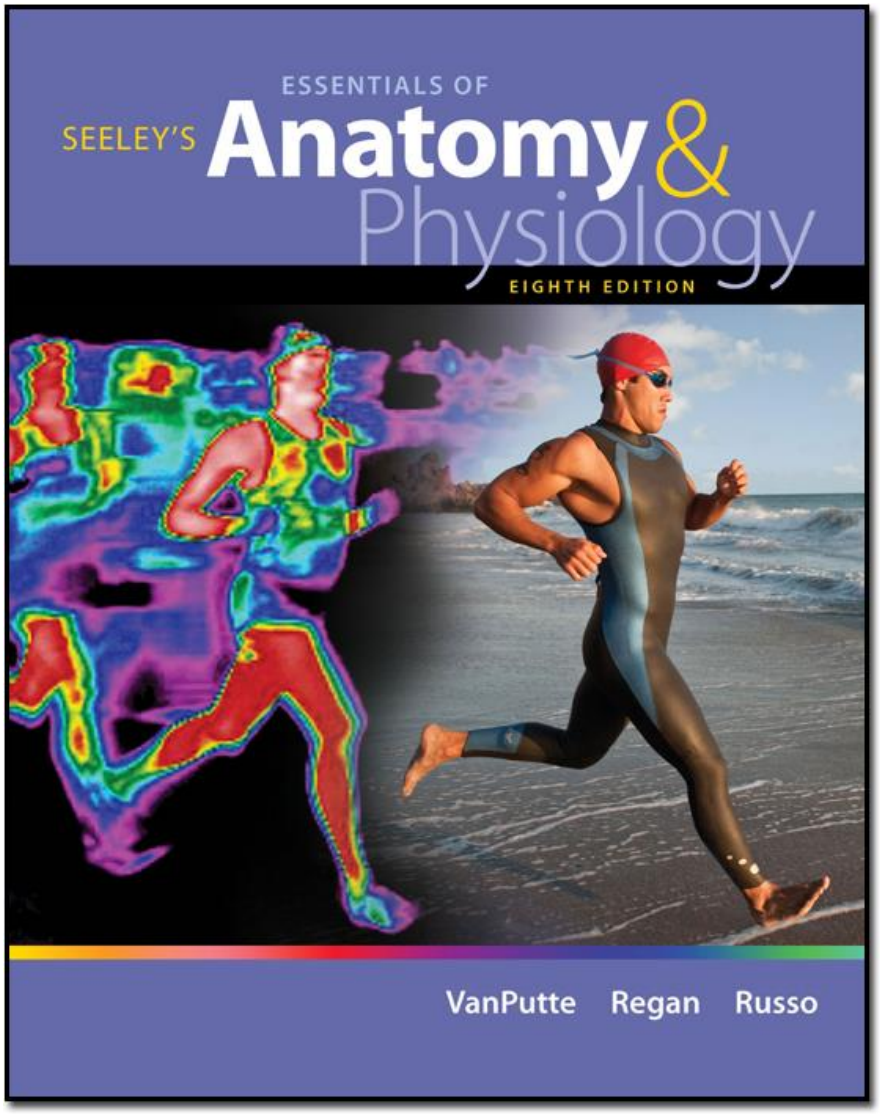


Chapter 07

Lecture and Animation Outline

To run the animations you must be in **Slideshow View**. Use the buttons on the animation to play, pause, and turn audio/text on or off.

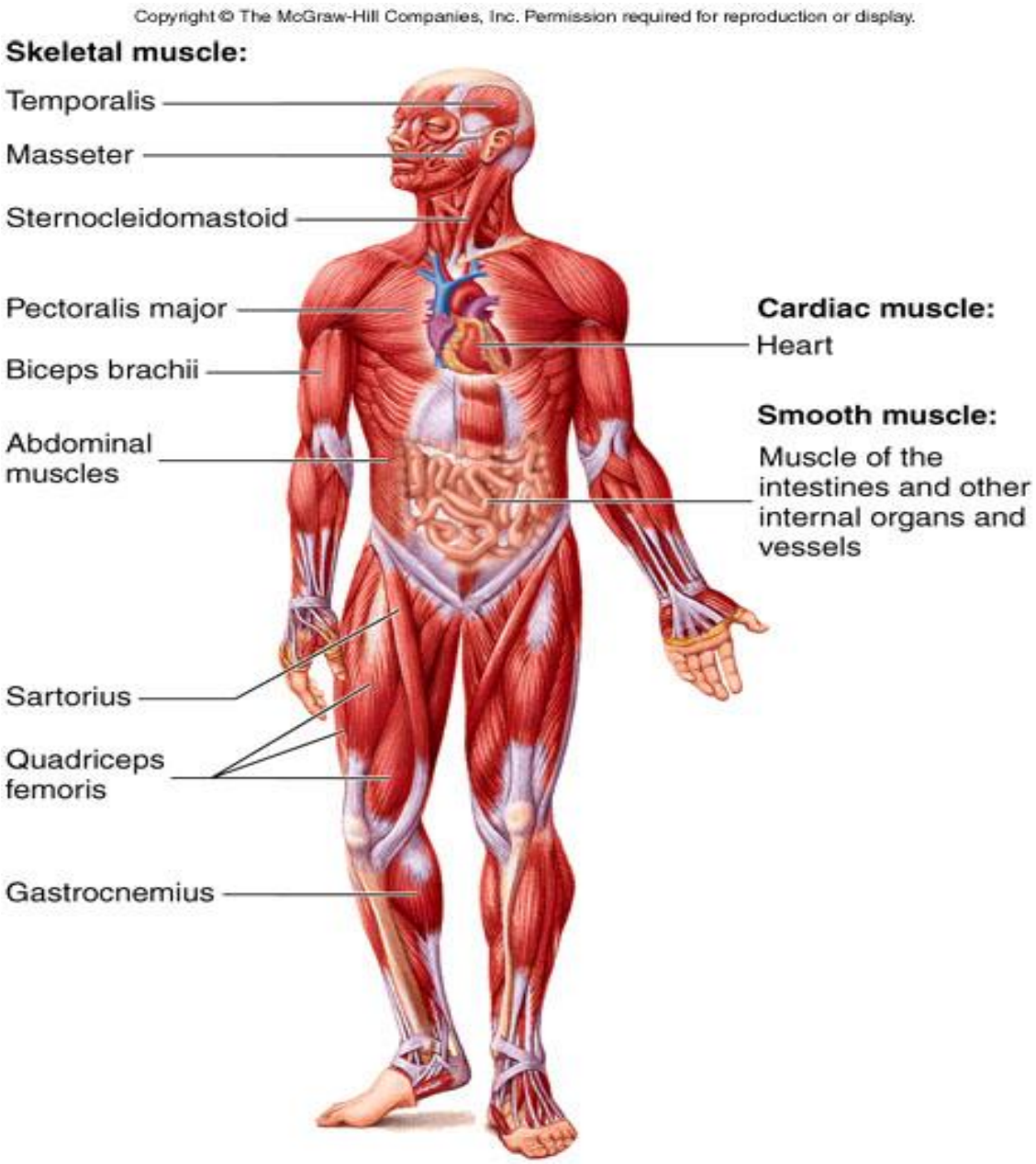
Please Note: Once you have used any of the animation functions (such as Play or Pause), you must first click on the slide's background before you can advance to the next slide.

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes and animations.

