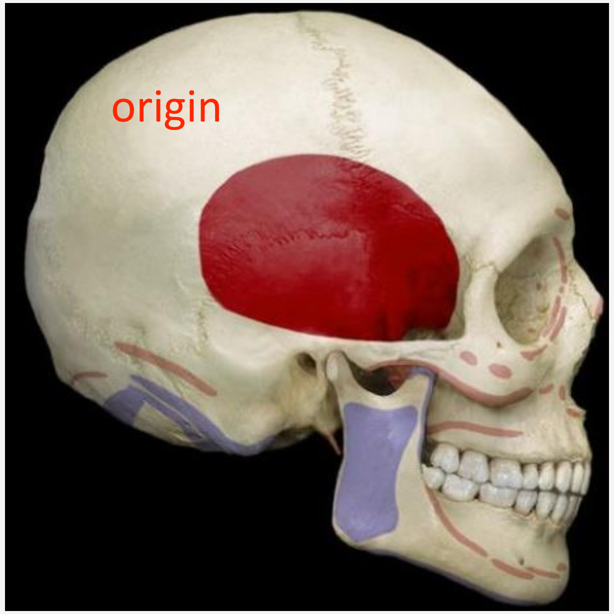
Muscles of Chewing

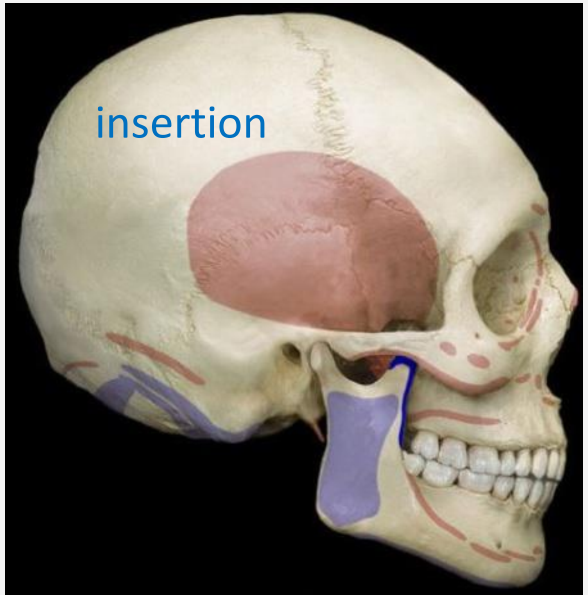


Temporalis

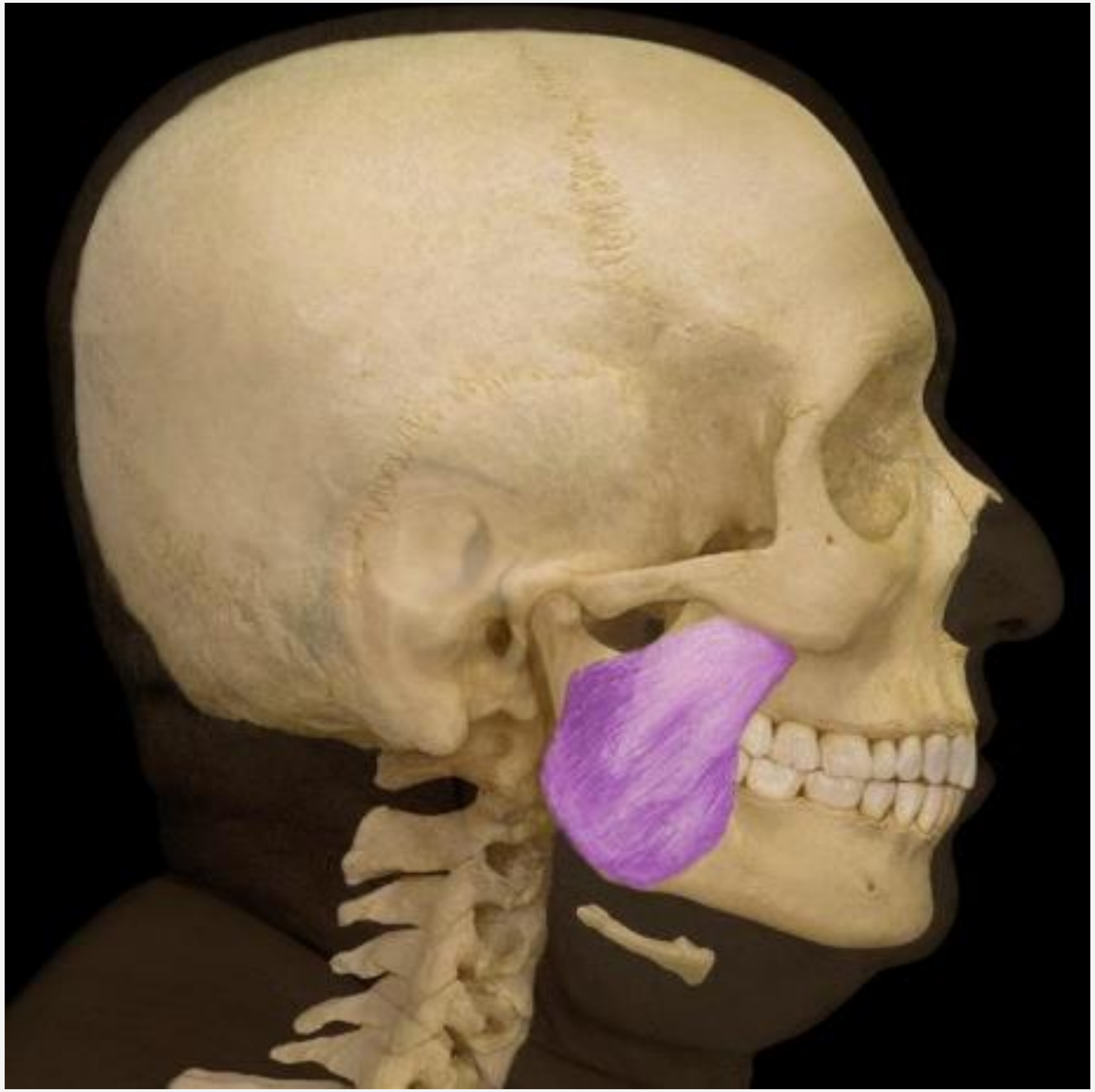


Temporalis

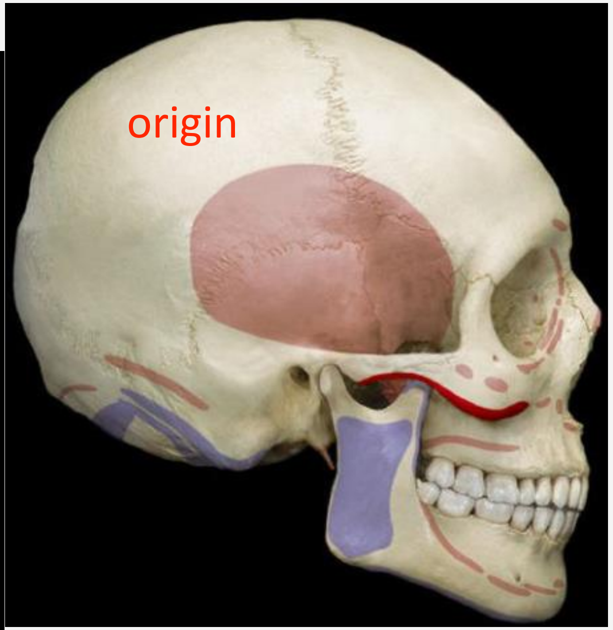


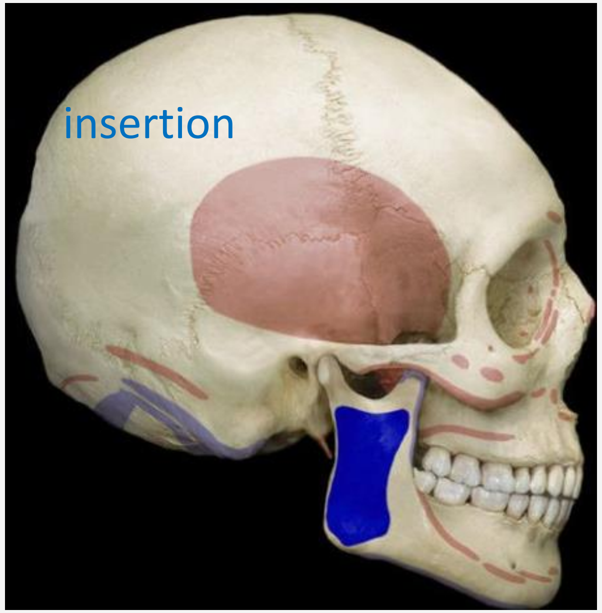


Masseter

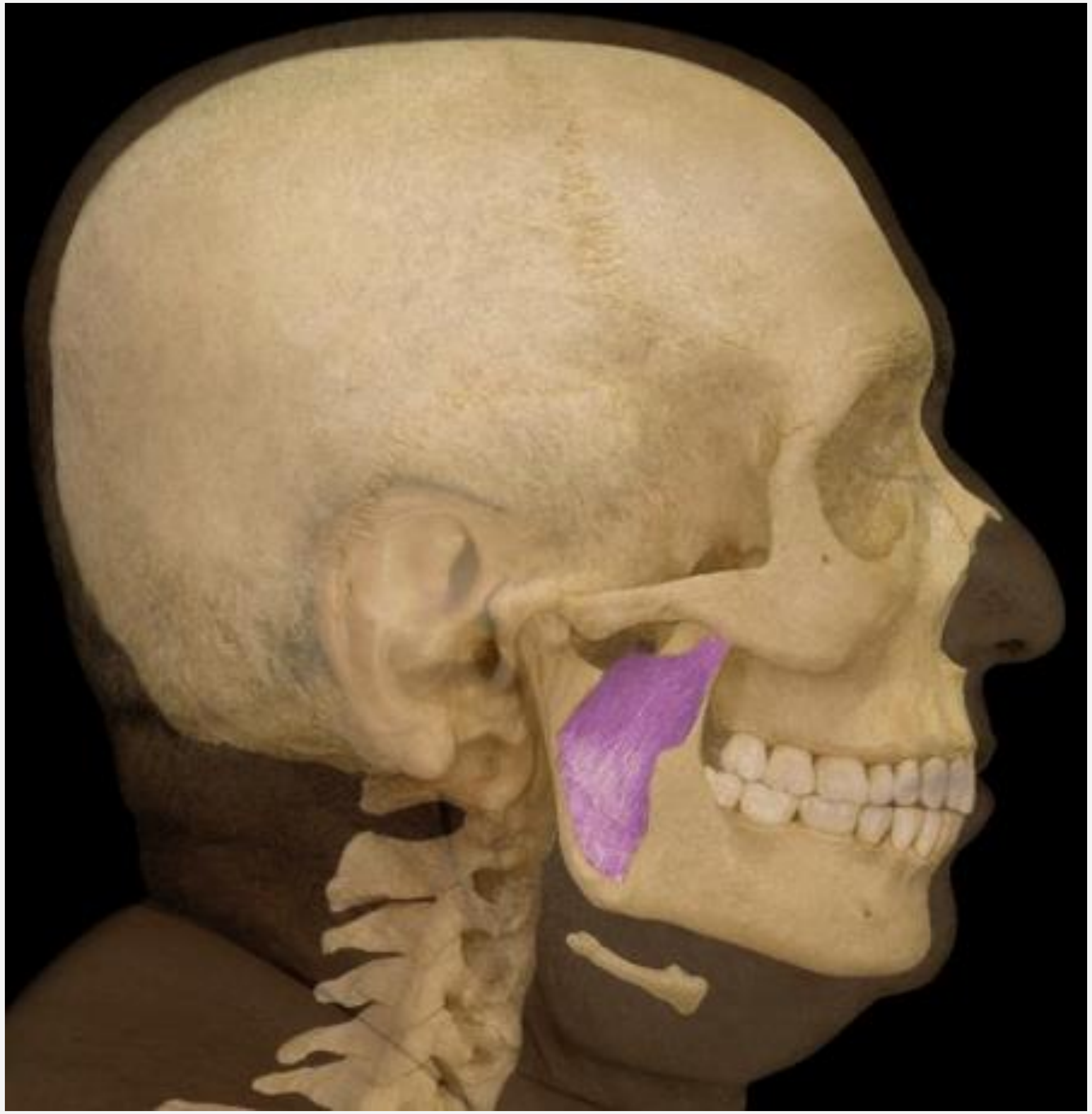


Masseter





Medial pterygoid



PART I

Muscles Acting on the Hip and Lower Limb

- **largest muscles** found in lower limb
- less for precision, more for strength needed to stand, maintain balance, walk, and run
- several cross and act on two or more joints
- **leg** – the part of the limb between the knee and ankle
- **foot** – includes tarsal region (ankle), metatarsal region, and the toes

Muscles Acting on the Hip and Femur

- **Anterior muscles of the hip**
  - *iliacus [**ili = loin, flank**]*
    - flexes thigh at hip
    - iliacus portion arises from iliac crest and fossa
  - *psoas major[psoa = loin]*
    - flexes thigh at hip
    - arises from lumbar vertebrae
  - they [**iliopsoas**]share a common tendon on the femur

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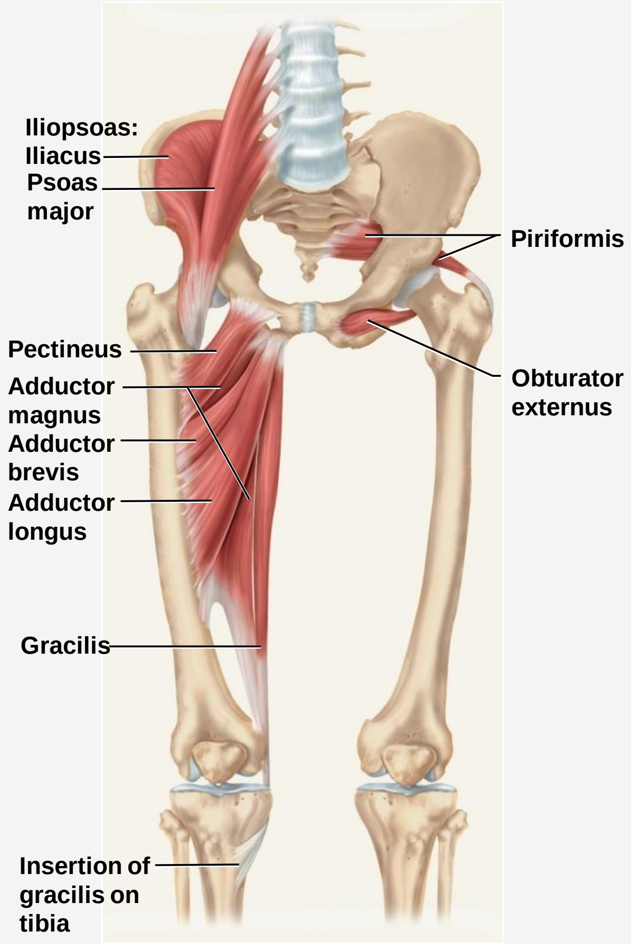
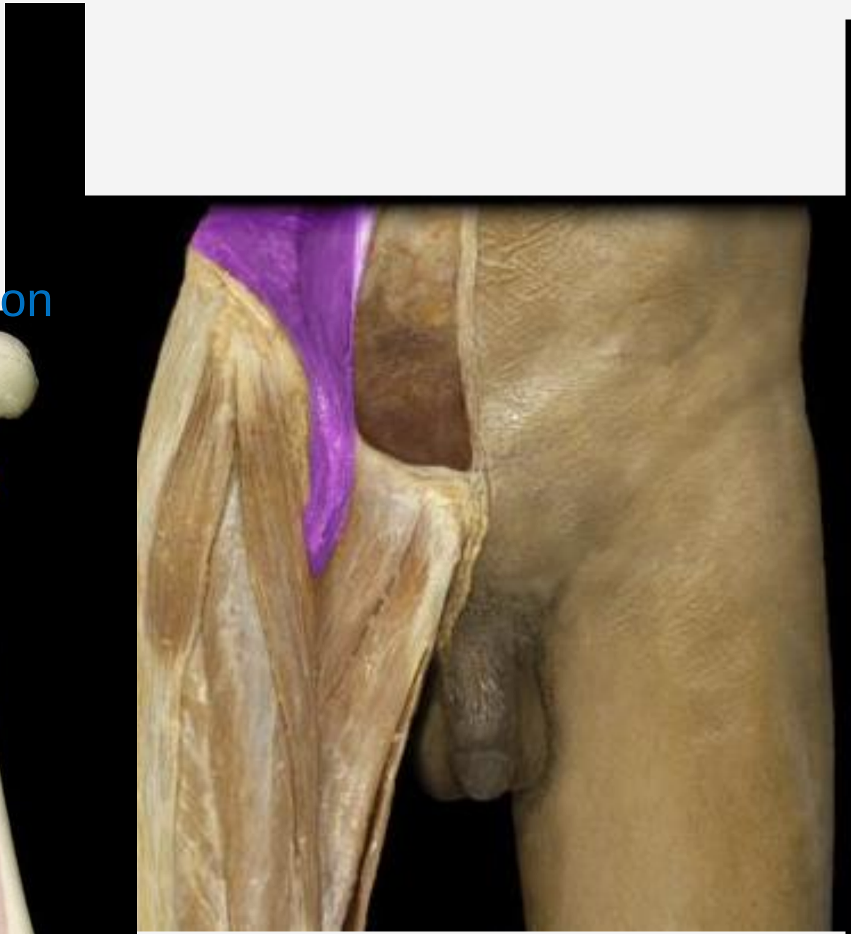
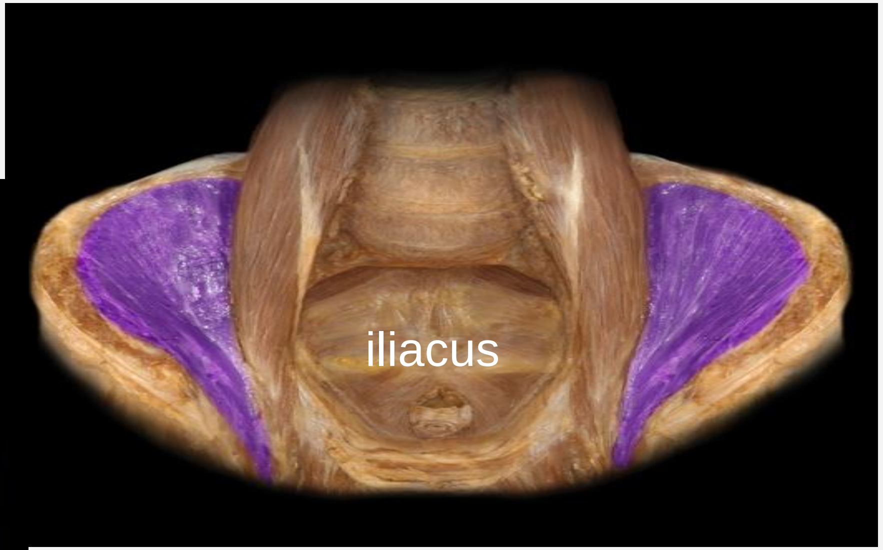
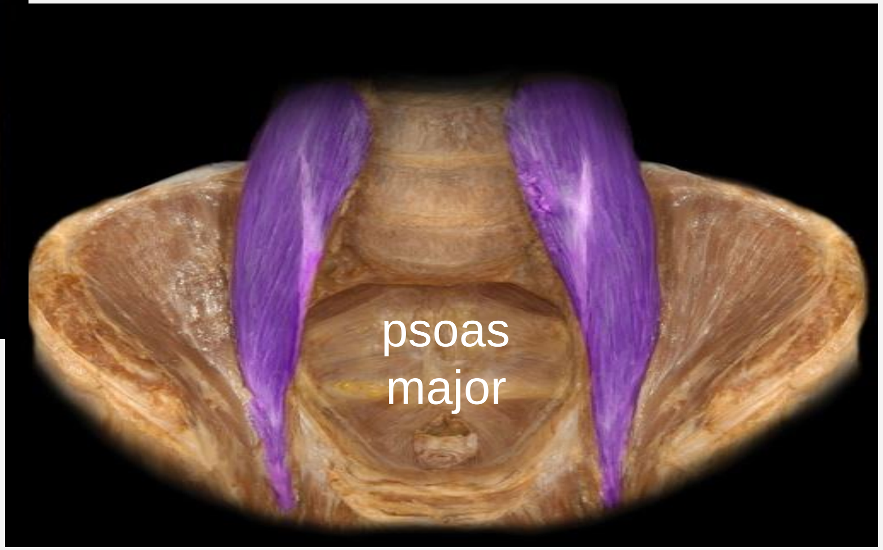


Figure 10.33

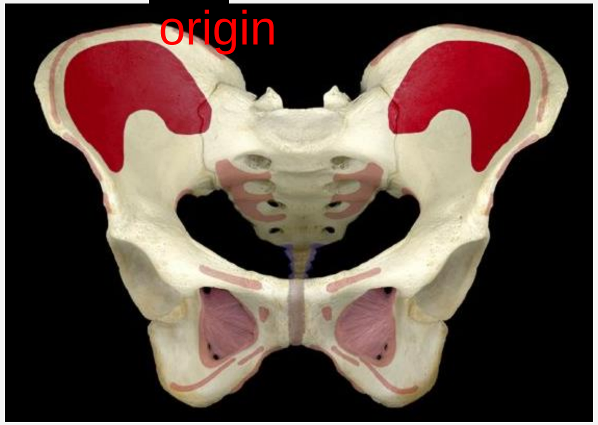
Muscles Acting on the Hip & Femur Iliopsoas

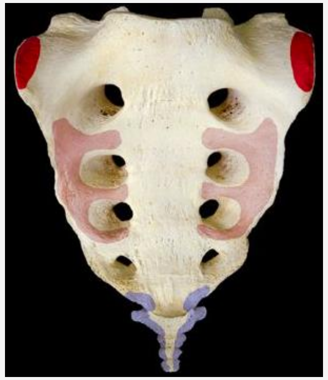




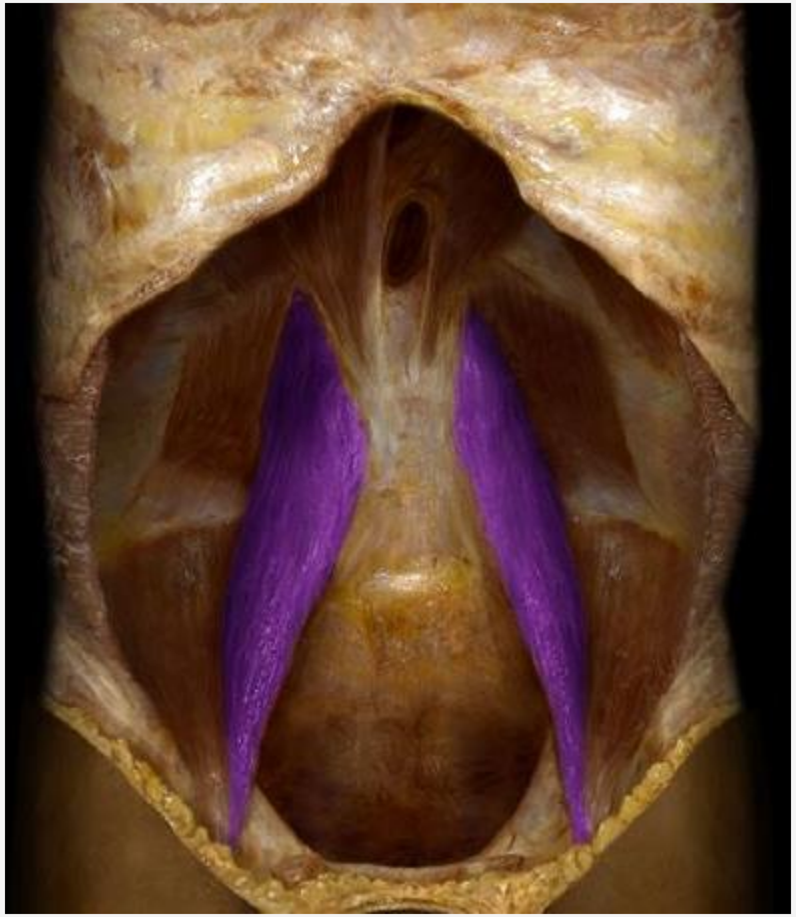


Muscles Acting on the Hip & Femur Iliacus

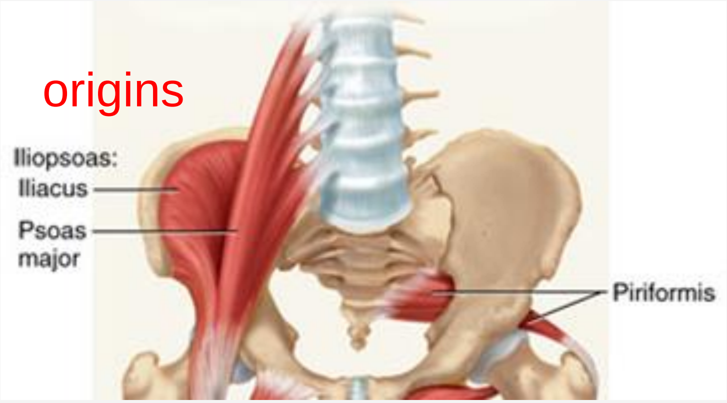




Muscles Acting on the Hip & Femur
Psoas major



insertion



Posterior Muscles Acting on Hip and Femur

- **lateral and posterior muscles of the hip**
  - *tensor fasciae latae [**fasc = band; lat = broad**]*
    - <u>extends knee, laterally rotates knee</u>
  - *gluteus maximus[**glut = buttock; maxim = largest**]*
  - *forms mass of the buttock*
    - prime hip extensor
    - provides most of lift when you climb stairs
  - *gluteus medius and minimus*
    - abduct and medially rotate thigh

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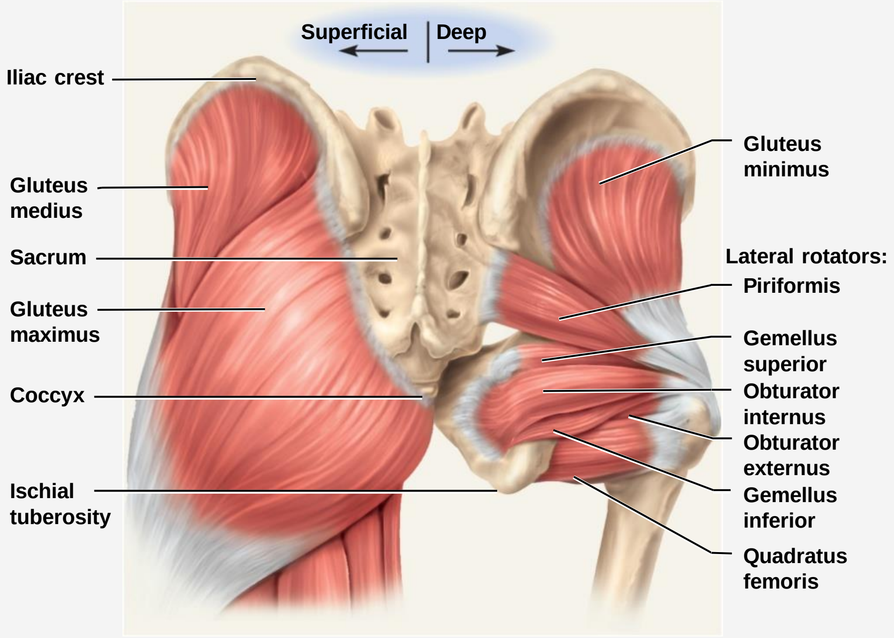
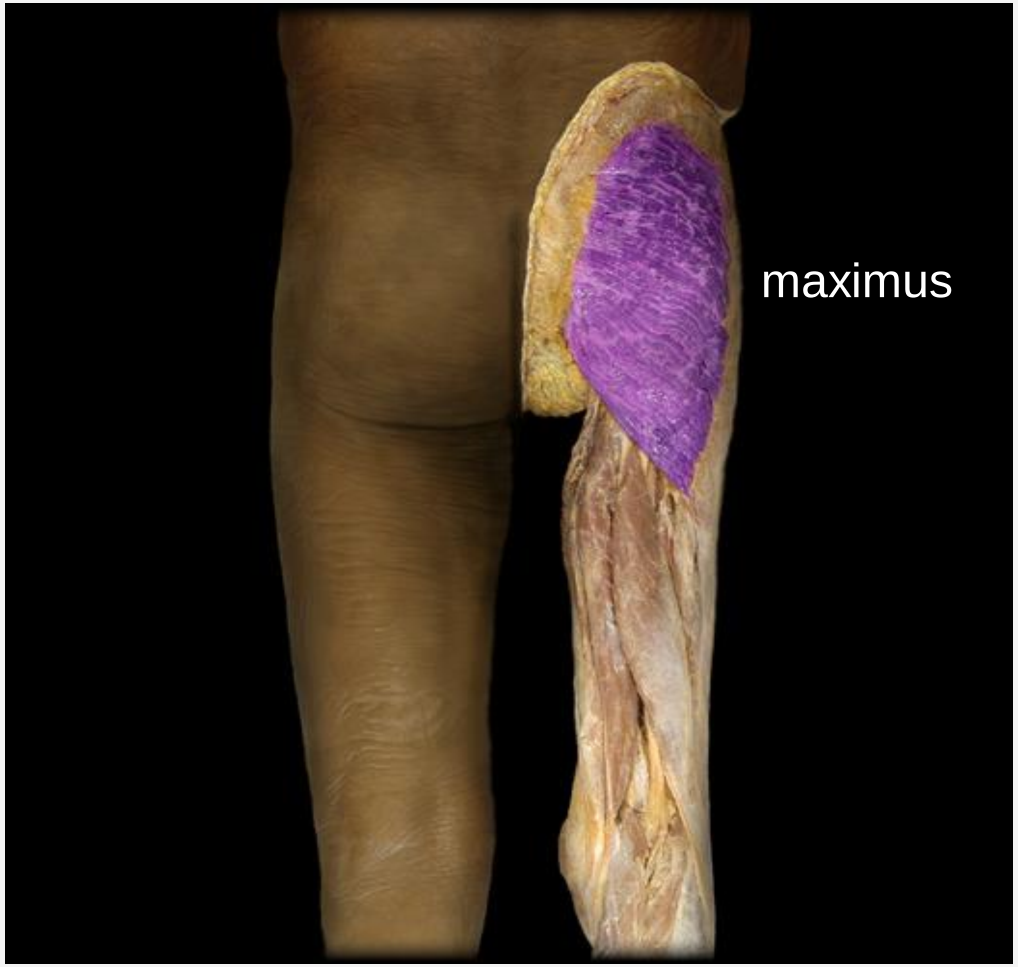
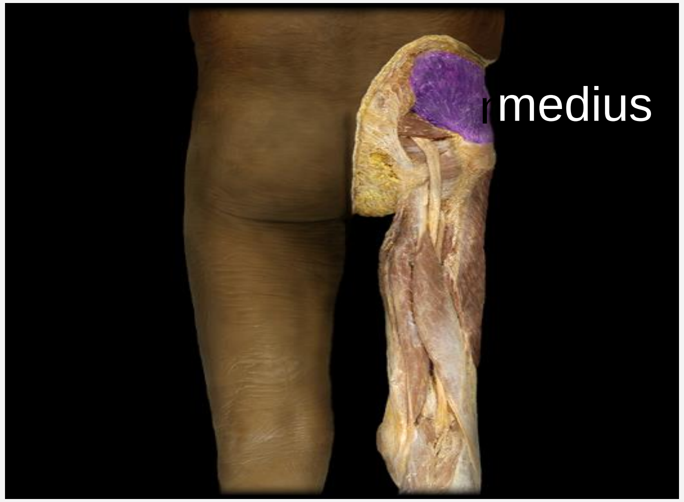


Figure 10.34

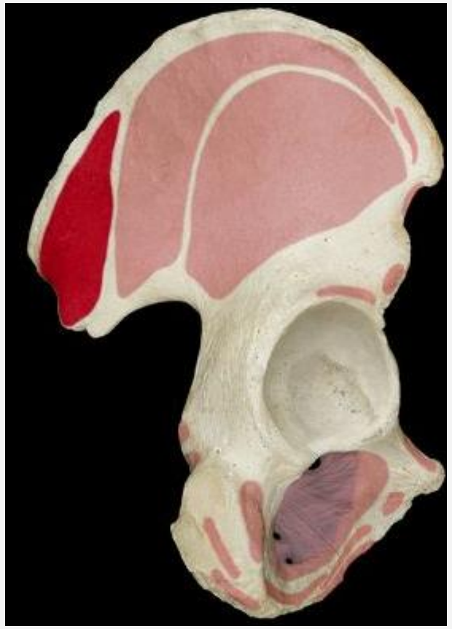
Muscles Acting on the Hip & Femur Tensor fasciae latae

Muscles Acting on the Hip & Femur Gluteal Muscles





Muscles Acting on the Hip & Femur Gluteus maximus



origin

insertion

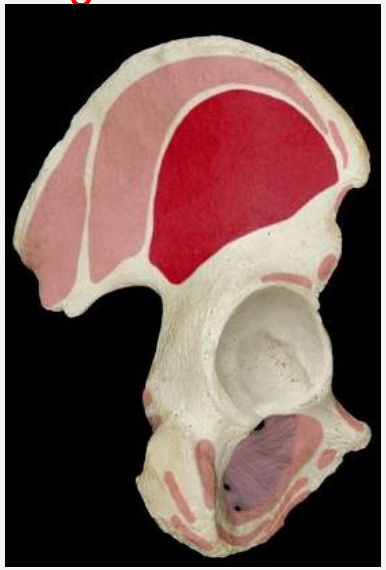
Muscles Acting on the Hip & Femur Gluteus medius

origin

insertion

Muscles Acting on the Hip & Femur Gluteus minimus

origin



insertion

Posterior Muscles Acting on Hip and Femur

- **lateral rotators - six muscles inferior to gluteus minimus**
- deep to the two other gluteal muscles
  - *gemellus[**gemellus = twin**] superior*
  - *gemellus inferior*
  - *obturator[**obtur = to close**] externus*
  - *obturator internus*
  - *piriformis[**piri = pear; form = shaped**]*
  - *quadratus femoris[**quadrat = four-sided; femoris = of the thigh or femur**]*

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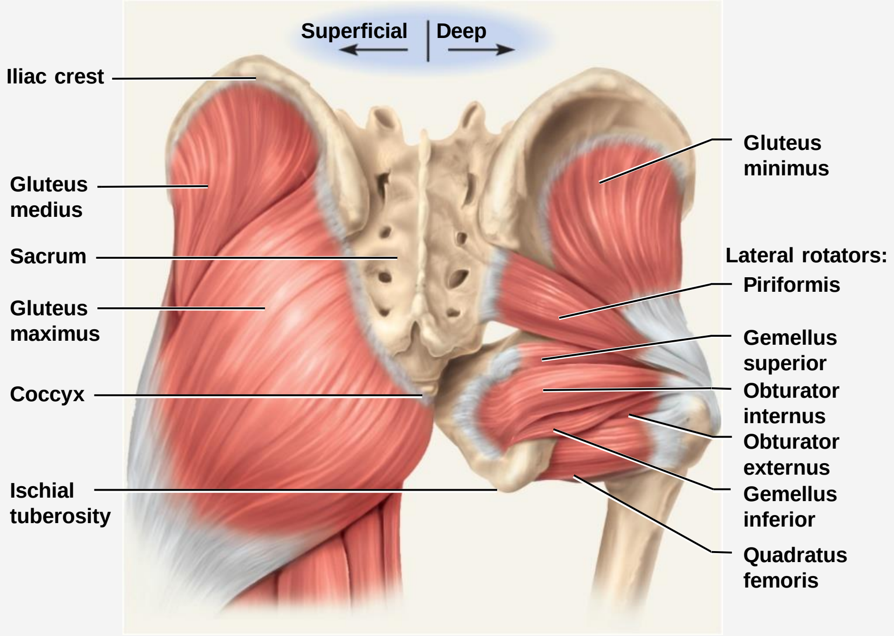
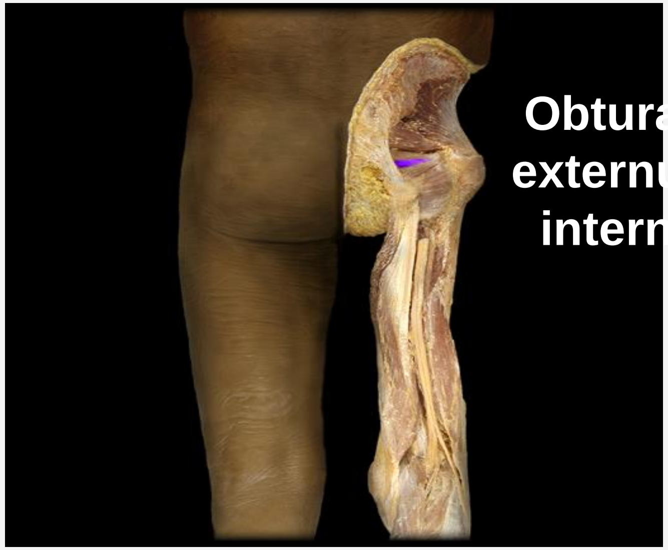
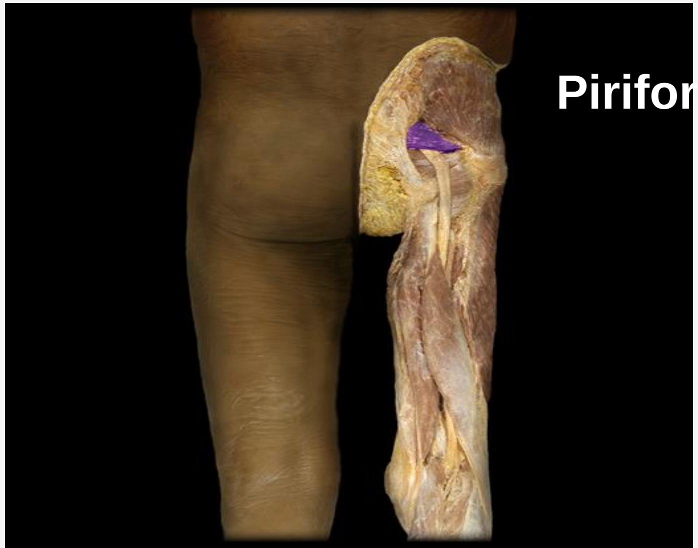
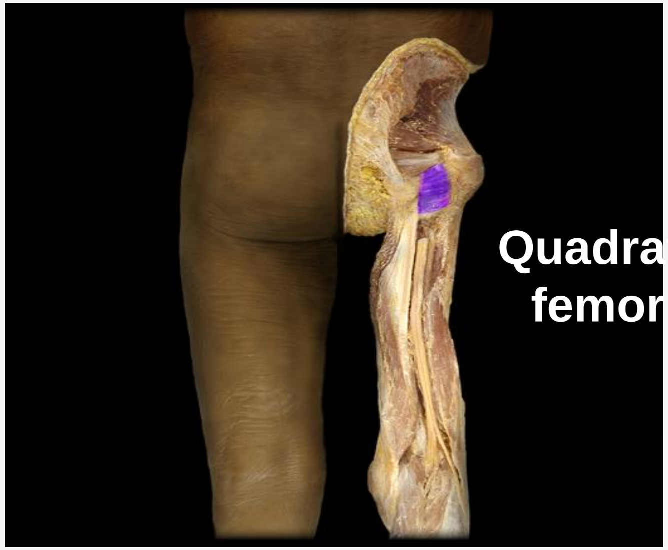


Figure 10.34

Muscles Acting on the Hip & Femur – Deep Muscles







Muscles Acting on Hip and Femur

- **medial (adductor) compartment of thigh**
- five muscles act as primary adductors of the thigh
  - *adductor brevis*
  - *adductor longus*
  - *adductor magnus*
  - *gracilis[**gracil = slender**]*
  - *pectineus[**pectin = comb**]*

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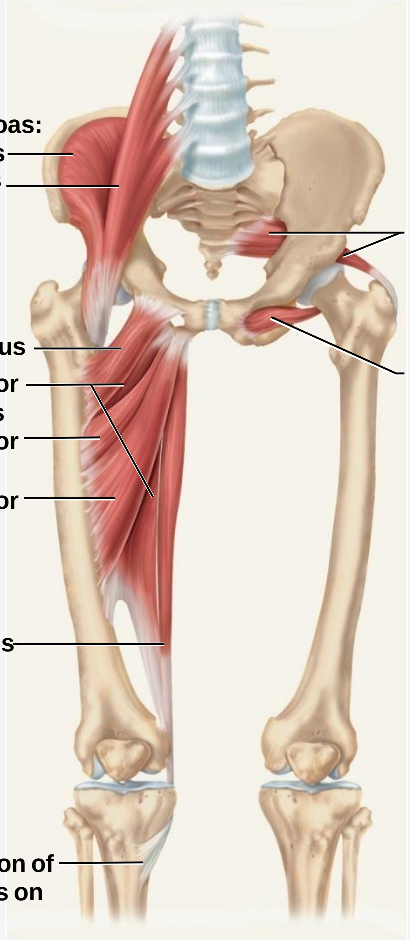
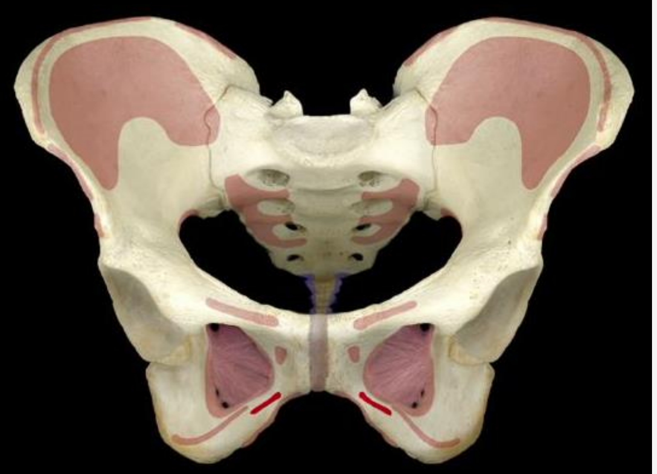


Figure 10.33

Muscles Acting on the Hip & Femur Adductor brevis



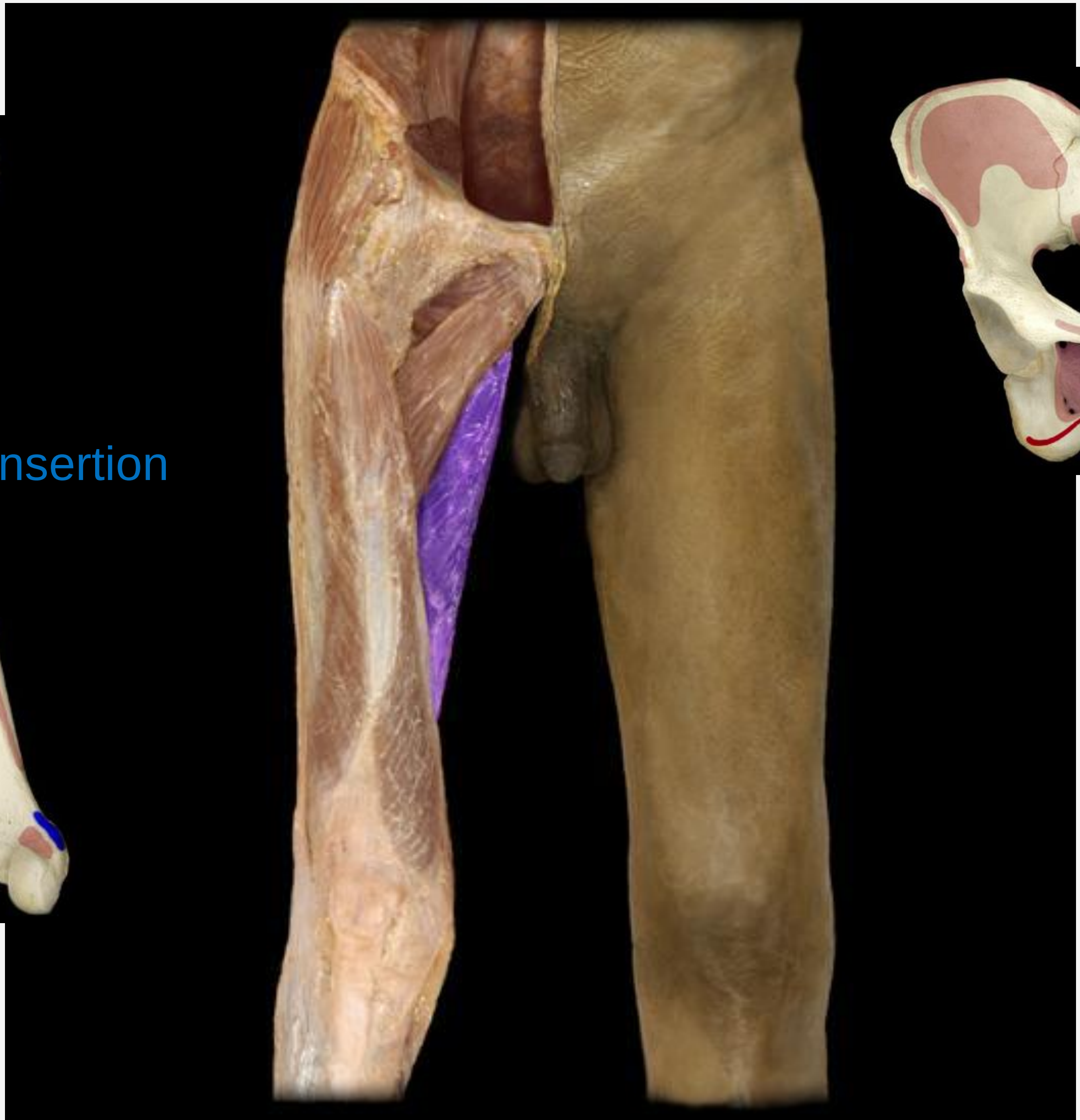
Muscles Acting on the Hip & Femur Adductor longus