Chapter 7-Muscular System

Functions

1. Movement
2. Maintain posture
3. Respiration
4. Production of body heat
5. Communication
6. Heart beat
7. Contraction of organs and vessels



Types of Muscles

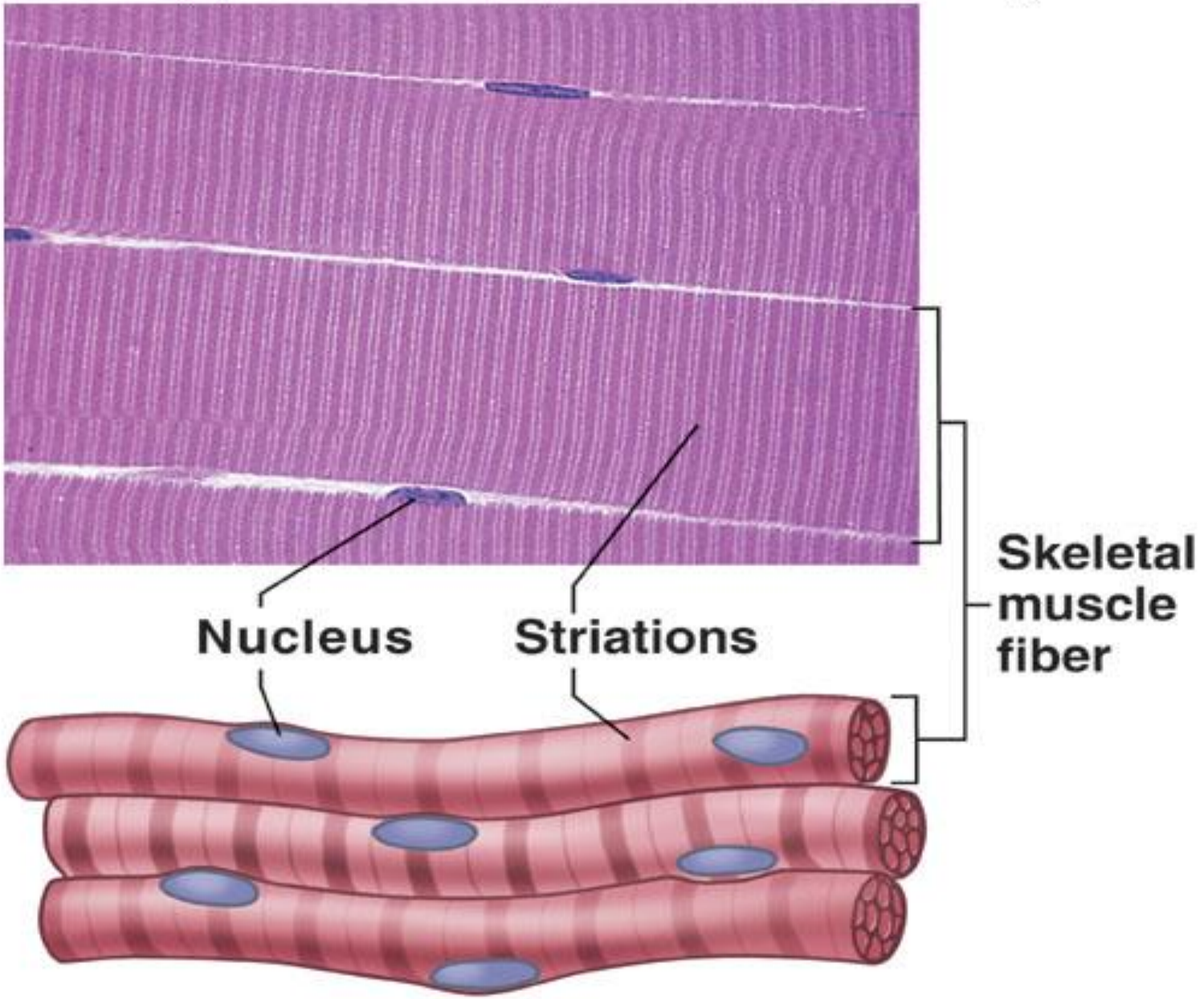
1. **Skeletal**
2. **Cardiac**
3. **Smooth**

Abilities of Skeletal Muscles

- **Contractility:**
  ability to shorten
- **Excitability:**
  respond to stimulus
- **Extensibility:**
  can stretch
- **Elasticity:**
  recoil

Skeletal Muscle Characteristics

- Makes up 40% of body weight
- Named because attached to bones (skeleton)
- Many nuclei per cell (near periphery)
- Striated
- Longest of muscle types



Skeletal Muscle Structures- Connective Tissue Coverings

- **Epimysium:**
  connective tissue that surrounds **entire** skeletal muscle (outside)

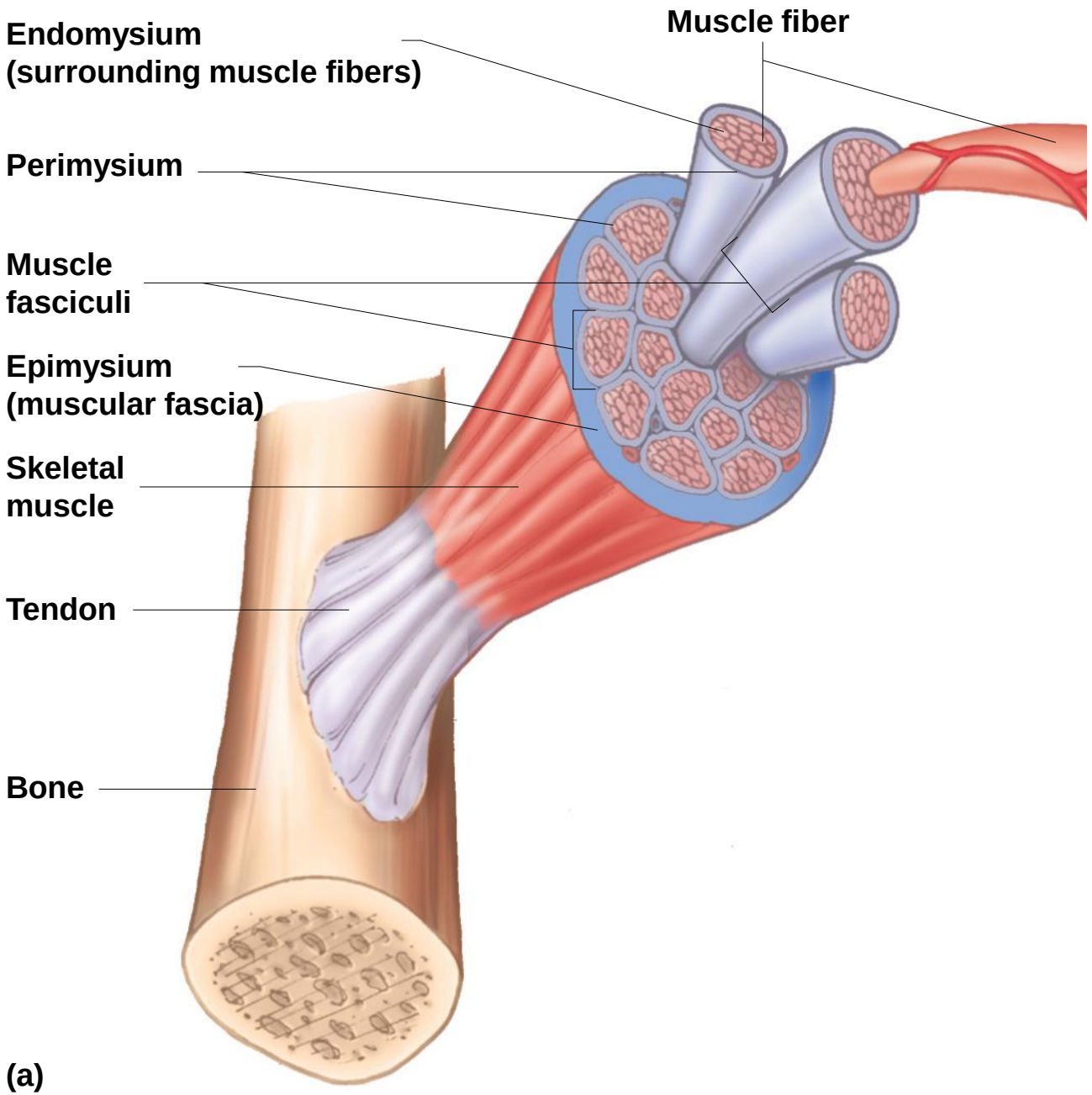
- **Muscle fasciculus:**
  bundle of muscle fibers