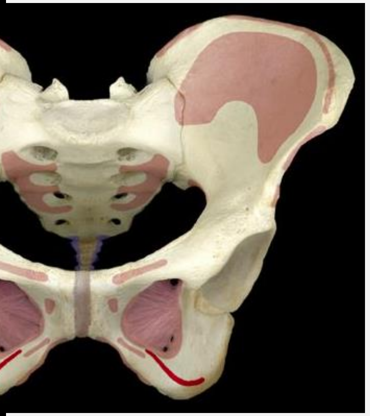
insertion

origin

Muscles Acting on the Hip & Femur Adductor magnus

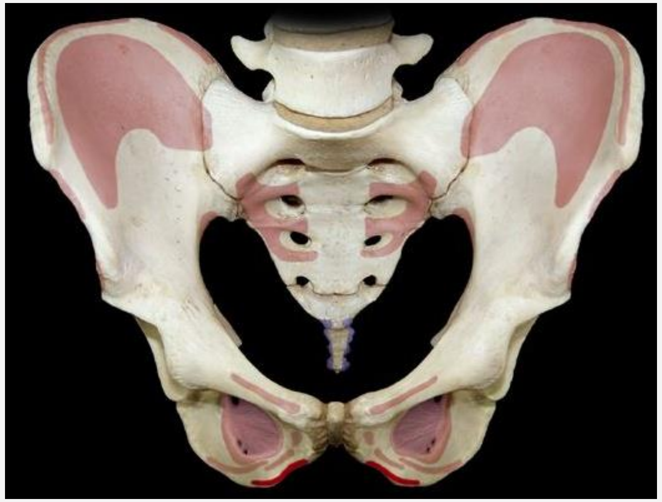
insertion





origin

Muscles Acting on the Hip & Femur Gracilis



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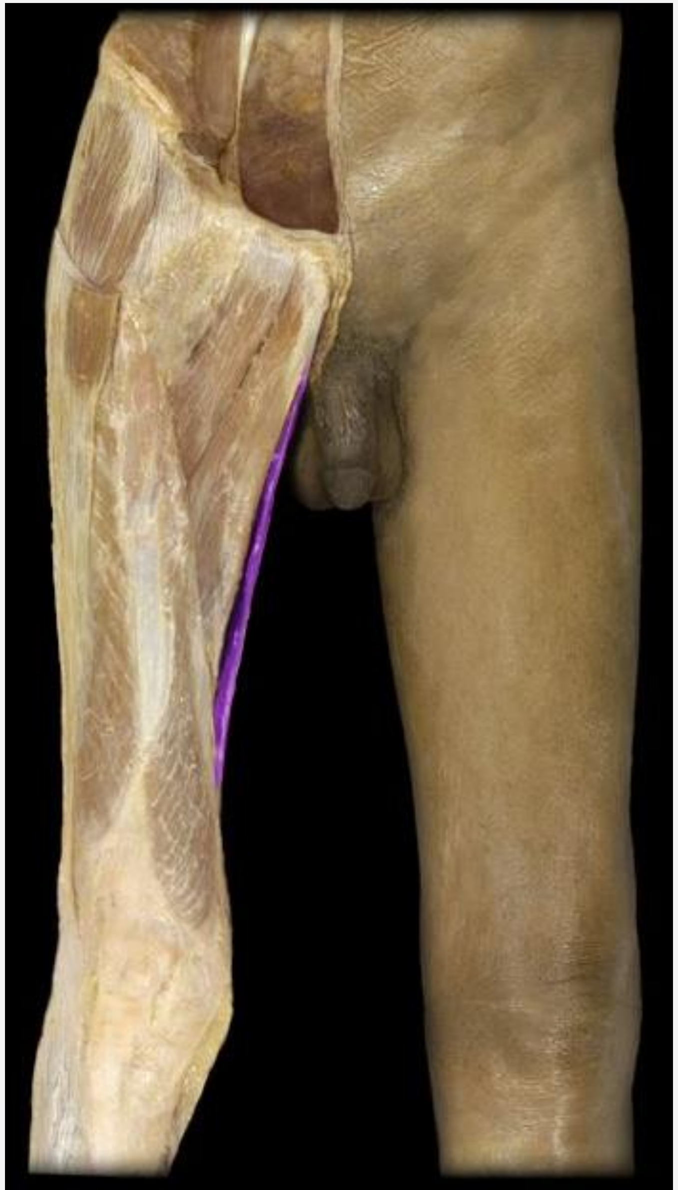
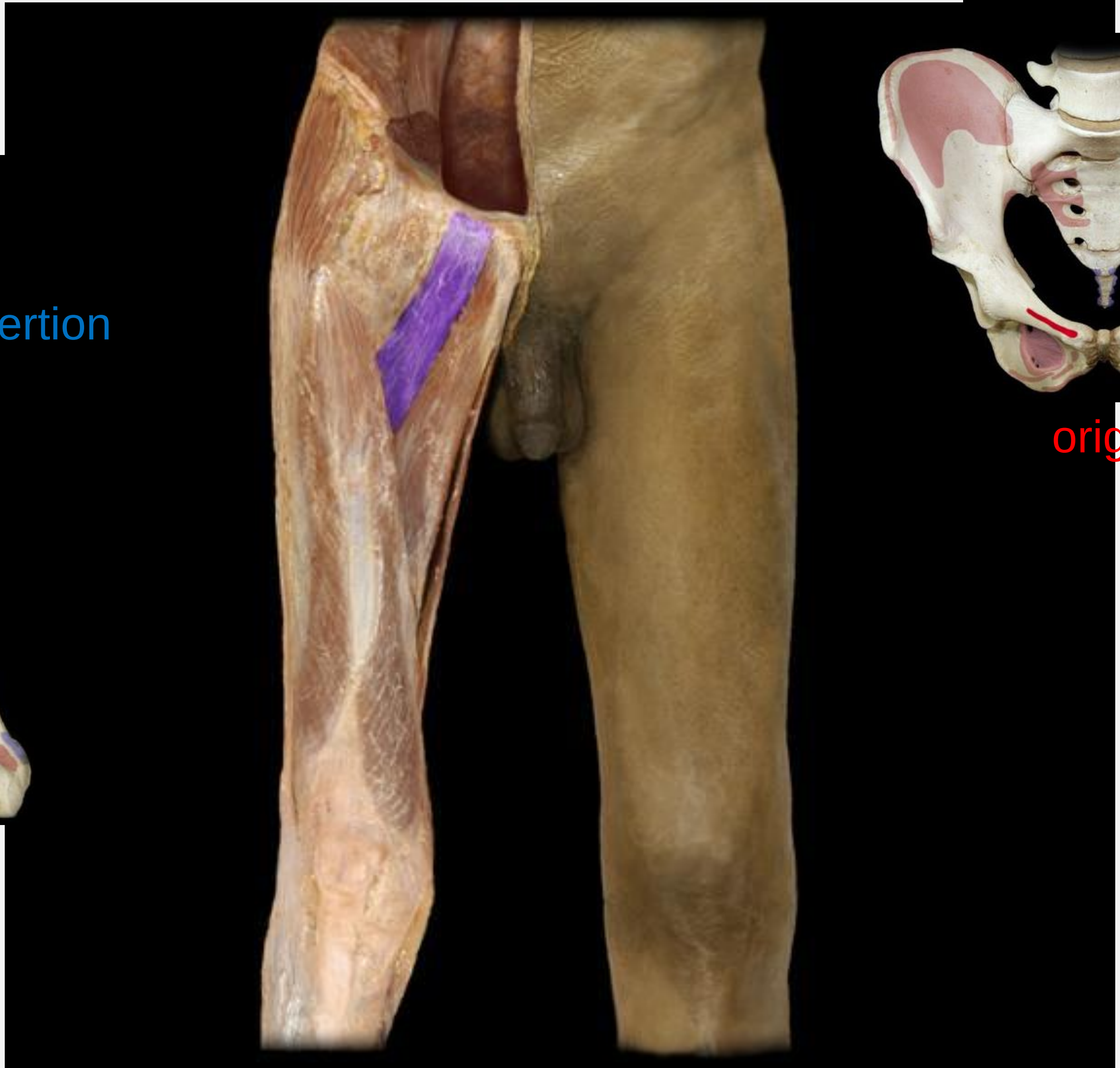


insertion

Muscles Acting on the Hip & Femur Pectineus



Muscles Acting on the Knee and Leg

- **anterior (extensor) compartment of the thigh**
  – contains large ***quadriceps femoris*** muscle
    - prime mover of knee extension
    - most powerful muscle in the body
    - has four heads – *rectus femoris, vastus lateralis[***vastus*** **= large, extensive** *], vastus medialis*, and *vastus intermedius*
      – all converge on single **quadriceps (patellar) tendon**
      – extends to **patella**
      – then continues as **patellar ligament**
      – inserts on **tibial tuberosity**

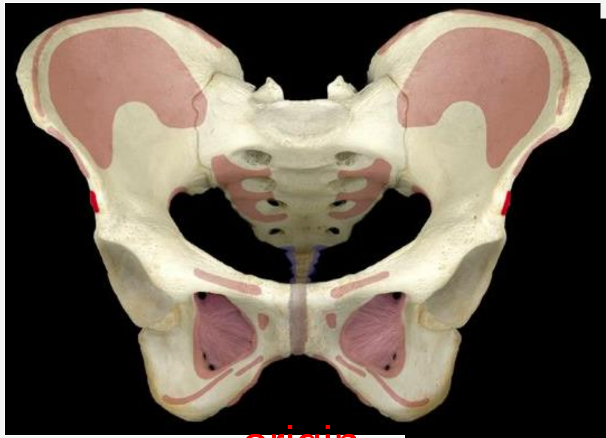
  – ***sartorius[sartor = tailor] – longest muscle in the body***
    - tailor's muscle

Muscles Acting on the Knee
Anterior (extensor) Compartment

Quadriceps femoris

Rectus femoris
Vastus lateralis
Vastus medialis
Vastus intermedius

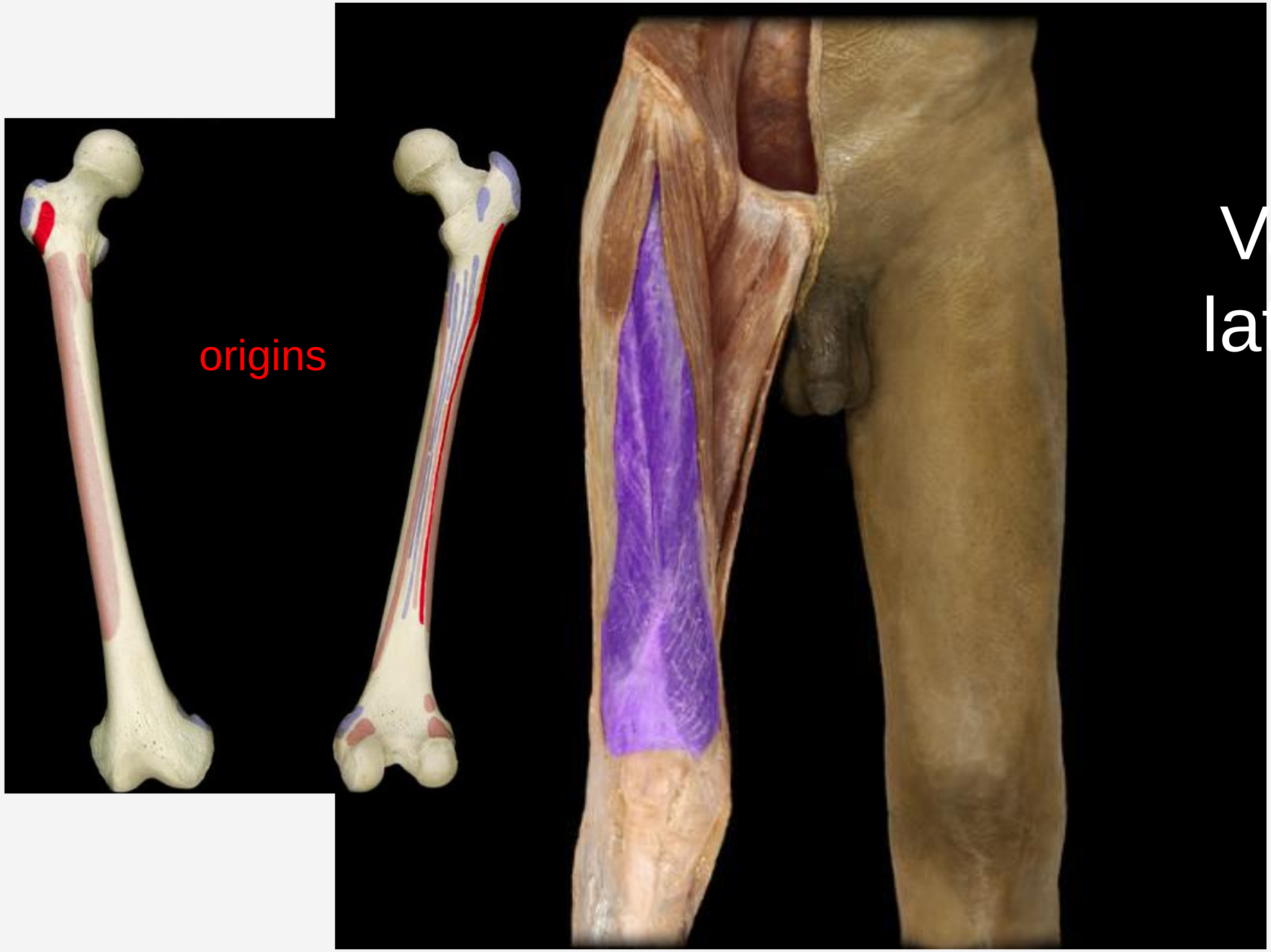
Muscles Acting on the Knee
Anterior (extensor) Compartment



origin

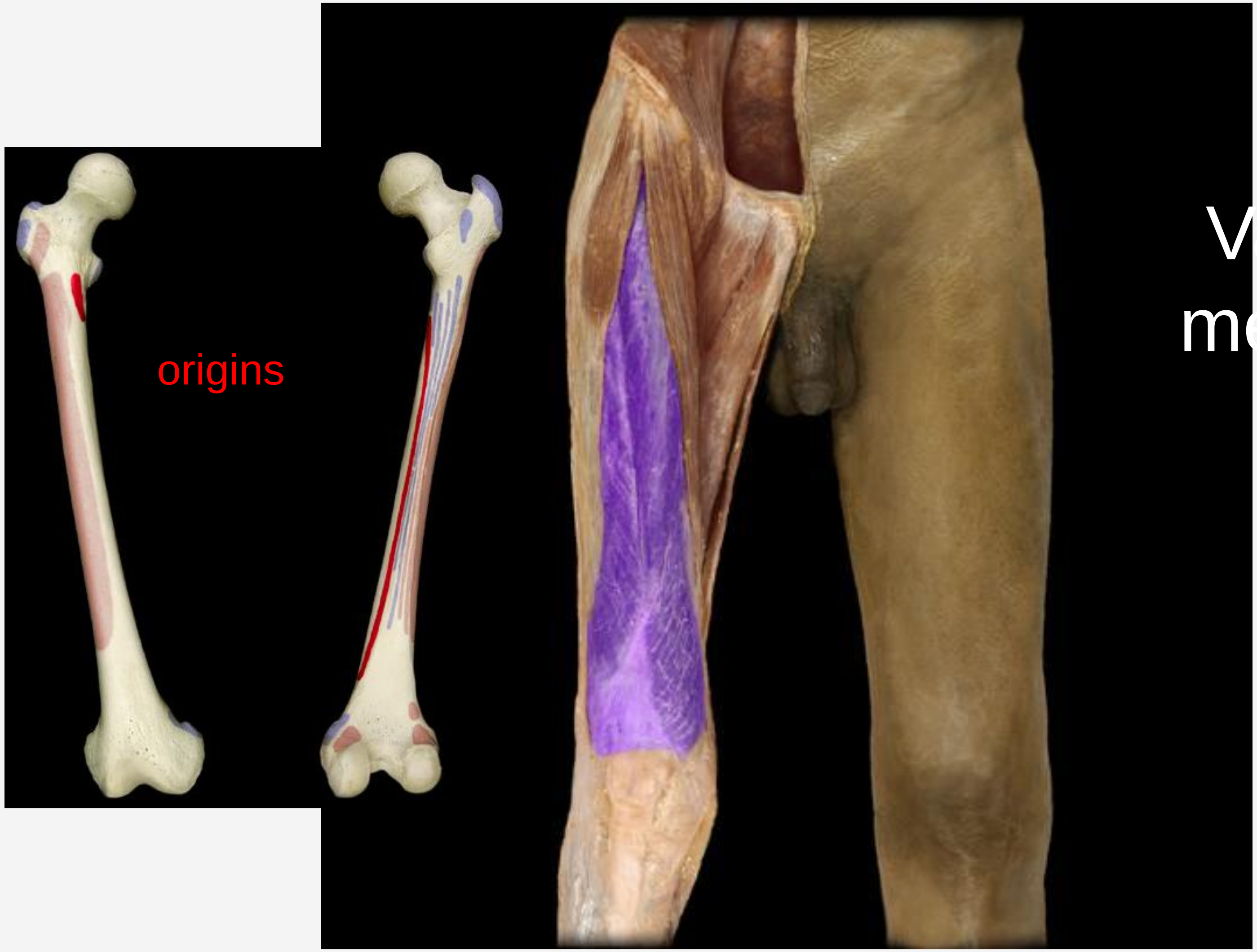
Rectus femoris

Muscles Acting on the Knee
Anterior (extensor) Compartment



Vastus lateralis

Muscles Acting on the Knee
Anterior (extensor) Compartment

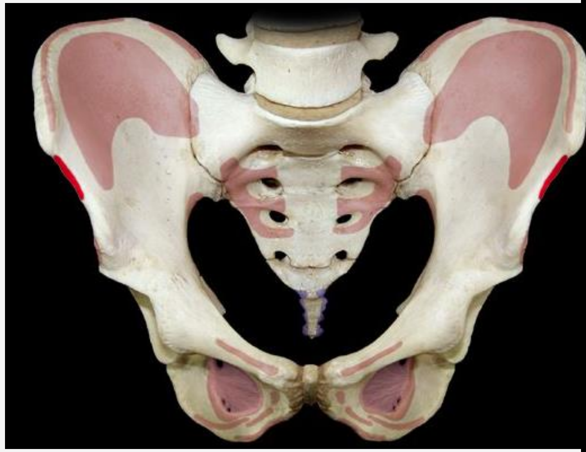


Vastus medialis

Muscles Acting on the Knee
Anterior (extensor) Compartment

Vastus intermedius

Muscles Acting on the Knee
Anterior (extensor) Compartment



origin

insertion

Sartorius

Anterior Thigh Cadaver Muscles

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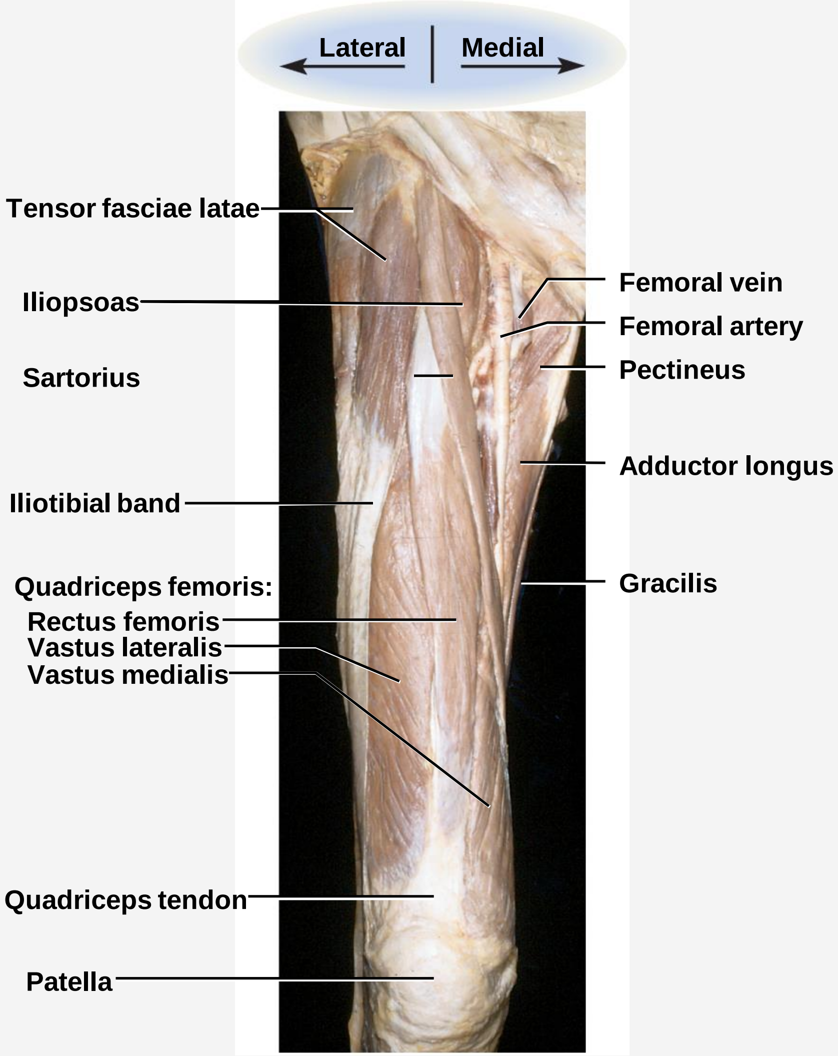

Figure 10.35

Muscles Acting on the Knee and Leg

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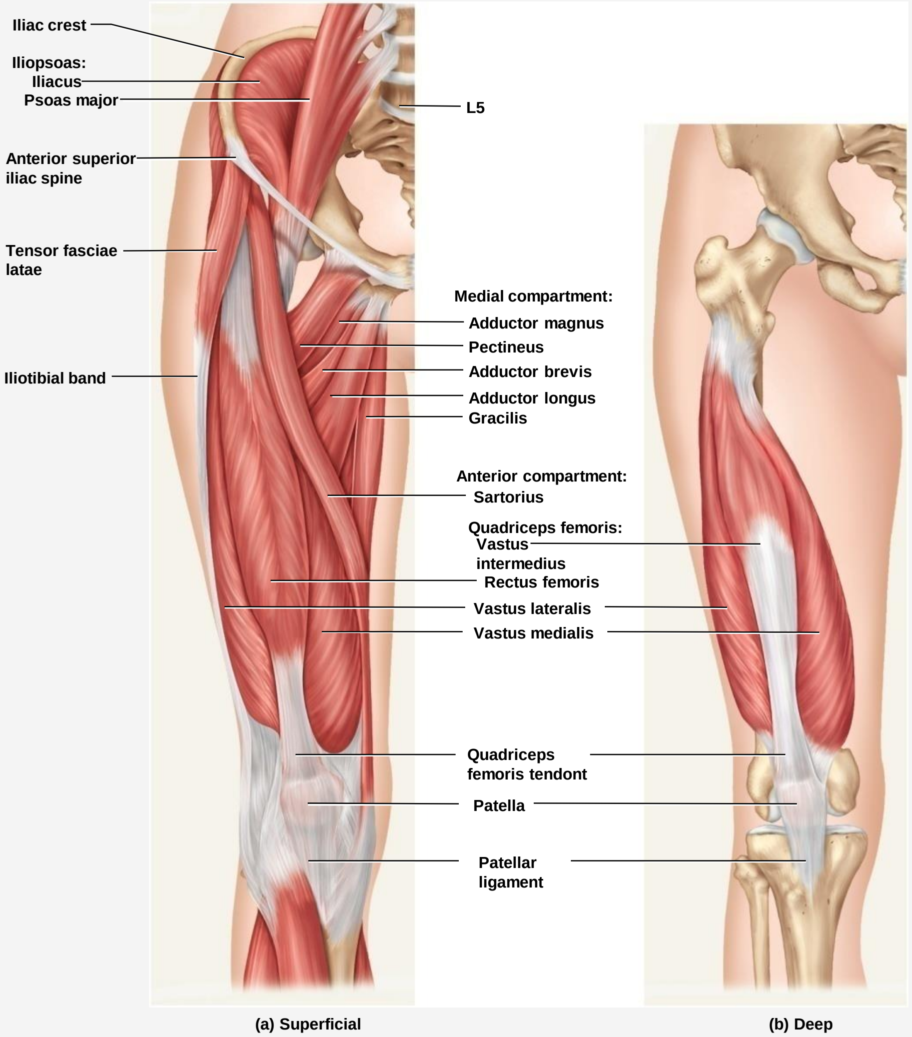

Figure 10.36

Muscles Acting on the Knee and Leg

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- **posterior (flexor) compartment of the thigh**
  - contains **hamstring muscles**
  - from lateral to medial;

    biceps femoris

    semitendinosus

    semimembranosus

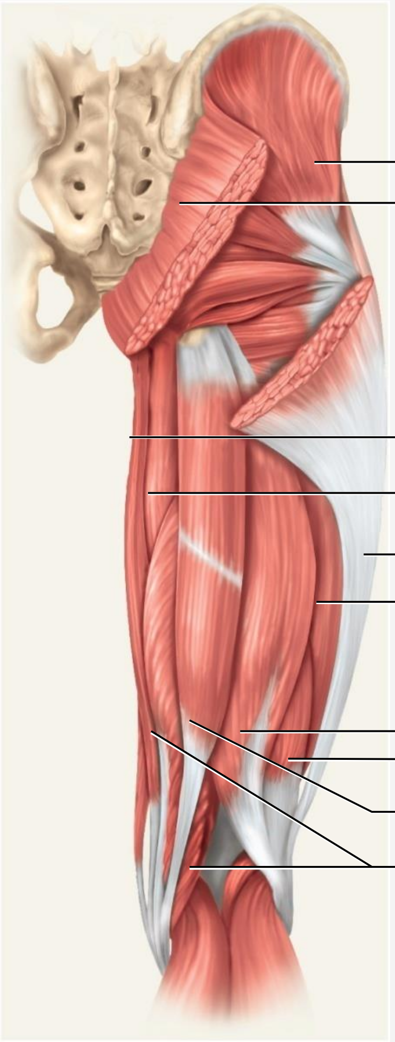
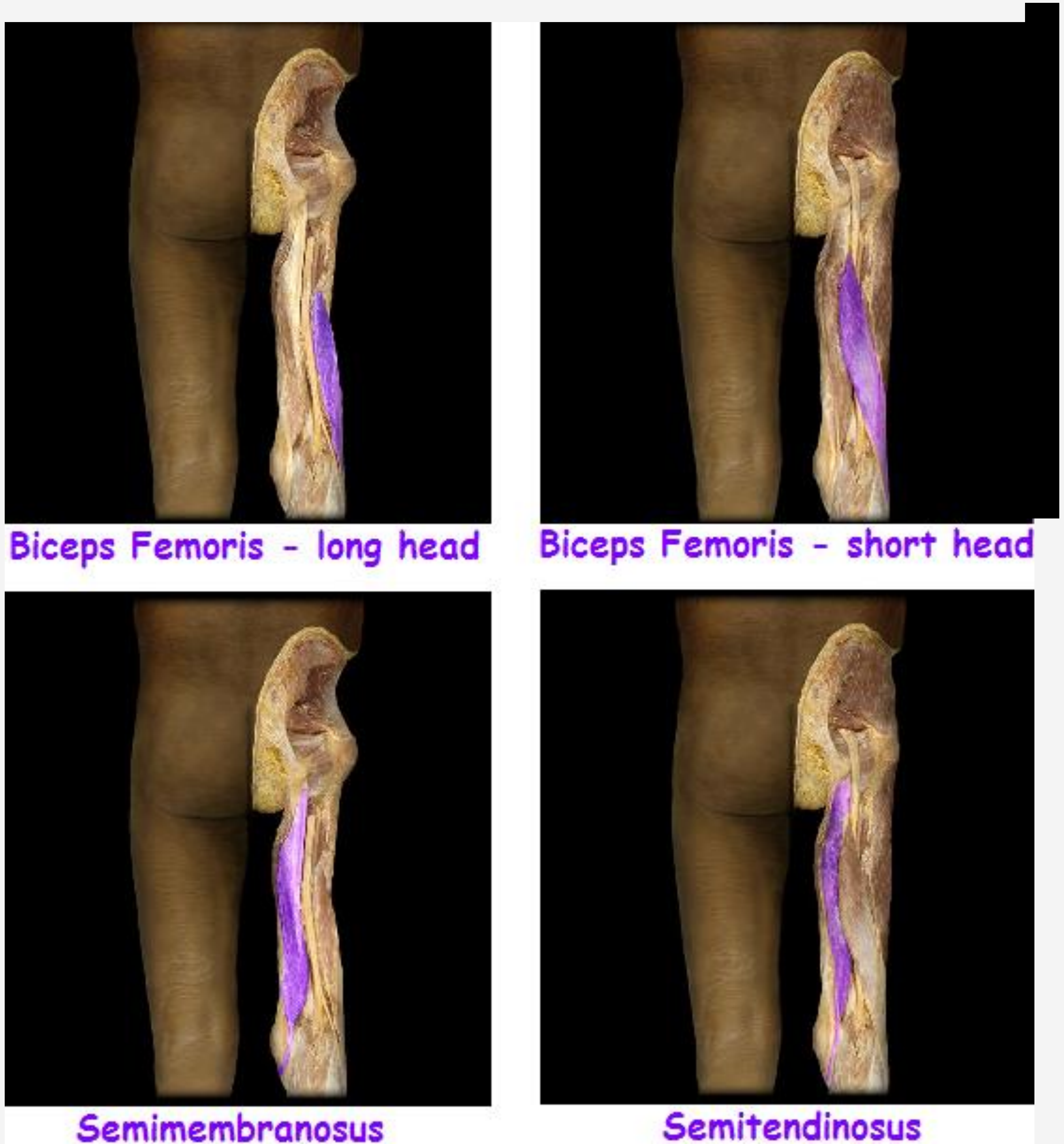


Figure 10.37

Muscles Acting on the Knee
Posterior (flexor) Compartment

Hamstring Group



Muscles Acting on the Knee
Posterior (flexor) Compartment

Muscles Acting on the Knee
Posterior (flexor) Compartment

origin

insertion

Biceps femoris

short head

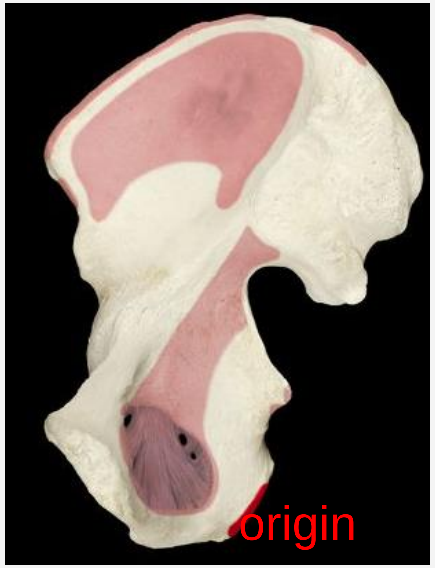
ng head

Muscles Acting on the Knee
Posterior (flexor) Compartment

Semimembranosus

insertion

Muscles Acting on the Knee
Posterior (flexor) Compartment

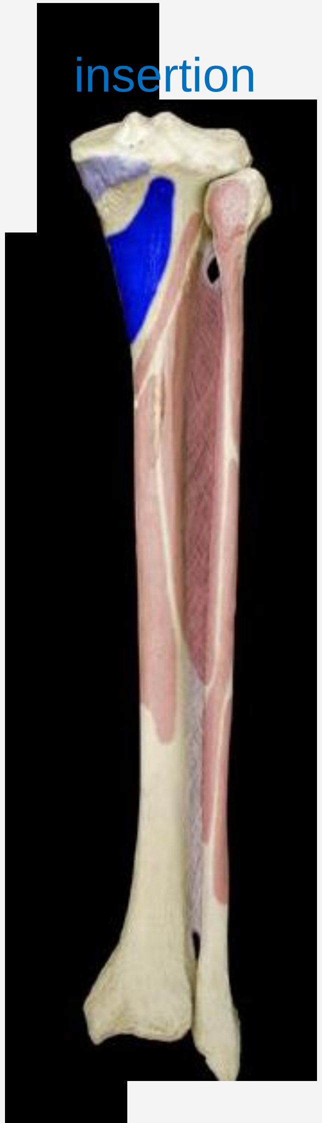


Semitendinosus

insertion

Muscles Acting on the Knee
Posterior (flexor) Compartment

Popliteus



◆ PART II

Muscles of the Leg

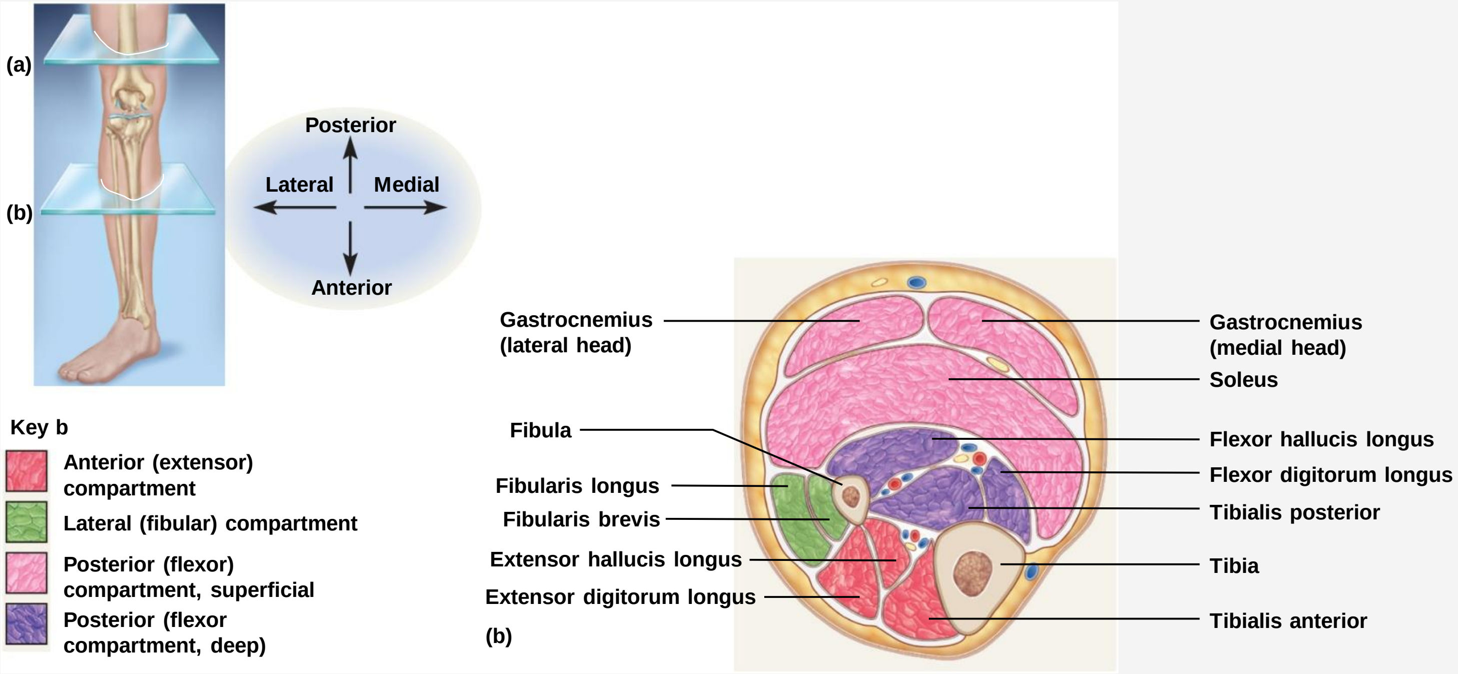


Figure 10.42b

- **crural muscles,** acting on the foot, are separated into 3 compartments.
  - anterior compartment (red)
  - fibular (lateral) compartment (green)
  - posterior (superficial = pink) (deep = purple)

Anterior Compartment of Leg

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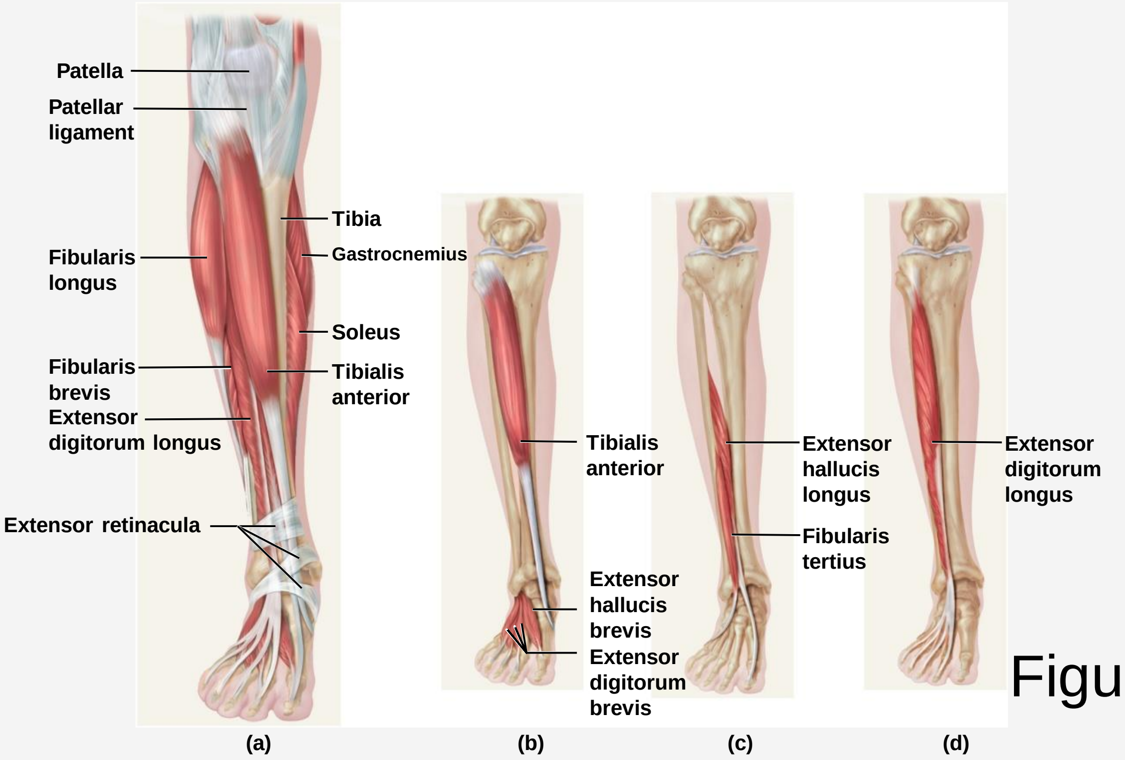


Figure 10.39

- **anterior (extensor) compartment of the leg**
  dorsiflex the ankle
  prevent toes from scuffing when walking
  - *fibularis (peroneus) tertius [**fibularis = of the fibula; tert = third**]*
  - *extensor digitorum longus*
  - *extensor hallucis longus*
  - *tibialis anterior*

Muscles Acting on the Foot
Anterior Compartment

Extensor digitorum longus

Muscles Acting on the Foot
Anterior Compartment

Extensor

hallicus

longus

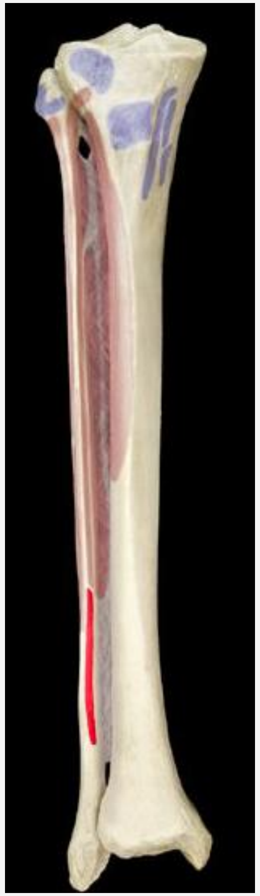
origin

insertion

Muscles Acting on the Foot
Anterior Compartment

Fibularis (Peroneus) tertius

origin



insertion

Muscles Acting on the Foot
Anterior Compartment

Tibialis anterior

origin

tendon

insertion

Posterior Compartment of Leg
Superficial Group

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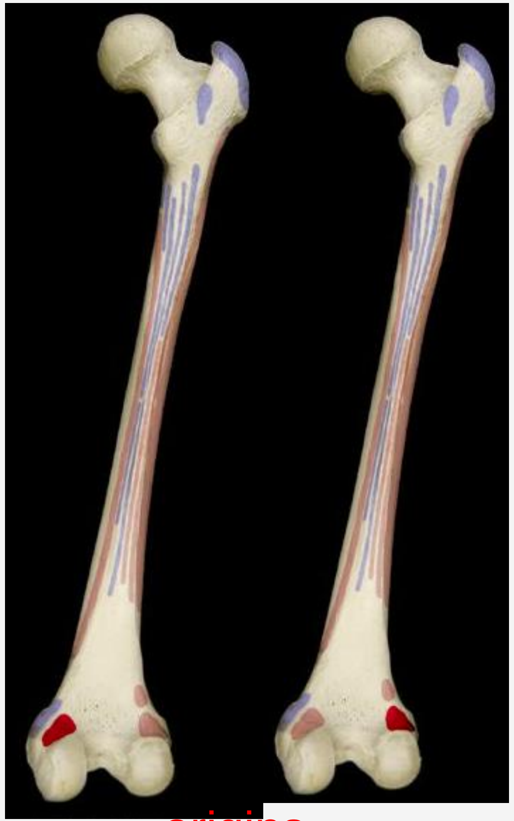
Figure 10.40

- three muscles of the superficial group
  - *gastrocnemius*[***gastro = belly; cnem = leg***]- plantar flexes foot, flexes knee
  - *soleus*[***Named for its resemblance to a flatfish (sole)***] – plantar flexes foot
  - *plantaris* - weak synergist of triceps surae
- **triceps surae** – collective name for *gastrocnemius* and *soleus*
  - inserts on **calcaneus** by way of the **calcaneal (Achilles) tendon**
  - strongest tendon in the body

Muscles Acting on the Foot
Posterior Compartment – sup.

Gastrocnemius

insertion



origins

medial head

lateral head

Muscles Acting on the Foot
Posterior Compartment – sup.

Soleus

insertion

origin

Muscles Acting on the Foot
Posterior Compartment – sup.

Plantaris

origin

insertion
Calcaneus

Posterior Compartment of Leg
Superficial Group

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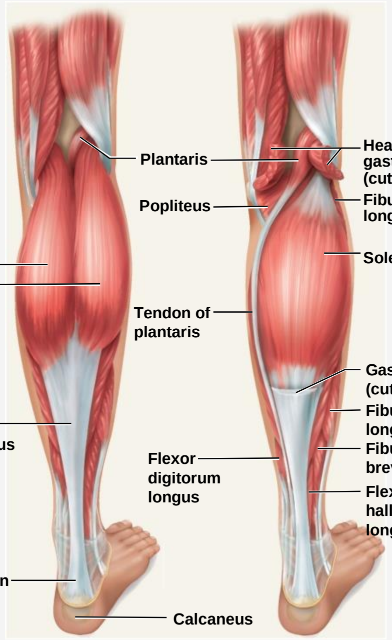

Figure 10.40

- three muscles of the superficial group
  - *gastrocnemius* - plantar flexes foot, flexes knee
  - *soleus* – plantar flexes foot
  - *plantaris* - weak synergist of triceps surae
- **triceps surae[*surae* = of the calf of the leg]** – collective name for *gastrocnemius* and *soleus*
  - inserts on **calcaneus** by way of the **calcaneal (Achilles) tendon**
  - strongest tendon in the body

Posterior Compartment of Leg
Deep Group

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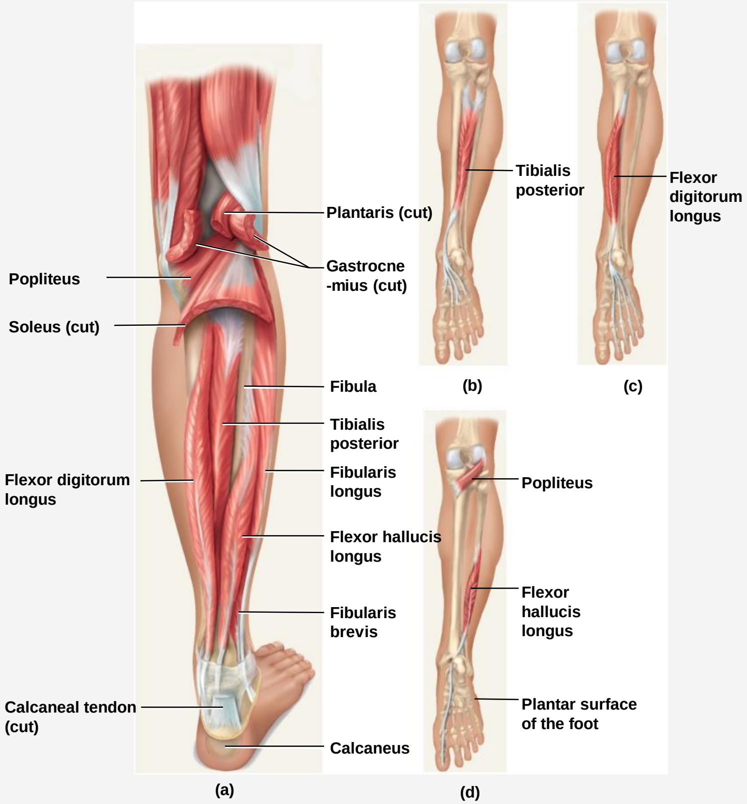


Figure 10.41

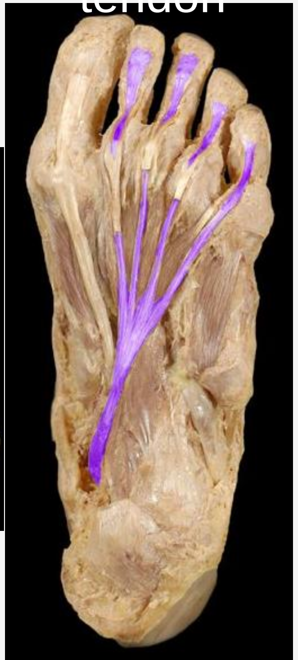
- **four muscles in the deep group**
  - *flexor digitorum longus* – flexes phalanges
  - *flexor hallucis longus* – flexes great toe
  - *tibialis posterior* – inverts foot
  - *popliteus [**poplit = ham (pit) of the knee**]*– acts on knee

Muscles Acting on the Foot
Posterior Compartment – deep

Flexor digitorum longus

tendon

tendon



insertion

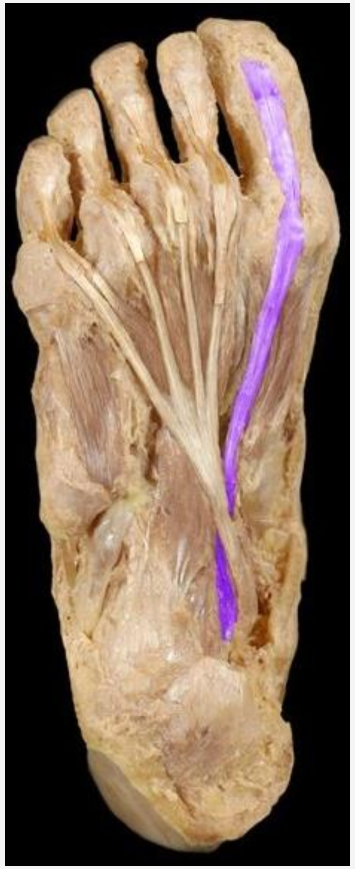
origin

Muscles Acting on the Foot
Posterior Compartment – deep

Flexor hallucis longus

origin

insertion

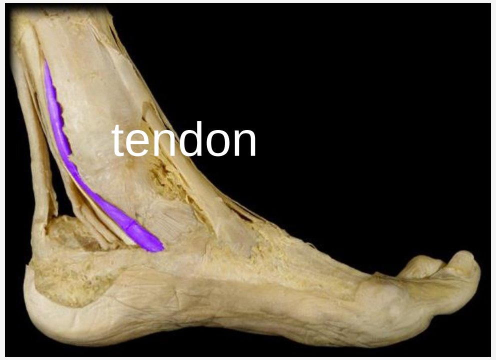


tendon

Muscles Acting on the Foot
Posterior Compartment – deep

Tibialis posterior

insertion



origin

Lateral (Fibular) Compartment of the Leg

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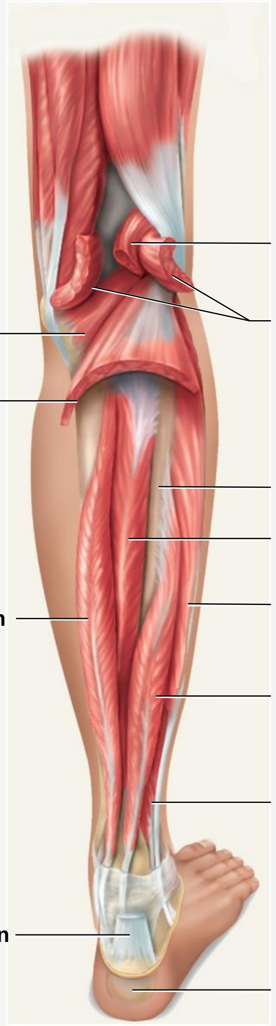


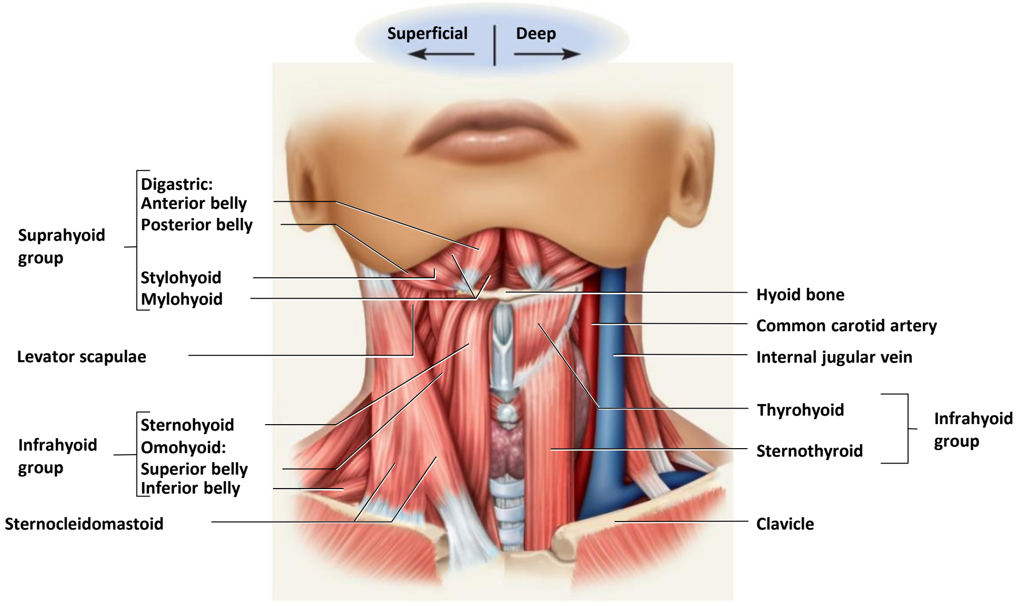
- two muscles in this compartment
  - *fibularis longus*
  - *fibularis brevis*
- both plantar flex and evert the foot
- provides lift and forward thrust

Figure 10.41a

◆ PART VI

Hyoid Muscles – Suprahyoid Group

- aspects of chewing, swallowing, and vocalizing
- **eight pairs of hyoid muscles** associated with hyoid bone
- *digastric(**di = two; gastr = bellies)*** - opens mouth widely
- *geniohyoid* (***genio = chin***)– depresses mandible
- *mylohyoid* (***mylo = mill, molar tooth***)– elevates floor of mouth at beginning of swallowing
- *stylohyoid* – elevates hyoid



(a) Anterior view

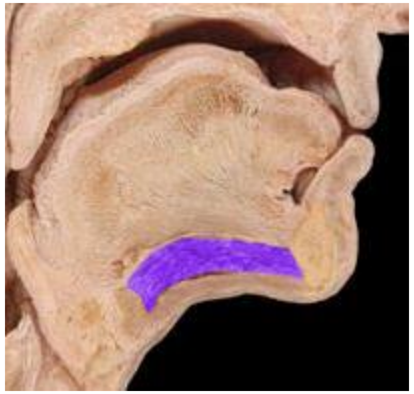
Figure 10.10a

Origin
Anterior Belly

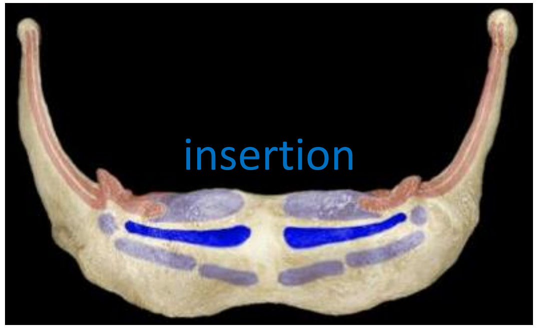
Origin
Posterior Belly

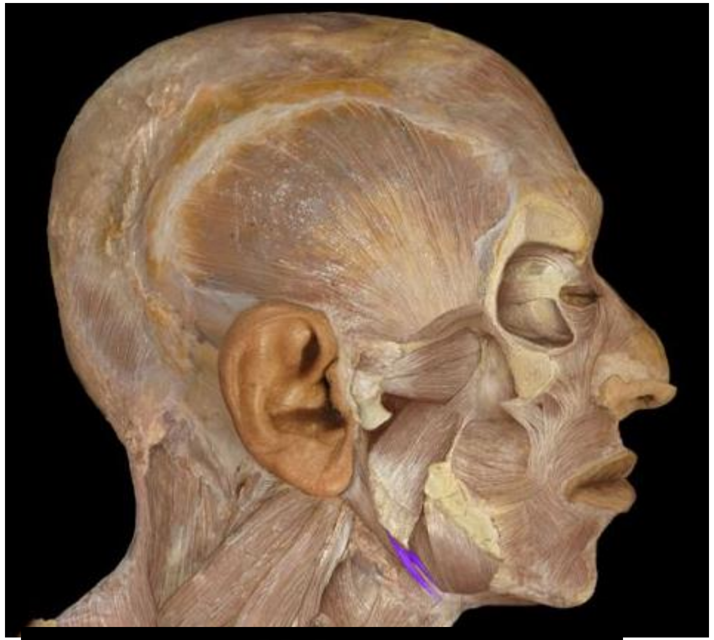

origin


insertion



origin





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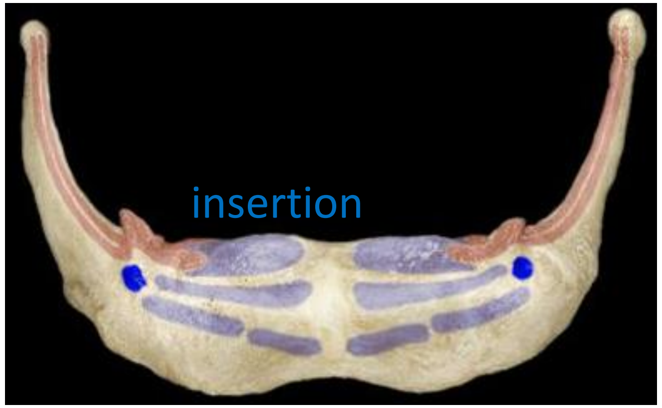

Hyoid Muscles – Infrahyoid Group

- fix hyoid bone from below…allowing suprahyoid muscles to open mouth
- *omohyoid(**omo = shoulder**)* – depresses hyoid after elevation
- *sternohyoid(**sterno = chest, sternum**)* – depresses hyoid after elevation
- *thyrohyoid(**thyro = shield, thyroid cartilage**)* – depresses hyoid and elevates larynx
- *sternothyroid(**sterno = chest, sternum, thyroid cartilage**)* – depresses larynx after elevation

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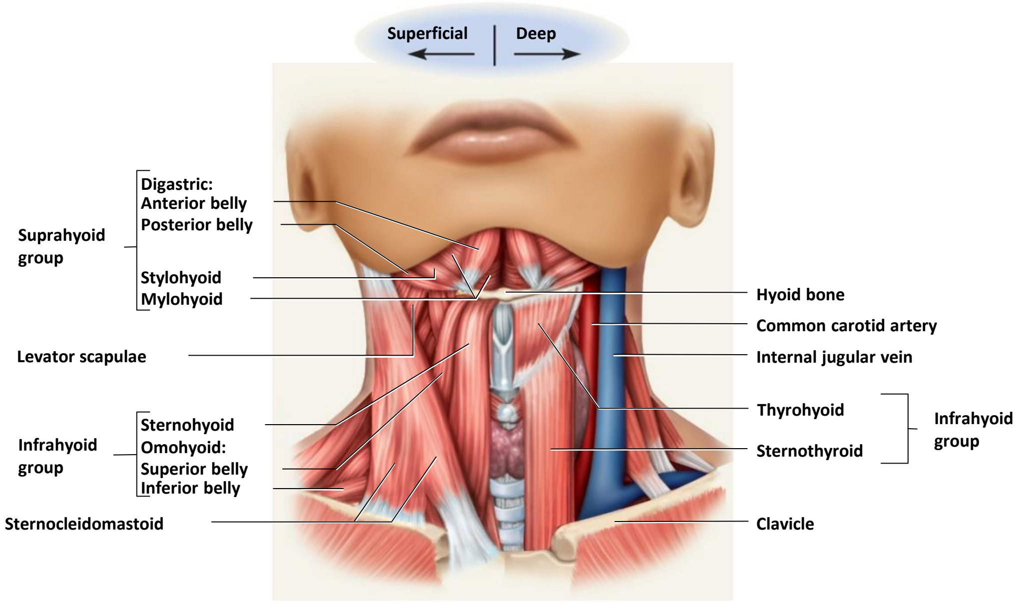
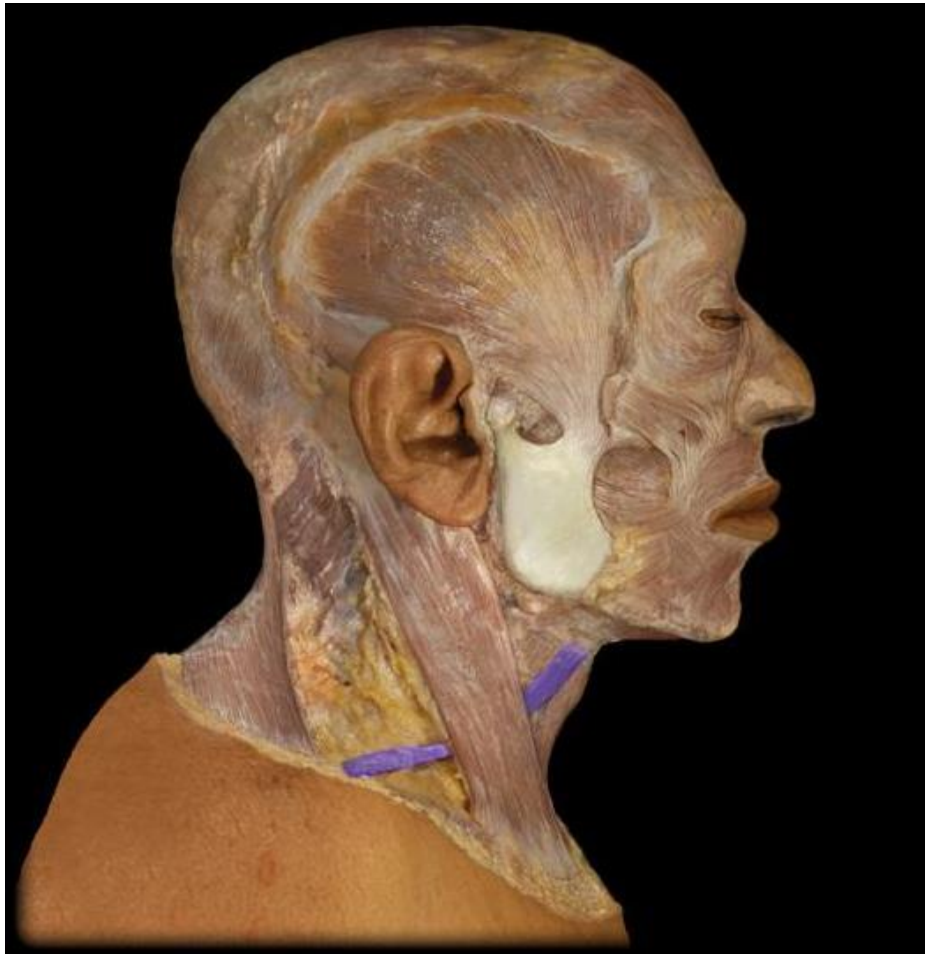
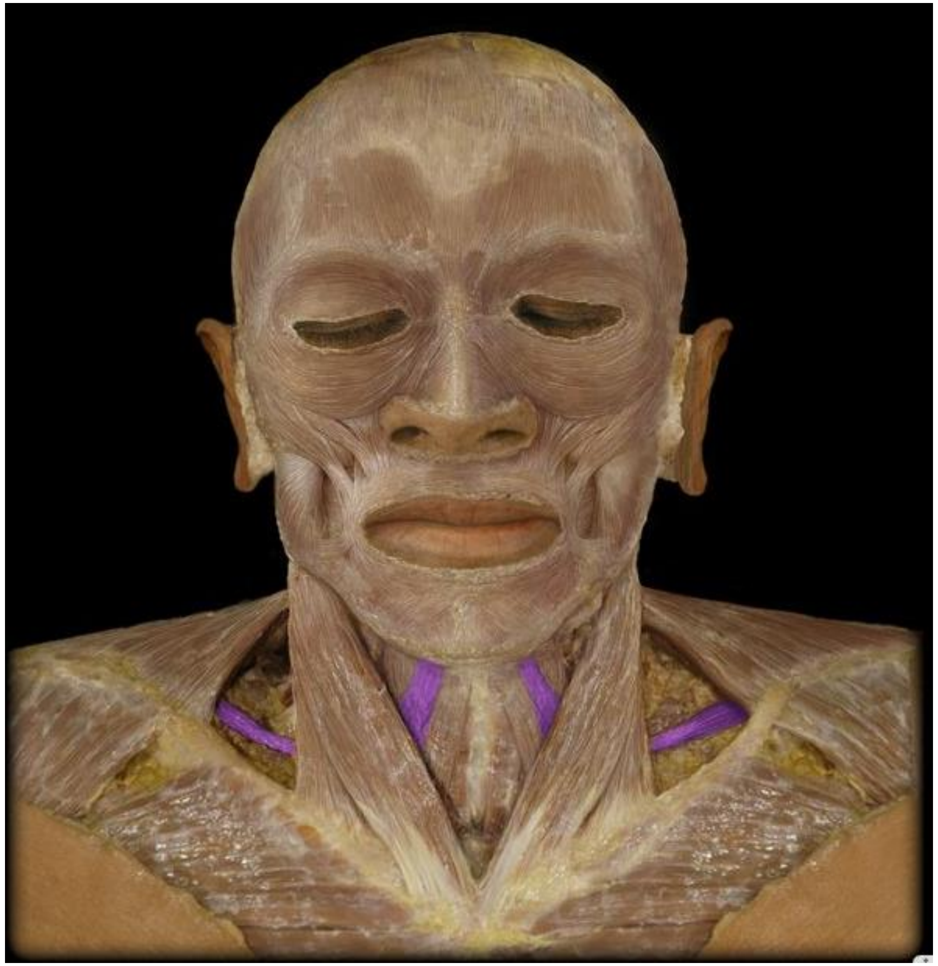


(a) Anterior view

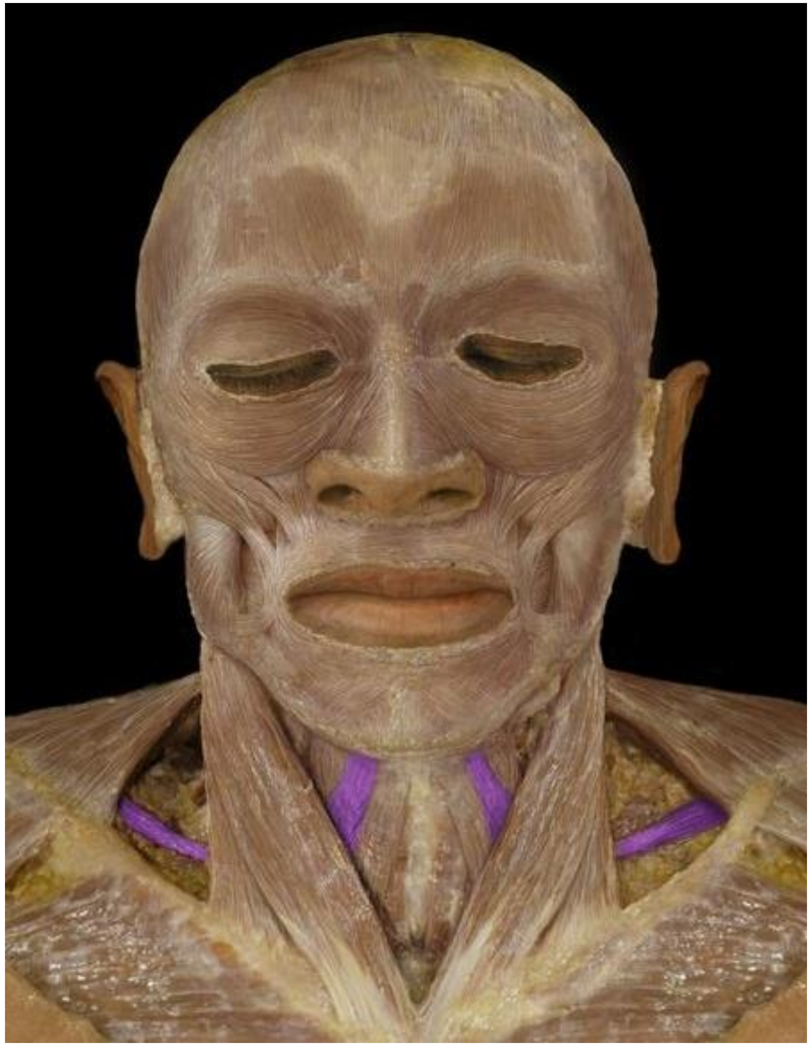
Figure 10.10a

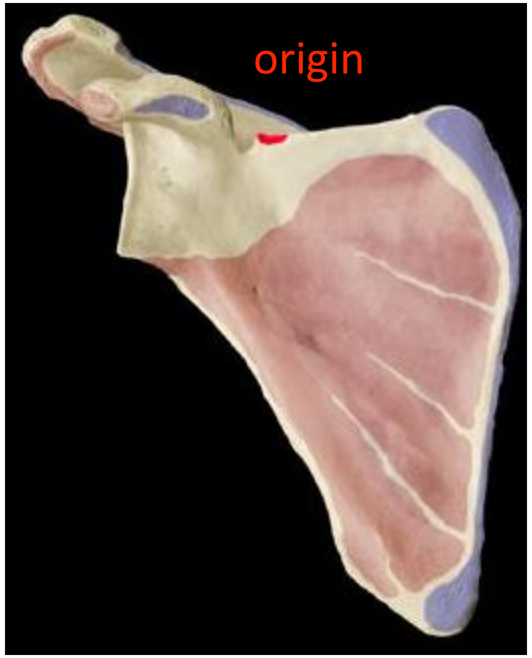
Infrahyoid Group - Omohyoid

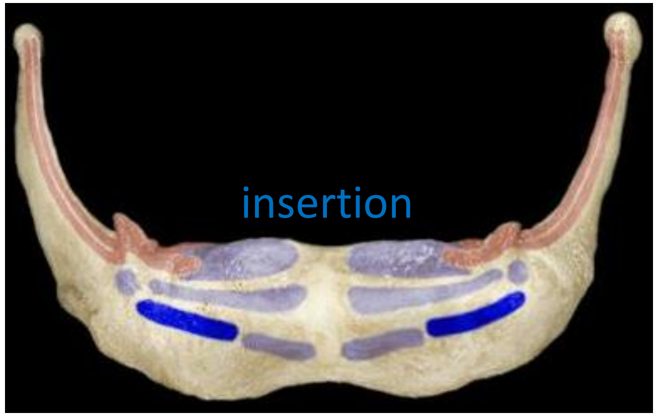




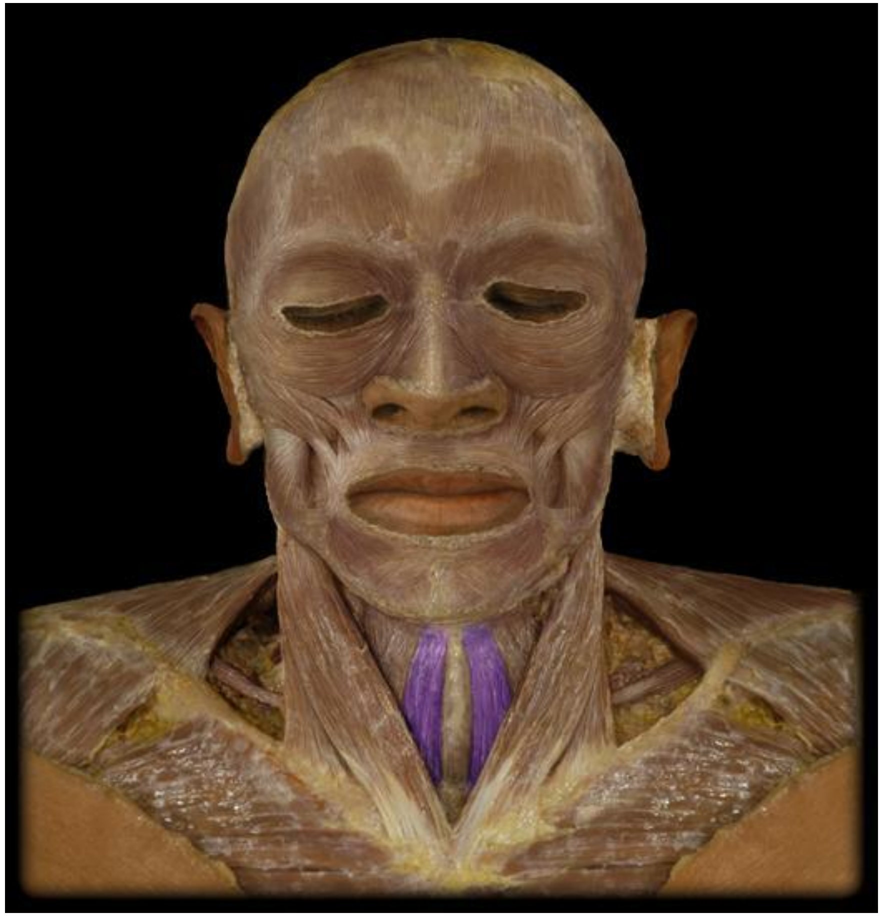
Infrahyoid Group - Omohyoid



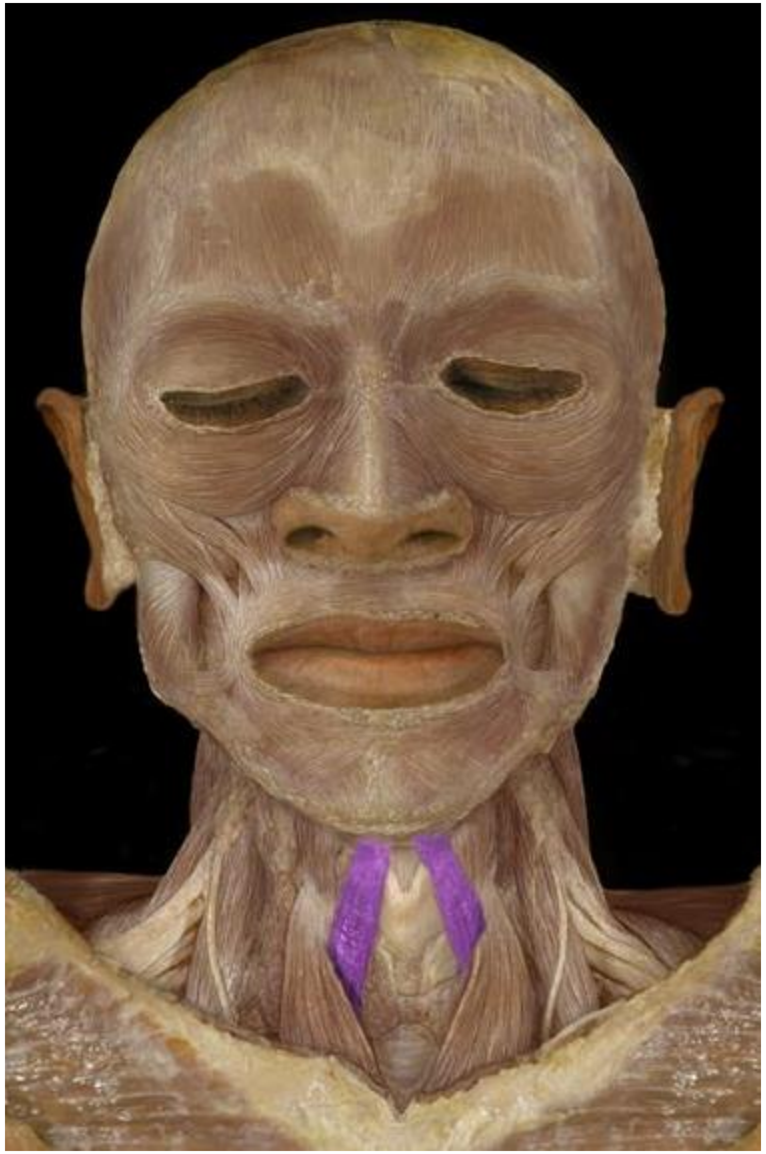


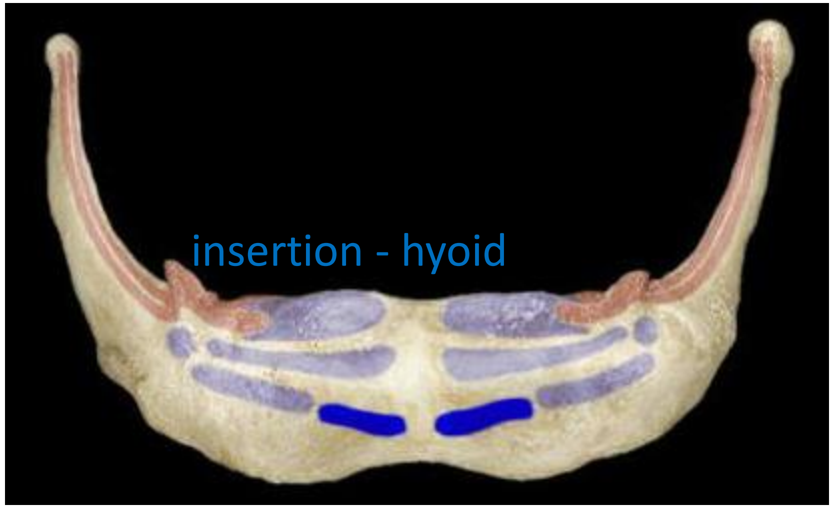


Infrahyoid Group - Sternohyoid

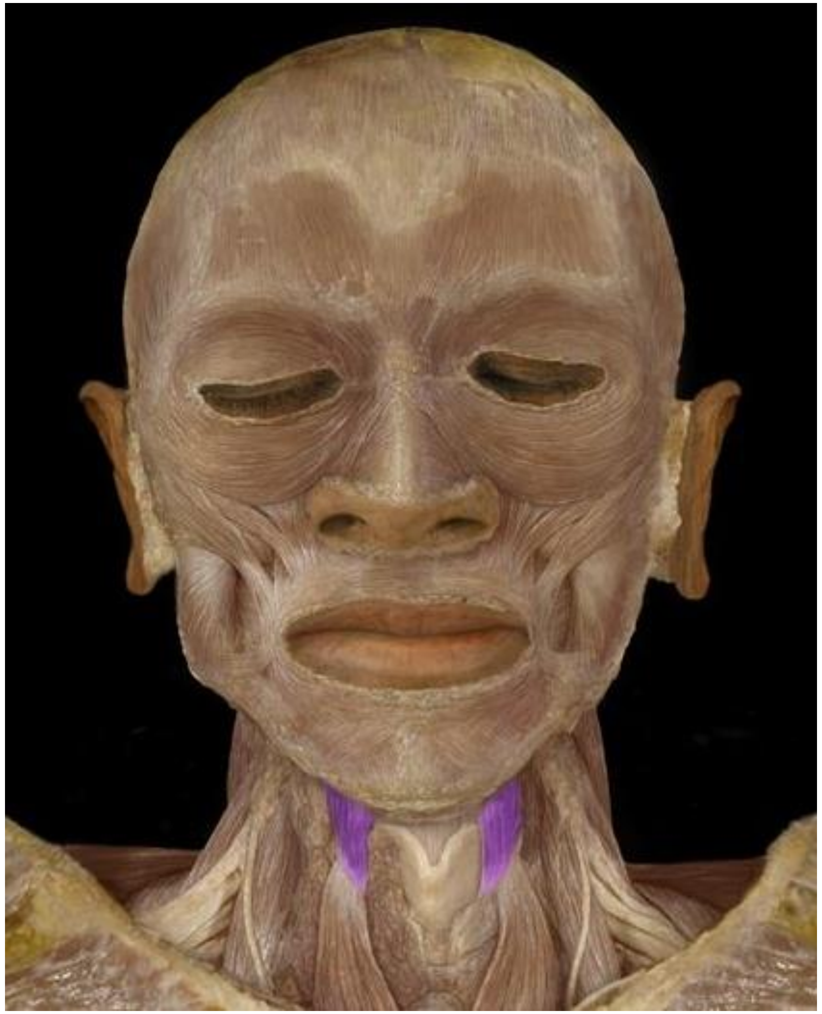


Infrahyoid Group - Sternohyoid





Infrahyoid Group -Thyrohyoid



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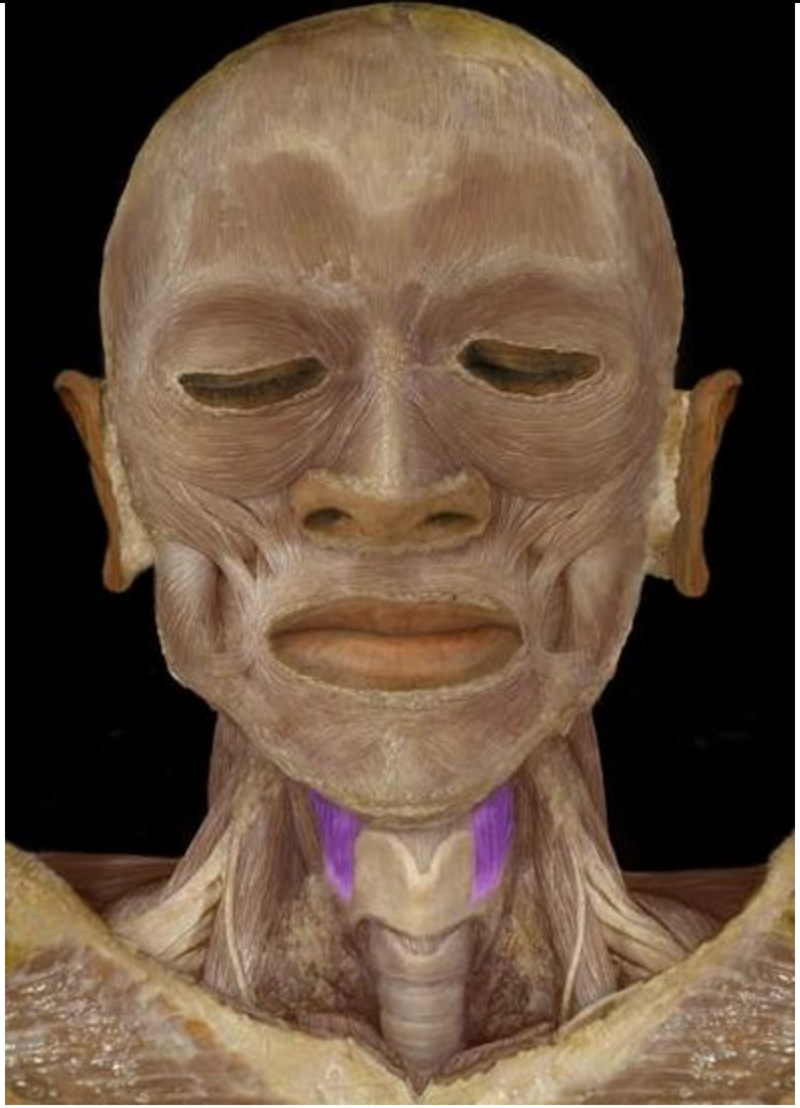

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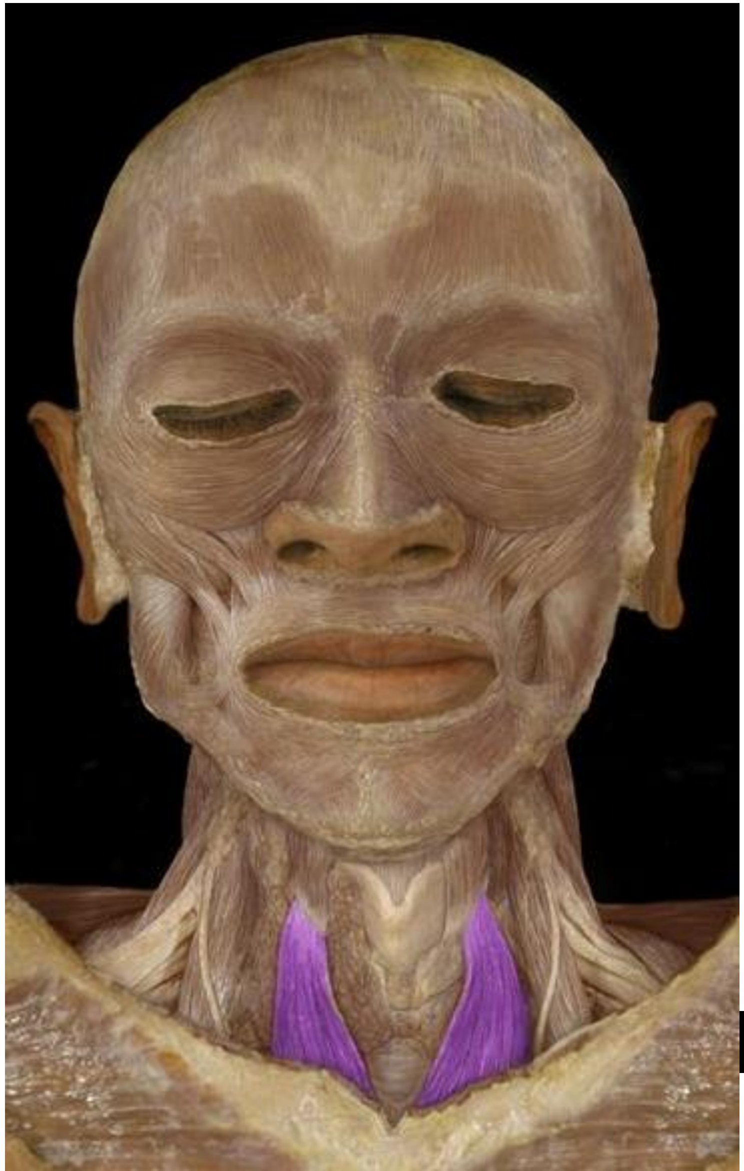

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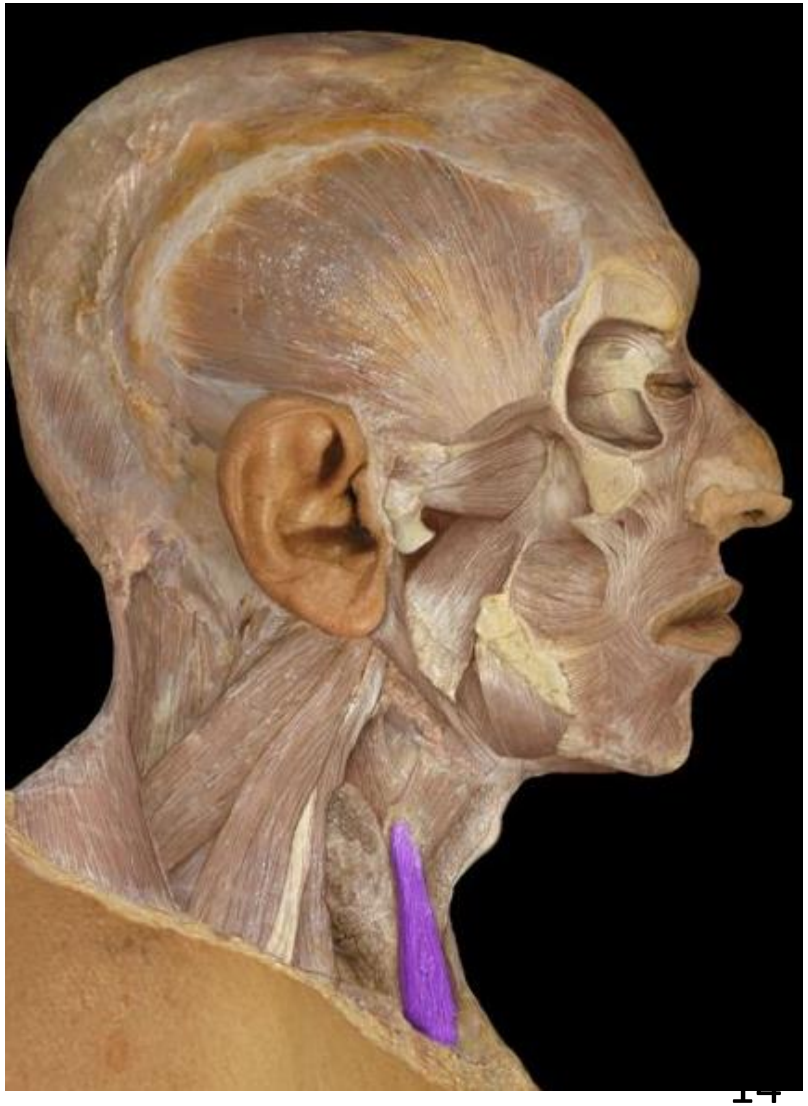

Muscles of Pharynx

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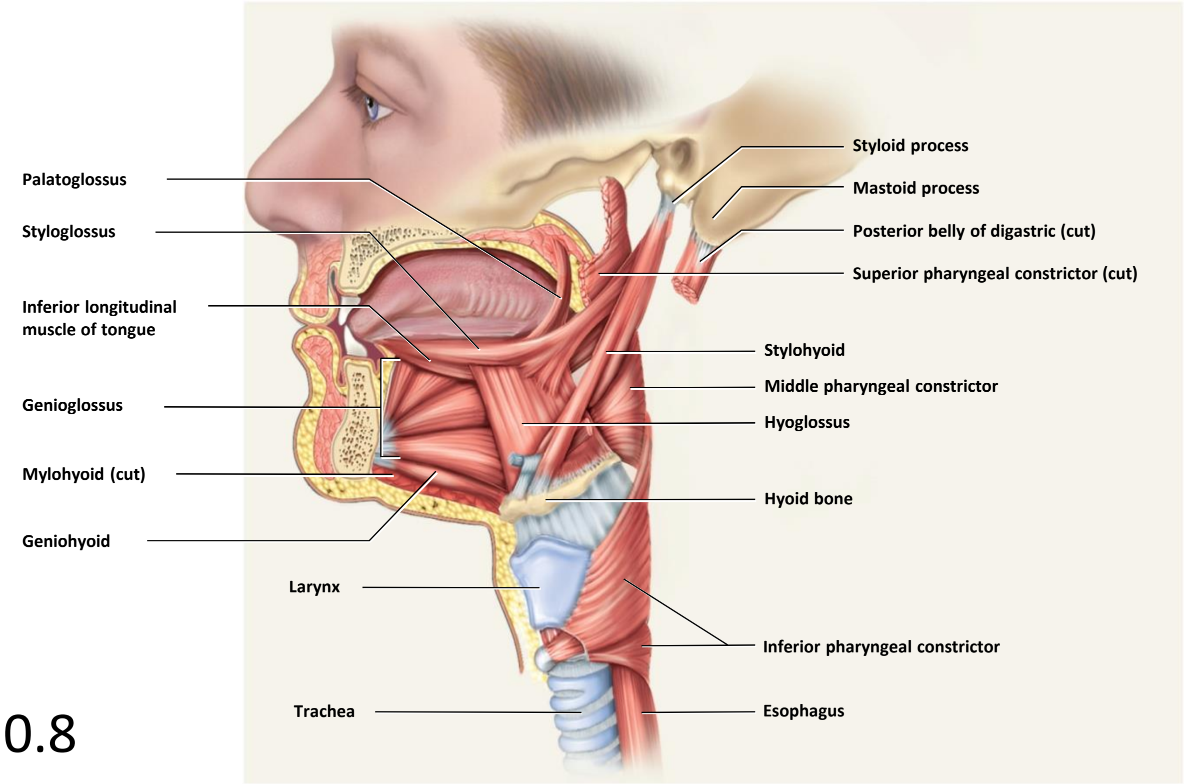
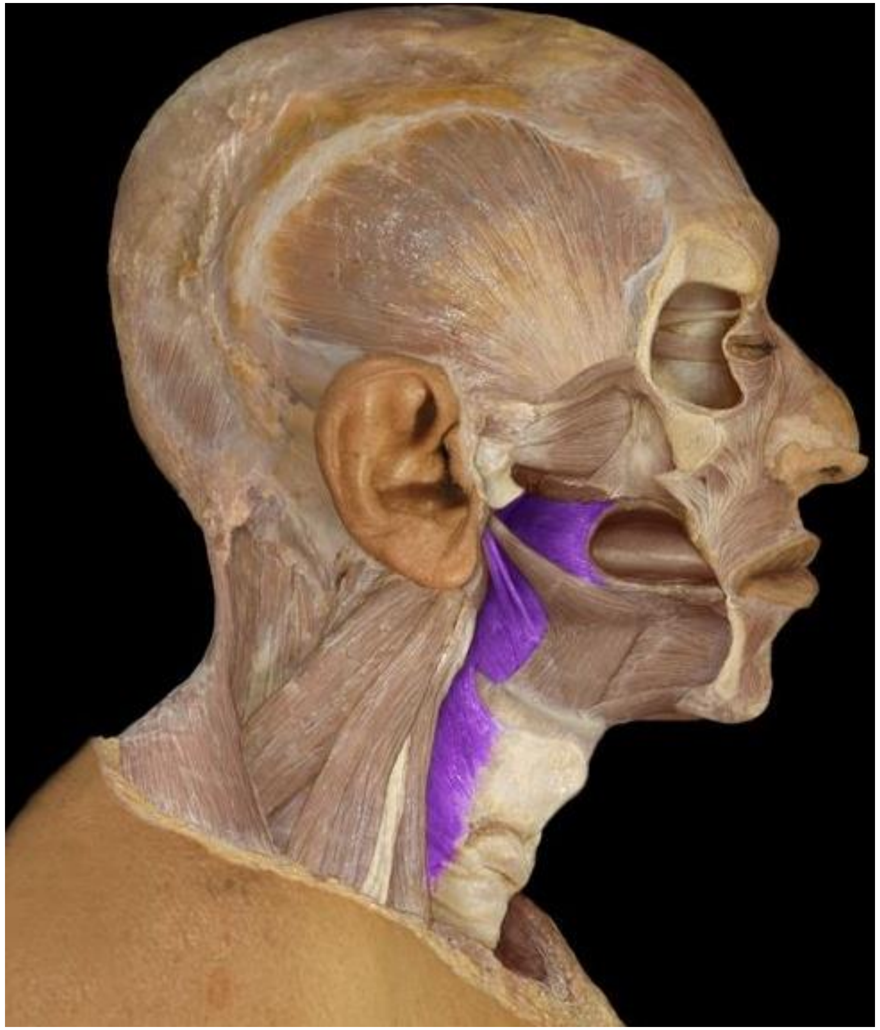
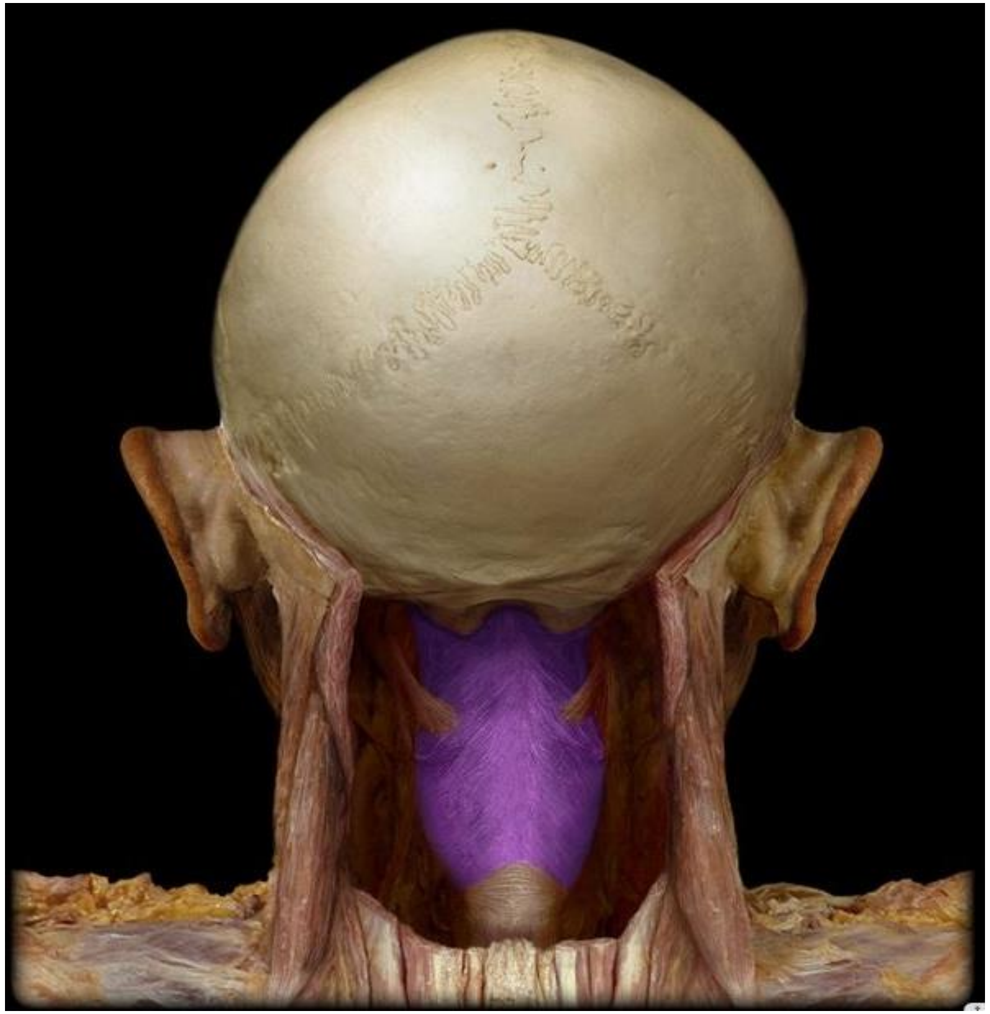