- **Perimysium:**
  connective tissue around each muscle fasciculus

- **Muscle fiber:**
  - skeletal muscle cells
  - many nuclei

- **Endomysium:**

  connective tissue that surrounds each muscle fiber



Skeletal Muscle Structures- Muscle Fiber Structure

- **Myofibril:**

  thread-like proteins that make up muscle fibers

- **Myofilament:**
  - proteins that make up myofibrils
  - Ex. actin and myosin

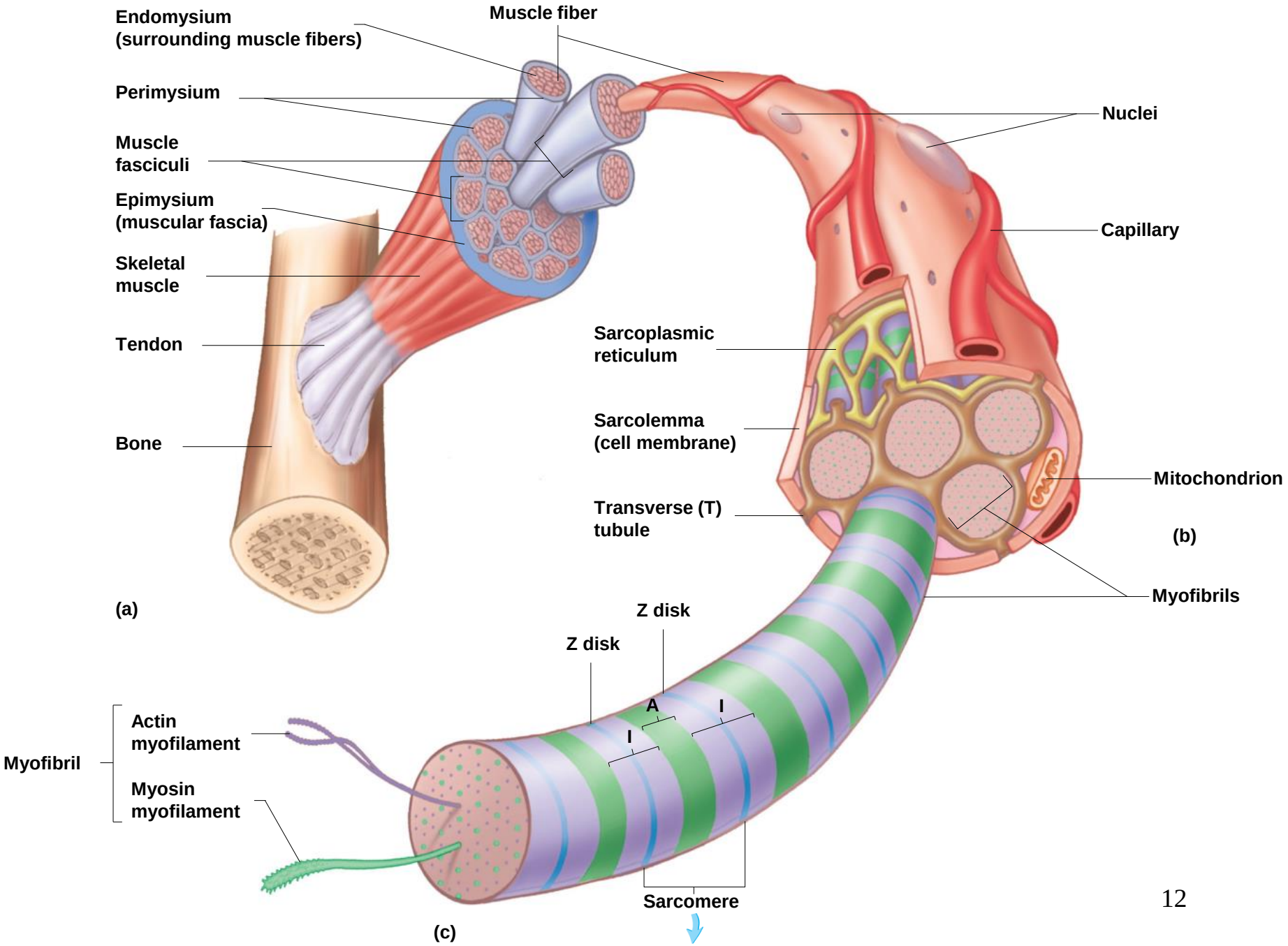
- **Sarcoplasm:**

  cytoplasm of muscle fiber (cell)

- **Sarcolemma:**
  - cell membrane
  - contains T-tubules

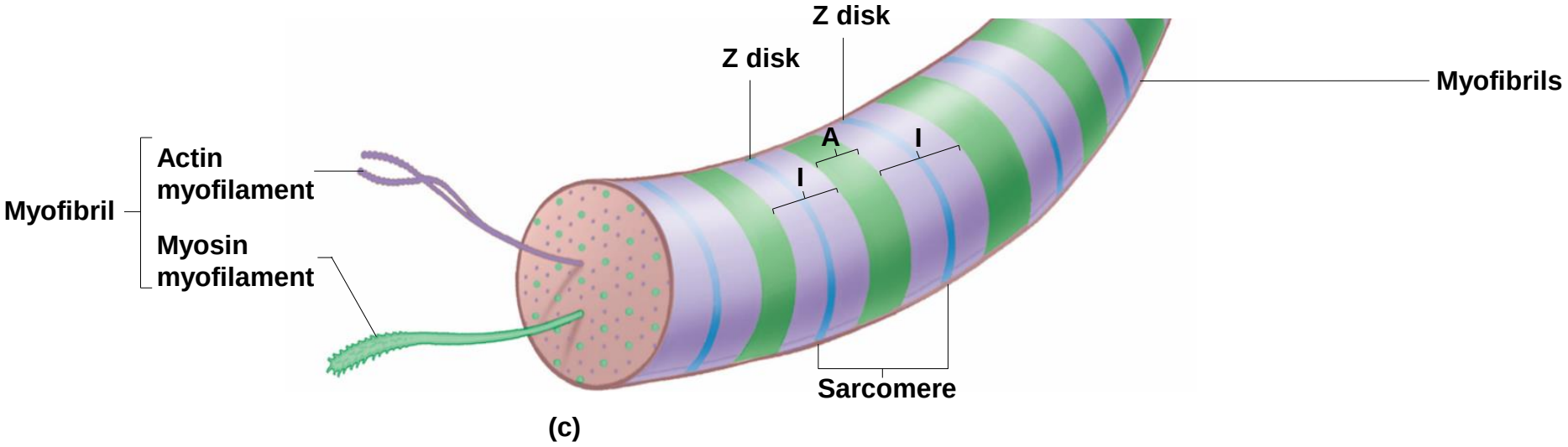
- **T-tubules (transverse):**
  - wrap around sarcomeres at A band
  - associated with sarcoplasmic reticulum

- **Sarcoplasmic reticulum:**
  - type of SER
  - surrounds myosin
  - stores and releases Ca^{2+}



Skeletal Muscle Structures-
Actin and Myosin Myofilaments

- **Actin:**
  - thin myofilament
  - resemble 2 strands of pearls
- **Myosin:**
  - thick myofilament
  - resemble golf clubs
- **Troponin:**
  attachment site on actin for Ca^{2+}
- **Tropomyosin:**
  - filament on grooves of actin
  - attachment site on actin for myosin