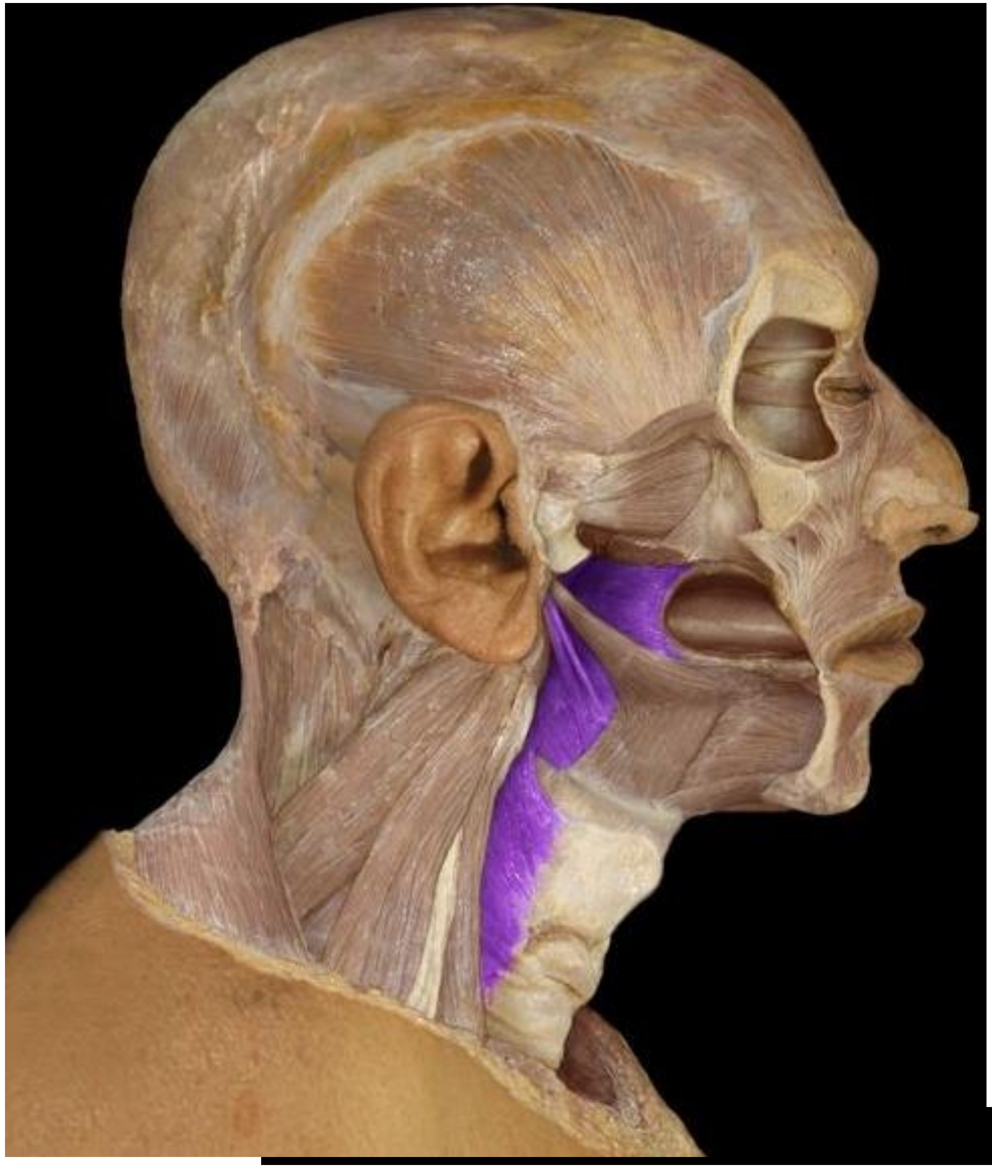
Figure 10.8

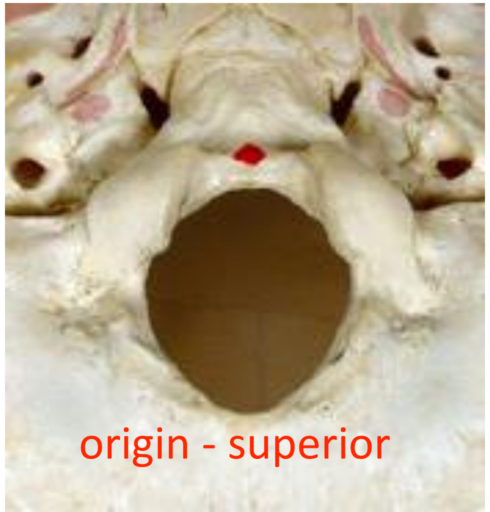
- **three pairs** *pharyngeal constrictors* (**Superior, middle, and inferior**)
  - encircle pharynx forming a muscular funnel
  - during swallowing drive food into the esophagus

Pharyngeal constrictors








origin - superior


origin - middle

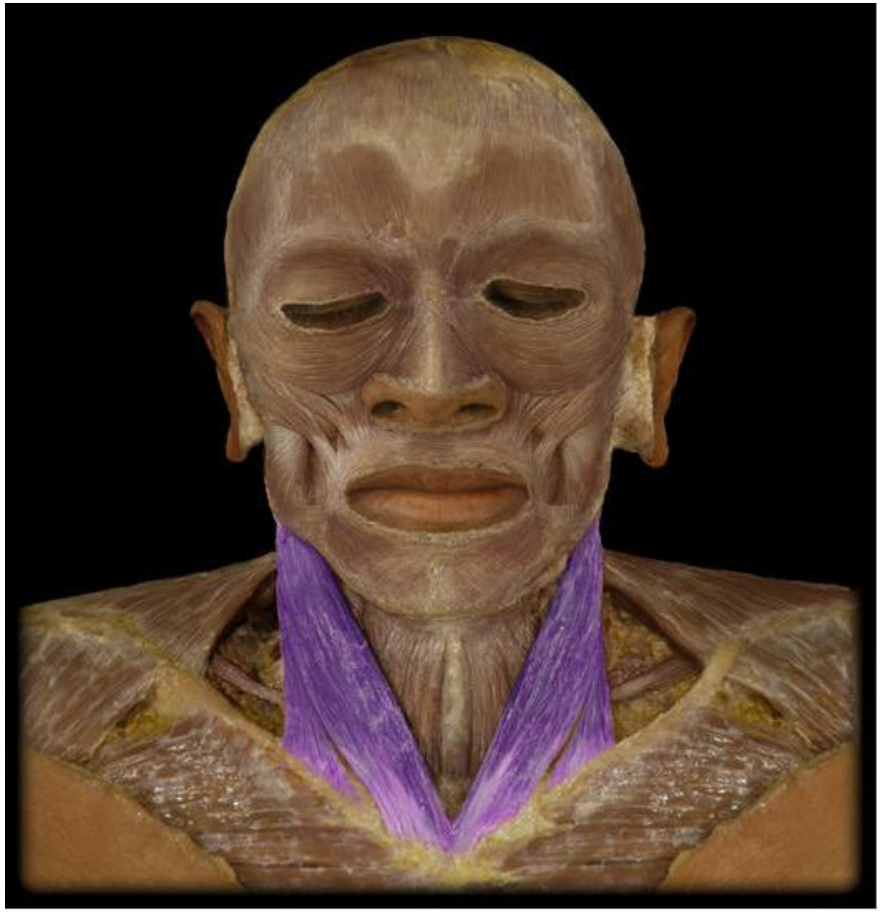
Muscles Acting on the Head

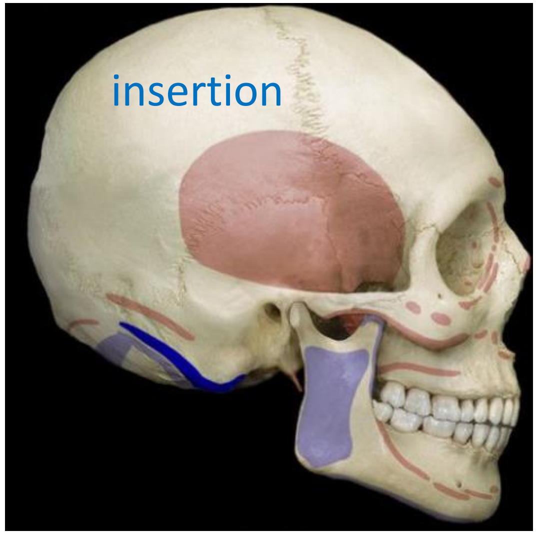
- **originate** on the vertebral column, thoracic cage, and pectoral girdle
- **insert** on the cranial bones
- **actions**
  - **flexion** (tipping head forward)
  - **extension** (holding the head erect)
  - **lateral flexion** (tipping head to one side)
  - **rotation** (turning the head to the left and right)
- may cause **contralateral** movement – movement of the head toward the opposite side
- may cause **ipsilateral** movement – movement of the head toward the same side

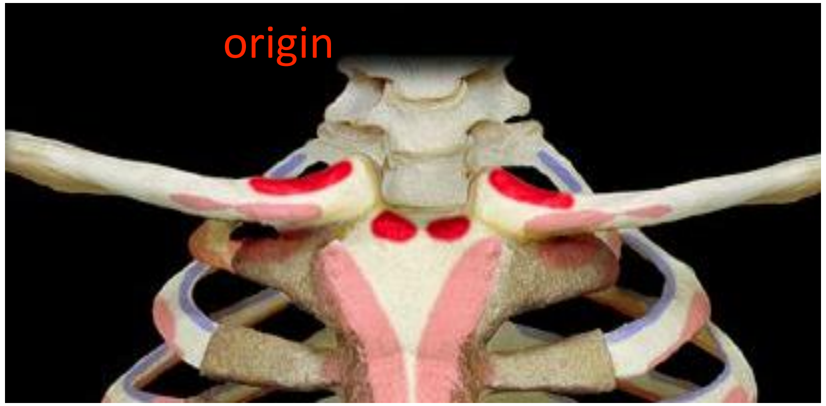
Muscles Acting on the Head

- neck **flexors**
  - *sternocleidomastoid(**sterno = chest, sternum; cleido = hammer, clavicle; masto = breastlike, mastoid process**)*
  - *scalenes(***scal = staircase***)*
- neck **extensors**
  - *trapezius (***trapez = table, trapezoid***)*
  - *splenius capitis (***splenius = bandage; capitis = of the head***) and and splenius cervicis (***cervicis = of the neck***)*
  - *semispinalis capitis(***semi-half ,partly***) and semispinalis cervicis*

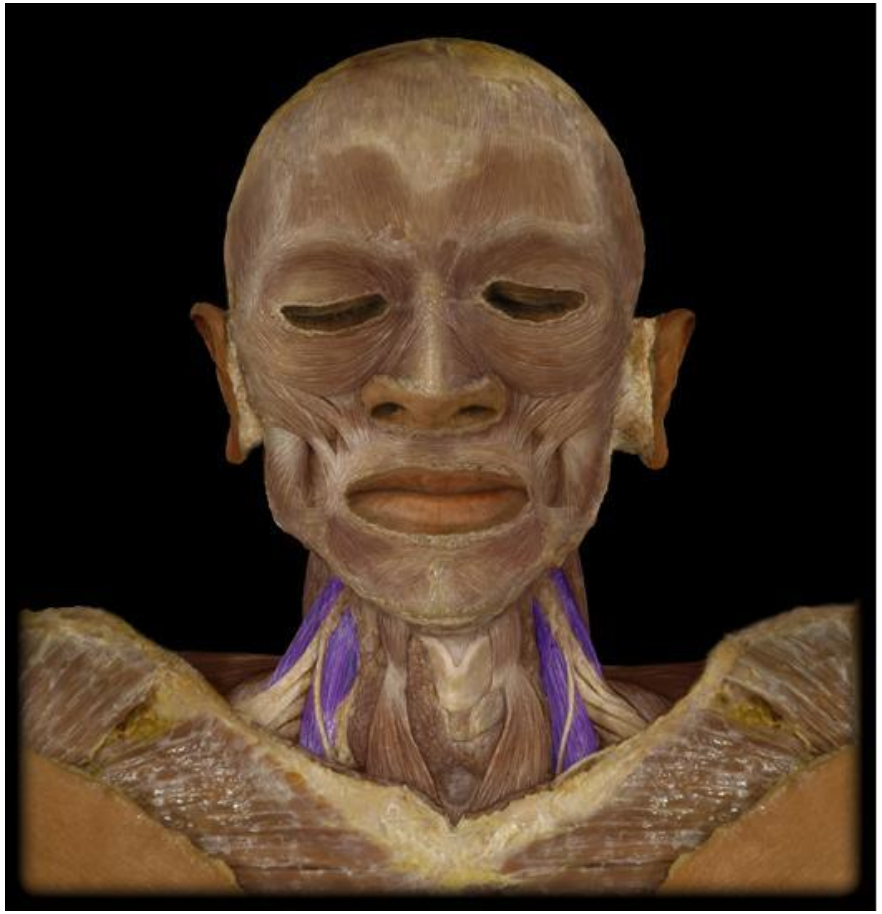
Neck Flexor - Sternocleidomastoid

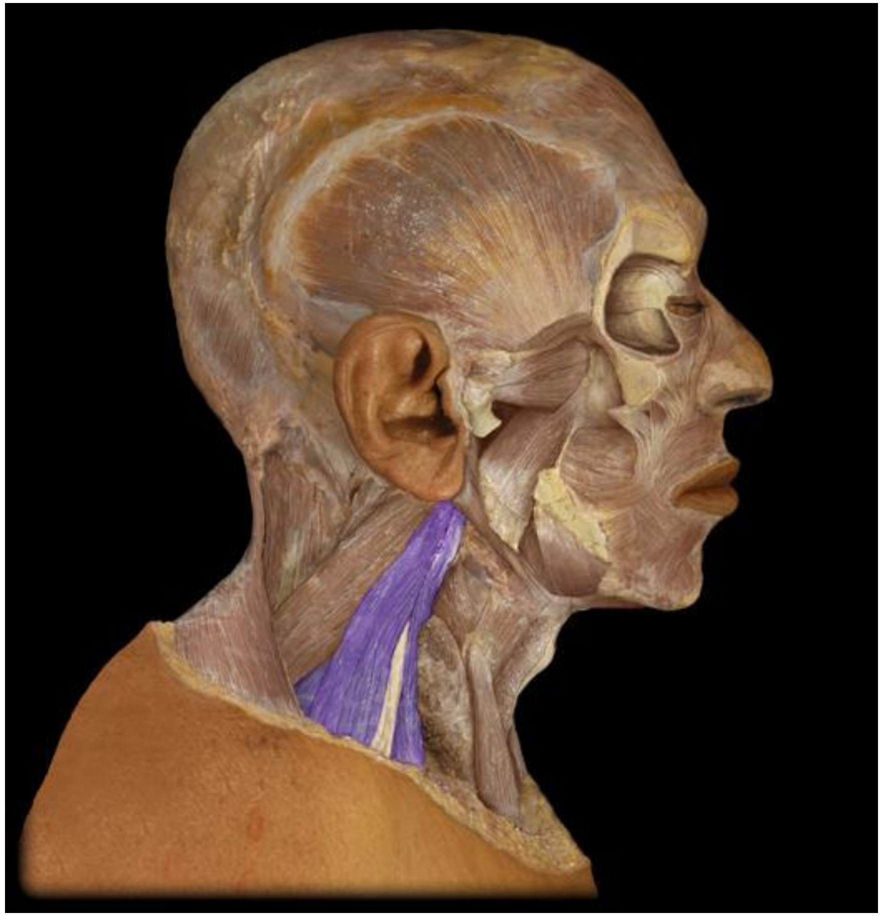



insertion

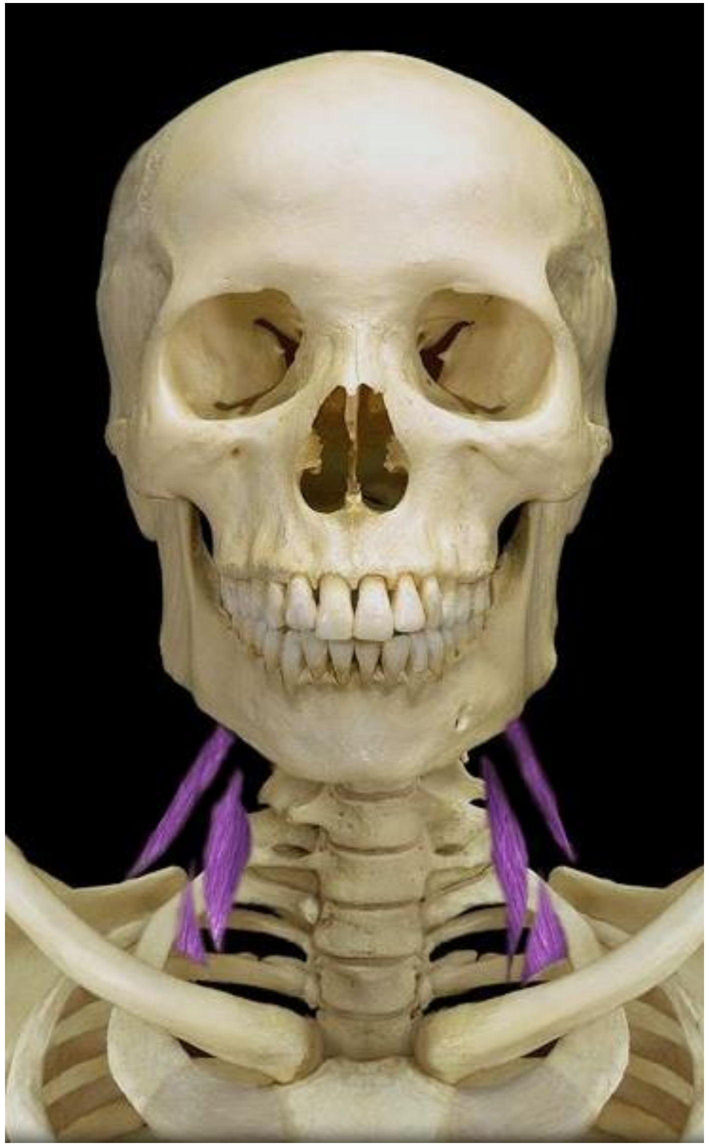

origin

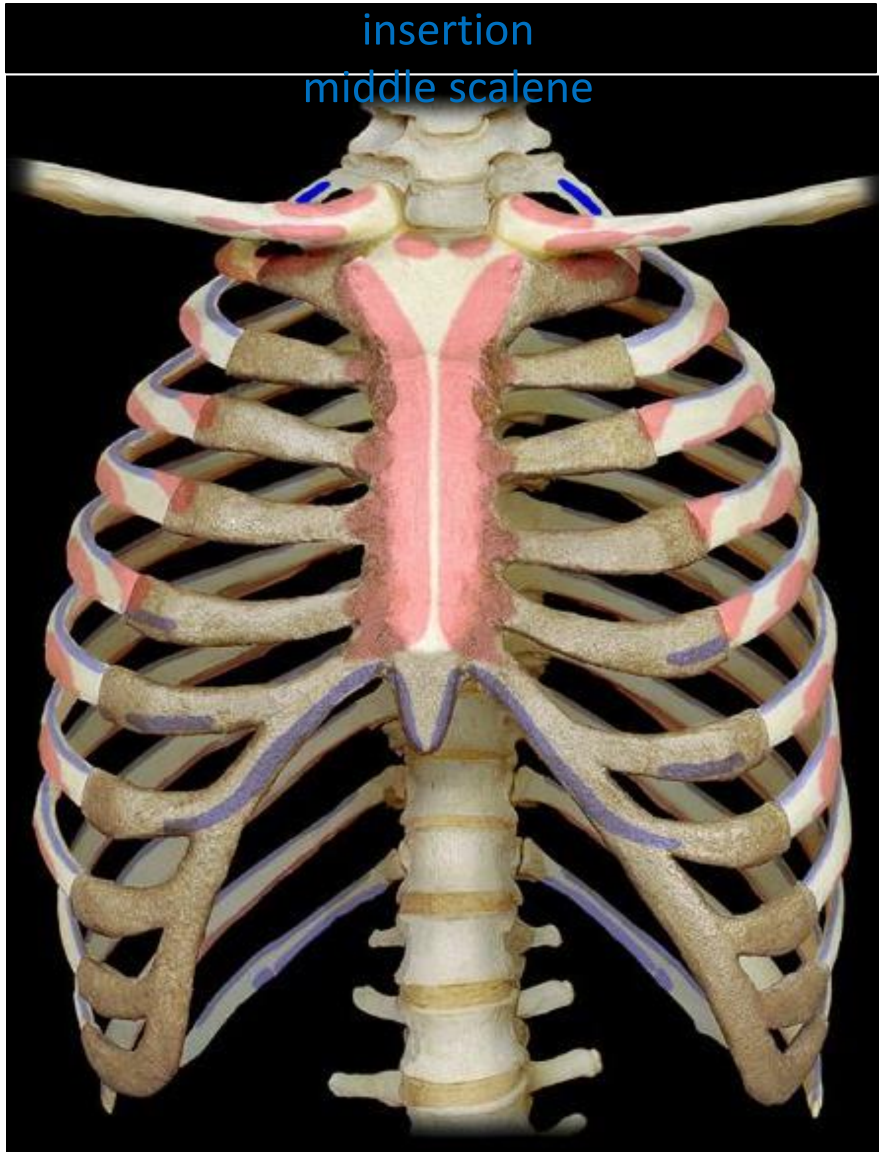
Neck Flexor – Scalenes (3)





Neck Flexor – Scalenes (3)





Triangles of the Neck

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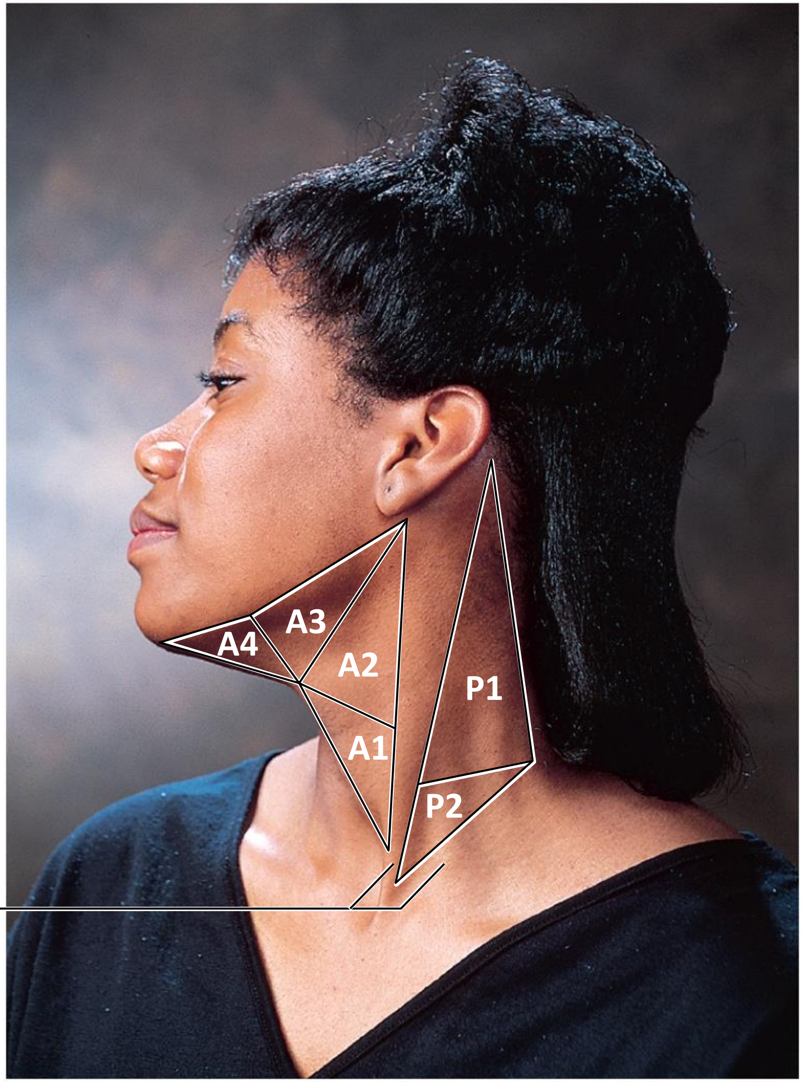
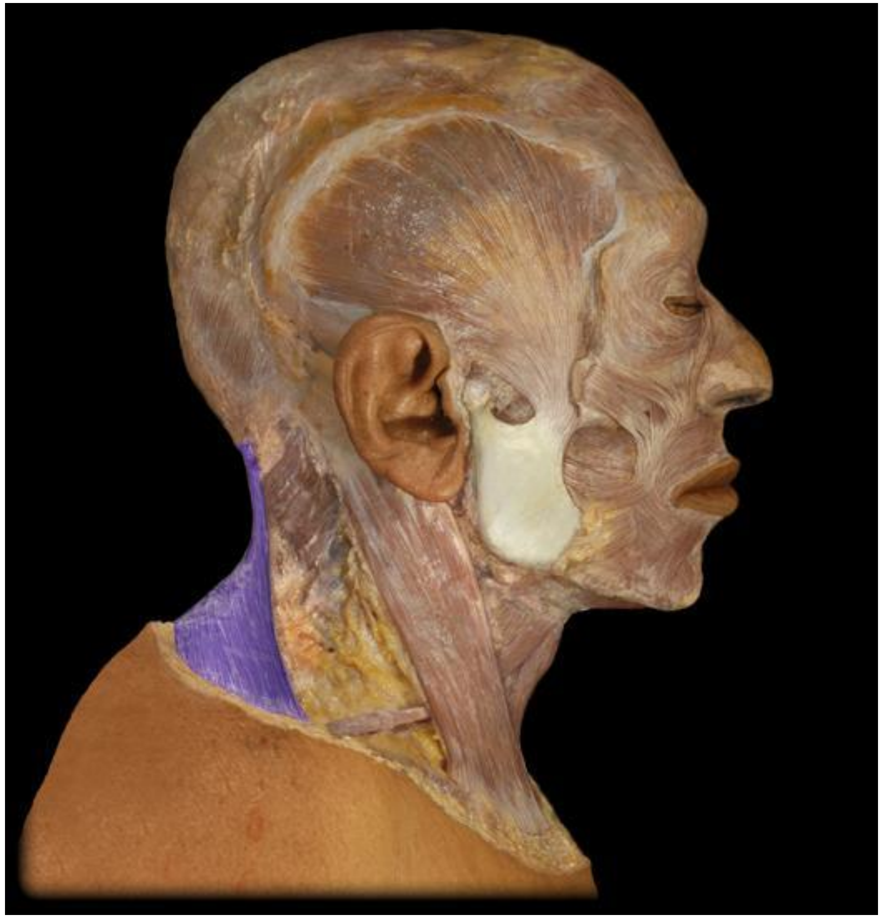
Anterior triangles
A1. Muscular
A2. Carotid
A3. Submandibular
A4. Suprahyoid

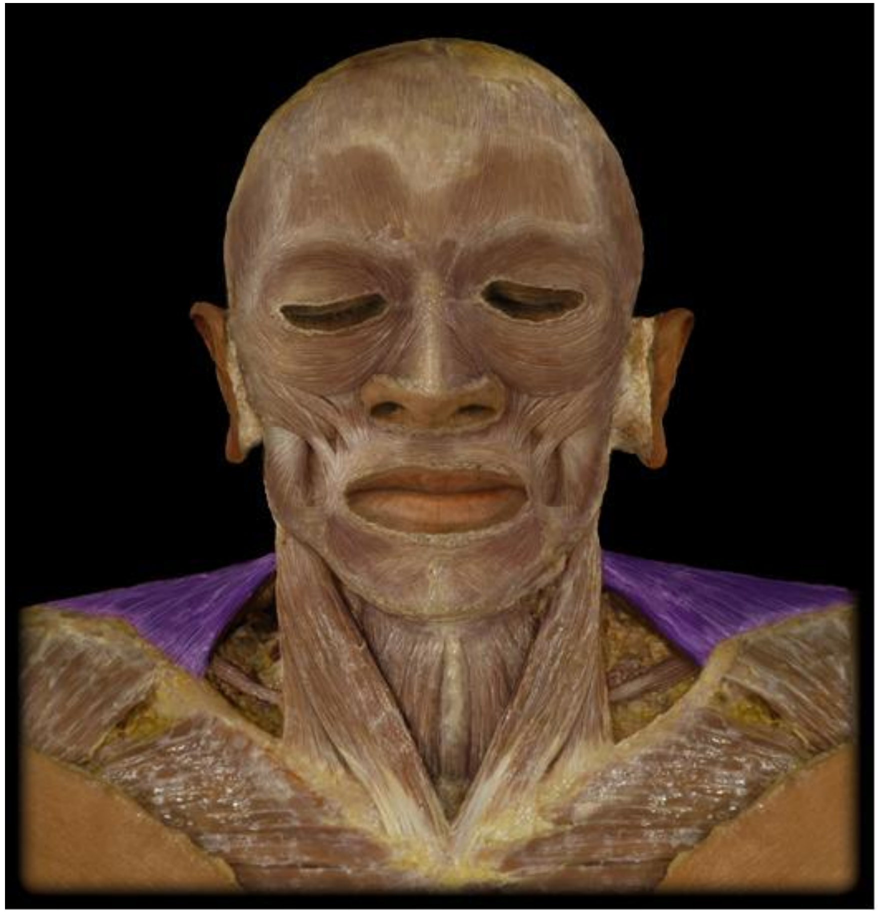
Posterior triangles
P1. Occipital
P2. Omoclavicular

Sternocleidomastoid

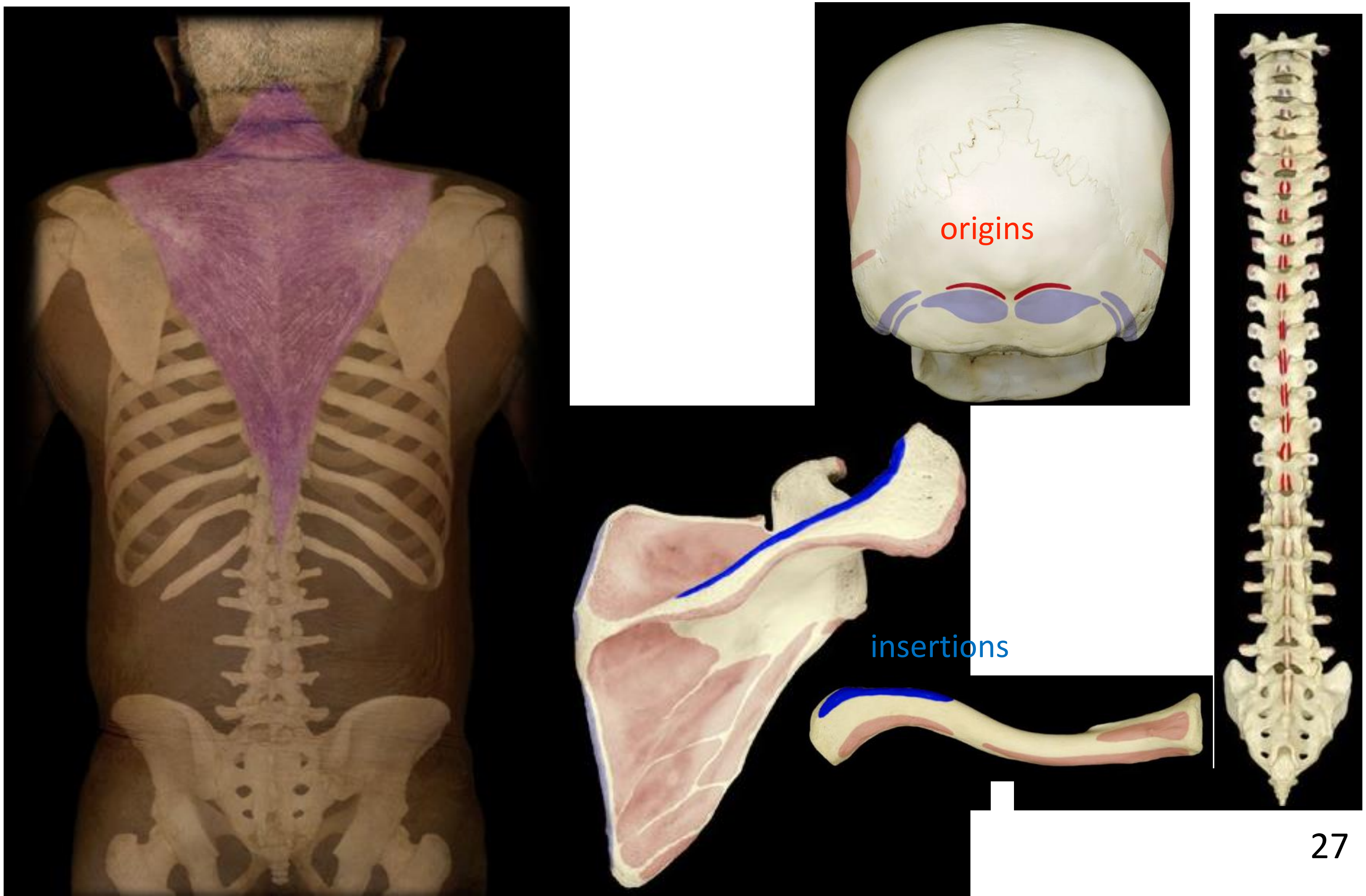


Neck Extensor - Trapezius

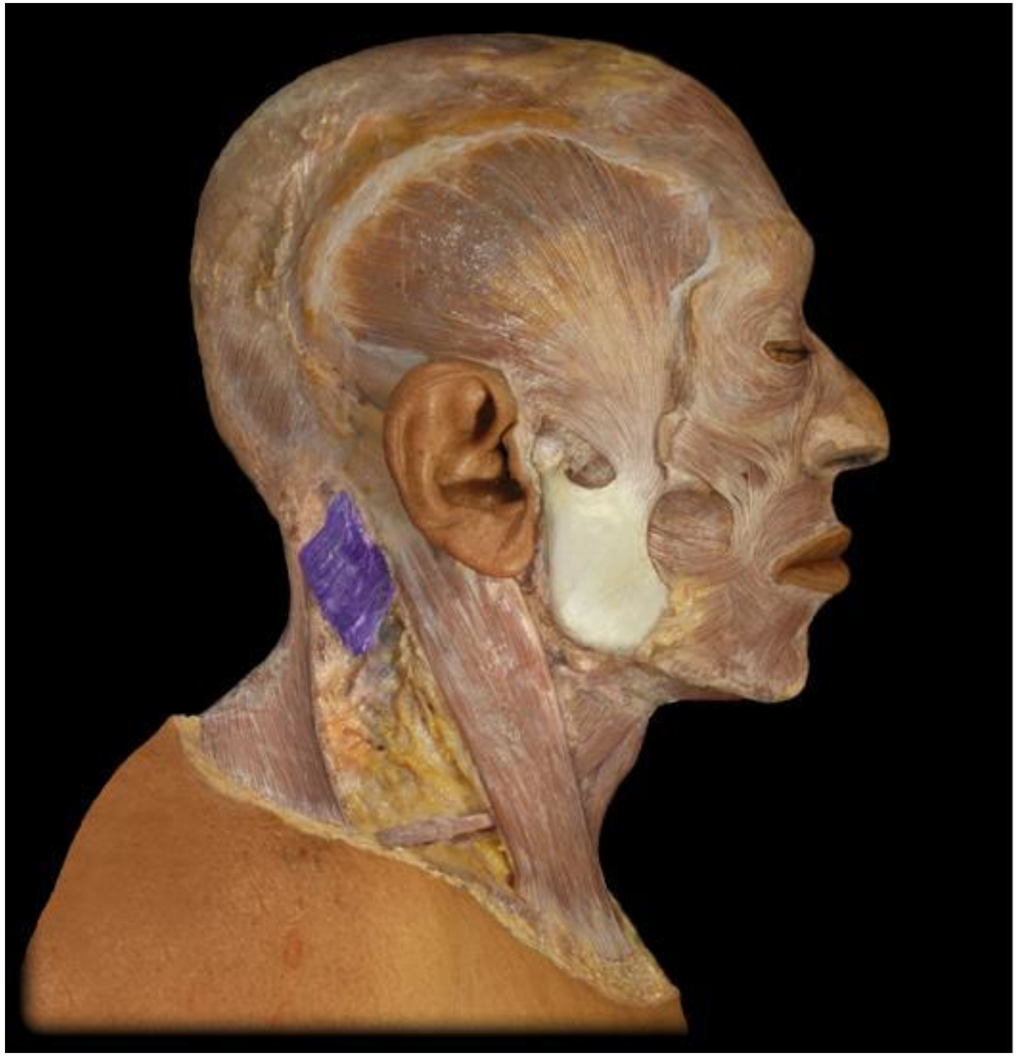


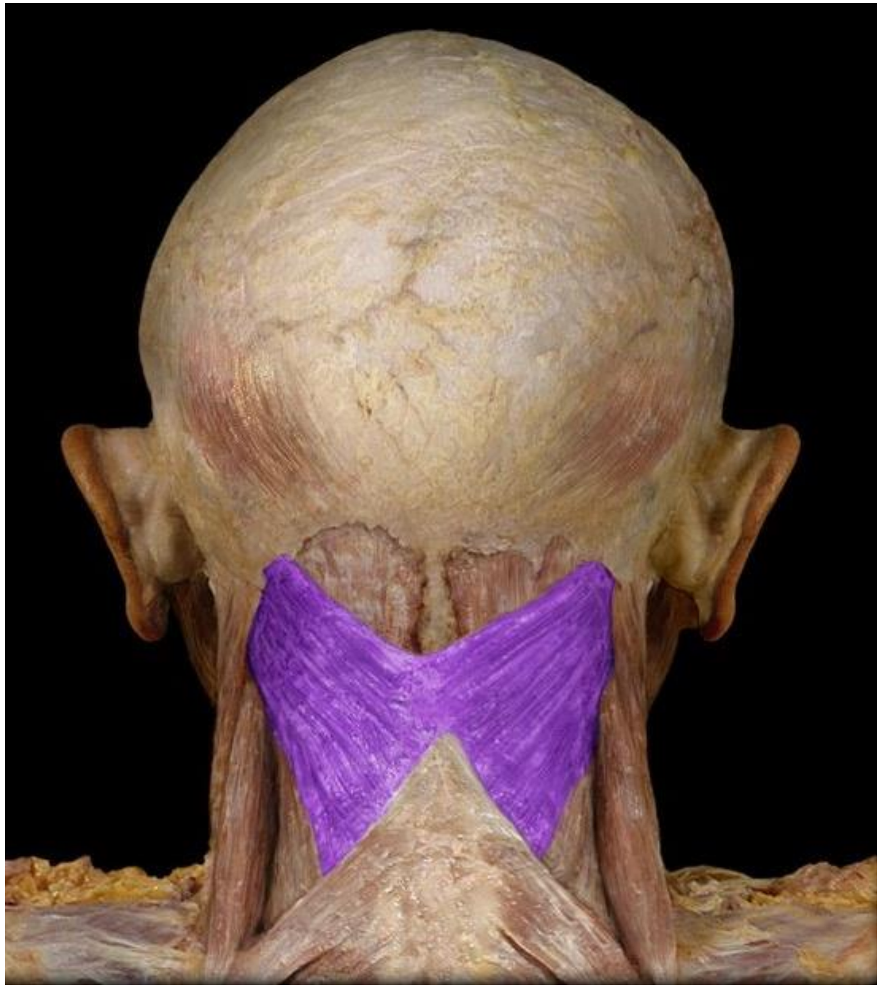


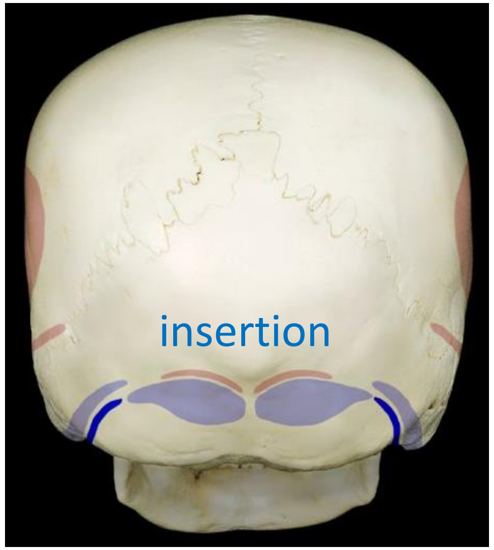
Neck Extensor - Trapezius


origins
insertions

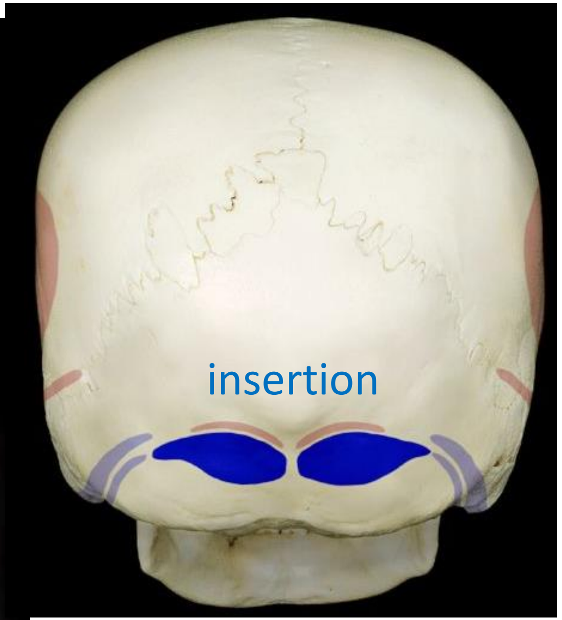
Neck Extensor – Splenius capitis





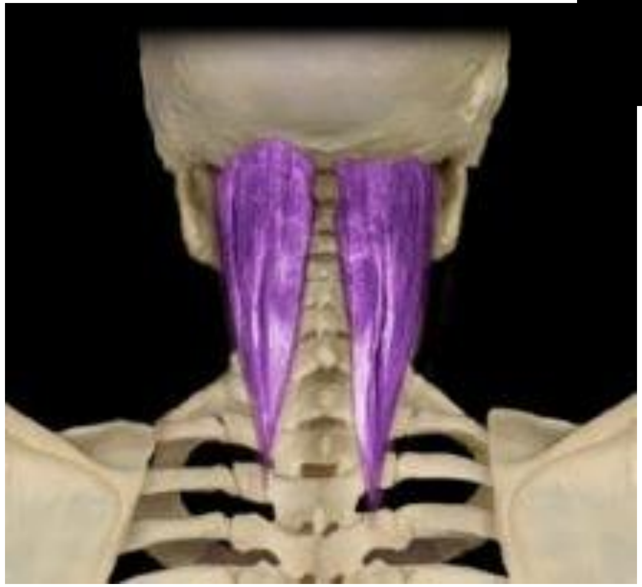

insertion

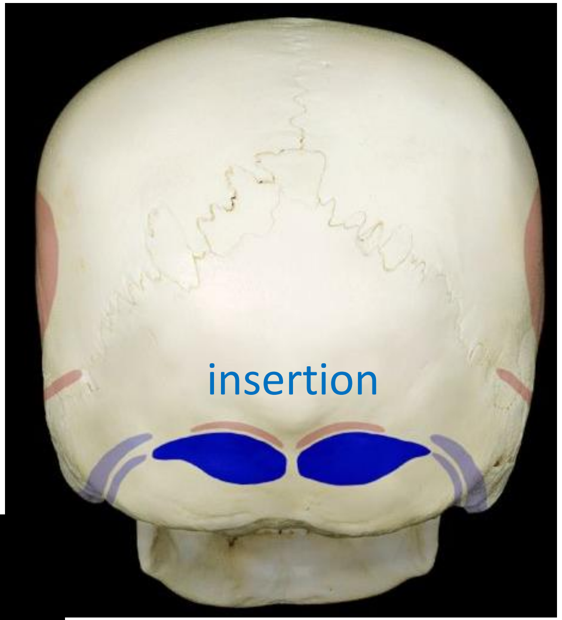

origin



origin

Neck Extensor – Semispinalis capitis





Muscles Acting on Arm

- nine muscles cross the shoulder joint and insert on humerus
- two are **axial muscles** because they originate on axial skeleton
  - *pectoralis major* – flexes, adducts, and medially rotates humerus
  - *latissimus dorsi* – adducts and medially rotated humerus

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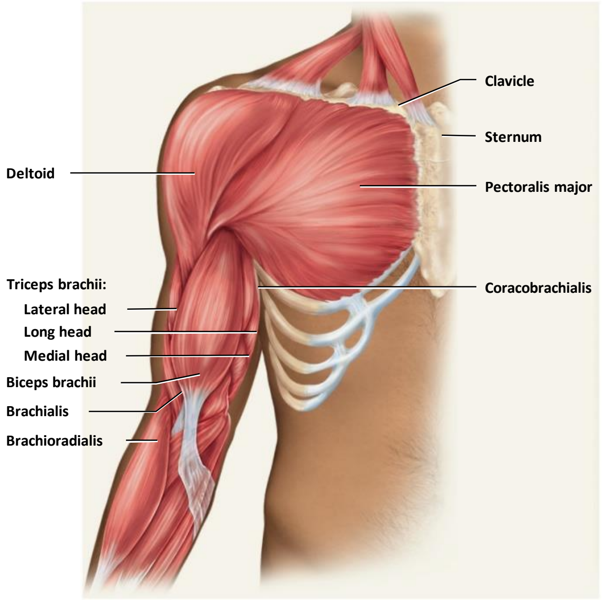

(a) Anterior view

Figure 10.24a

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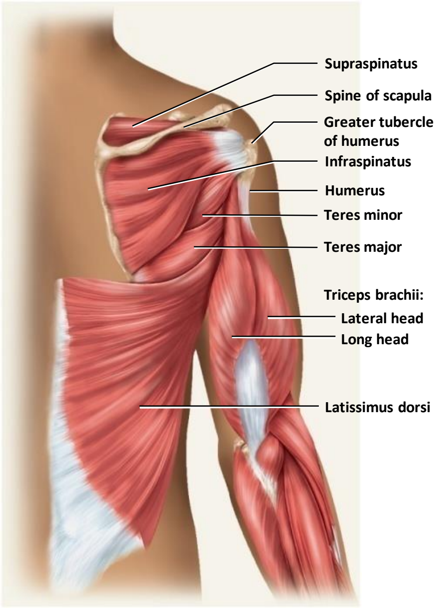

(b) Posterior view

Figure 10.24b

Muscles Acting on Arm

- seven **scapular muscles**
- **originate on scapula**
  - *deltoid*
    - rotates and abducts arm
    - intramuscular injection site
  - *teres major*
    - extension and medial rotation of humerus
  - *coracobrachialis*
    - flexes and medially rotates arm
  - **remaining four** form the rotator cuff that reinforce the shoulder joint

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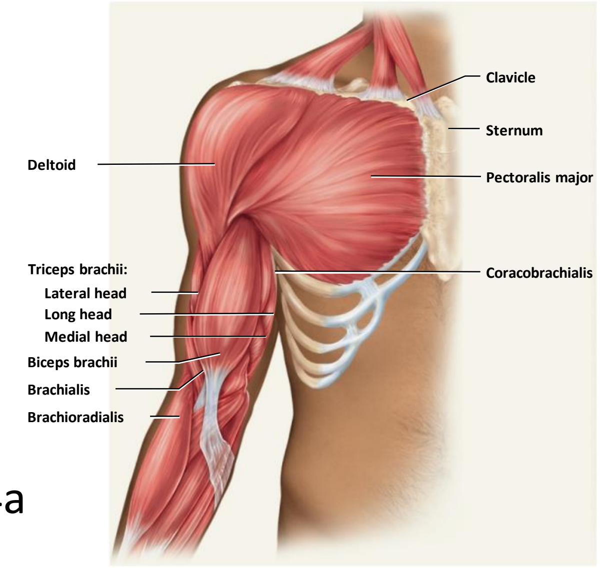

(a) Anterior view

Figure 10.24a

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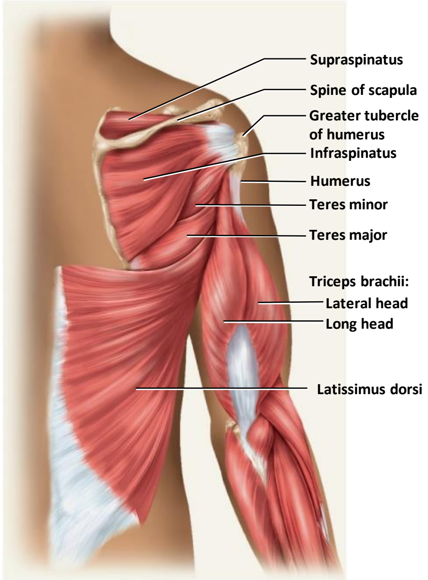


(b) Posterior view

Figure 10.24b

Rotator Cuff Muscles

- tendons of the remaining four scapular muscles form the **rotator cuff**

- **"SITS" muscles** – for the first letter of their names
  - ***supraspinatus* 【*supra = above; spin = spine of scapula* 】**
  - ***infraspinatus* 【*infra = below, under; spin = spine of scapula* 】**
  - ***teres minor***
  - ***subscapularis* 【*sub = below, under* 】**
- tendons of these muscles merge with the joint capsule of the shoulder as they cross it in route to the humerus

- holds head of humerus into glenoid cavity

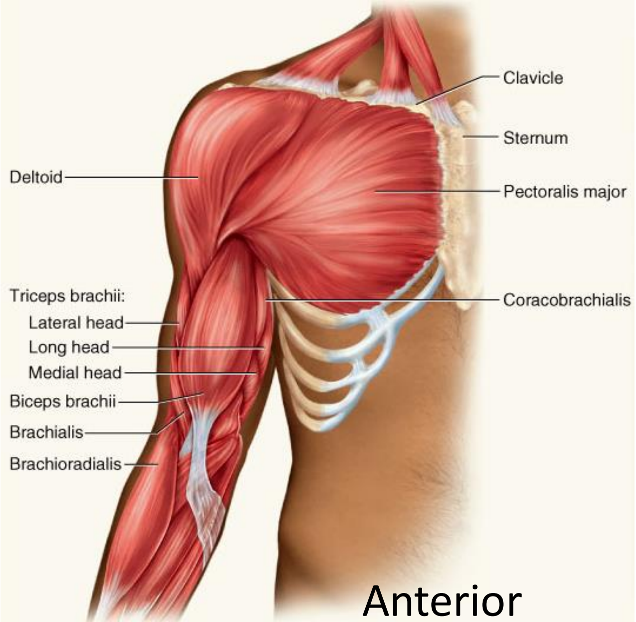
- supraspinatus tendon most easily damaged

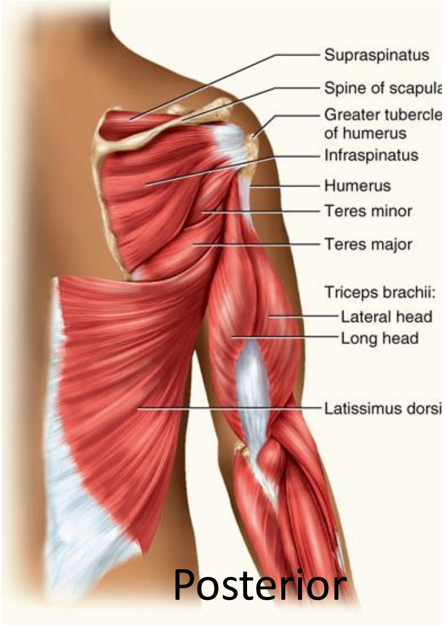
Rotator Cuff Muscles

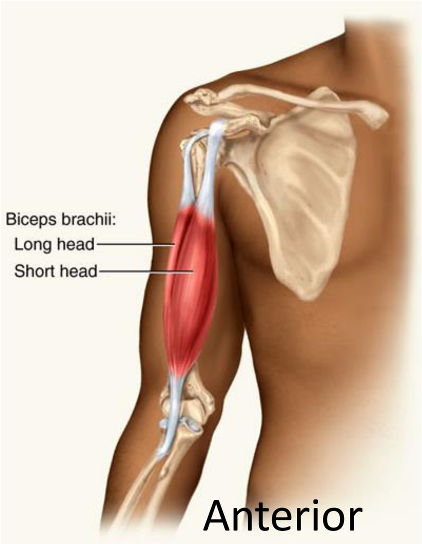
- **The rotator cuff** is a group of muscles and tendons that surround the shoulder joint, keeping the head of your upper arm bone firmly within the shallow socket of the shoulder. A rotator cuff injury can cause a dull ache in the shoulder, which often worsens when you try to sleep on the involved side.
- The tendons of these muscles **merge with the joint capsule of the shoulder as they cross it en route to the humerus.** They insert on the proximal end of the humerus, forming a partial sleeve around it. The rotator cuff reinforces the **joint capsule and holds the head of the humerus in the glenoid cavity**. The rotator cuff, especially the supraspinatus tendon, is easily damaged by strenuous circumduction or hard blows to the shoulder.

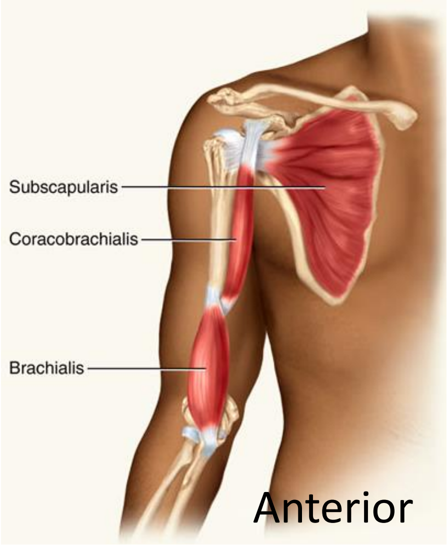
Rotator Cuff Muscles

- Tendons of the remaining four scapular muscles form the **rotator cuff** (fig. 10.25).
- These muscles are nicknamed the “**SITS muscles**” for the first letters of their names—*supraspinatus, infraspinatus, teres minor,* and *subscapularis*.
- The first three muscles lie on the posterior side of the scapula. The supraspinatus and infraspinatus occupy the supraspinous and infraspinous fossae, above and below the scapular spine. The teres minor lies inferior to the infraspinatus. The subscapularis occupies the subscapular fossa on the anterior surface of the scapula, between the scapula and ribs.

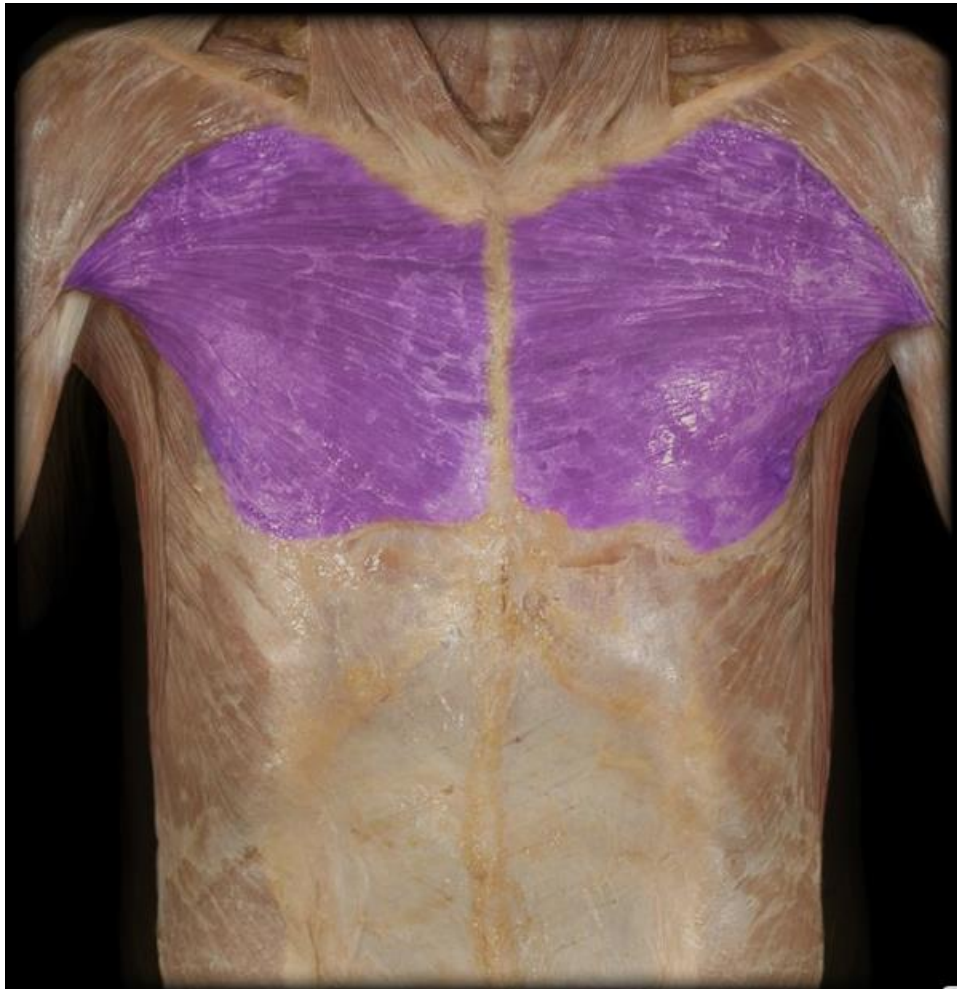

Clavicle
Sternum
Deltoid
Pectoralis major
Triceps brachii:
Lateral head
Long head
Medial head
Biceps brachii
Brachialis
Brachioradialis
Coracobrachialis
Anterior

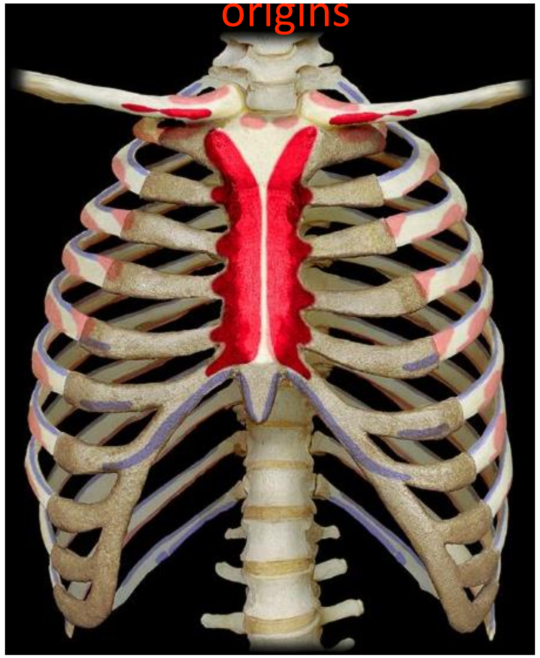

Supraspinatus
Spine of scapula
Greater tubercle of humerus
Infraspinatus
Humerus
Teres minor
Teres major
Triceps brachii:
Lateral head
Long head
Latissimus dorsi
Posterior


Biceps brachii:
Long head
Short head
Anterior


Subscapularis
Coracobrachialis
Brachialis
Anterior

Muscles Acting on Humerus Pectoralis major

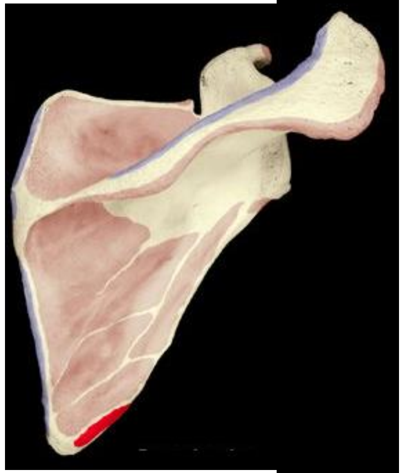



origins


insertion

Muscles Acting on Humerus Latissimus dorsi

insertion



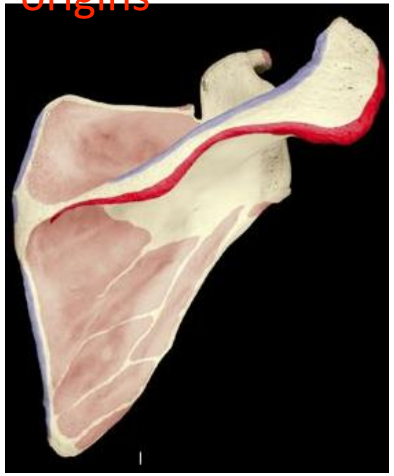
origins

[redacted]

Muscles Acting on Humerus
Deltoid

insertion

origins

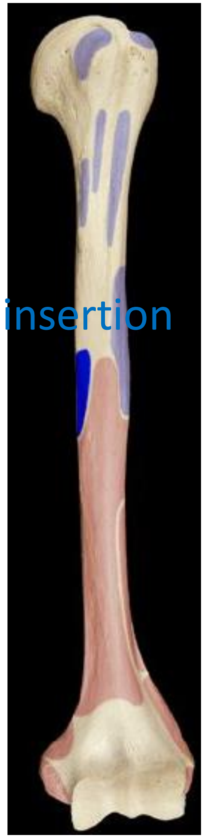


Muscles Acting on Humerus
Teres major

insertion

origin


origin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Back Muscles of Cadaver

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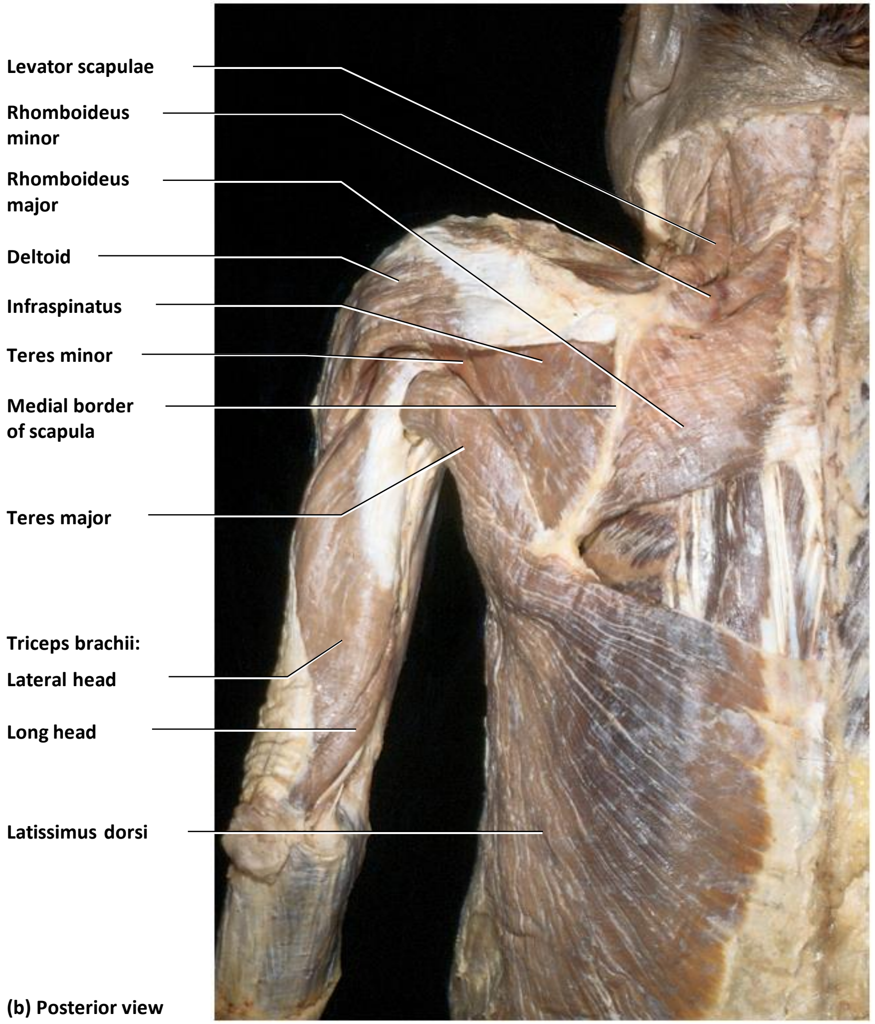

Figure 10.25b

Rotator Cuff Muscles

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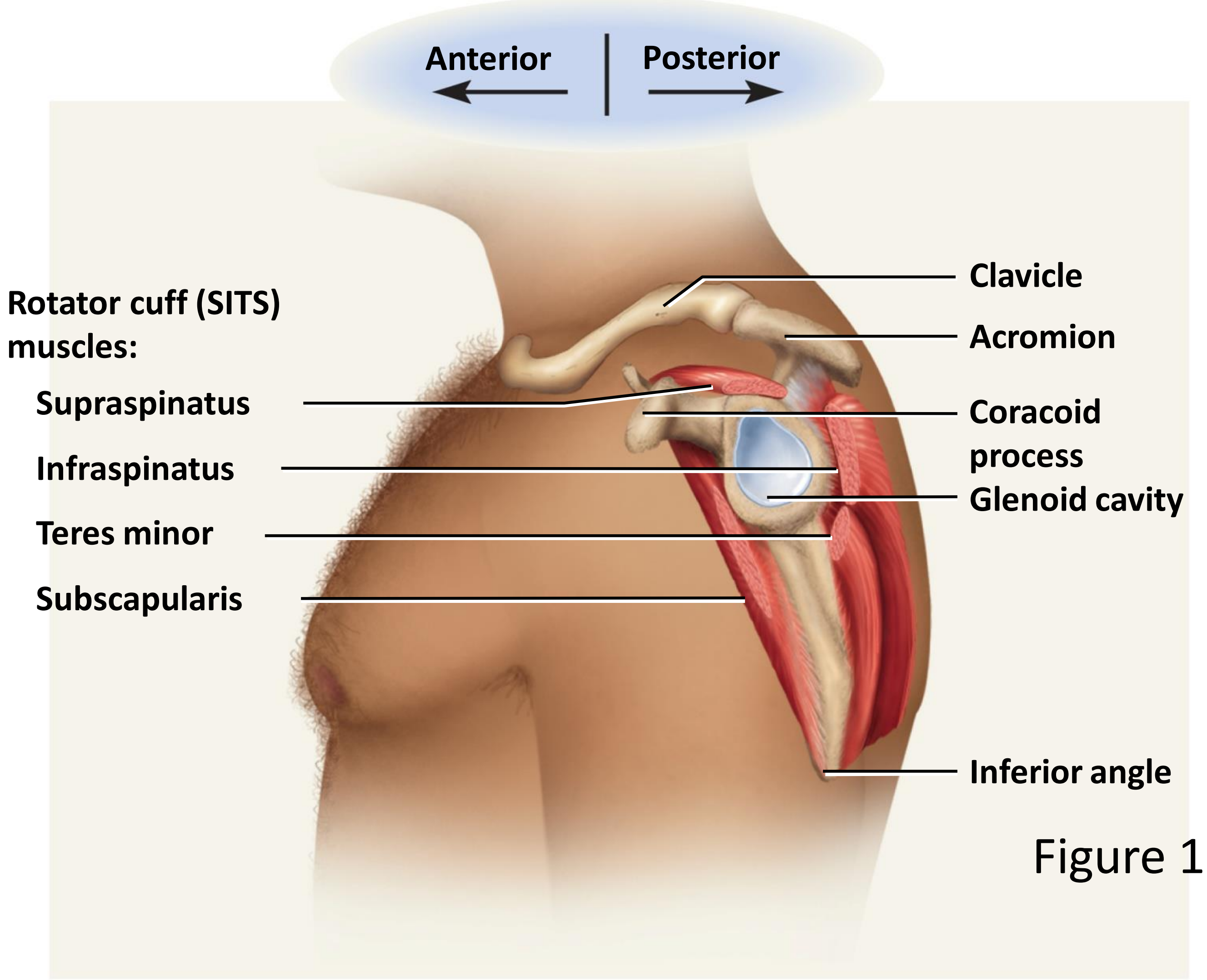
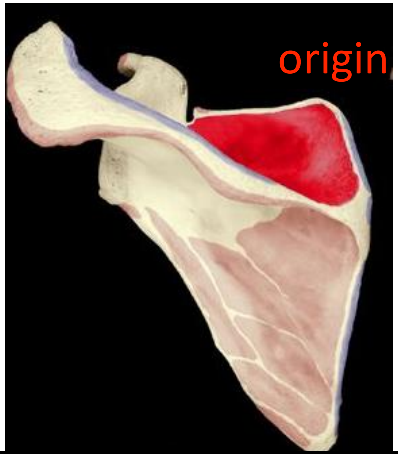
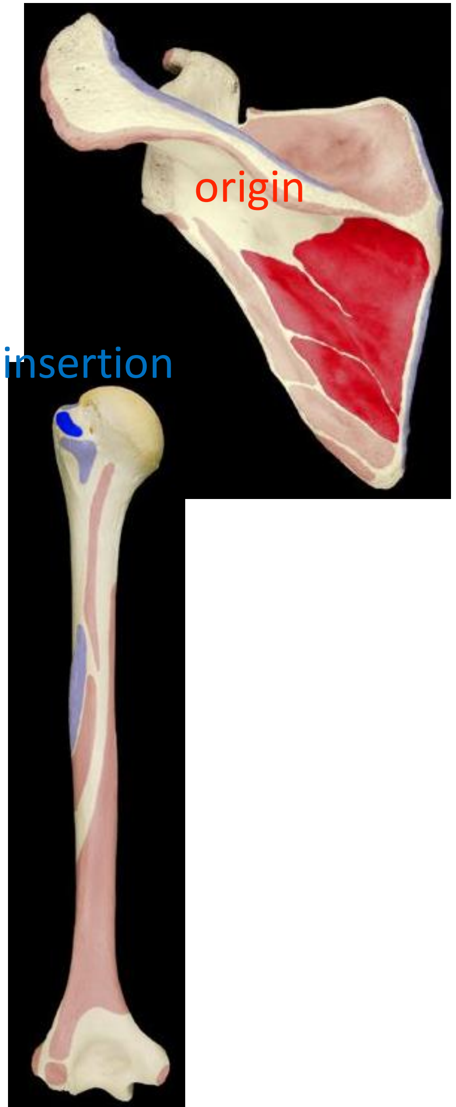


Figure 10.26

insertion

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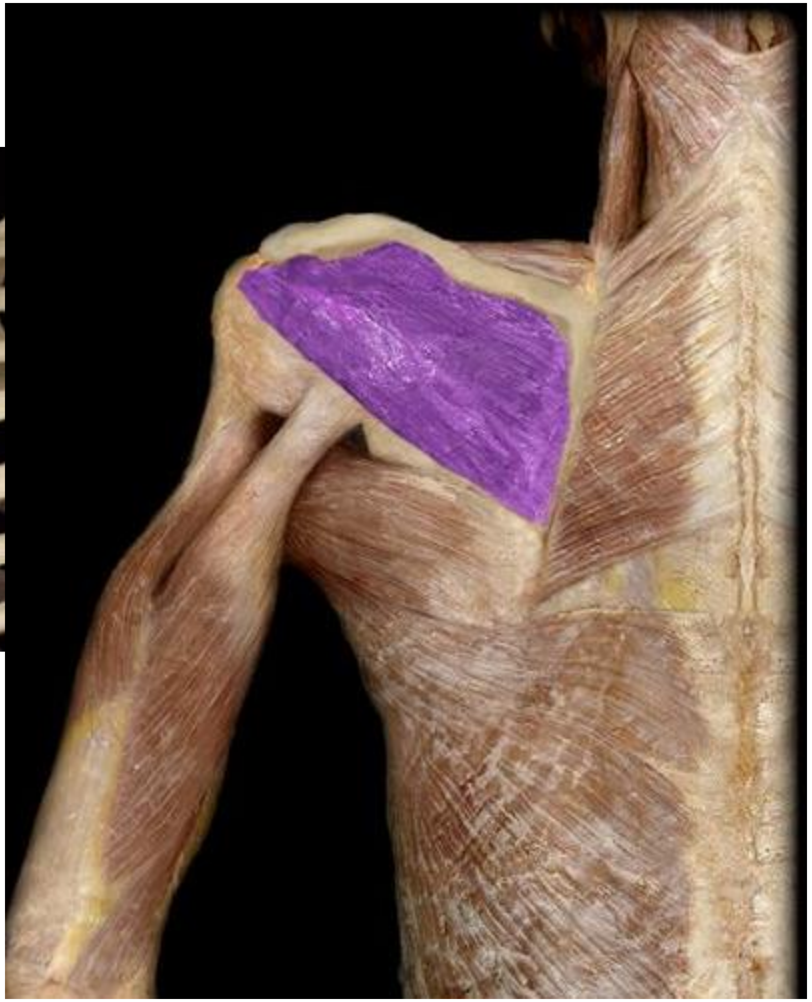
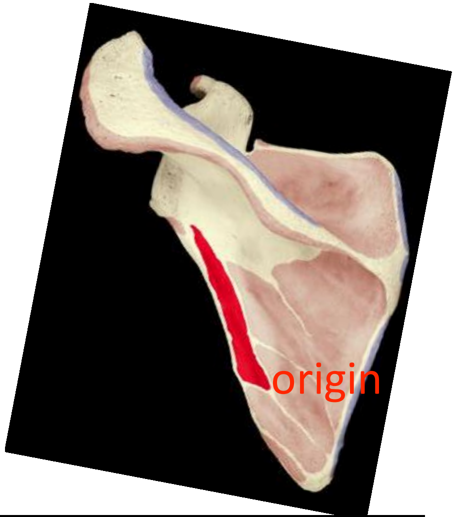
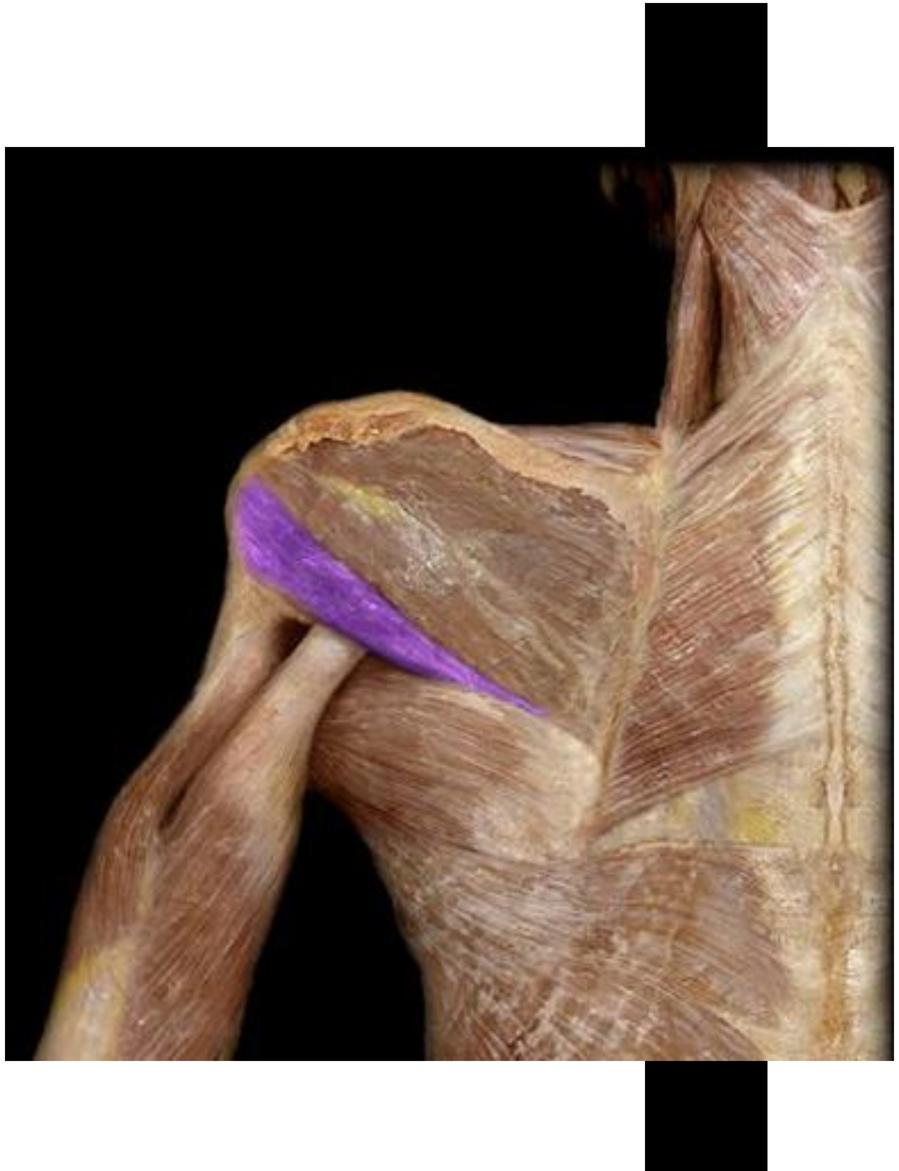


Muscles Acting on Humerus
Rotator Cuff –Teres minor

insertion





insertion

Anterior View of Cadaver Chest

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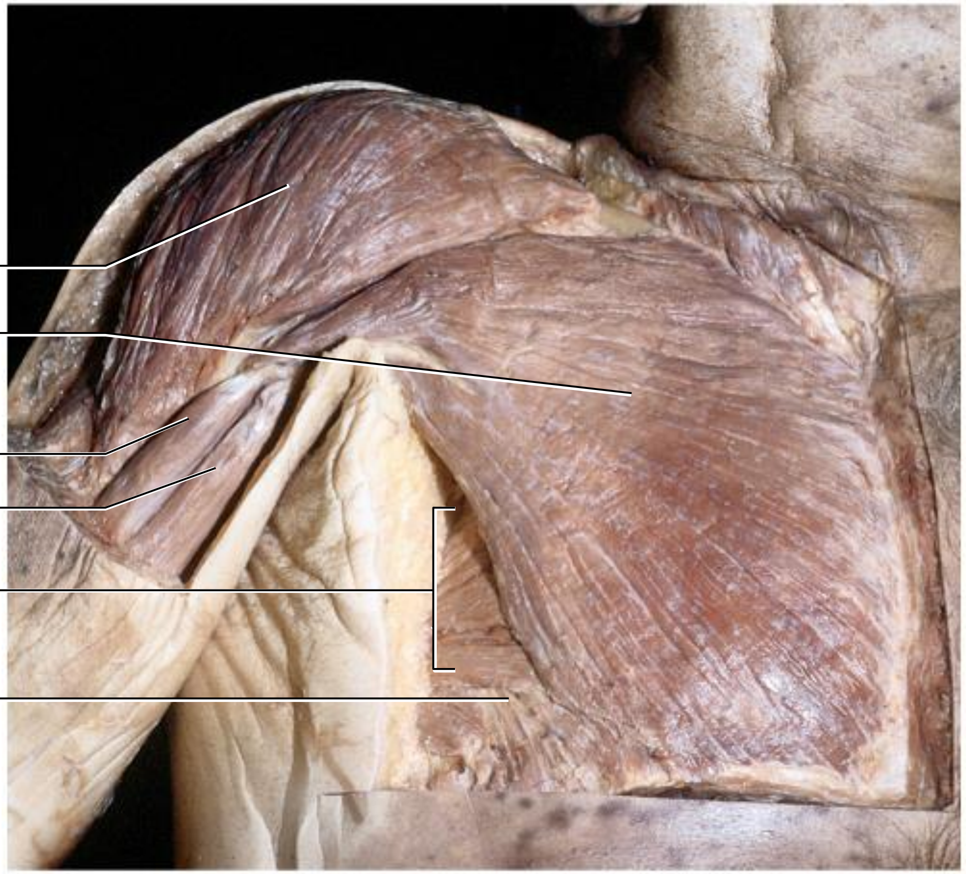

(a) Anterior view

Figure 10.25a

Apply what you know

- **Radical mastectomy, once a common treatment for breast cancer, involved removal of the pectoralis major along with the breast. What functional impairments would result from this? What synergists could a physical therapist train a patient to use to recover some lost function?**

Apply what you know

- **Because the pectoralis major flexes the shoulder, adducts and rotates the humerus, and depresses the pectoral girdle, its absence would make such actions as climbing, pushing, throwing, and adducting the arm (as in reaching across to the other side of the chest) difficult. Some synergists that could partially take over these functions include the latissimus dorsi, teres major and minor, coracobrachialis, subscapularis, and anterior portion of the deltoid.**

Apply what you know

- ❑ **Removal of cancerous lymph nodes from the neck sometimes requires removal of the sternocleidomastoid on that side. How would this affect a patient's range of head movement?**

❑

Apply what you know

- ❑ **If the left sternocleidomastoid were removed, for example, it would make it more difficult to rotate the head to the right, look upward toward the right, and bow the head.**

PART VII

LEARNING OUTCOMES

As a result of the lesson you will be able to:

- ***name and locate the muscles that produce facial expressions***
- ***name and locate the muscles used for chewing and swallowing;***
- ***name and locate the neck muscles that move the head;***
- ***identify the attachments, action, and innervation of these muscles.***

Muscles Acting on Forearm

- elbow and forearm capable of **flexion**, **extension**, **pronation**, and **supination**
  - carried out by muscles in both **brachium (arm)** and **antebrachium (forearm)**

- muscles with bellies in the **arm (brachium)**
  - principal **elbow flexors** – anterior compartment
    - ***brachialis*** and **biceps *brachii***
      - *brachialis* produces 50% more power than biceps brachii
      - *brachialis* is prime mover of elbow flexion
  - principal **elbow extensor** – posterior compartment
    - ***triceps brachii***
      - prime mover of elbow extension

Muscles Acting on Forearm

- muscles with bellies in the **forearm (antebrachium)**
- most forearm muscles **act on the hand and wrist**
  - ***brachioradialis*** – flexes elbow
  - ***anconeus*** – extends elbow
  - ***pronator quadratus*** – prime mover in forearm pronation
  - ***pronator teres*** – assists pronator quadratus in pronation
  - ***supinator*** – supinates the forearm

Muscles Acting on Forearm

- **principal flexor**
  - *brachialis*
- **synergistic flexors**
  - *biceps brachii*
  - *brachioradialis*
- **principal extensor**
  - *triceps brachii*

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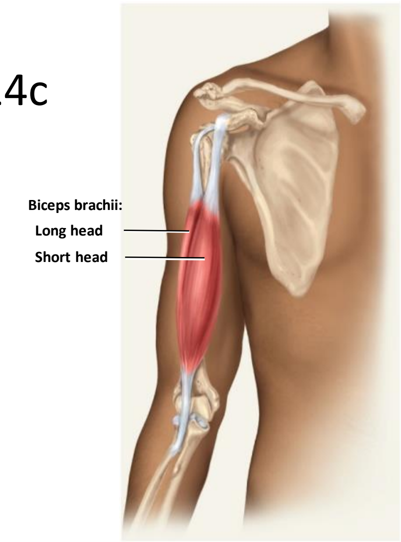
Figure 10.24c



(c) Anterior view

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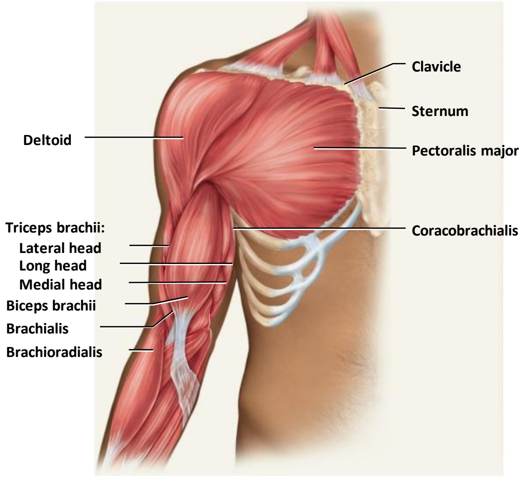

(a) Anterior view

Figure 10.24a

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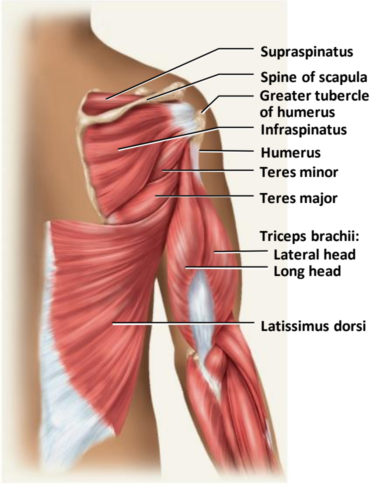
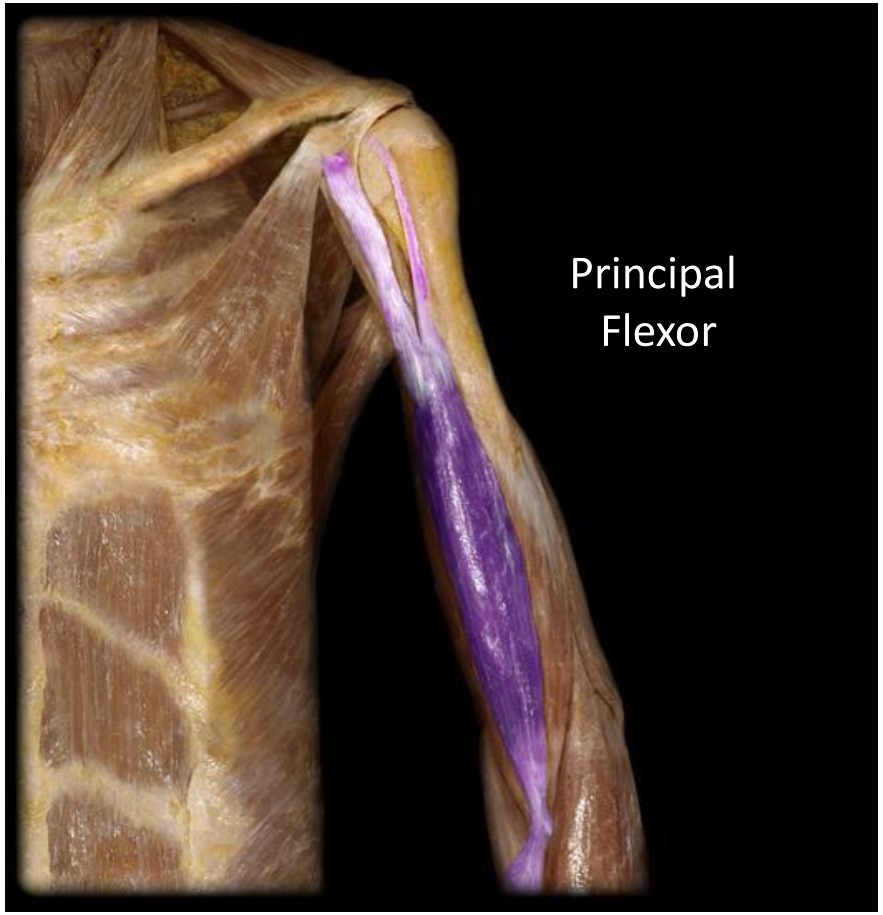


Figure 10.24b

(b) Posterior view



Long Head

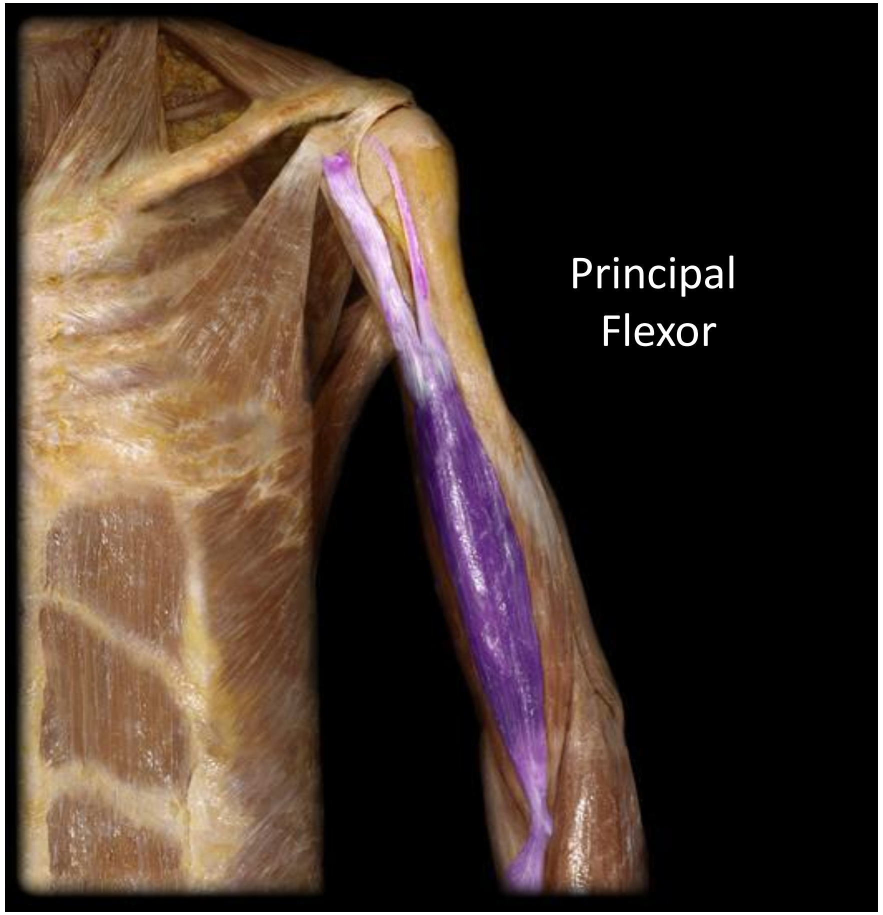
Short Head

origin

insertion

Muscles Acting on Forearm

Bellies in Brachium - Biceps brachii



Long Head

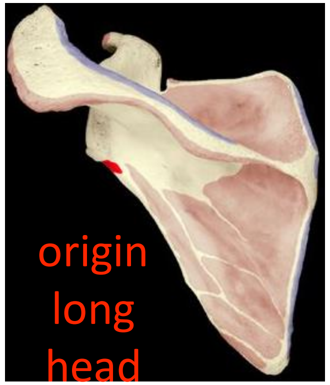
Short Head

origin
long head

origin
short head

insertion

origin
lateral
head

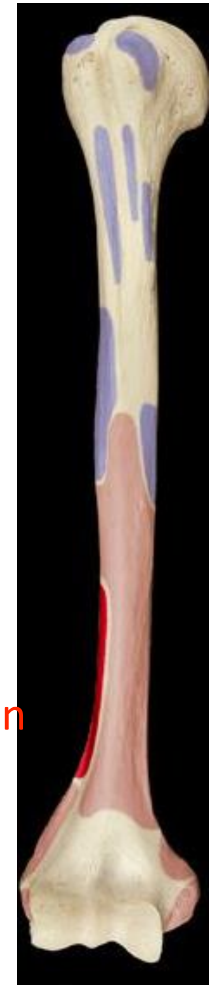


origin
long
head

origin
medial
head

insertion

origin



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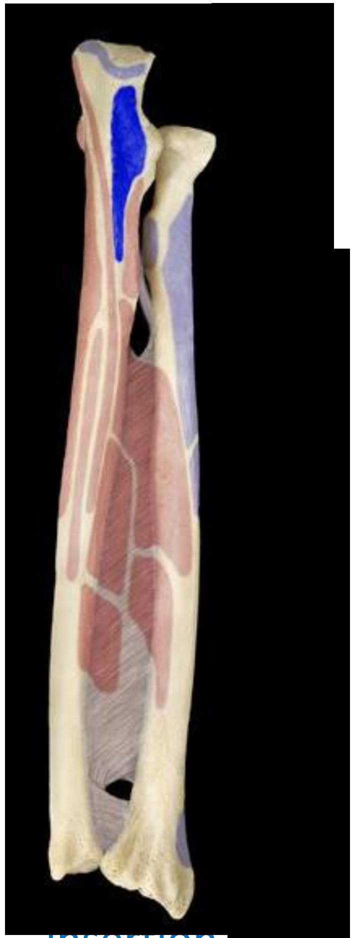