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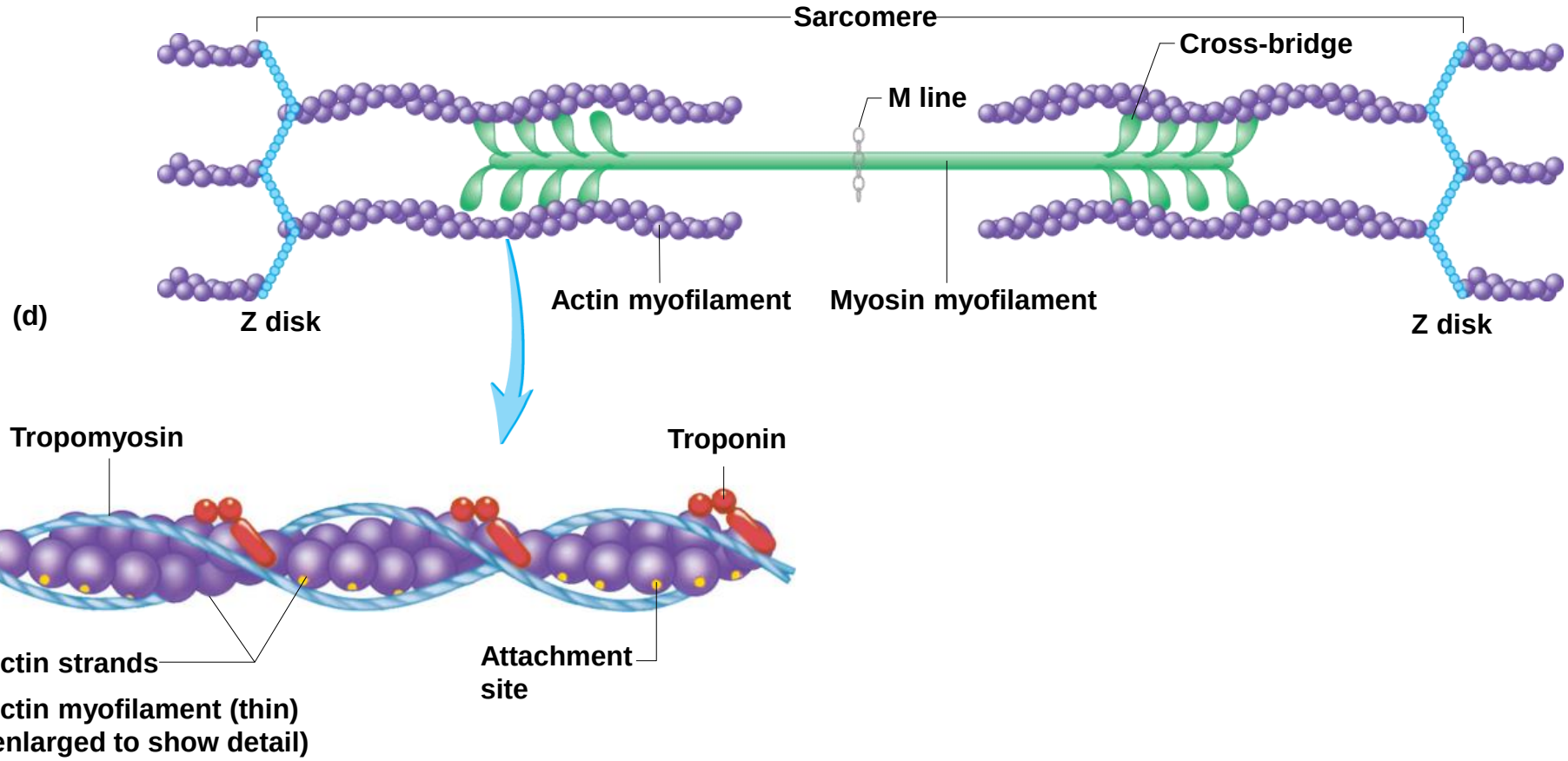

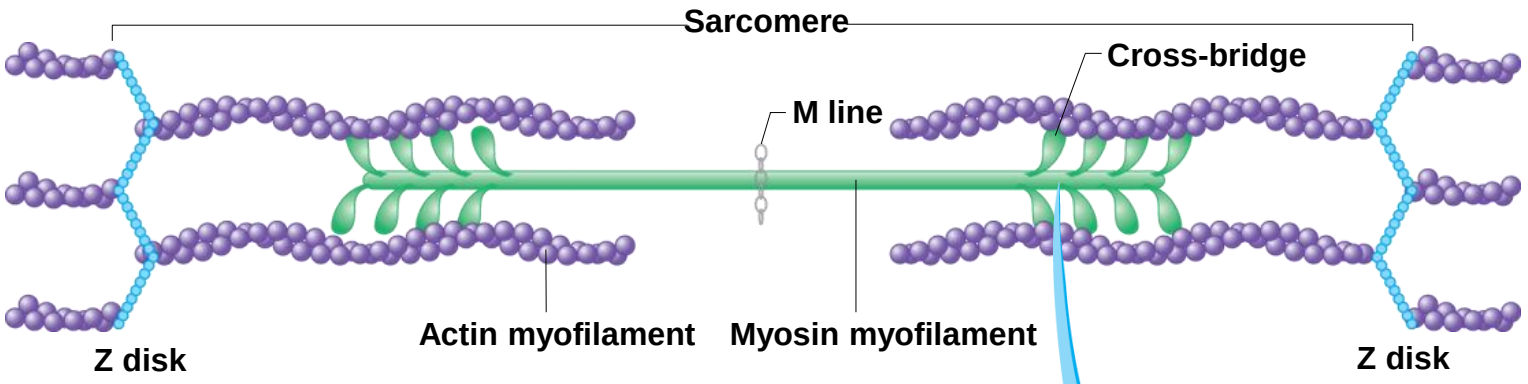

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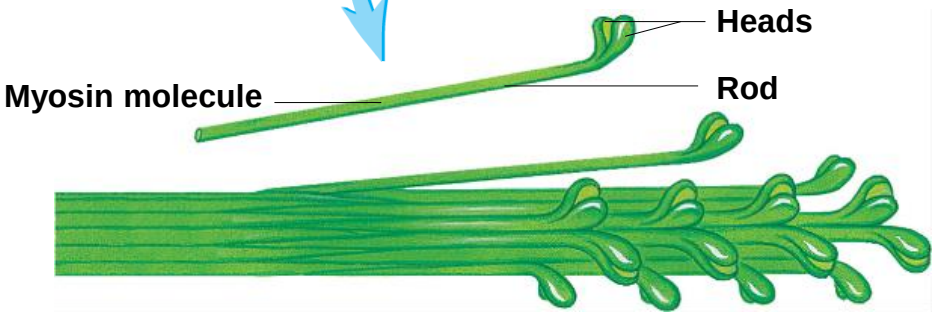


(f) Myosin myofilament (thick)