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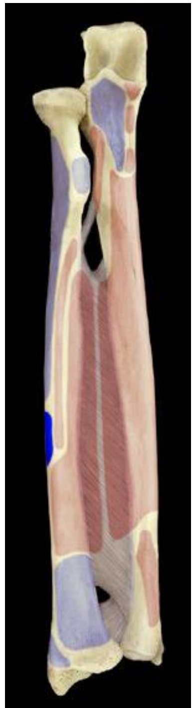
Muscles Acting on Forearm

Bellies in Antebrachium – Pronators

Pronator teres

Pronator quadratus

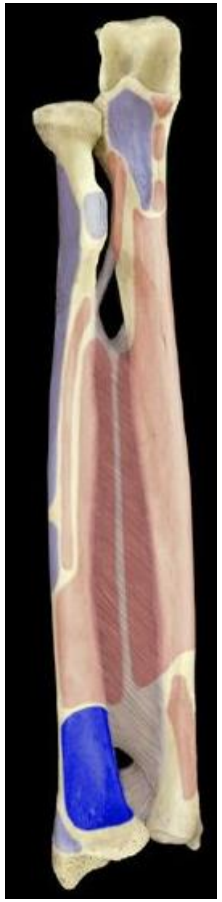


origins

insertion

Pronator quadratus

insertion



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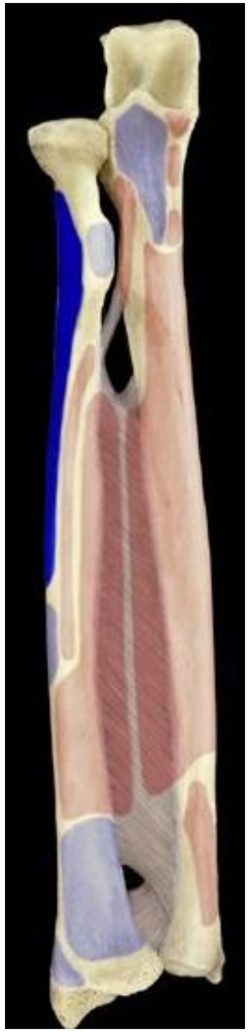

Apply what you know

- ❑ **What do the names of the pronator teres and pronator quadratus muscles indicate about their shapes?**

Supination and Pronation

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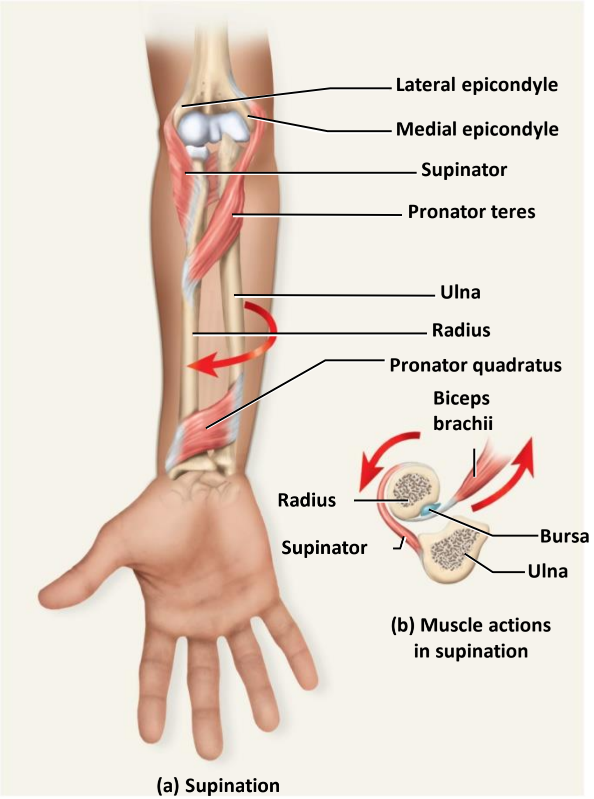

Figure 10.27a

supination

- ***supinator* muscle**
- **palm facing anteriorly or superiorly**

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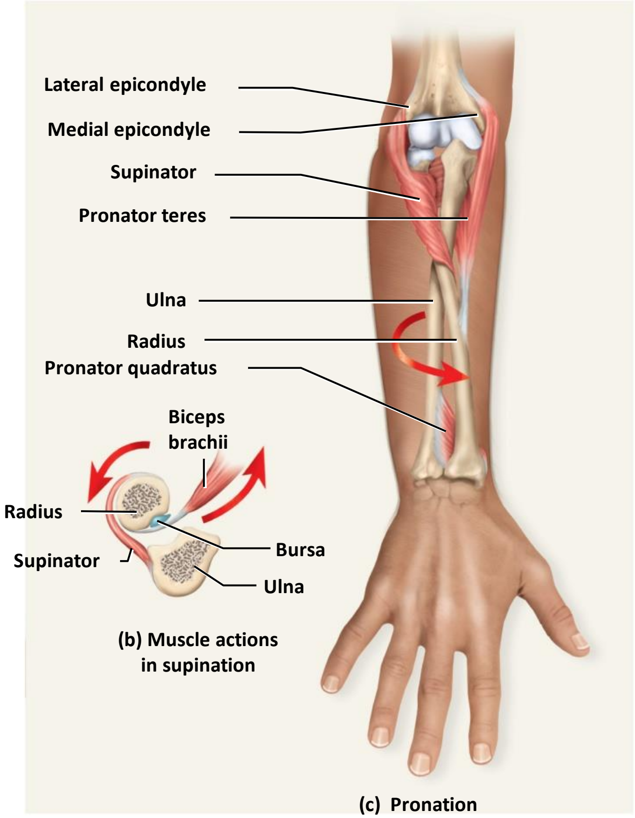

Figure 10.27c

pronation

- ***pronator quadratus and pronator teres***
- **palm faces posteriorly or inferiorly**

Cross Section of Upper Limb

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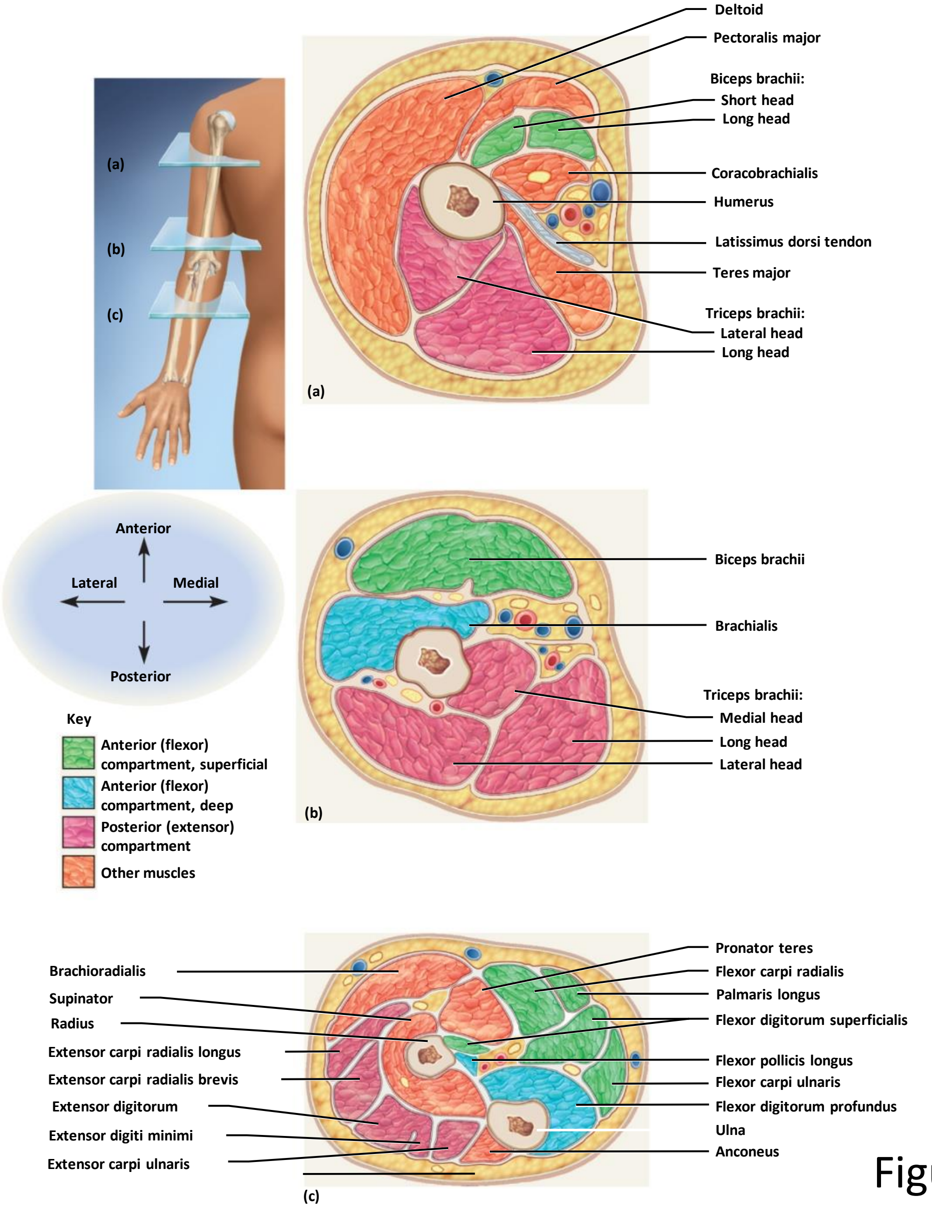


Figure 10.28

Anterior Muscles Acting on Wrist and Hand

- extrinsic muscles of the forearm
- intrinsic muscles in the hand itself
- extrinsic muscle actions
  - flexion and extension of wrist and digits
  - radial and ulnar flexion
  - finger abduction and adduction
  - thumb opposition

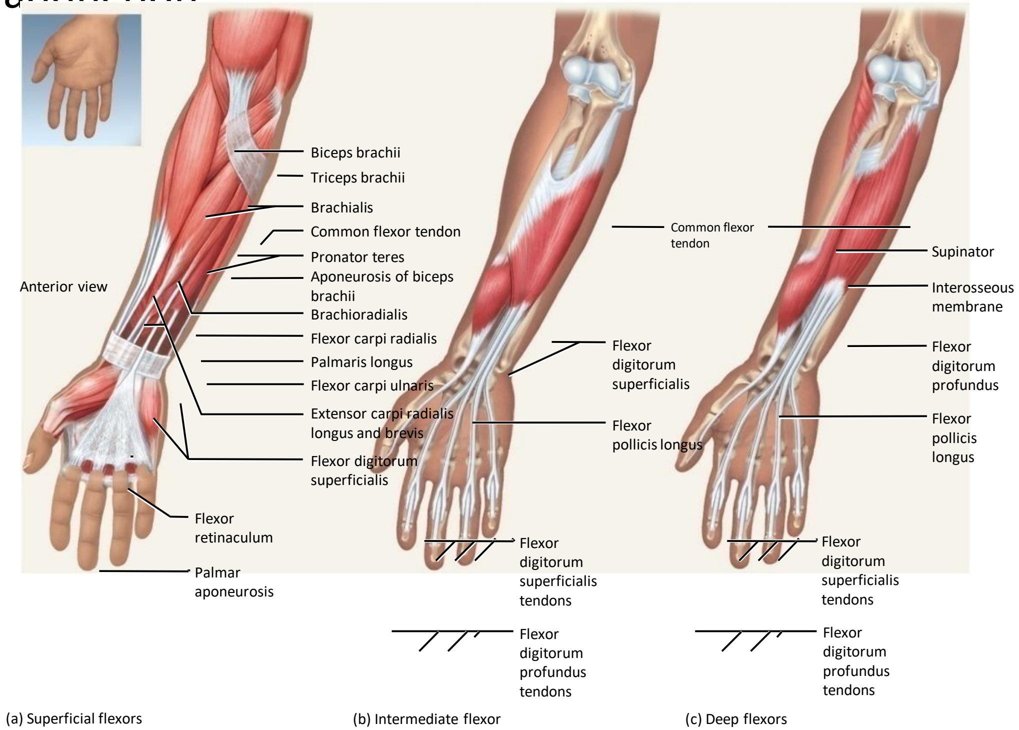


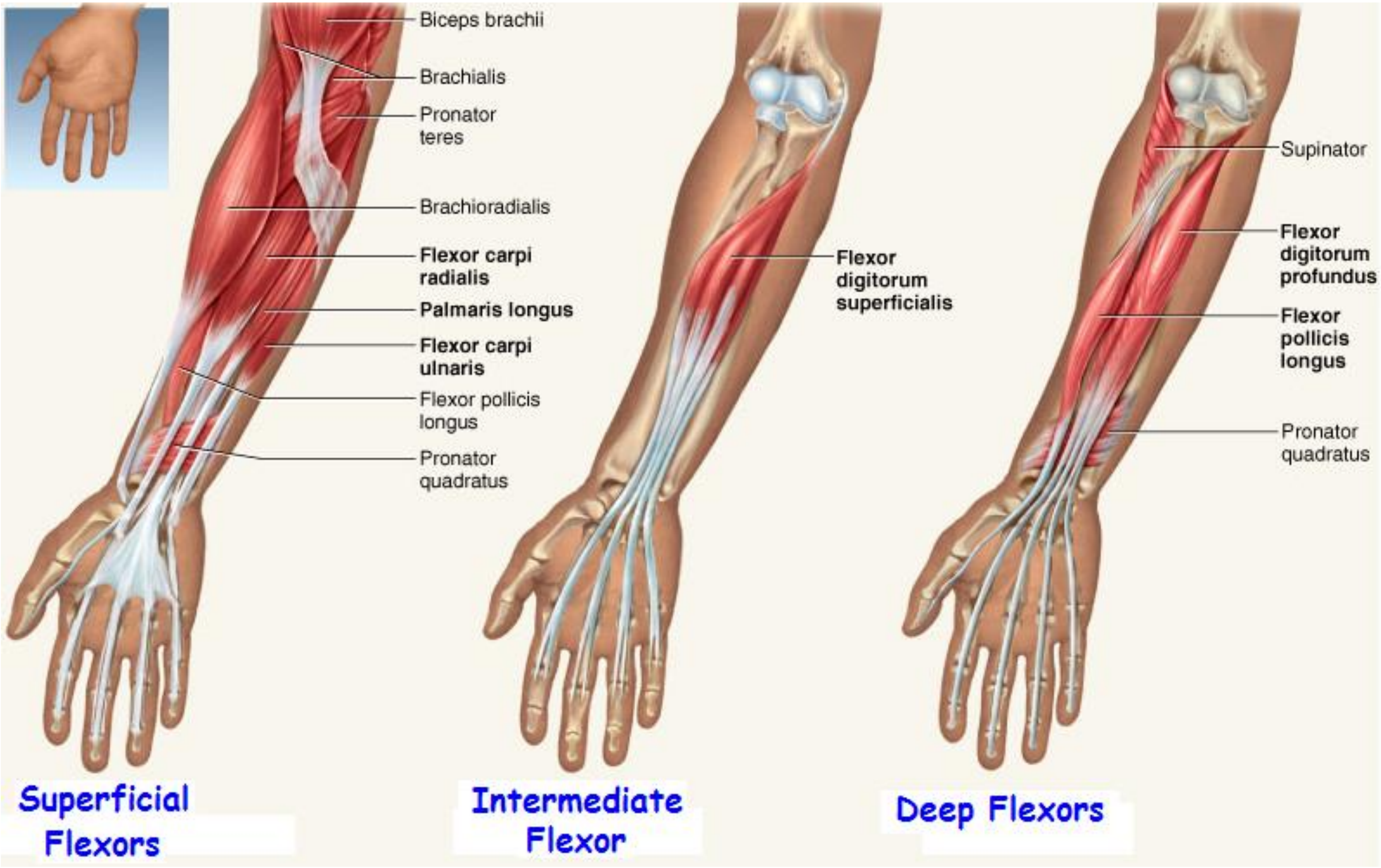
Figure 10.29

Anterior Muscles Acting on Wrist and Hand

- Anterior (Flexor) Compartment – superficial layer
  - ***flexor carpi radialis***
  - ***flexor carpi ulnaris***
  - ***flexor digitorum superficialis***
  - ***palmaris longus***

- Anterior (Flexor) Compartment – deep layer
  - ***flexor digitorum profundus***
  - ***flexor pollicis longus***

Flexors of Wrist & Hand



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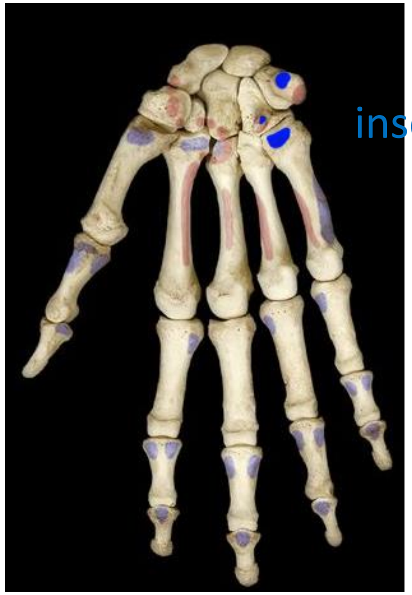

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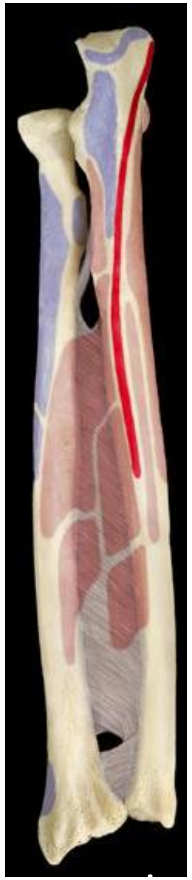

origin

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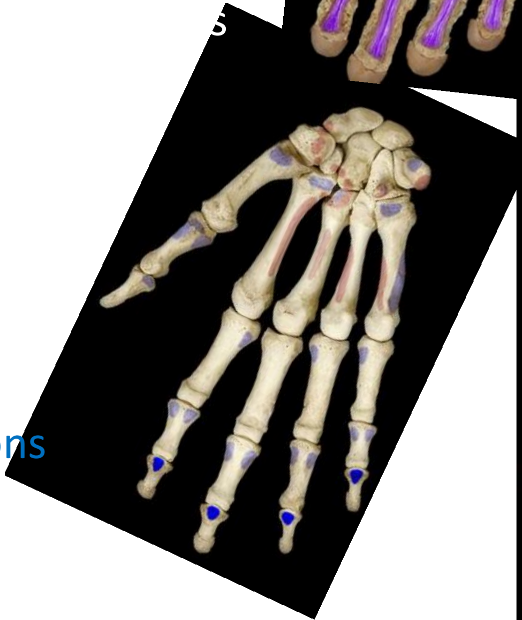
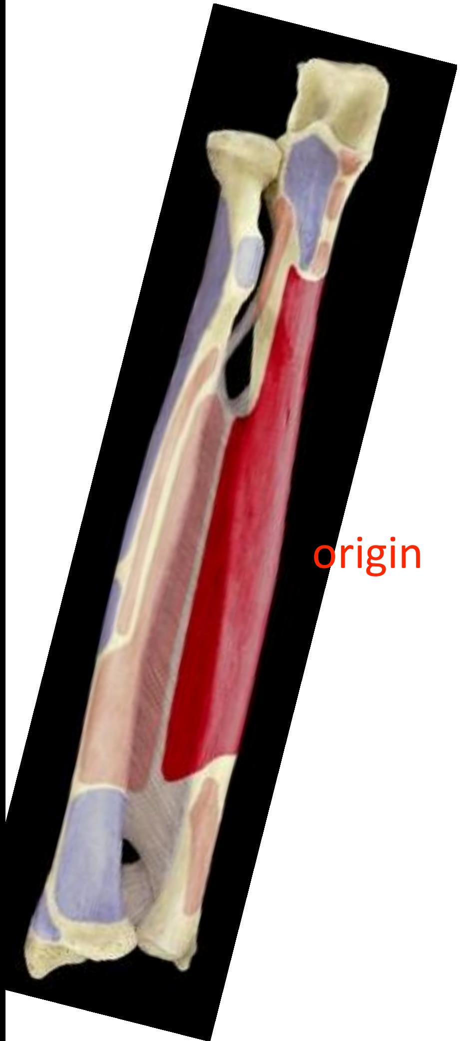
Muscles Acting on Wrist and Hand

Anterior Compartment Palmaris longus

Palmaris longus tendon

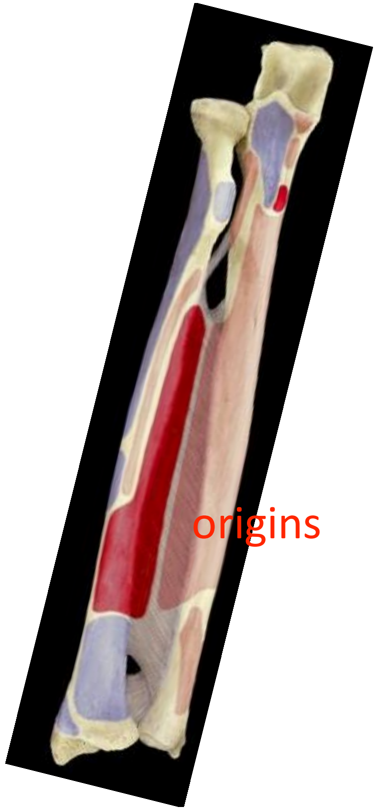




origin

insertions

insertion



origins

Posterior Muscles Acting on Wrist & Hand

- extension of wrist and fingers, adduct / abduct wrist
- extension and abduction of thumb (pollicis)
- brevis - short,   ulnaris - on ulna side of forearm

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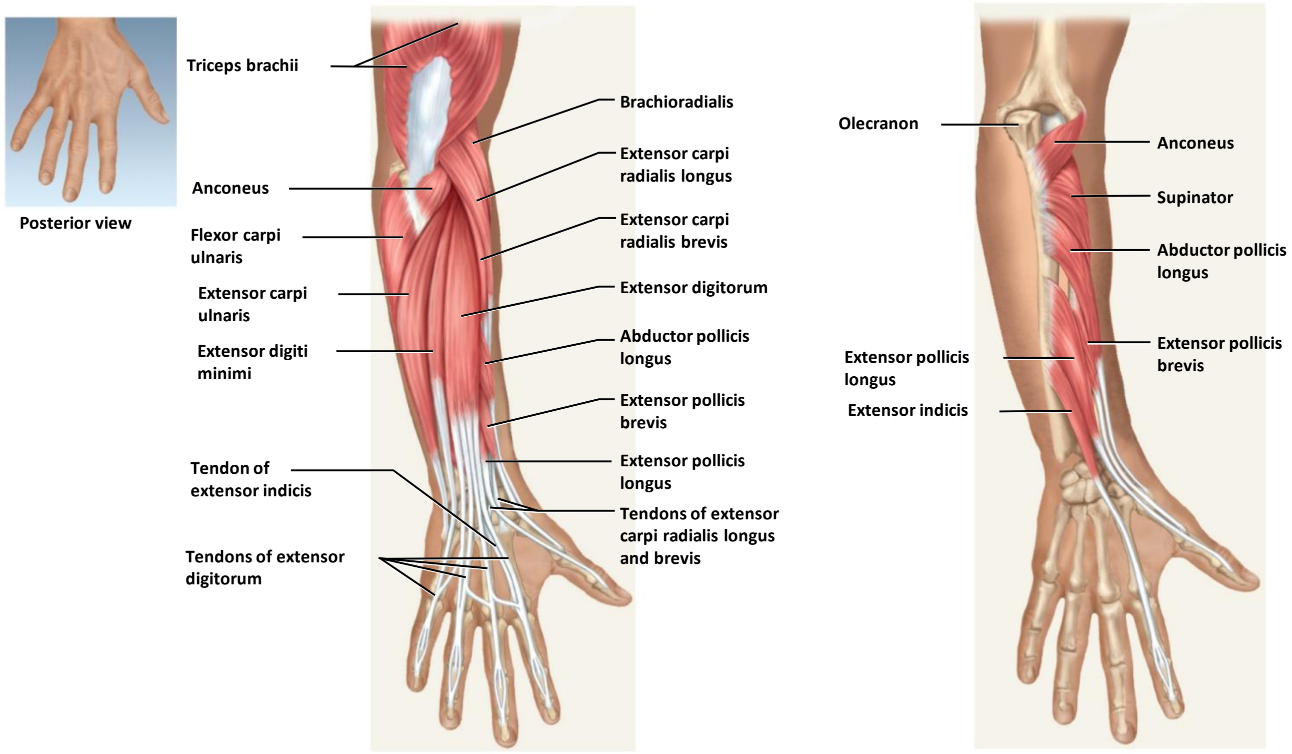


(a) Superficial extensors

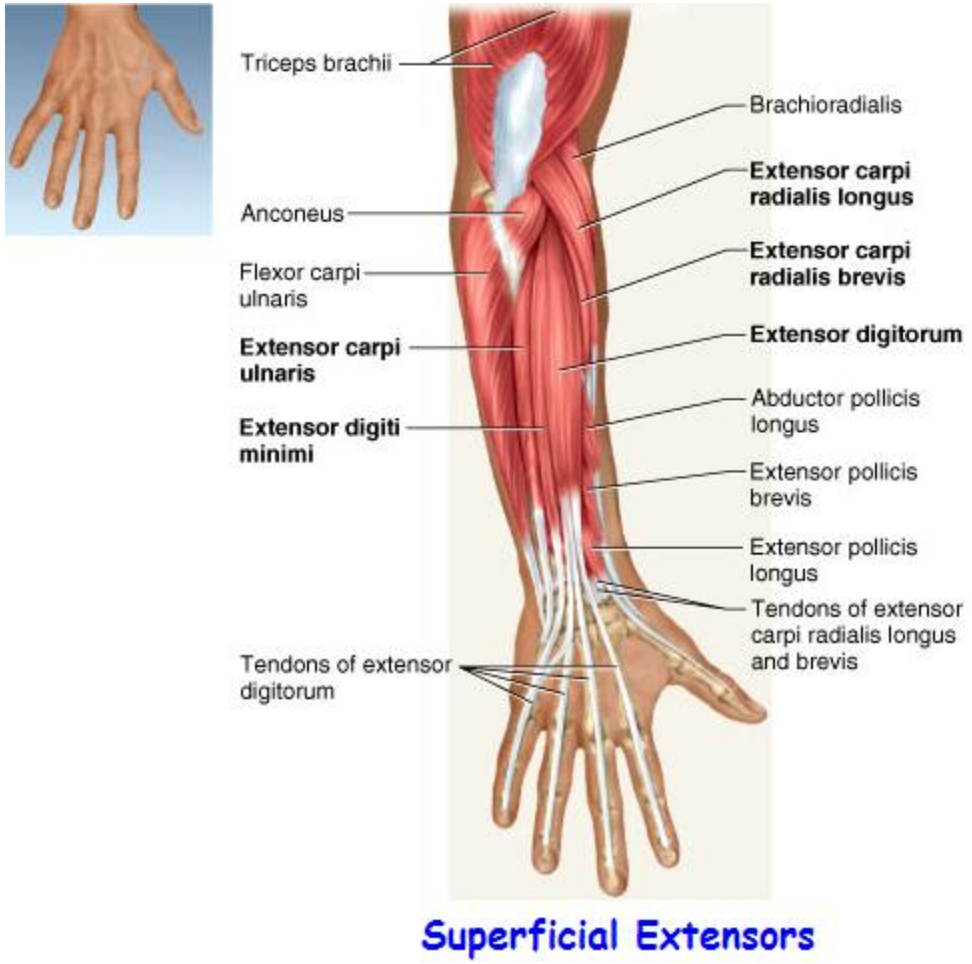
(b) Deep extensors

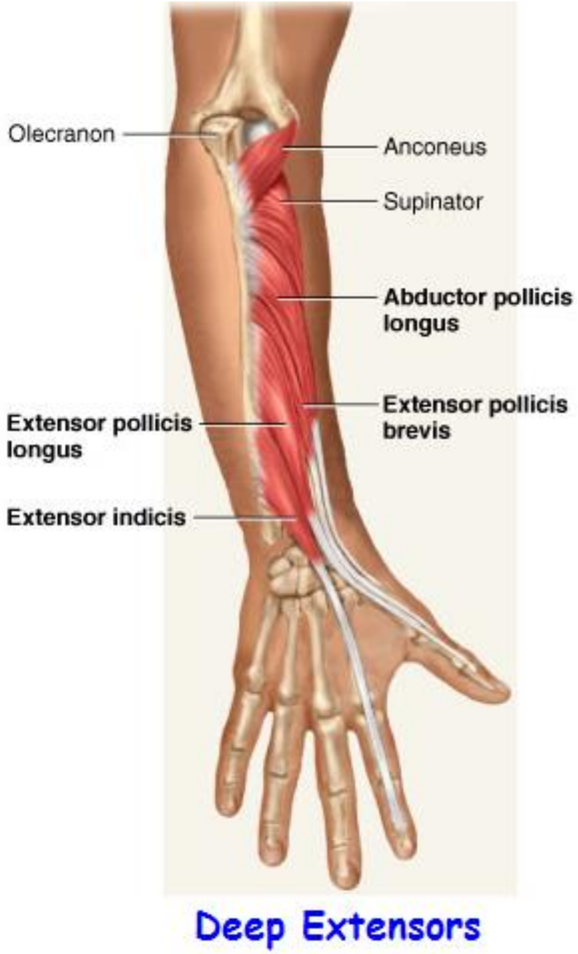
Figure 10.30

Posterior Muscles Acting on Wrist and Hand

- Posterior (Extensor) Compartment – superficial layer
  - ***extensor carpi radialis longus***
  - ***extensor carpi radialis brevis***
  - ***extensor digitorum***
  - ***extensor digiti minimi***
  - ***extensor carpi ulnaris***
- Posterior (Extensor) Compartment – deep layer
  - ***abductor pollicis longus***
  - ***extensor pollicis brevis***
  - ***extensor pollicis longus***
  - ***extensor indicis***

Extensors of Wrist and Hand





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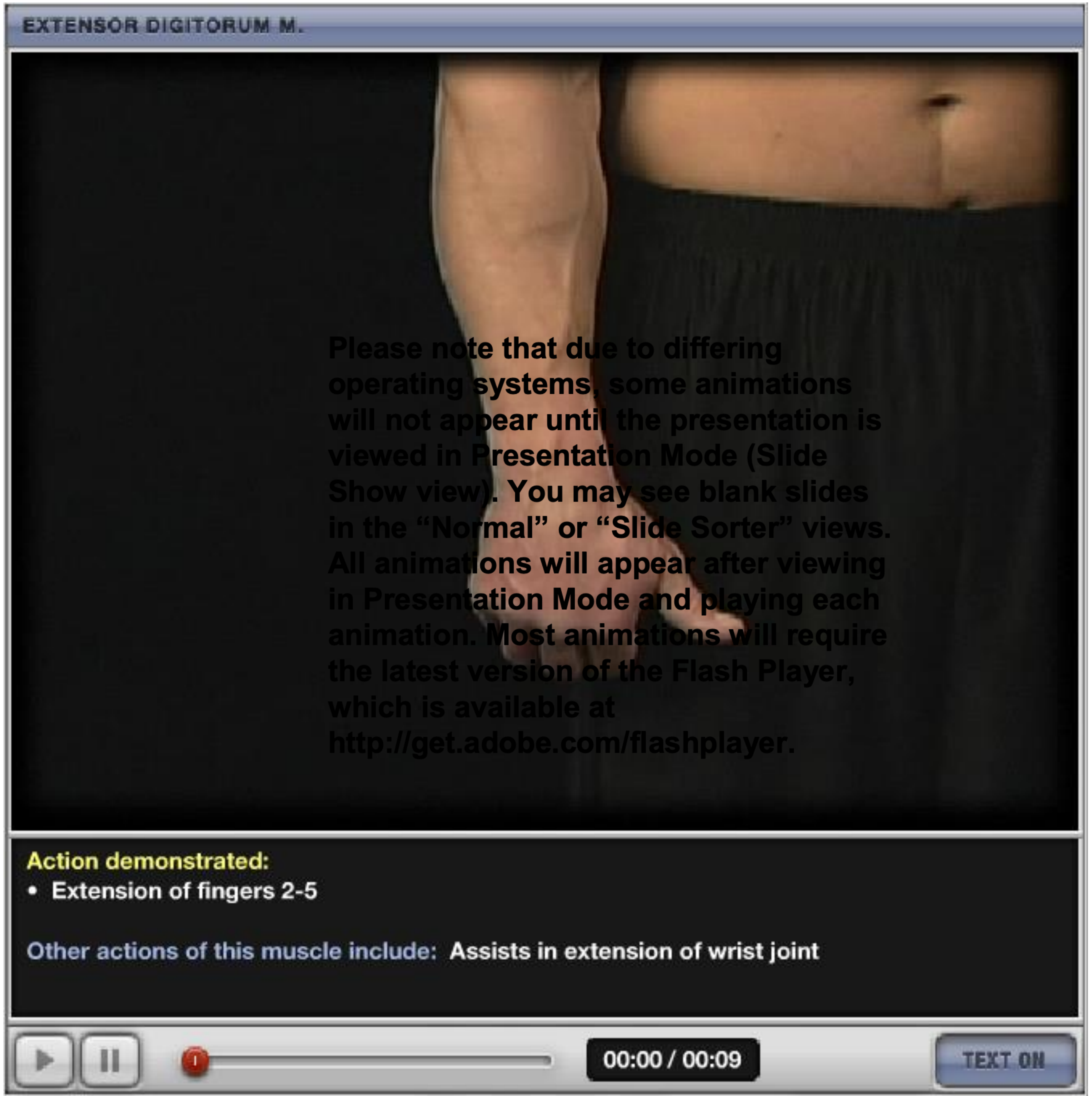
Extensor Digitorum M.



origin

insertion

Muscles Acting on Wrist and Hand

Posterior Compartment

Extensor carpi radialis longus & brevis

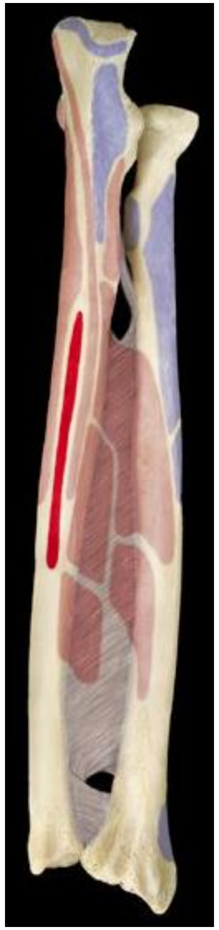
origin

insertion

insertion

[redacted]

origin



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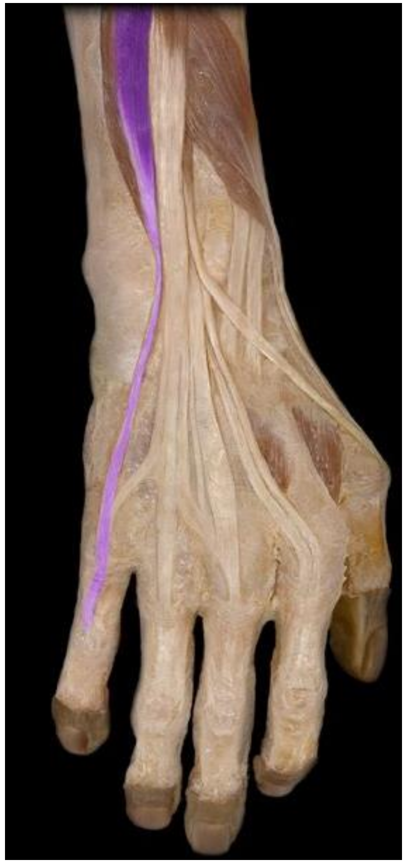

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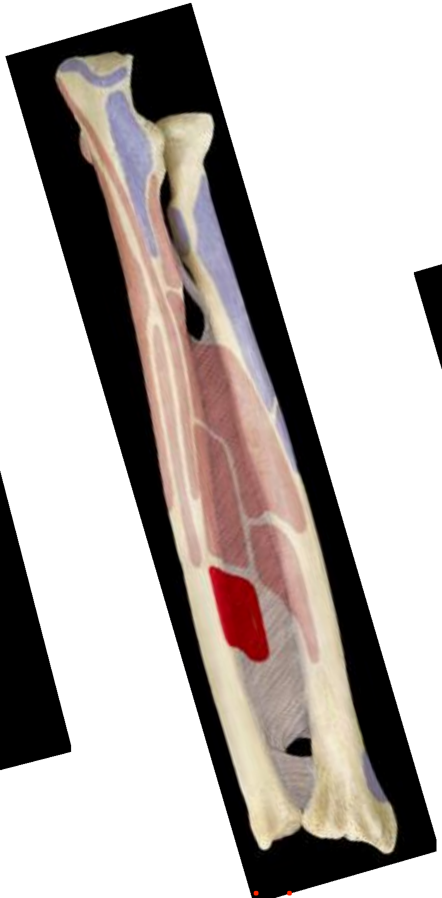

origin

insertion

Carpal Tunnel Syndrome

- **flexor retinaculum –** bracelet-like fibrous sheet that the flexor tendons of the extrinsic muscles that flex the wrist pass on their way to their insertions

- **carpal tunnel** – tight space between the flexor retinaculum and the carpal bones
  - flexor tendons passing through the tunnel are enclosed in **tendon sheaths**
    - enable tendons to slide back and forth quite easily

- **carpal tunnel syndrome** - prolonged, repetitive motions of wrist and fingers can cause tissues in the carpal tunnel to become inflamed, swollen, or fibrotic
  - puts pressure on the **median nerve** of the wrist that passes through the carpal tunnel along with the flexor tendons
  - tingling and muscular weakness in the palm and medial side of the hand
  - pain may radiate to arm and shoulder
  - **treatment** – anti-inflammatory drugs, immobilization of the wrist, and sometimes surgery to remove part or all of flexor retinaculum

Carpal Tunnel Syndrome

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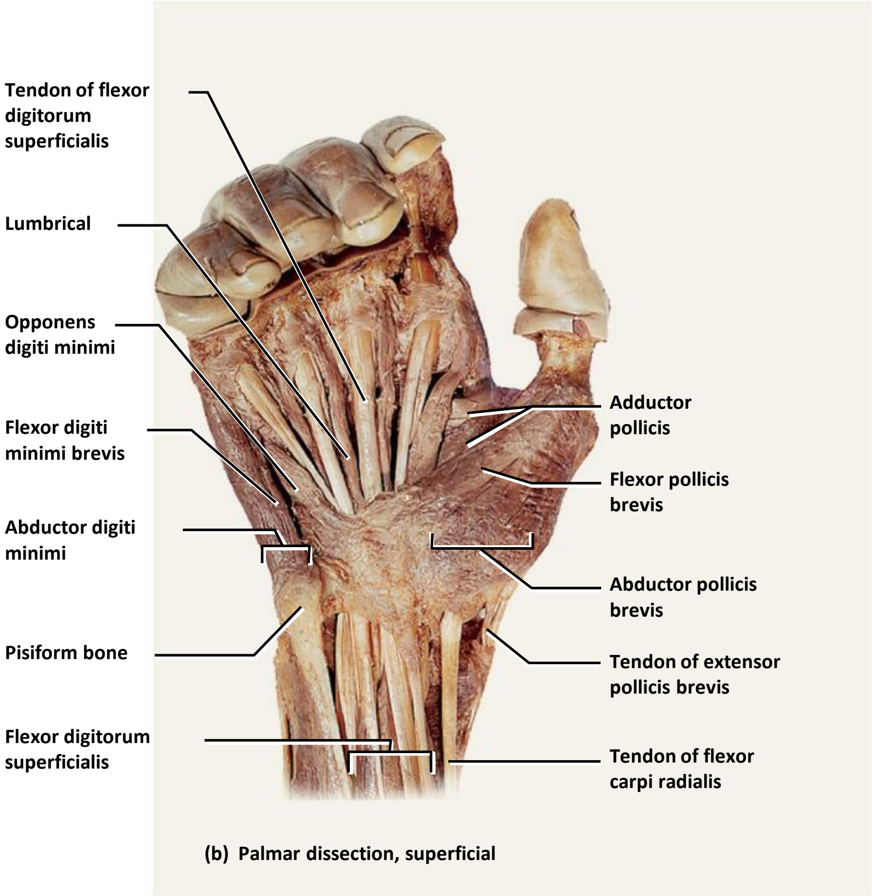

Figure 10.32b

repetitive motions cause inflammation and pressure on median nerve

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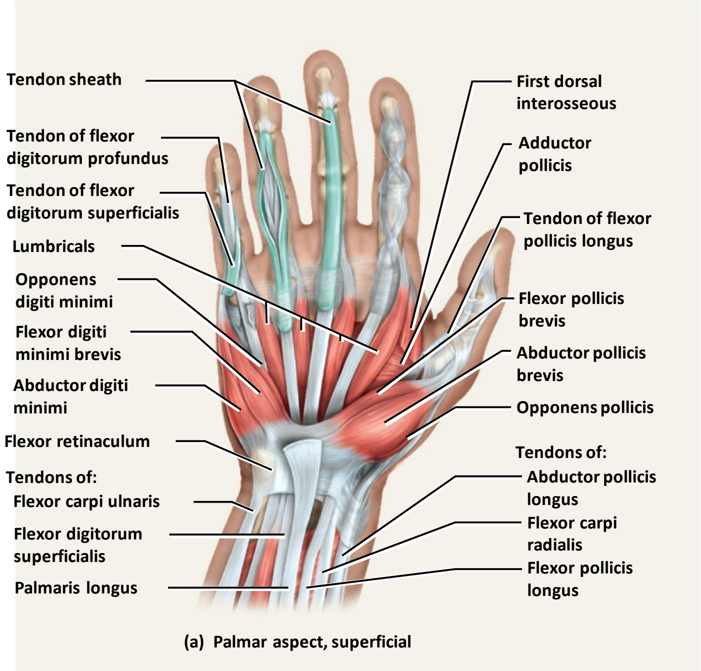
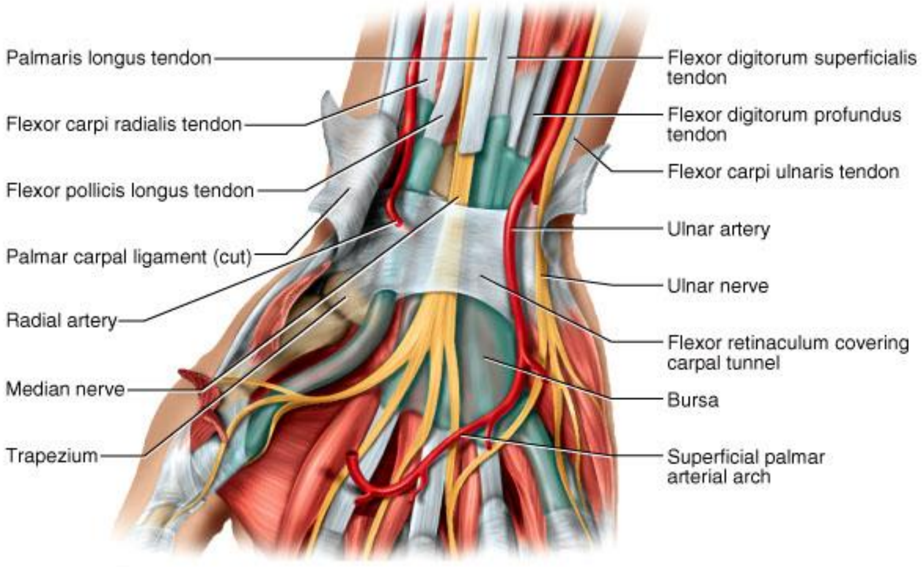
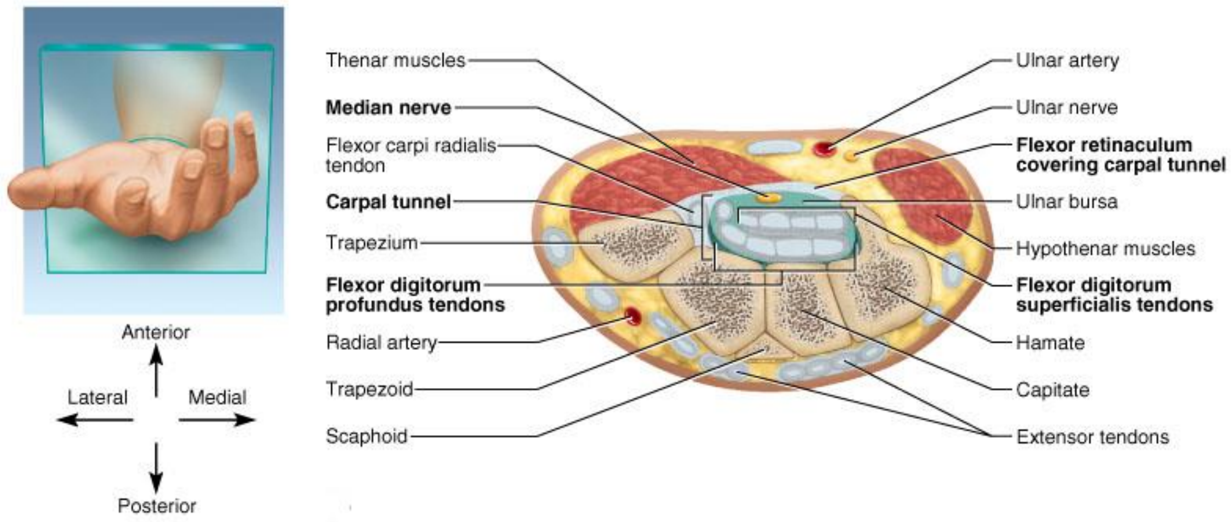