Skeletal Muscle Structures- Sarcomeres

- **Sarcomere:**
  - contractile unit
  - contains actin and myosin

- **Z disk:**
  protein fibers that form attachment site for actin

- **H zone:**
  - center of sarcomere
  - contains only myosin

- **I band:**

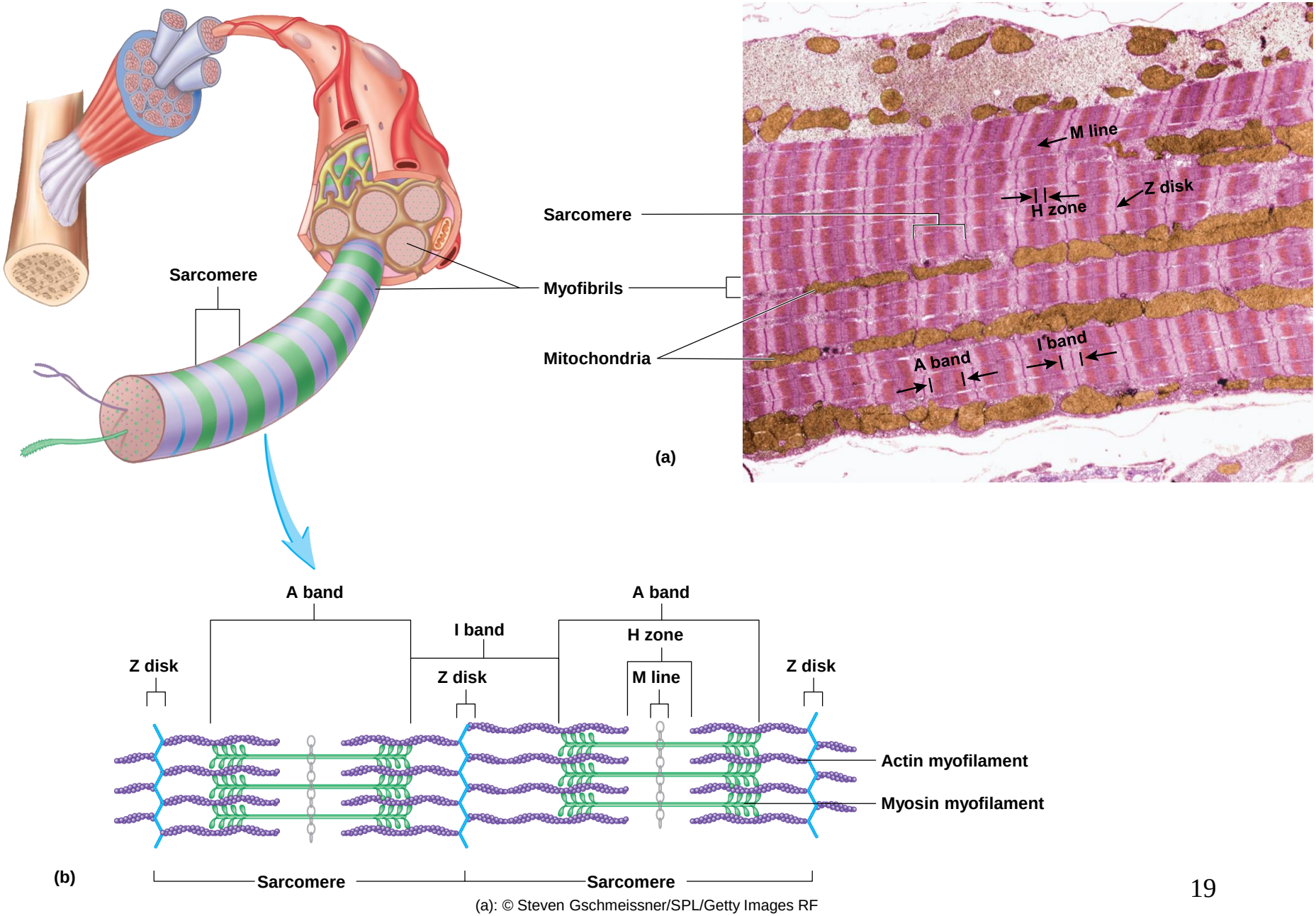
  contains only actin

- **A band:**

  where actin and myosin overlap

- **M line:**

  where myosin are anchored



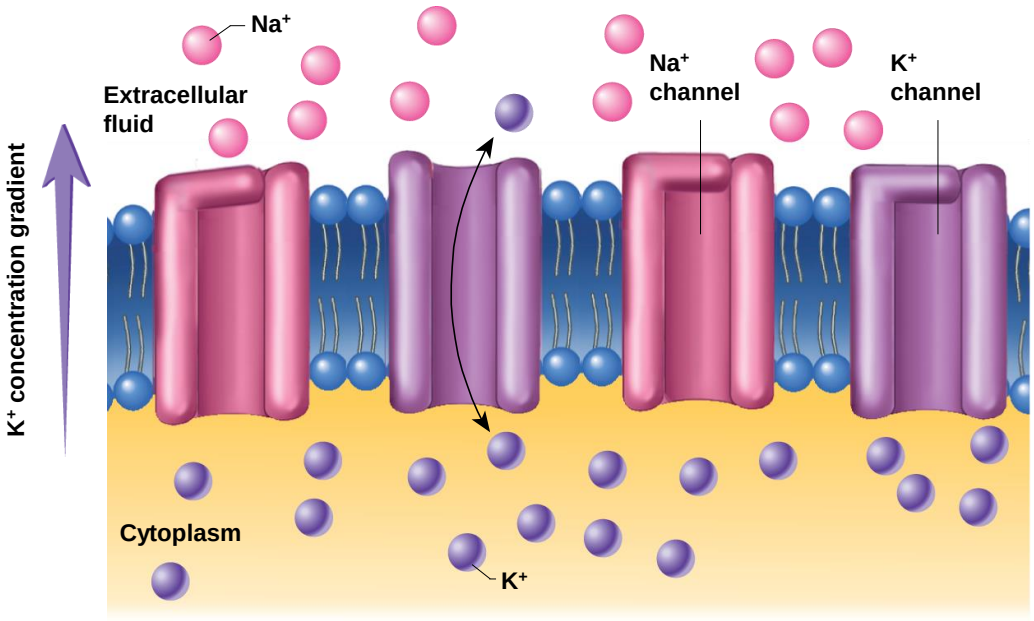
(a): © Steven Gschmeissner/SPL/Getty Images RF

Resting Membrane Potential

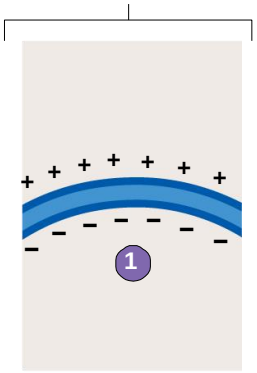
Outside cell	Inside cell
Na^+	K^+
+ charge	– charge
Na^+ channels closed	Some K^+ channels open

- **Why is the inside of cell negative if K^+ is positive?**

  K^+ is able to diffuse out of cell freely but other larger negative molecules cannot.



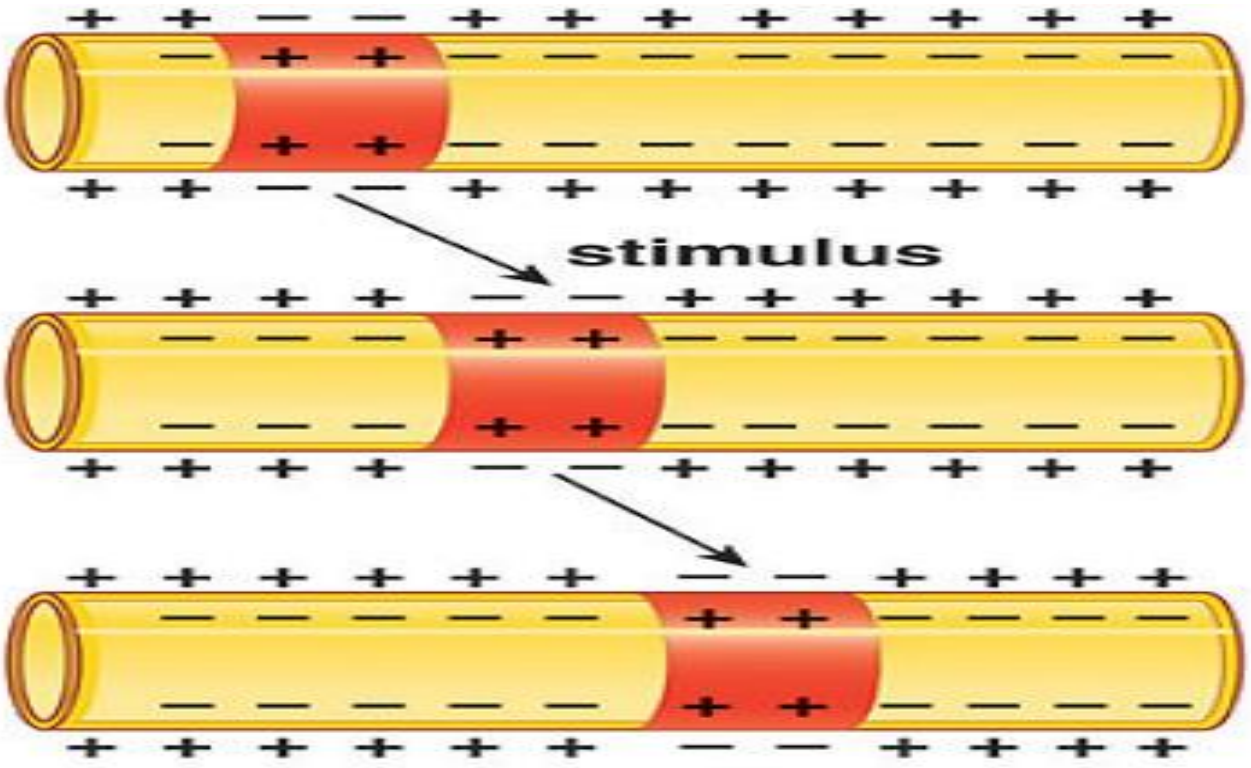
Charge Difference Across the Cell Membrane



1 **Resting membrane potential. Na^+ channels (*pink*) and some, but not all, K^+ channels (*purple*) are closed. K^+ diffuses down its concentration gradient through the open K^+ channels, making the inside of the cell membrane negatively charged compared to the outside.**

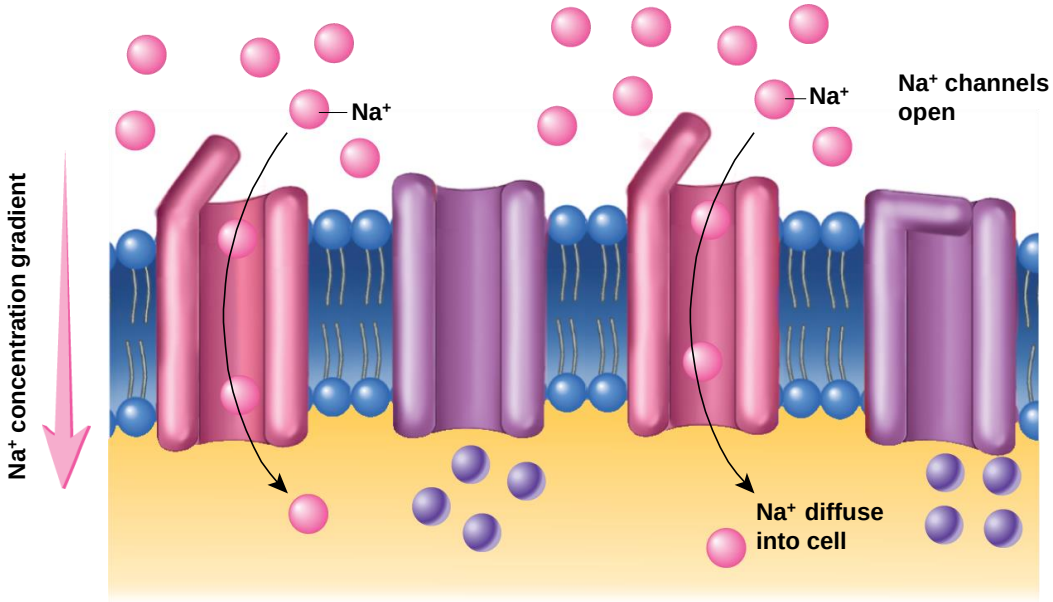
Action Potential

- “electricity”
- stimulus that causes rapid depolarization and repolarization
- causes muscle to contract

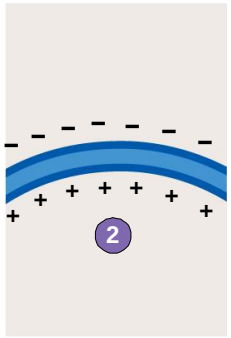


Depolarization

- change in charges
- inside becomes more + and outside more –
- Na^+ channels open

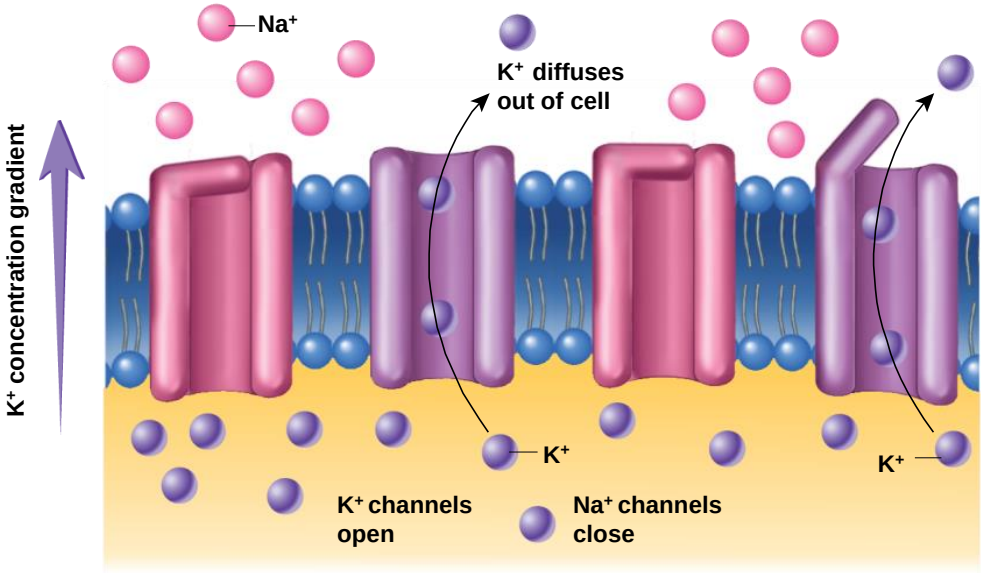


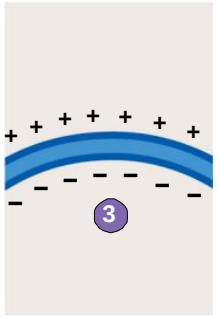
2 **Depolarization. Na^+ channels are open. Na^+ diffuses down its concentration gradient through the open Na^+ channels, making the inside of the cell membrane positively charged compared to the outside.**



Repolarization

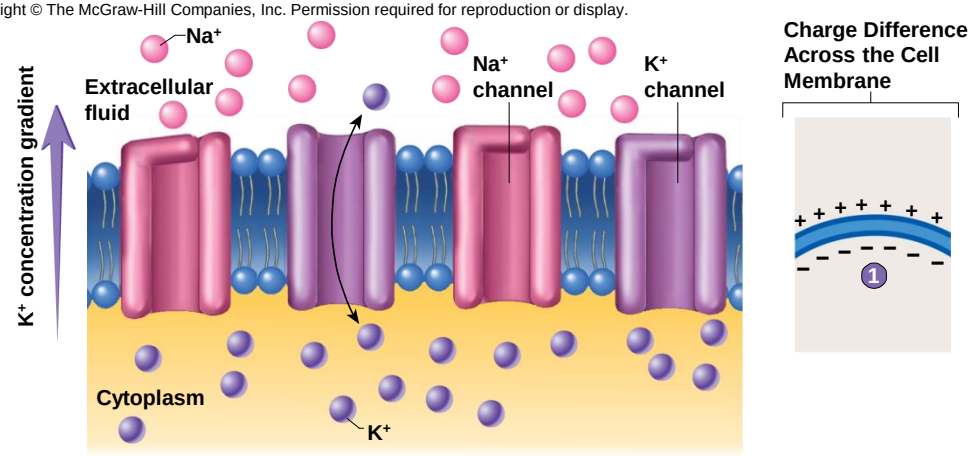
- Na^+ channels close
- change back to resting potential