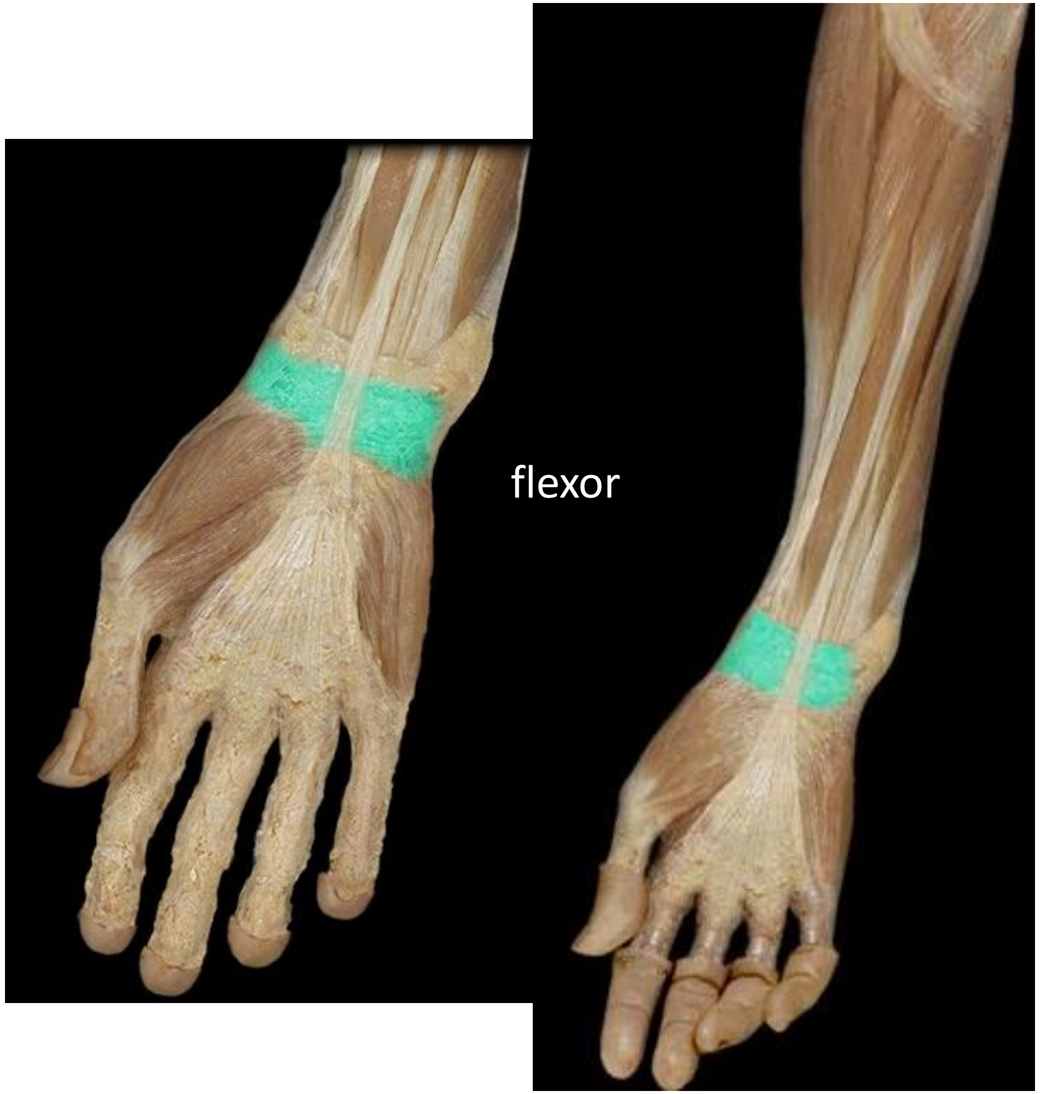
Figure 10.32a

Carpal Tunnel Syndrome

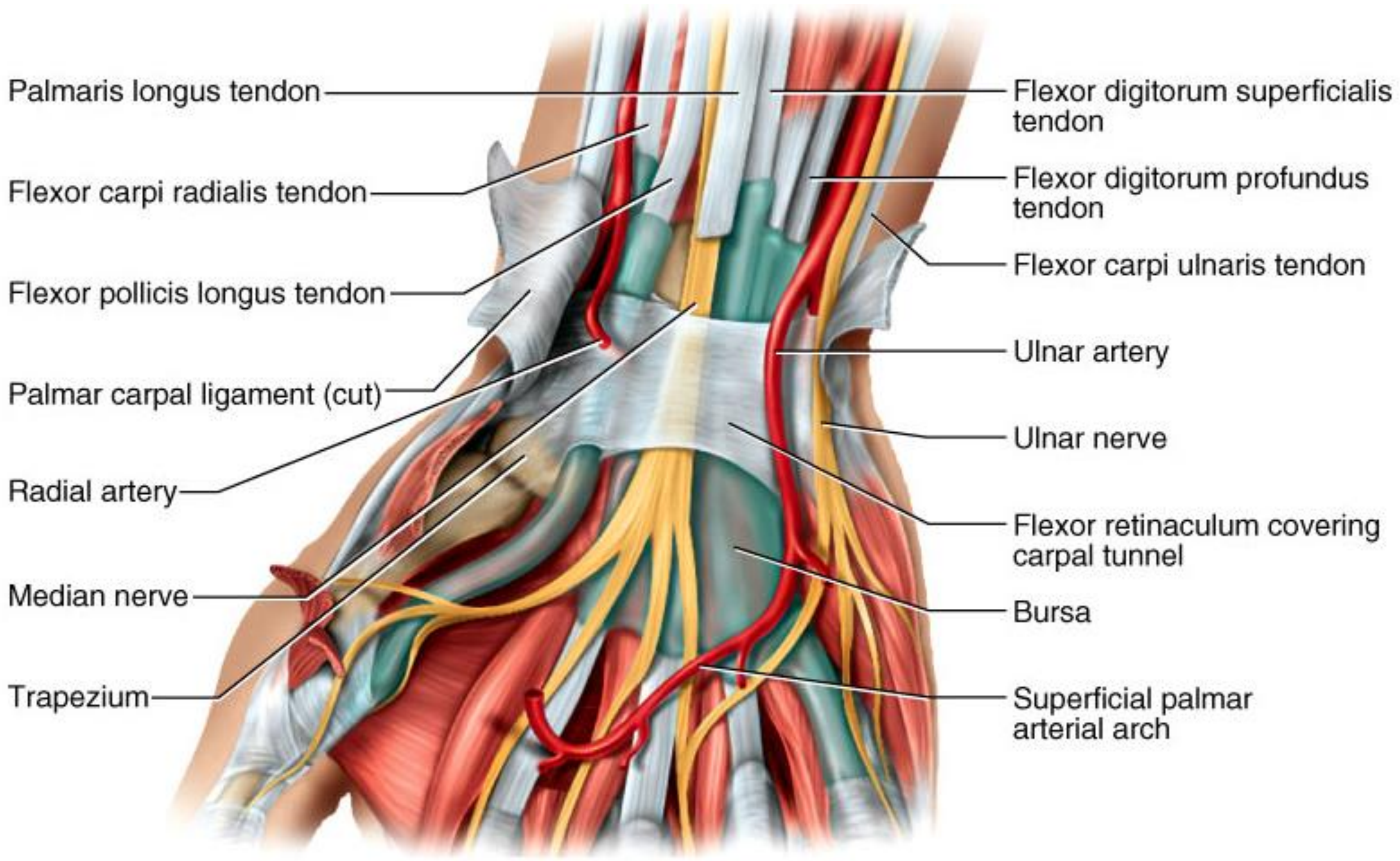




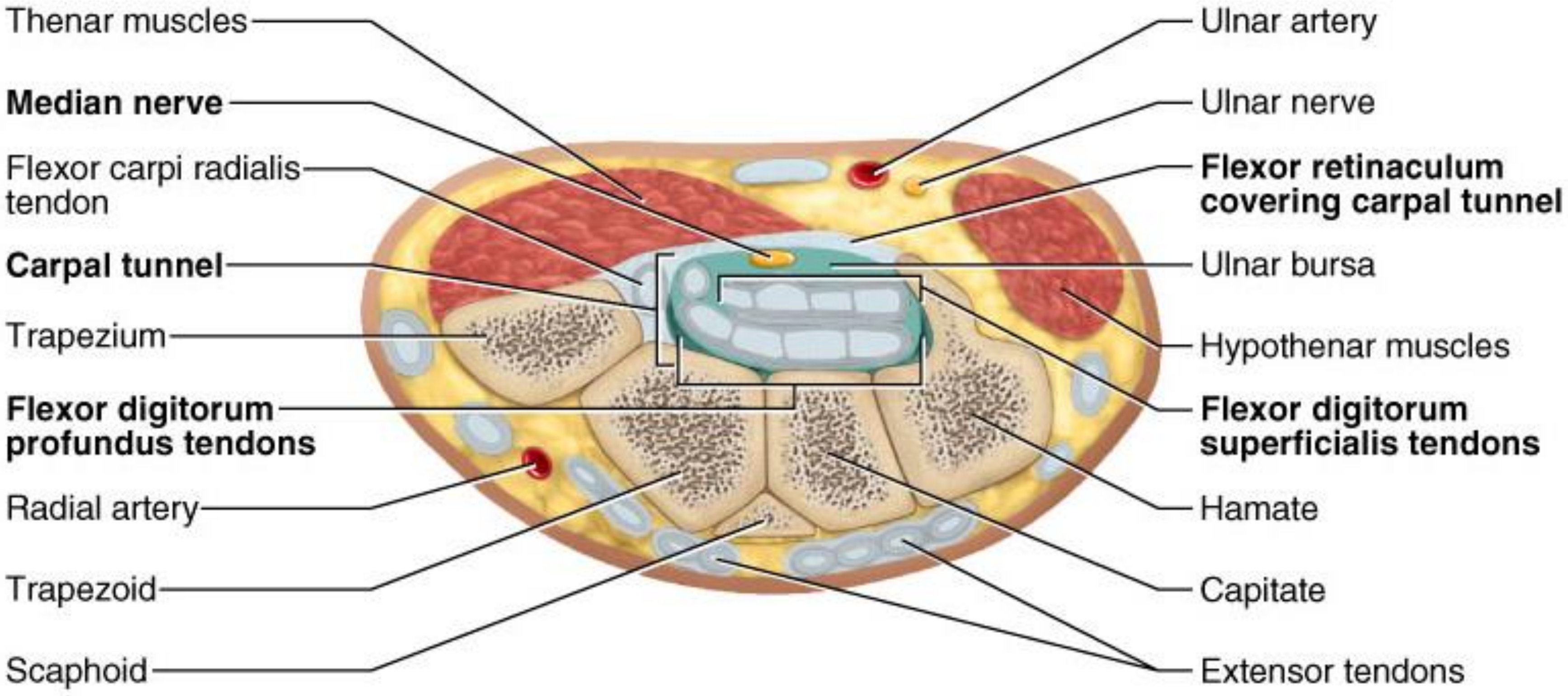
Flexor & Extensor Retinaculum



Median Nerve & Flexor Retinaculum



Median Nerve & Flexor Retinaculum



Intrinsic Hand Muscles

- **Thenar group –** form thick, fleshy mass at base of thumb
  - *adductor pollicis*
  - *abductor pollicis brevis*
  - *flexor pollicis brevis*
  - *opponens pollicis*

- **Hypothenar group -** fleshy base of the little finger
  - *abductor digiti minimi*
  - *flexor digiti minimi brevis*
  - *opponens digiti minimi*

- **Midpalmar group –** hollow of palm
  - *dorsal interosseous* muscles (4)
  - *palmar interosseous* muscles (3)
  - *lumbricals* (4 muscles)

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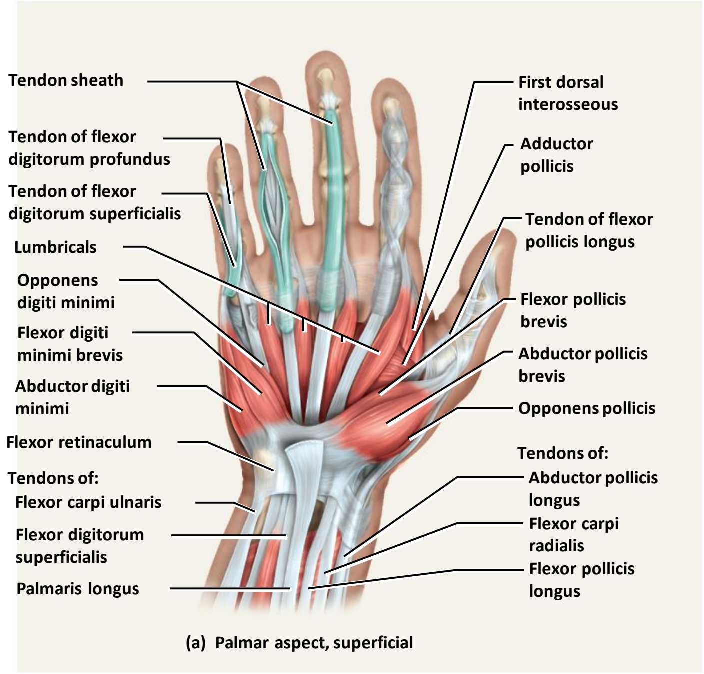
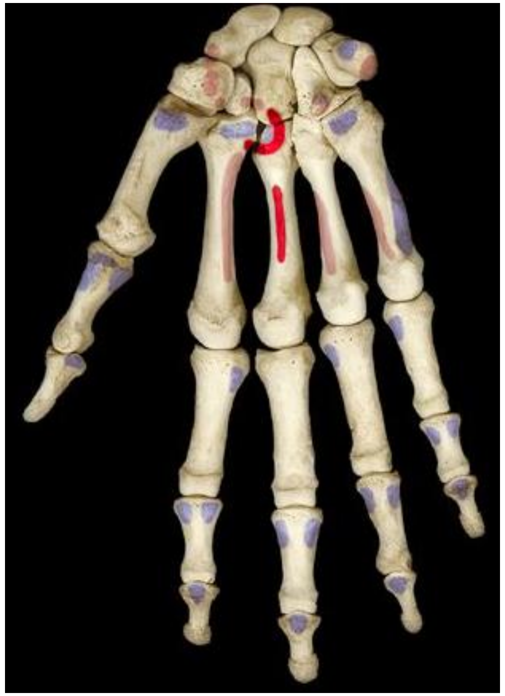


Figure 10.32a

origin

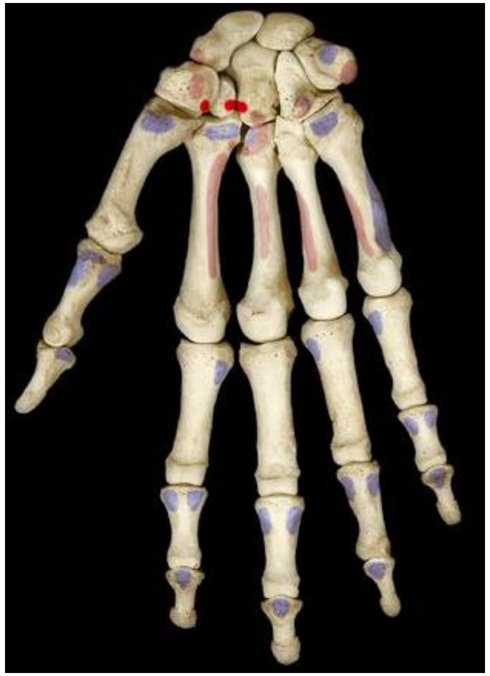


insertion

origin

insertion

origin



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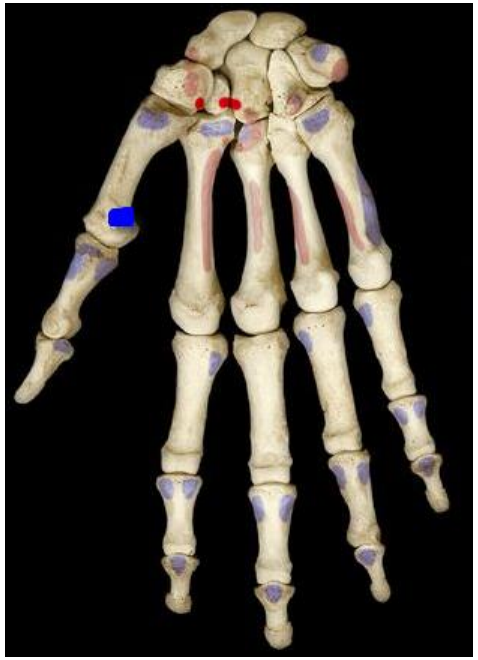

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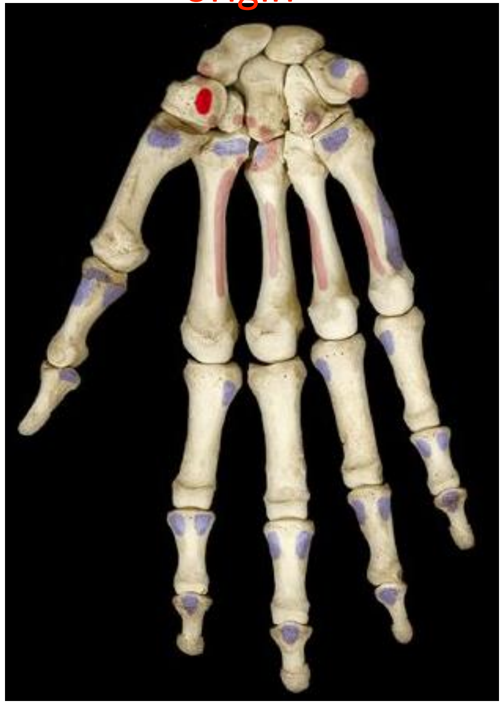

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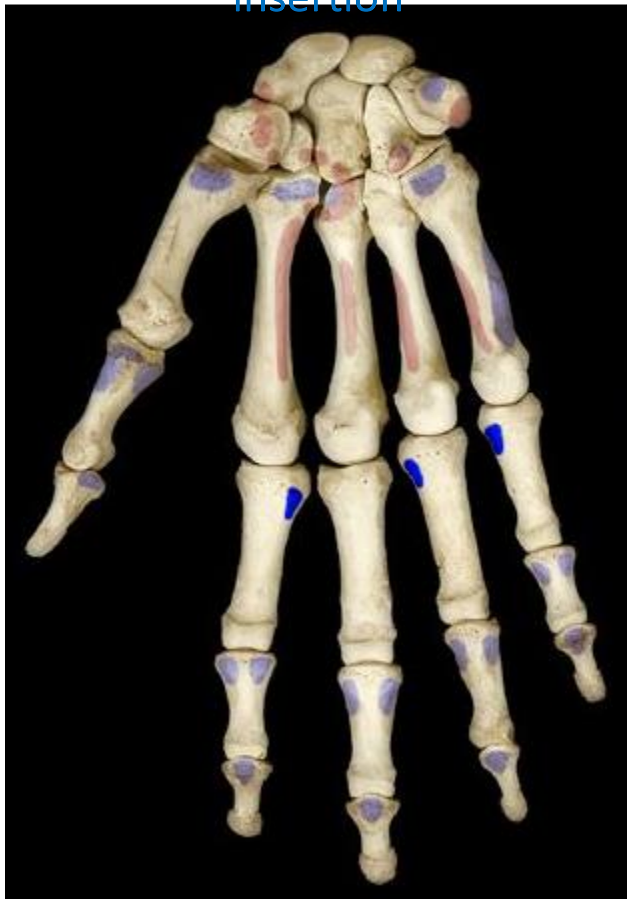


insertion

The Muscular System

Al-Farabi Kazakh National University Higher School of Medicine

◆ PART I

LEARNING OUTCOMES

As a result of the lesson you will be able to:

- ❑ ***Describe the various functions of muscular tissue***
- ❑ ***Relate muscle fascicles to the shapes and relative strengths of muscles;***
- ❑ ***Name the types of muscle bone attachments and explain the shortcoming of calling their attachments origins and insertions;***
- ❑ ***Distinguish between intrinsic and extrinsic muscles;***

Organization of Muscles

- about **600** human skeletal muscles
- constitute about half of our body weight
- three kinds of muscle tissue
  - **skeletal, cardiac, smooth**
- specialized for one major purpose
  - converting the chemical energy in ATP into the mechanical energy of motion
- **myology** – the study of the muscular system

The Functions of Muscles

- **Movement**
  - move from place to place, movement of body parts and body contents in breathing, circulation, feeding and digestion, defecation, urination, and childbirth
  - role in communication – speech, writing, and nonverbal communications
- **Stability**
  - maintain posture by preventing unwanted movements
  - **antigravity muscles** – resist the pull of gravity and prevent us from falling or slumping over
  - stabilize joints
- **Control of openings and passageways**
  - **sphincters** – internal muscular rings that control the movement of food, bile, blood, and other materials
- **Heat production by skeletal muscles**
  - as much as 85% of our body heat

Introduction to Muscle

- movement is a fundamental characteristic of all living things
- muscle cells are capable of converting the chemical energy of ATP into mechanical energy
- types of muscle
  - skeletal, cardiac, and smooth
- physiology of skeletal muscle
  - basis of warm-up, quickness, strength, endurance, and fatigue

Characteristics of Muscle

- **responsiveness (excitability)**
  - to chemical signals, stretch and electrical changes across the plasma membrane
- **conductivity**
  - local electrical change triggers a wave of excitation that travels along the muscle fiber
- **contractility**
  - shortens when stimulated
- **extensibility**
  - capable of being stretched between contractions
- **elasticity**
  - returns to its original resting length after being stretched

Why is elasticity an important quality of muscle tissue?

Skeletal Muscle

- **skeletal muscle** - voluntary, striated muscle attached to one or more bones

- **striations** - alternating light and dark transverse bands
  - results from an overlapping of internal contractile proteins

- **voluntary –** usually subject to conscious control

- **muscle cell**, **muscle fiber**, (**myofiber**) as long as 30 cm

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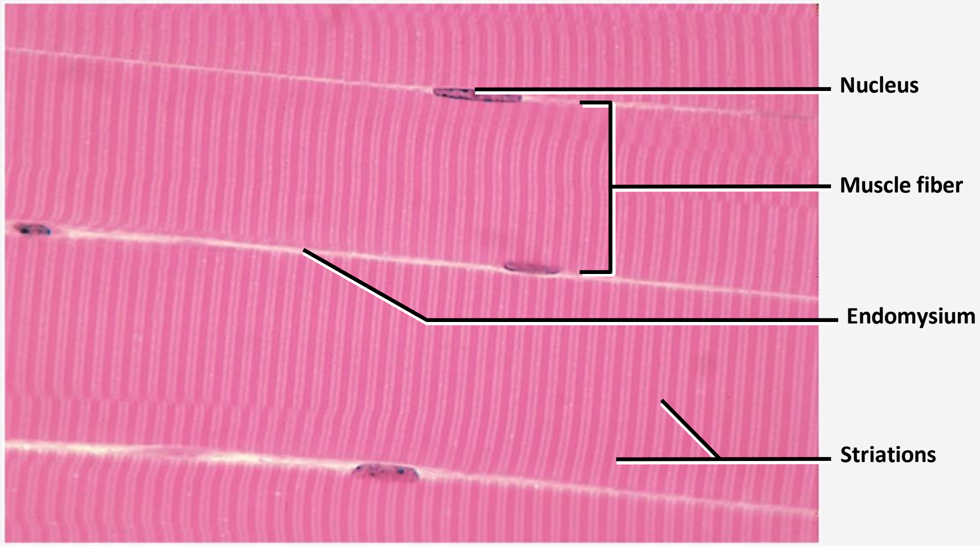

Figure 11.1

What causes the striated appearance of skeletal muscle tissue?

Connective Tissue Elements

- **tendons** are attachments between muscle and bone matrix
  - **endomysium** – connective tissue around **muscle cells**
  - **perimysium** – connective tissue around **muscle fascicles**
  - **epimysium** – connective tissue surrounding **entire muscle**
  - continuous with collagen fibers of tendons
  - in turn, with connective tissue of bone matrix

- **collagen** is somewhat extensible and elastic
  - stretches slightly under tension and recoils when released
    - resists excessive stretching and protects muscle from injury
    - returns muscle to its resting length
    - contribute to power output and muscle efficiency

Describe how tendons facilitate body movement?

Connective Tissues of a Muscle

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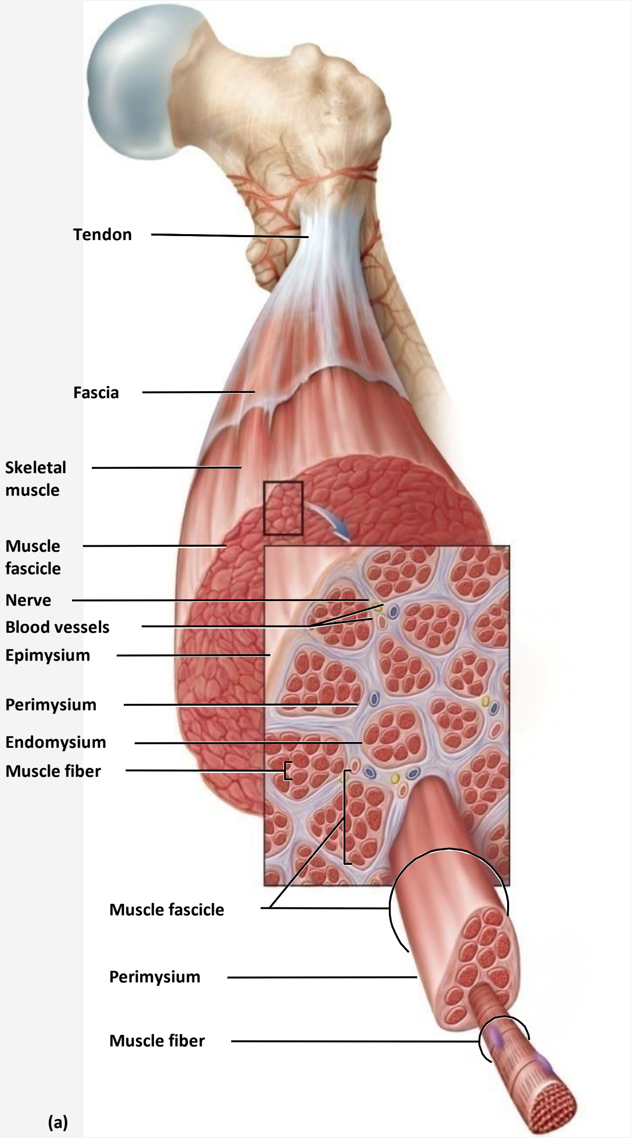


(a)

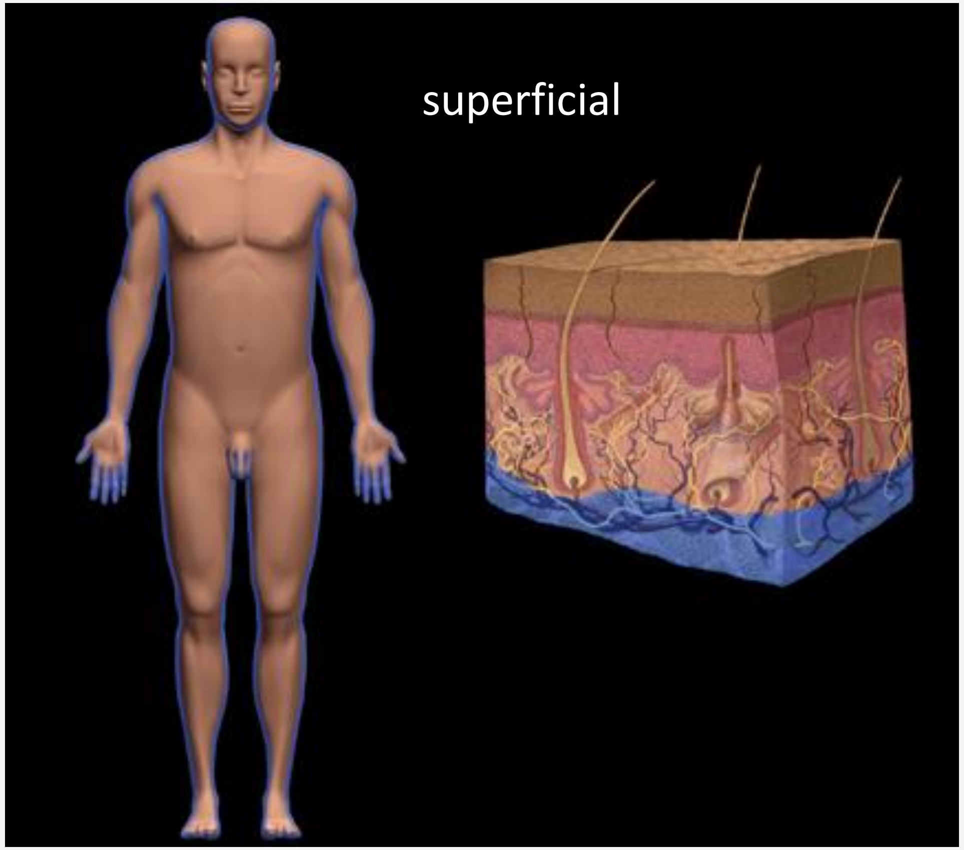
Connective Tissues of a Muscle

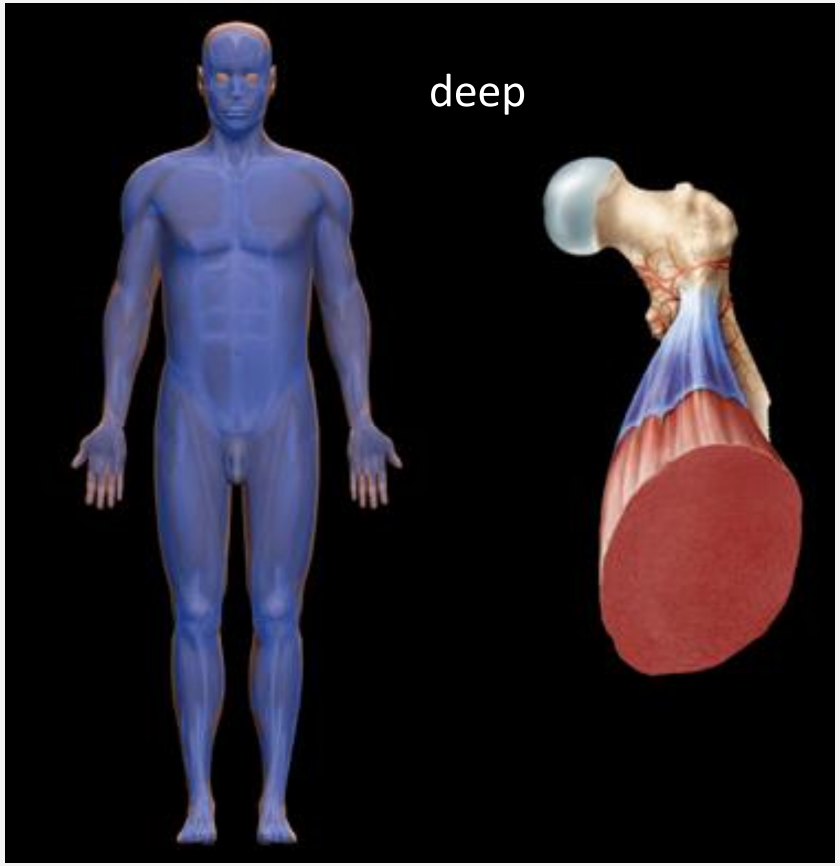
- **endomysium**
  - thin sleeve of loose connective tissue surrounding each **muscle fiber**
  - allows room for capillaries and nerve fibers to reach each muscle fiber
- **perimysium**
  - slightly thicker layer of connective tissue
  - **fascicles** – bundles of muscle fibers wrapped in perimysium
  - carry larger nerves and blood vessels, and stretch receptors
- **epimysium**
  - fibrous sheath surrounding the entire muscle
  - outer surface grades into the fascia
  - inner surface sends projections between fascicles to form perimysium
- **fascia**
  - sheet of connective tissue that separates neighboring muscles or muscle groups from each other and the subcutaneous tissue

What would happen to skeletal muscle if the epimysium were destroyed?

What effect does fascicle arrangement have on a muscle’s action?

Superficial and Deep Fasciae





Connective Tissue in a Muscle

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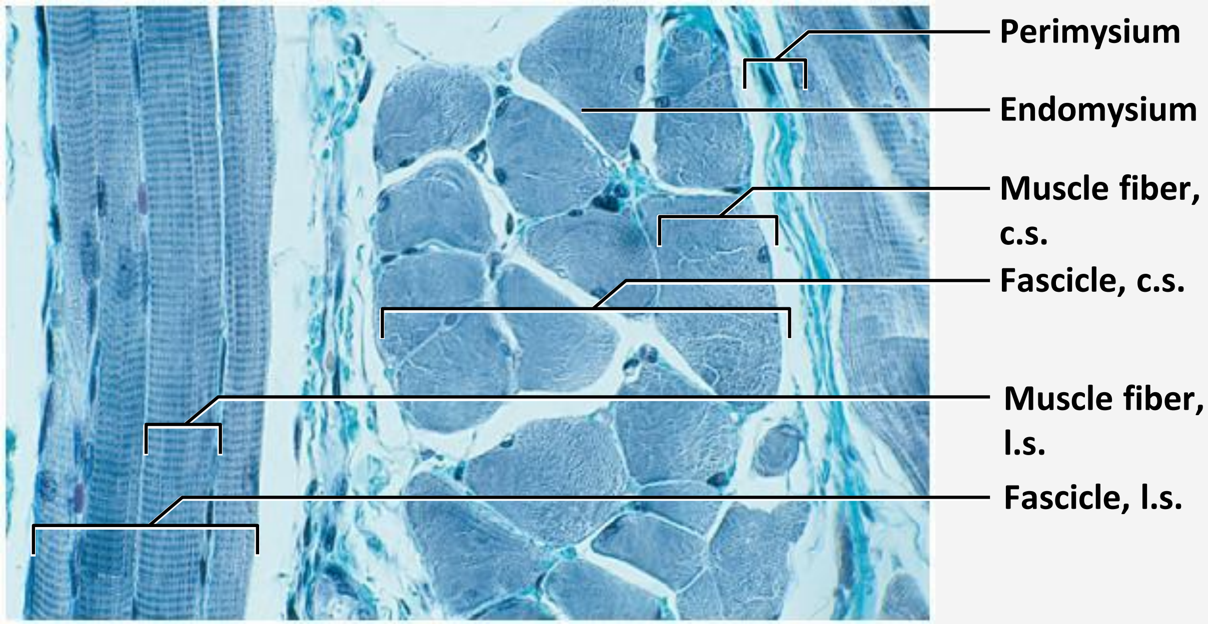

(c)

Victor Eroschenko

Figure 10.1c

Fascicle Orientation of Muscles

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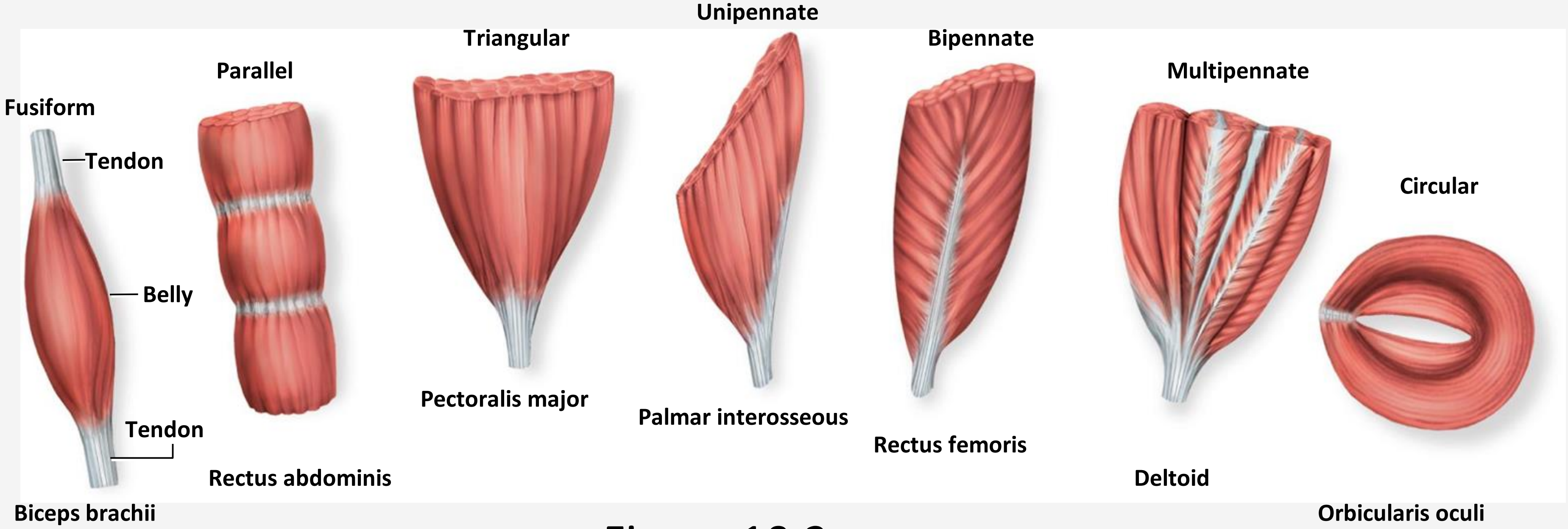
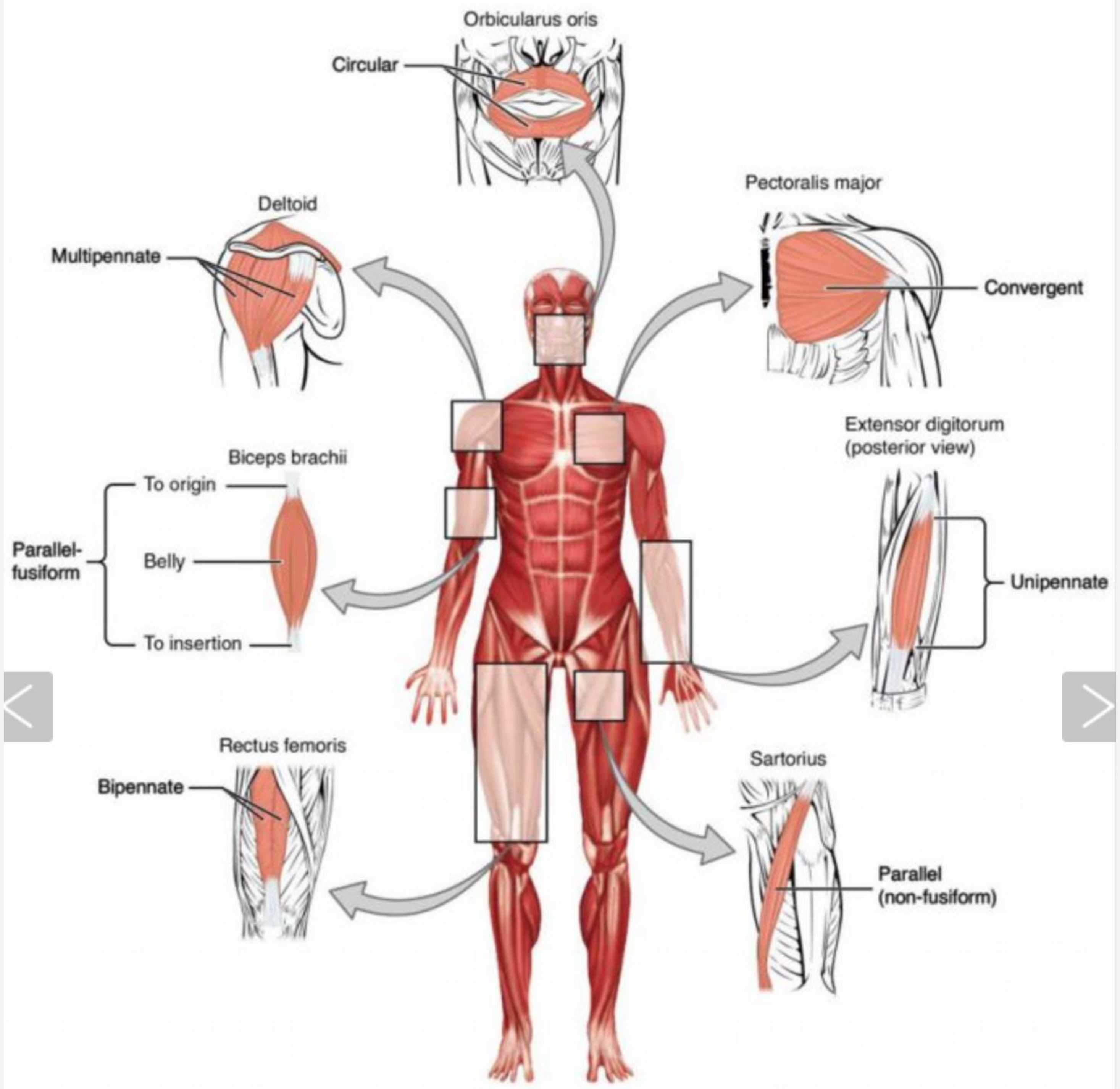


Figure 10.2

strength of a muscle and the direction of its pull are determined partly by the orientation of its fascicles.

Classification of Muscles According to Fascicle Orientation

- **fusiform muscles**
  - thick in middle and tapered at ends
  - *biceps brachii* , *gastrocnemius*
- **parallel muscles**
  - have uniform width and parallel fascicles
  - can span longer distances than other shapes
  - *rectus abdominis*, *zygomaticus major*
- **triangular (convergent) muscles**
  - fan-shaped, broad at origin and tapering to a narrower insertion
  - *pectoralis major*, *temporalis*
- **pennate muscles**
  - fascicles insert obliquely on a tendon (feather shaped)
  - unipennate, bipennate or multipennate
  - *palmar interosseus*, *rectus femoris* and *deltoid*
- **circular muscles (sphincters)**
  - ring around body opening
  - *orbicularis oculi, urethral* and *anal sphincters*


Orbicularus oris
Circular
Pectoralis major
Convergent
Deltoid
Multipennate
Extensor digitorum
(posterior view)
Unipennate
Biceps brachii
To origin
Parallel-
fusiform
Belly
To insertion
Rectus femoris
Bipennate
Sartorius
Parallel
(non-fusiform)

DEEPER INSIGHT 10.1

CLINICAL APPLICATION

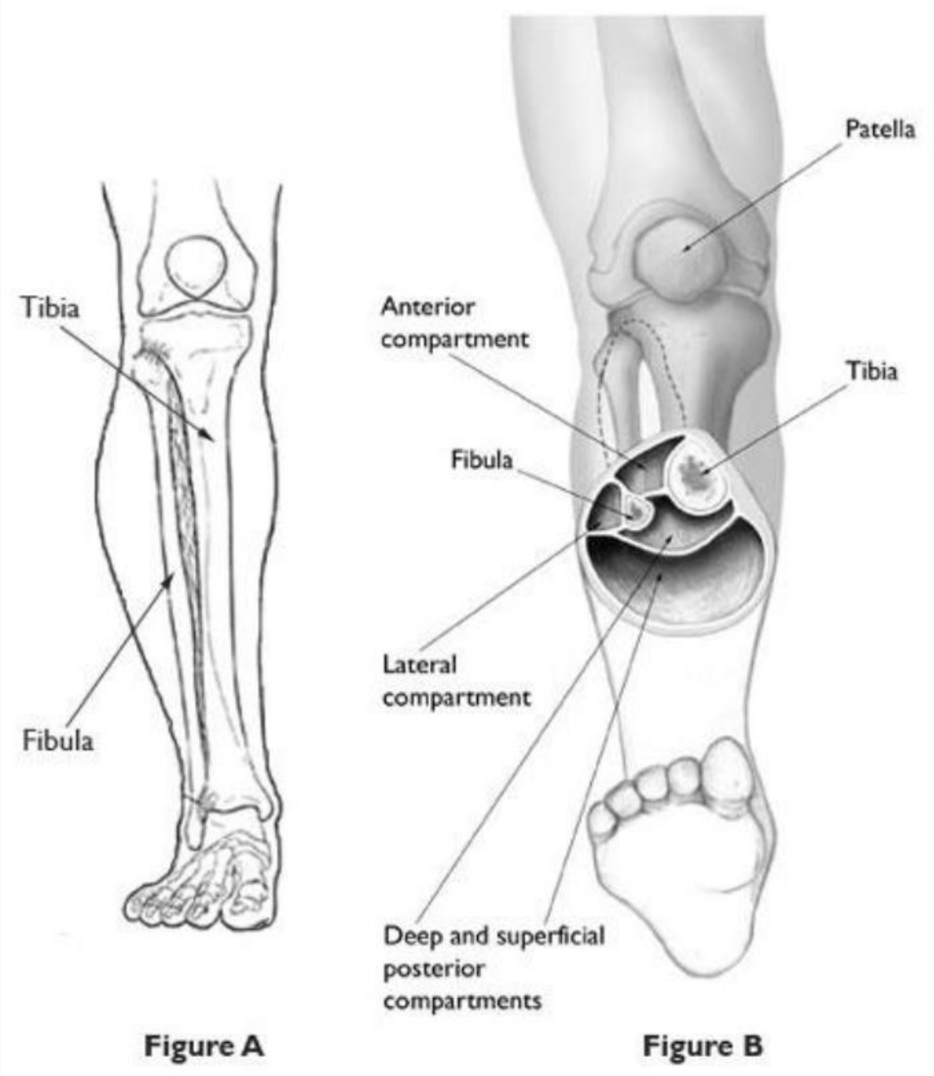
Compartment Syndrome

Muscle compartments are very snugly contained in their fasciae. If a blood vessel in a compartment is damaged by overuse or contusion (a bruising injury), blood and tissue fluid accumulate in the compartment. The inelastic fascia prevents the compartment from expanding to relieve the pressure. Mounting pressure on the muscles, nerves, and blood vessels triggers a sequence of degenerative events called *compartment syndrome.* Blood flow to the compartment is obstructed by pressure on its arteries. If *ischemia* (poor blood flow) persists for more than 2 to 4 hours, nerves begin to die, and after 6 hours, so does muscle tissue. Nerves can regenerate after the pressure is relieved, but muscle necrosis is irreversible. The breakdown of muscle releases myoglobin into the blood. *Myoglobinuria,* the presence of myoglobin in the urine, gives the urine a dark color and is one of the key signs of compartment syndrome and some other degenerative muscle disorders. Compartment syndrome is treated by immobilizing and resting the limb and, if necessary, making an incision (*fasciotomy*) to relieve the pressure.