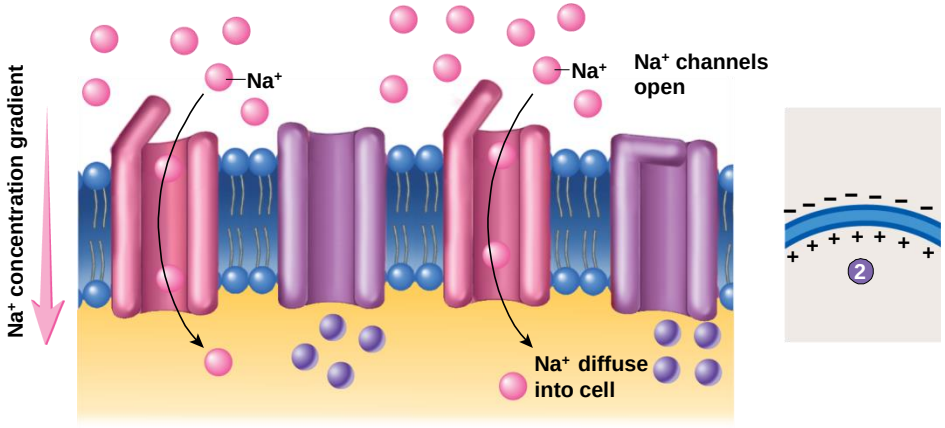


3 **Repolarization. Na^+ channels are closed, and Na^+ movement into the cells stops. More K^+ channels open. K^+ movement out of the cell increases, making the inside of the cell membrane negatively charged compared to the outside, once again**

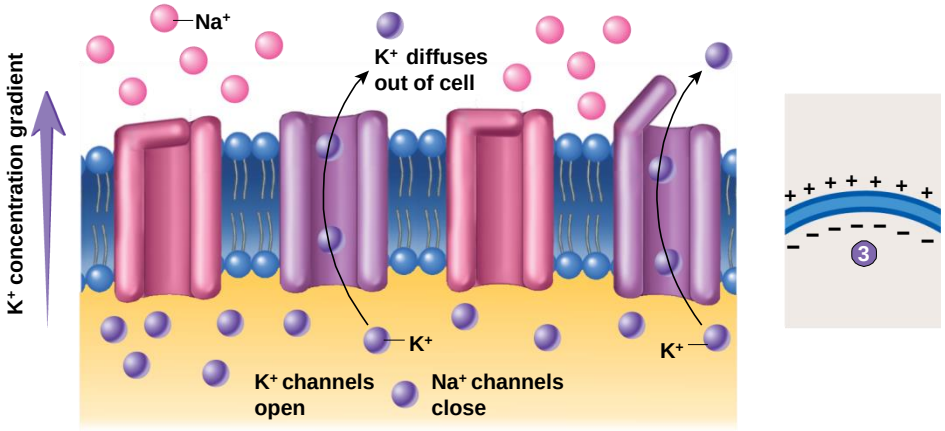
1. **Resting membrane potential.** Na^+ channels (*pink*) and some, but not all, K^+ channels (*purple*) are closed. K^+ diffuses down its concentration gradient through the open K^+ channels, making the inside of the cell membrane negatively charged compared to the outside.



2. **Depolarization.** Na^+ channels are open. Na^+ diffuses down its concentration gradient through the open Na^+ channels, making the inside of the cell membrane positively charged compared to the outside.



3. **Repolarization.** Na^+ channels are closed, and Na^+ movement into the cells stops. More K^+ channels open. K^+ movement out of the cell increases, making the inside of the cell membrane negatively charged compared to the outside, once again



Nerve Supply

- **Motor neuron:**

  nerve cells that carry action potentials **to** muscle fibers

- **Neuromuscular junction (synapse):**

  where nerve cell and muscle fiber meet

- **Presynaptic terminal:**

  end of nerve cell (axon)

- **Postsynaptic membrane:**

  muscle fiber membrane

- **Synpatic cleft:**

  space between presynpatic terminal and postsynaptic membrane

- **Synaptic vesicle:**

  - in presynaptic terminal
  - store and release neurotransmitters

- **Neurotransmitter:**
  - chemicals that stimulate or inhibit a muscle fiber
  - Ex. Acetylcholine

- **Motor unit:**

  group of muscle fibers that motor neuron stimulates

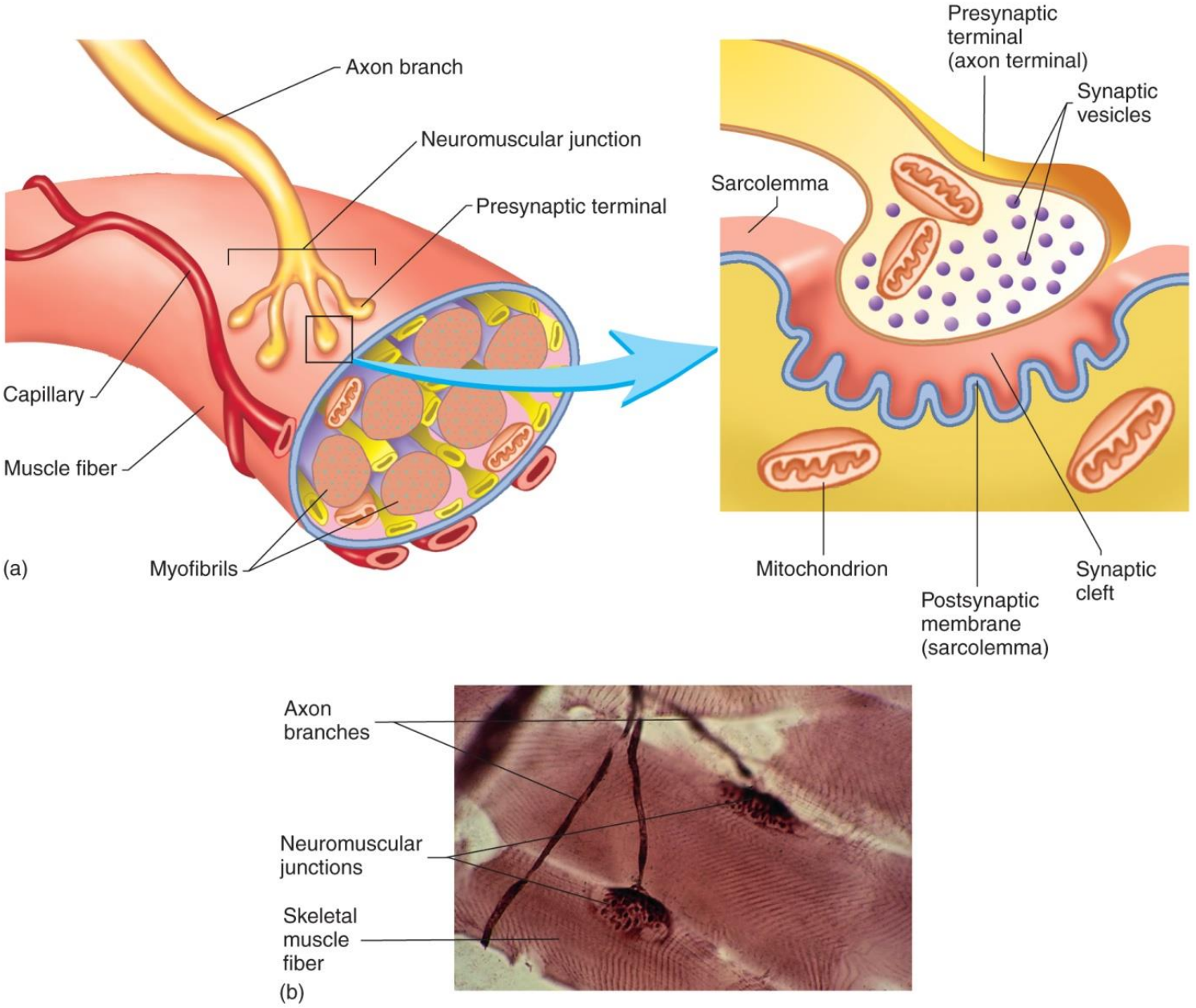
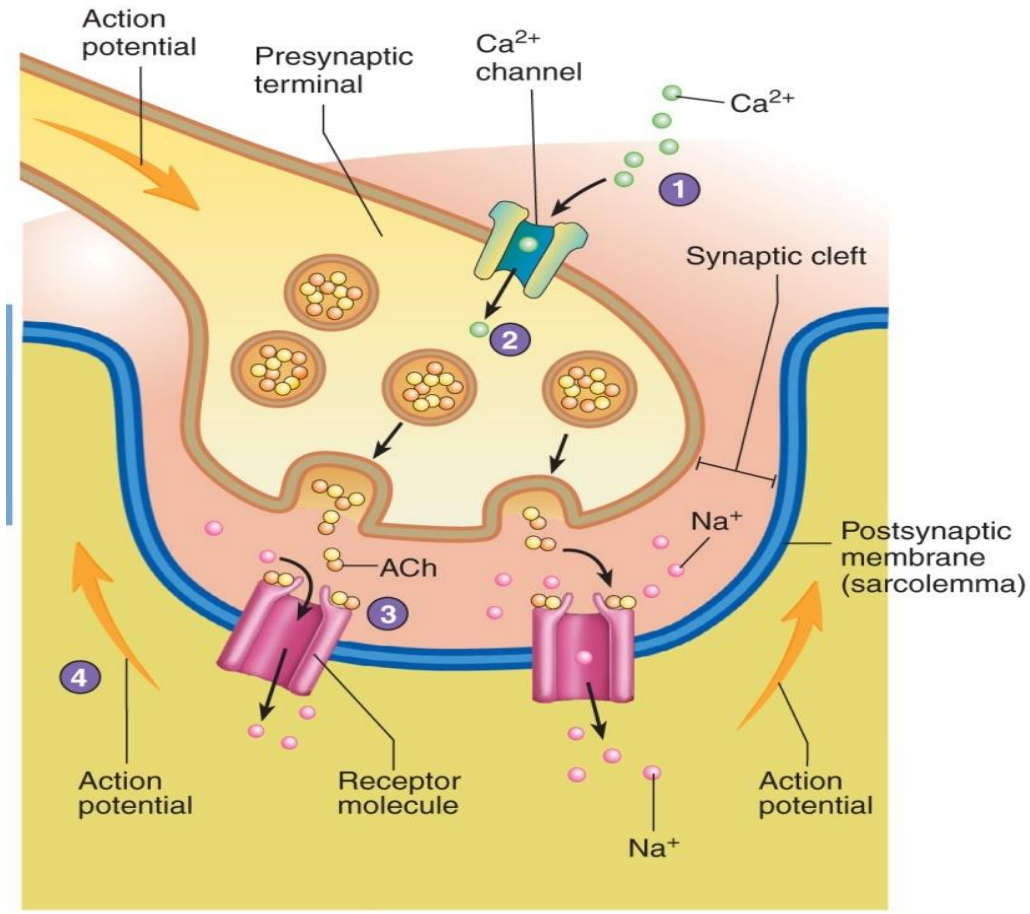