The fasciae are not components of the muscles themselves, but package groups of functionally related muscles into muscle compartments and stand between the muscles and the overlying hypodermis and skin.

A compartment also contains the nerves and blood vessels that supply the muscle group. Such compartmentalization occurs in the thoracic and abdominal walls, pelvic floor, and limbs.

Some of these fasciae are particularly thick and are called intermuscular septa. The tight binding of muscles by these fasciae contributes to *compartment syndrome.*



The area between the knee and ankle has four major muscle compartments: anterior, lateral, superficial posterior, deep posterior.

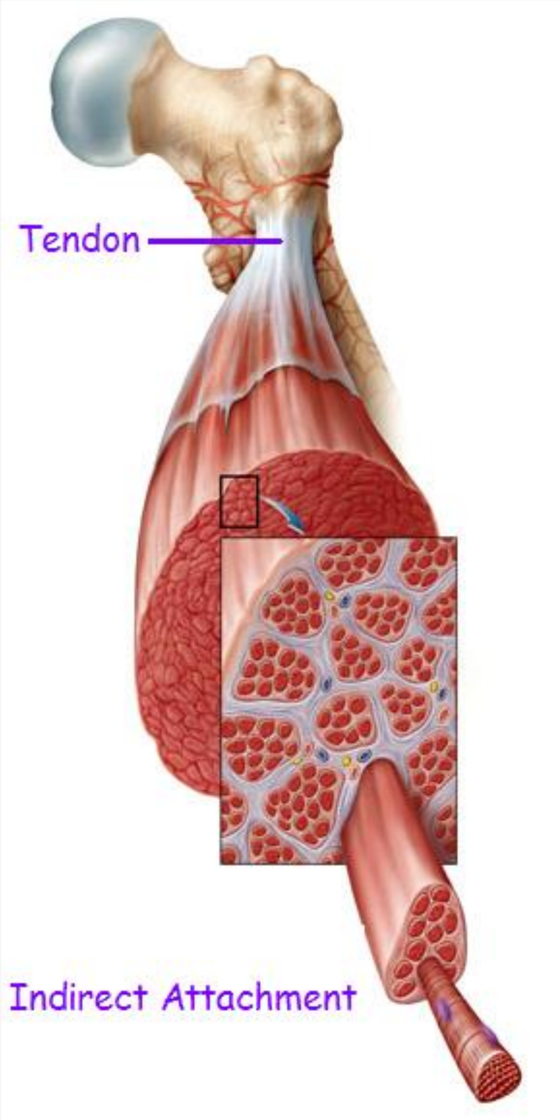
Muscle Attachments

- **indirect attachment to bone**
  - **tendons** bridge the gap between muscle ends and bony attachment
    - the collagen fibers of the endo-, peri-, and epimysium continue into the tendon
    - from there into the periosteum and the matrix of bone
    - very strong structural continuity from muscle to bone
    - *biceps brachii, Achilles tendon*
    - **aponeurosis** – tendon is a broad, flat sheet *(palmar aponeurosis)*
    - **retinaculum** – connective tissue band that tendons from separate muscles pass under

- **direct (fleshy) attachment to bone**
  - little separation between muscle and bone
  - muscle seems to immerge directly from bone
  - margins of *brachialis*, lateral head of *triceps brachii*

- some skeletal muscles do not insert on bone, but in dermis of the skin – muscles of facial expression

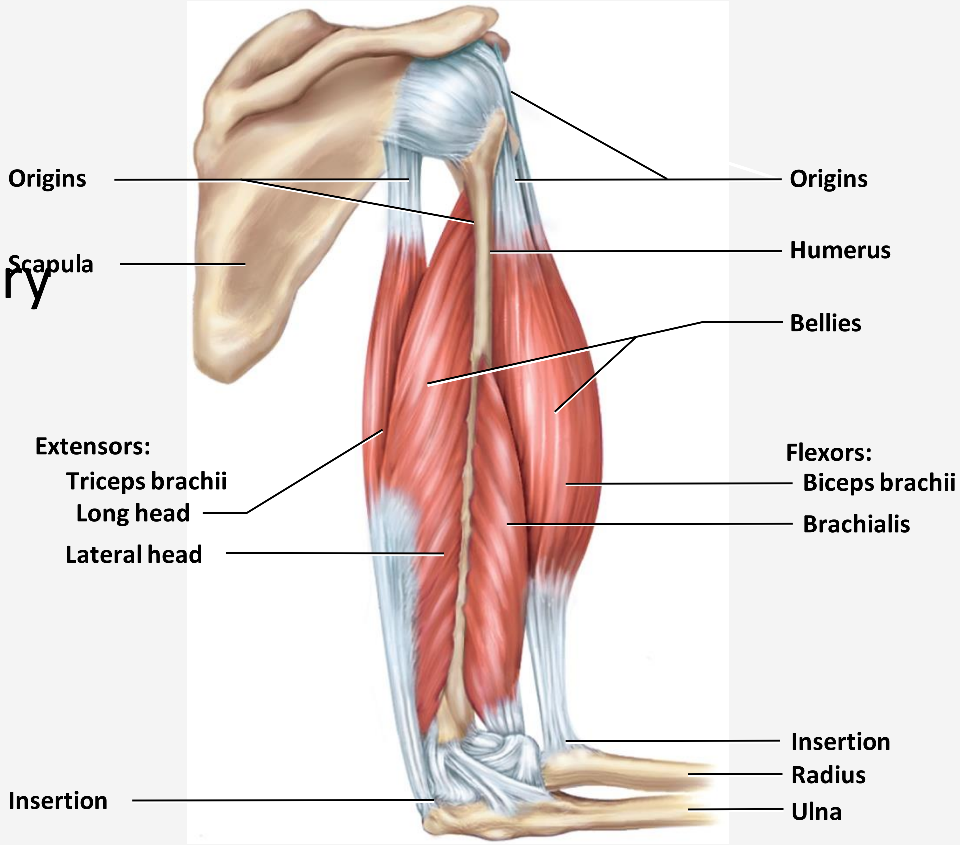
Muscle Attachment to Bone



Direct Attachment

Muscle Origins and Insertions

Which of these muscles have direct attachments to the bones, and which have indirect attachments?



- **Origin**
  - bony attachment at stationary end of muscle
- **Belly**
  - thicker, middle region of muscle between origin and insertion
- **Insertion**
  - bony attachment to mobile end of muscle

Functional Groups of Muscles

- **action –** the effects produced by a muscle
  - to produce or prevent movement
- **prime mover (agonist) -** muscle that produces most of force during a joint action
- **synergist -** muscle that aids the prime mover
  - stabilizes the nearby joint
  - modifies the direction of movement
- **antagonist -** opposes the prime mover
  - relaxes to give prime mover control over an action
  - preventing excessive movement and injury
  - **antagonistic pairs** – muscles that act on opposite sides of a joint
- **fixator -** muscle that prevents movement of bone

Muscle Actions Across Elbow

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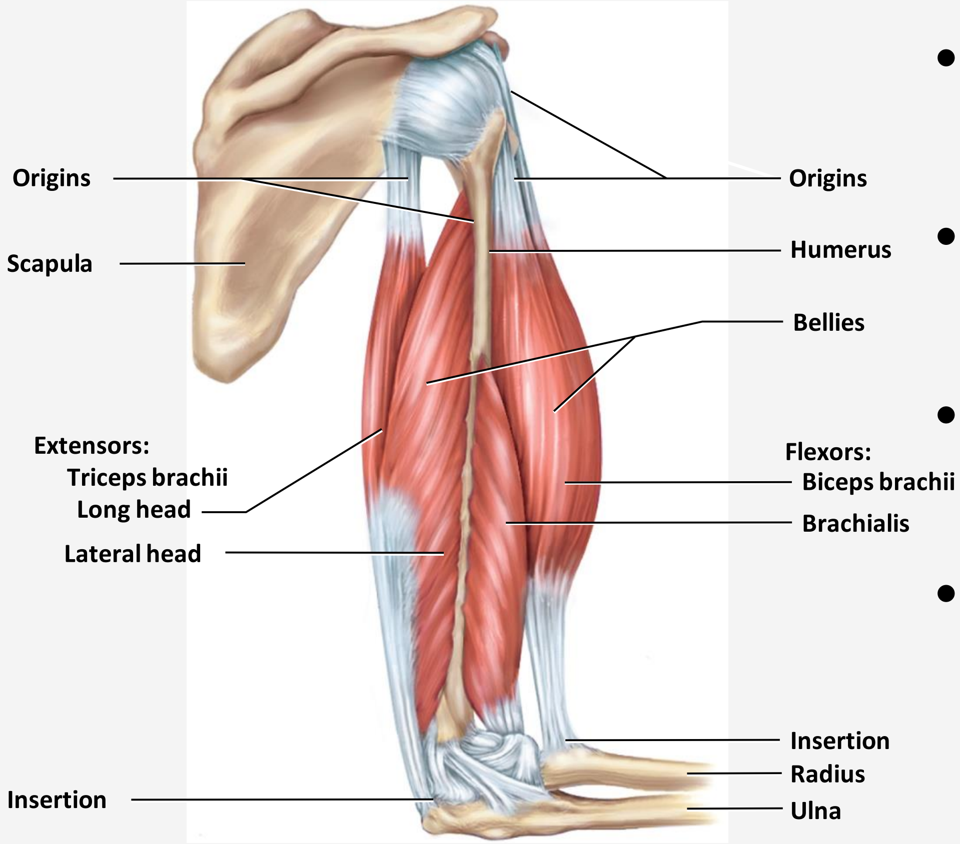

Figure 10.3

- **prime mover** - brachialis
- **synergist** - biceps brachii
- **antagonist** - triceps brachii
- **fixator** - muscle that holds scapula firmly in place
  - *rhomboids*

Intrinsic and Extrinsic Muscles

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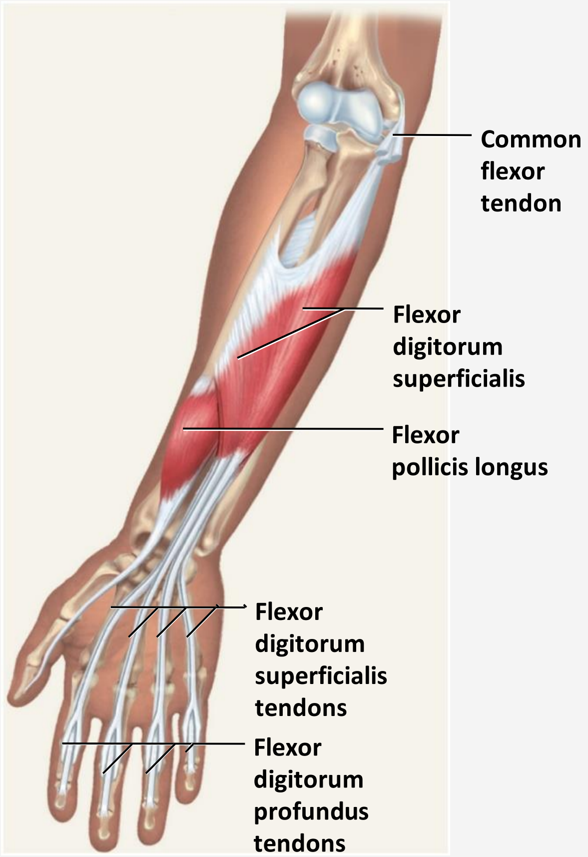

(b) Intermediate flexor

Figure 10.29b

- **intrinsic muscles –** entirely contained within a region, such as the hand
  - both its origin and insertion there
- **extrinsic muscles –** act on a designated region, but has its origin elsewhere
  - fingers – extrinsic muscles in the forearm

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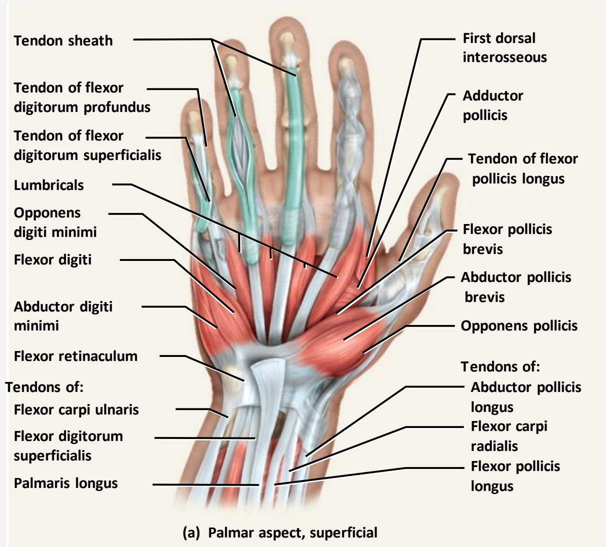
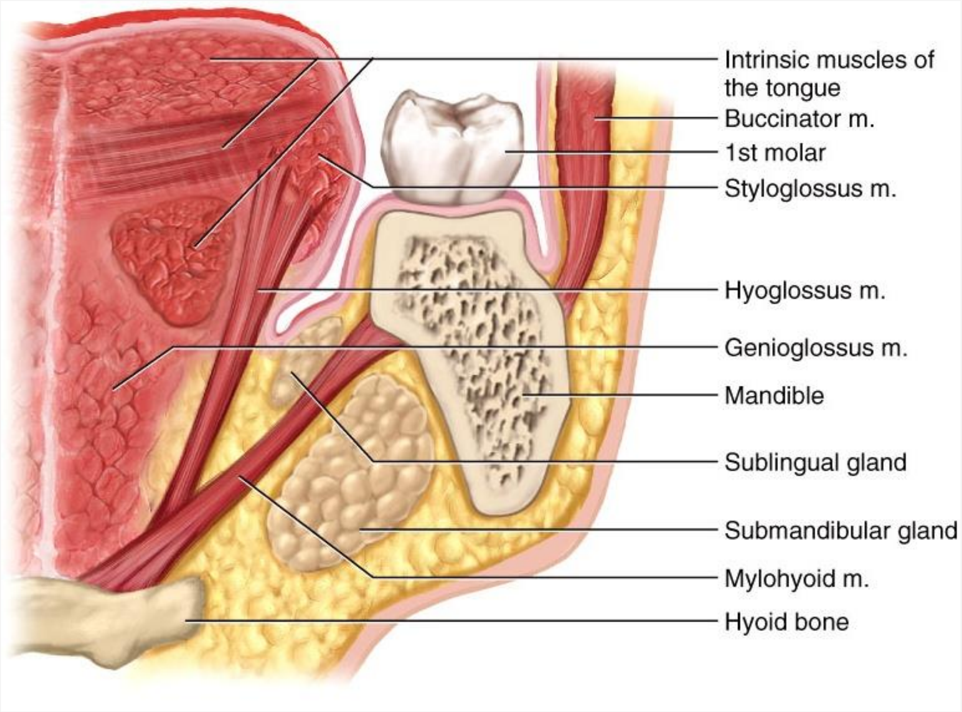


(a) Palmar aspect, superficial

Figure 10.32a

Intrinsic & Extrinsic Muscles



Muscle Innervation

- **innervation of a muscle** – refers to the identity of the nerve that stimulates it
  - enables the diagnosis of nerve, spinal cord, and brainstem injuries from their effects on muscle function
- **spinal nerves** arise from the spinal cord
  - emerge through intervertebral foramina
  - immediately branch into a posterior and anterior ramus
  - innervate muscles below the neck
  - **plexus** – weblike network of spinal nerves adjacent to the vertebral column
- **cranial nerves** arise from the base of the brain
  - emerge through skull foramina
  - innervate the muscles of the head and neck
  - numbered I to XII

Learning Strategy

- **examine** models, cadavers, dissected animals, or a photographic atlas to get **visual images of the muscle**

- when studying a particular muscle, **palpate** it on yourself if possible

- locate **origins and insertions** of muscles on an articulated skeleton

- study derivation of each **muscle name**
  - usually describes the muscle's location, appearance, origin, insertion or action

- **say the names** aloud to yourself or study partner, and spell them correctly

The Muscular System

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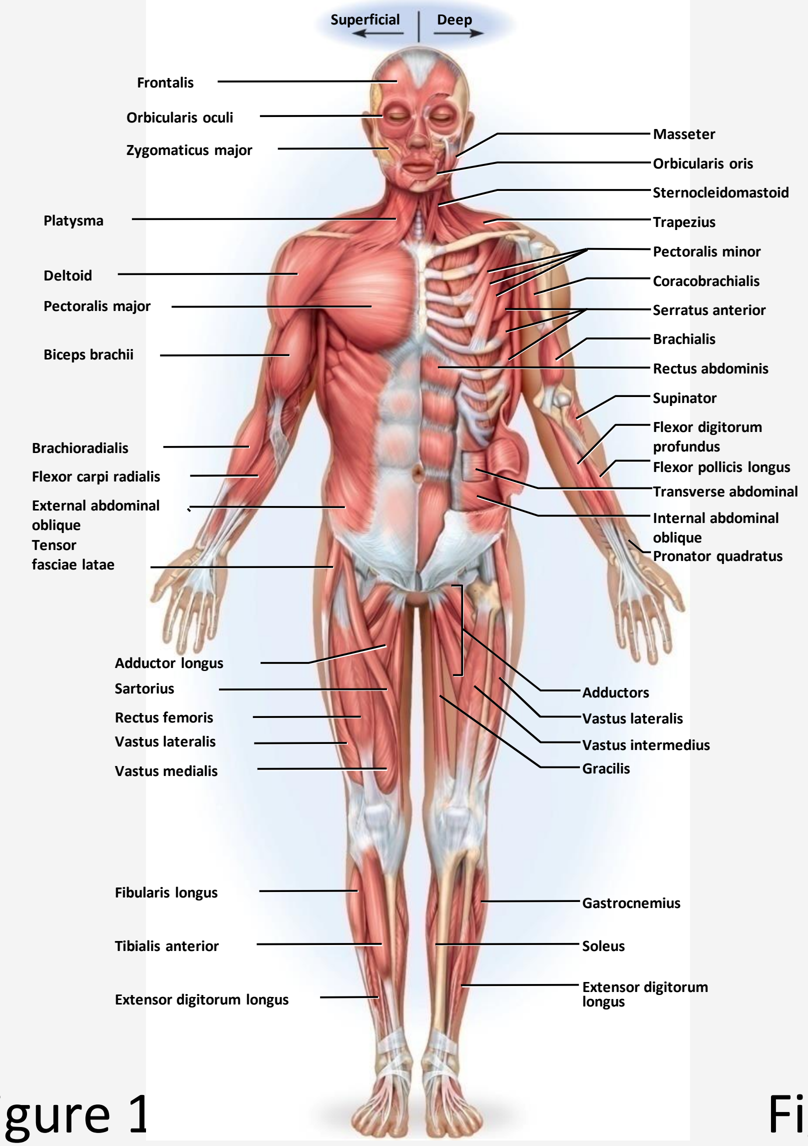

Figure 1

(a) Anterior view

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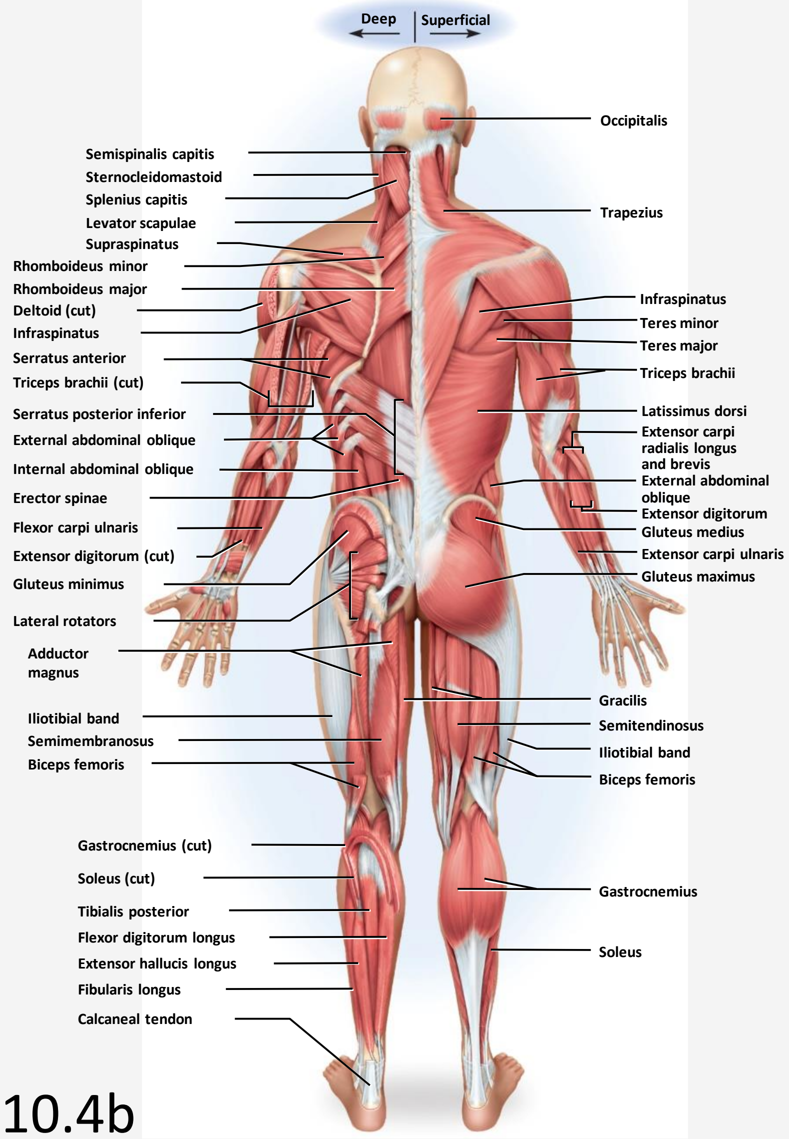

Figure 10.4b

(b) Posterior view

Building Your Medical Vocabulary

State a meaning of each word element, and give a medical term that uses it or a slight variation of it.

1. capito-
2. ergo-
3. fasc-
4. labio-
5. lumbo-
6. mus-
7. mys-
8. omo-
9. penn-
10. tert-

Behavior of Whole Muscles

- the response of a muscle to weak electrical stimulus seen in frog gastrocnemius - sciatic nerve preparation
- **myogram** – a chart of the timing and strength of a muscle's contraction
- weak, subthreshold electrical stimulus causes no contraction
- **threshold** - the minimum voltage necessary to generate an action potential in the muscle fiber and produce a contraction
- **twitch** – a quick cycle of contraction when stimulus is at threshold or higher

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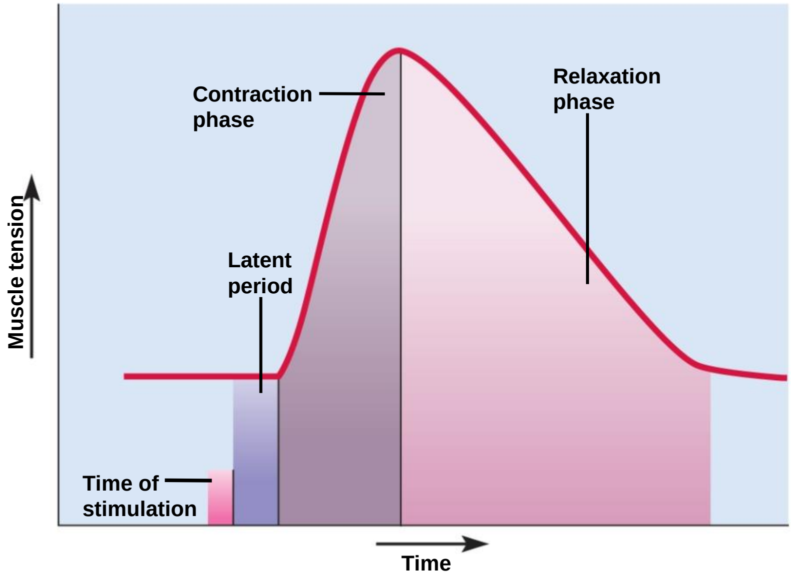

Figure 11.13

Phases of a Twitch Contraction

- **latent period** - 2 msec delay between the onset of stimulus and onset of twitch response
  - time required for excitation, excitation-contraction coupling and tensing of elastic components of the muscle
  - **internal tension** – force generated during latent period and no shortening of the muscle occurs
- **contraction phase –** phase in which filaments slide and the muscle shortens
  - once elastic components are taut, muscle begins to produce **external tension** – in muscle that moves a load
  - short-lived phase
- **relaxation phase** - **SR quickly reabsorbs Ca^{+2}, myosin releases the thin filaments and tension declines**
  - muscle returns to resting length
  - entire twitch lasts from 7 to 100 msec

Contraction Strength of Twitches

- at **subthreshold stimulus** – no contraction at all
- at **threshold intensity and above** - a twitch is produced
  - twitches caused by increased voltage are no stronger than those at threshold
- **not exactly true** that muscle fiber obeys an **all-or-none law** -contracting to its maximum or not at all
  - electrical excitation of a muscle follows all-or-none law
  - not true that muscle fibers follow the all or none law
  - twitches vary in strength depending upon:
    - **stimulus frequency** - stimuli arriving closer together produce stronger twitches
    - **concentration of Ca^{+2}** in sarcoplasm can vary the frequency
    - how **stretched** muscle was before it was stimulated
    - **temperature** of the muscles – warmed-up muscle contracts more strongly – enzymes work more quickly
    - lower than normal **pH** of sarcoplasm weakens the contraction - **fatigue**
    - **state of hydration** of muscle affects overlap of thick & thin filaments
- muscles need to be able to contract with variable strengths for different tasks

Recruitment and Stimulus Intensity

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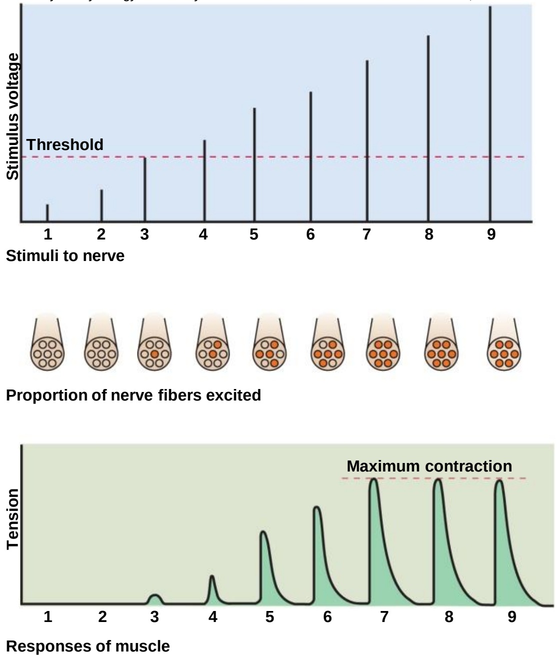


Figure 11.14

- stimulating the nerve with higher and higher voltages produces stronger contractions
  - higher voltages excite more and more nerve fibers in the motor nerve which stimulates more and more motor units to contract
- **recruitment** or **multiple motor unit (MMU) summation** – the process of bringing more motor units into play

Twitch Strength & Stimulus Frequency

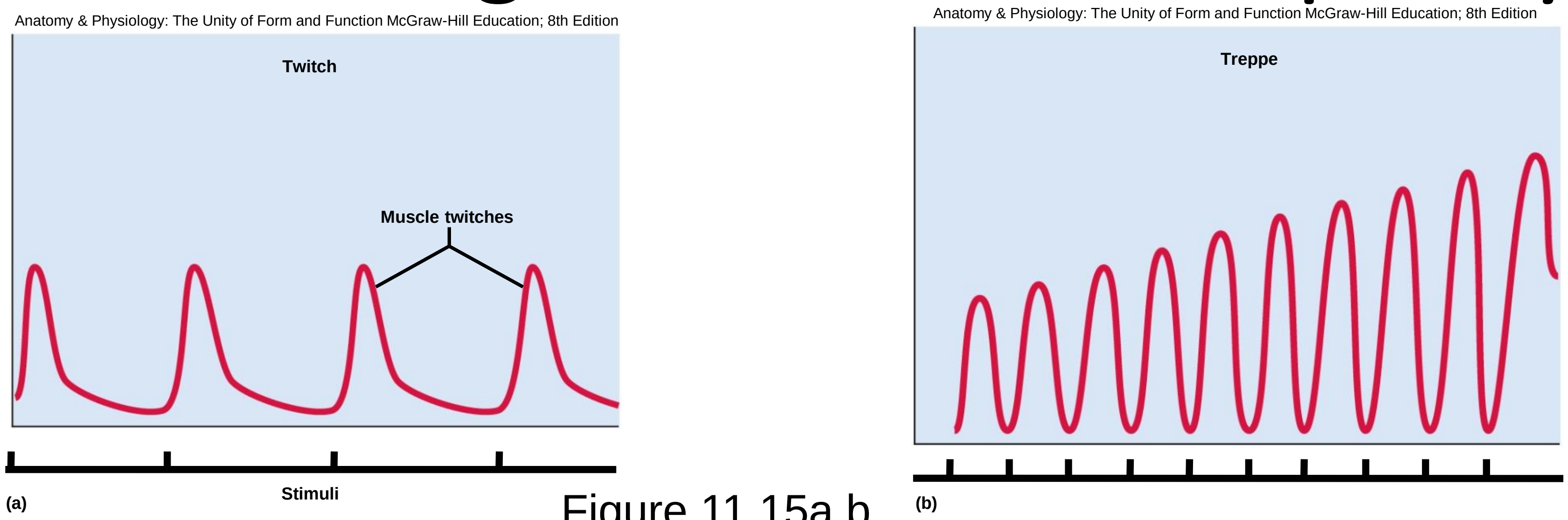
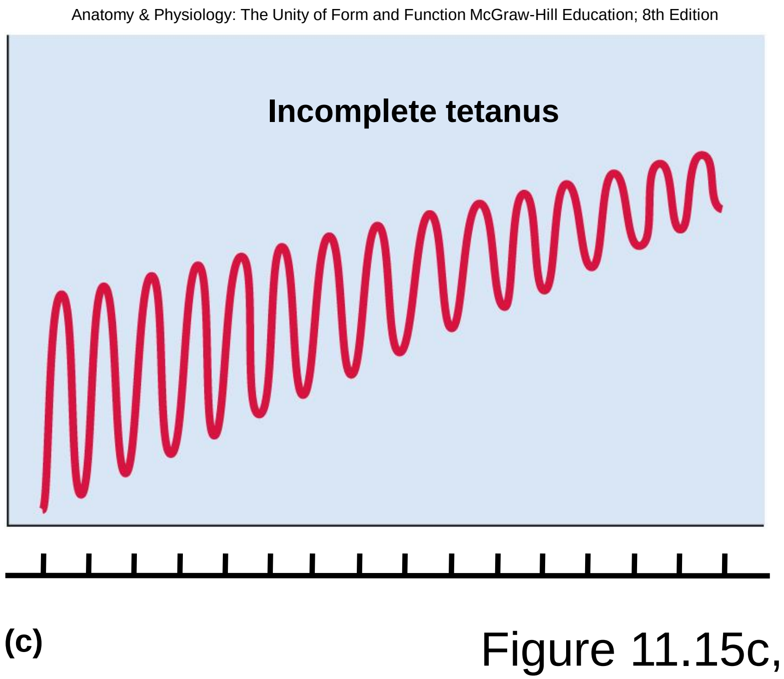


Figure 11.15a,b

- when stimulus intensity (voltage) remains constant twitch strength can vary with the stimulus frequency
- **up to 10 stimuli per second**
  - each stimulus produces identical twitches and full recovery between twitches
- **10-20 stimuli per second** produces **treppe** (staircase) phenomenon
  - muscle still recovers fully between twitches, but each twitch develops more tension than the one before
  - stimuli arrive so rapidly that the SR does not have time between stimuli to completely reabsorb all of the Ca^{+2} it released
  - Ca^{+2} concentration in the cytosol rises higher and higher with each stimulus causing subsequent twitches to be stronger
  - heat released by each twitch cause muscle enzymes such as myosin ATPase to work more efficiently and produce stronger twitches as muscle warms up

Incomplete and Complete Tetanus



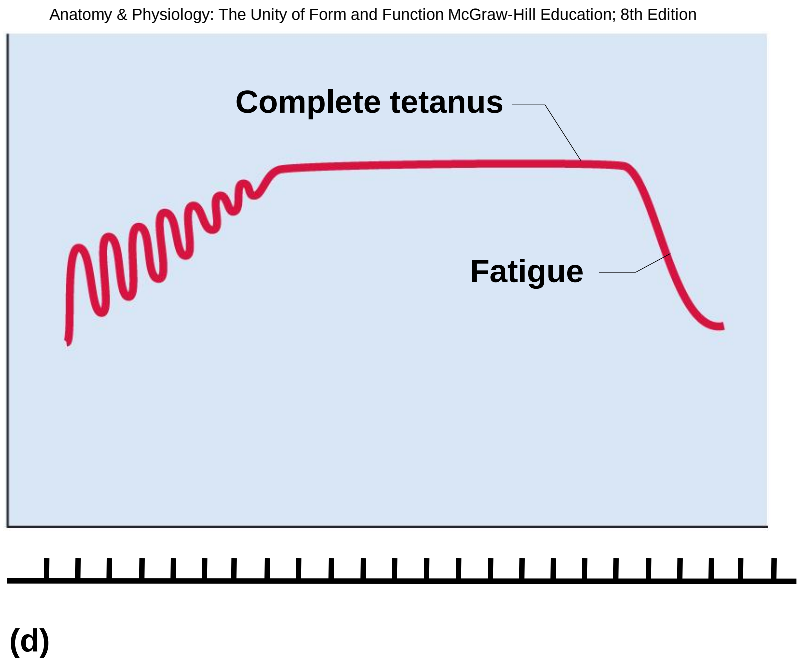


Figure 11.15c,d

- **20-40 stimuli per second** produces **incomplete tetanus**
  - each new stimulus arrives before the previous twitch is over
  - new twitch “rides piggy-back” on the previous one generating higher tension
  - **temporal summation** – results from two stimuli arriving close together
  - **wave summation** – results from one wave of contraction added to another
  - each twitch reaches a higher level of tension than the one before
  - muscle relaxes only partially between stimuli
  - produces a state of sustained fluttering contraction called **incomplete tetanus**

Incomplete and Complete Tetanus

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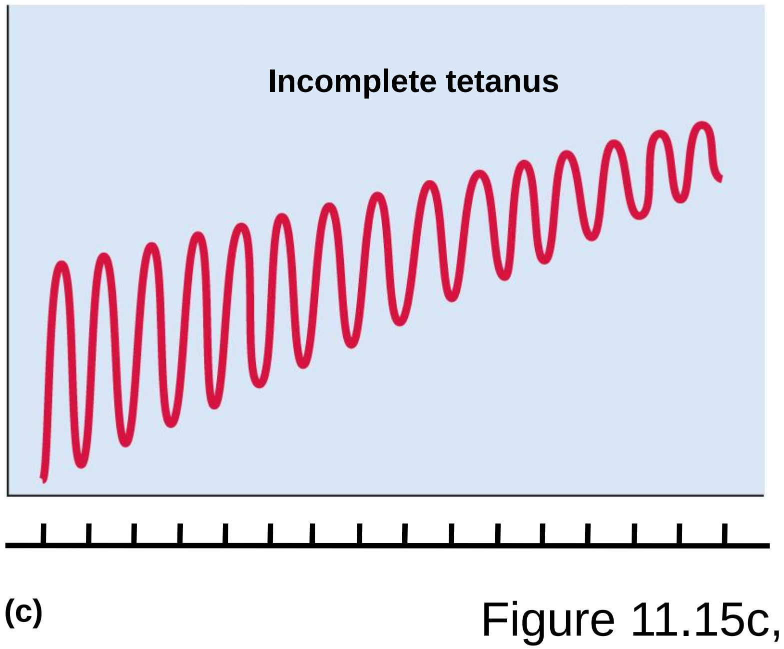

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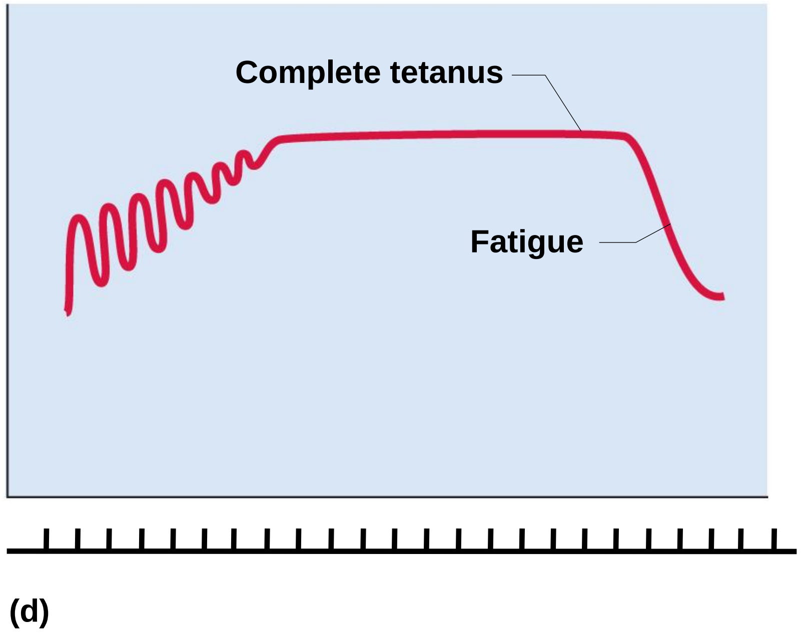

Figure 11.15c,d

- **40-50 stimuli per second** produces **complete tetanus**
  - muscle has no time to relax at all between stimuli
  - twitches fuse to a smooth, prolonged contraction called complete tetanus
  - a muscle in complete tetanus produces about four times the tension as a single twitch
  - rarely occurs in the body, which rarely exceeds 25 stimuli per second
  - smoothness of muscle contractions is because motor units function asynchronously
    - when one motor unit relaxes, another contracts and takes over so the muscle does not lose tension

Isometric and Isotonic Contractions

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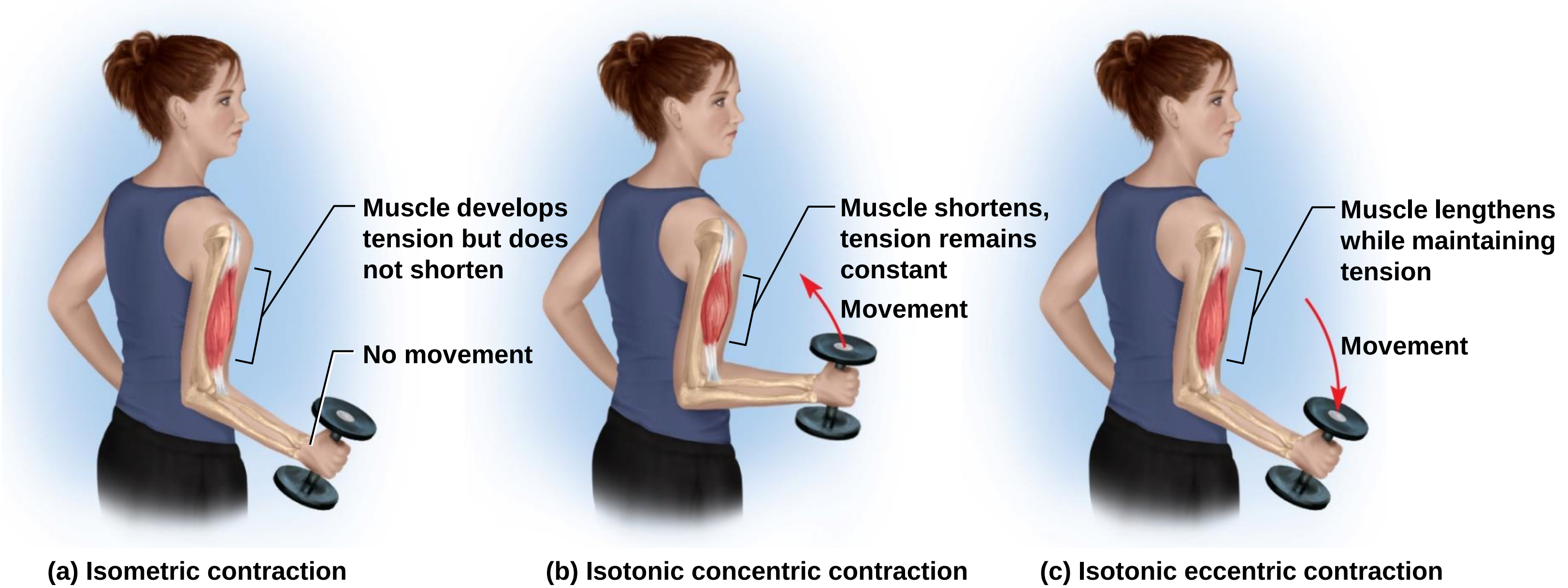

Figure 11.16

- **isometric muscle contraction**
  - muscle is producing internal tension while an external resistance causes it to stay the same length or become longer
  - can be a prelude to movement when tension is absorbed by elastic component of muscle
  - important in postural muscle function and antagonistic muscle joint stabilization
- **isotonic muscle contraction**
  - muscle changes in length with no change in tension
  - **concentric contraction** – muscle shortens while maintains tension
  - **eccentric contraction** – muscle lengthens as it maintains tension

Isometric and Isotonic Phases of Contraction

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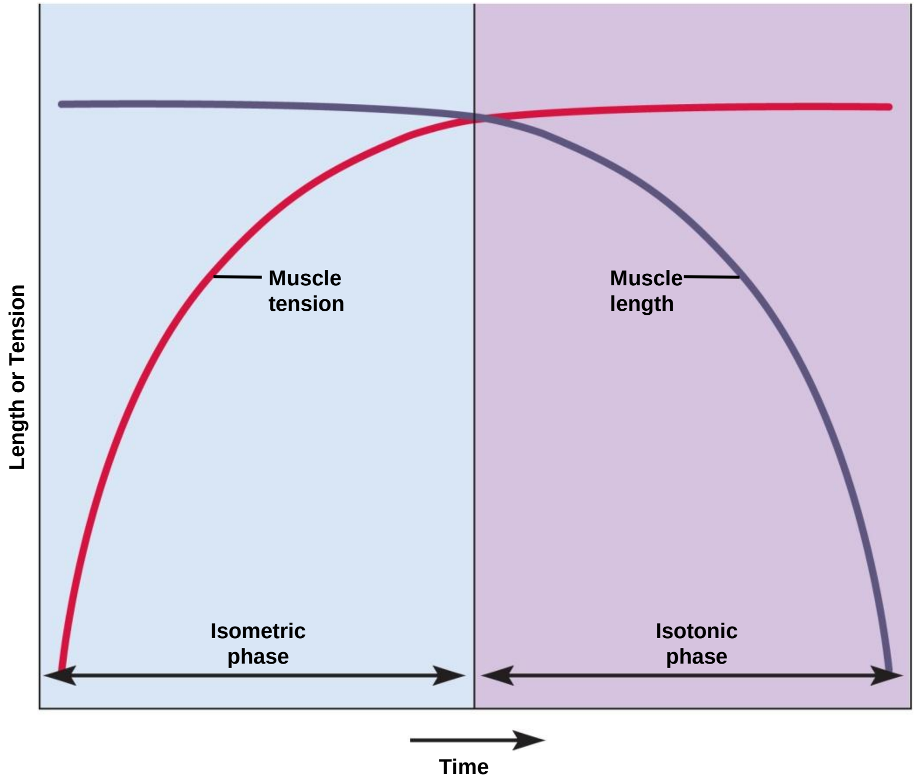

Figure 11.17

- at the beginning of contraction – **isometric phase**
  - muscle tension rises but muscle does not shorten
- when tension overcomes resistance of the load
  - tension levels off
- muscle begins to shorten and move the load – **isotonic phase**

DEEPER INSIGHT 11.2

CLINICAL APPLICATION

Rigor Mortis

- *Rigor mortis* is the hardening of the muscles and stiffening of the body that begins 3 to 4 hours after death. It occurs partly because the deteriorating sarcoplasmic reticulum releases calcium into the cytosol, and the deteriorating sarcolemma admits more calcium from the extracellular fluid. The calcium activates myosin–actin cross-bridging. Once bound to actin, myosin cannot release it without first binding an ATP molecule, and of course no ATP is available in a dead body. Thus, the thick and thin filaments remain rigidly cross-linked until the myofilaments begin to decay. Rigor mortis peaks about 12 hours after death and then diminishes over the next 48 to 60 hours.

Rigor Mortis

- **rigor mortis** - hardening of muscles and stiffening of body beginning 3 to 4 hours after death
  - deteriorating sarcoplasmic reticulum releases Ca^{+2}
  - deteriorating sarcolemma allows Ca^{+2} to enter cytosol
  - Ca^{+2} activates myosin-actin cross-bridging
  - muscle contracts, but can not relax.
- muscle relaxation requires ATP, and ATP production is no longer produced after death
  - fibers remain contracted until myofilaments begins to decay
- rigor mortis peaks about 12 hours after death, then diminishes over the next 48 to 60 hours