Figure 7.5 **Neuromuscular Junction**

(*a*) In a neuromuscular junction, several branches of an axon junction with a single muscle fiber. (*b*) Photomicrograph of neuromuscular junctions.



1. An action potential arrives at the presynaptic terminal, causing Ca^{2+} channels to open.
2. Calcium ions (Ca^{2+}) enter the presynaptic terminal and initiate the release of a neurotransmitter, acetylcholine (ACh), from synaptic vesicles into the presynaptic cleft.
3. Diffusion of ACh across the synaptic cleft and binding of ACh to ACh receptors on the postsynaptic muscle fiber membrane opens Na^+ channels.
4. Sodium ions (Na^+) diffuse down their concentration gradient, which results in depolarization of the muscle fiber membrane; once threshold has been reached, a postsynaptic action potential results.

PROCESS Figure 7.6 Function of the Neuromuscular Junction

ACh is released in response to an action potential at the neuromuscular junction.

Steps in a Muscle Contraction (Sliding Filament Theory)

1. An action potential travels down motor neuron to presynaptic terminal causing Ca^{2+} channels to open.

2. Ca^{2+} causes synaptic vesicles to release acetylcholine into synaptic cleft.

3. Acetylcholine binds to receptor sites on Na^{+} channels, Na^{+} channels open, and Na^{+} rushes into postsynaptic terminal **(depolarization).**

4. Na^+ causes sarcolemma and t-tubules to increase the permeability of sarcoplasmic reticulum which releases stored calcium.

5. Ca^{2+} binds to troponin which is attached to actin.

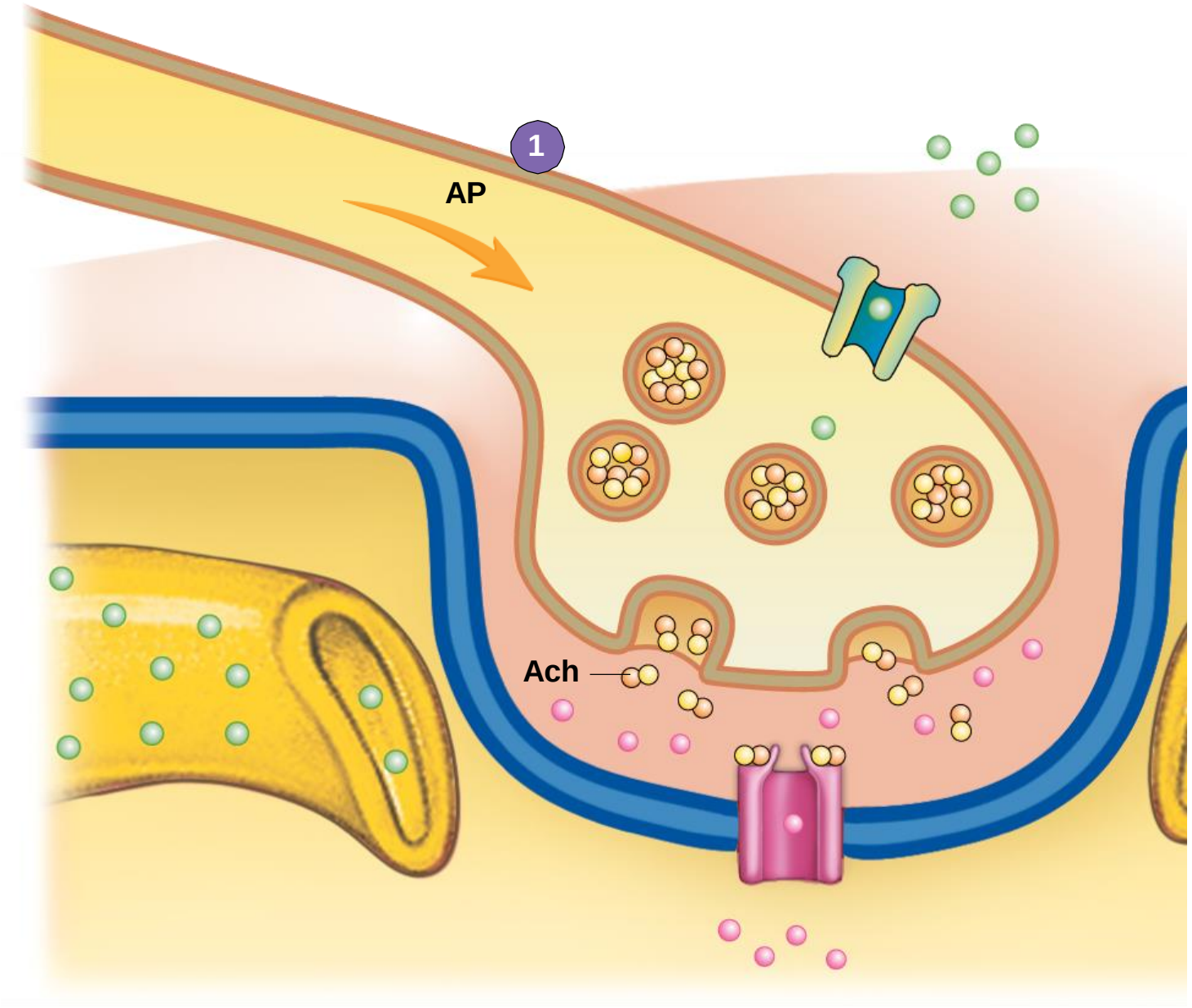
6. Ca^{2+} binding to troponin causes tropomyosin to move exposing attachment sites for myosin.

7. Myosin heads bind to actin.

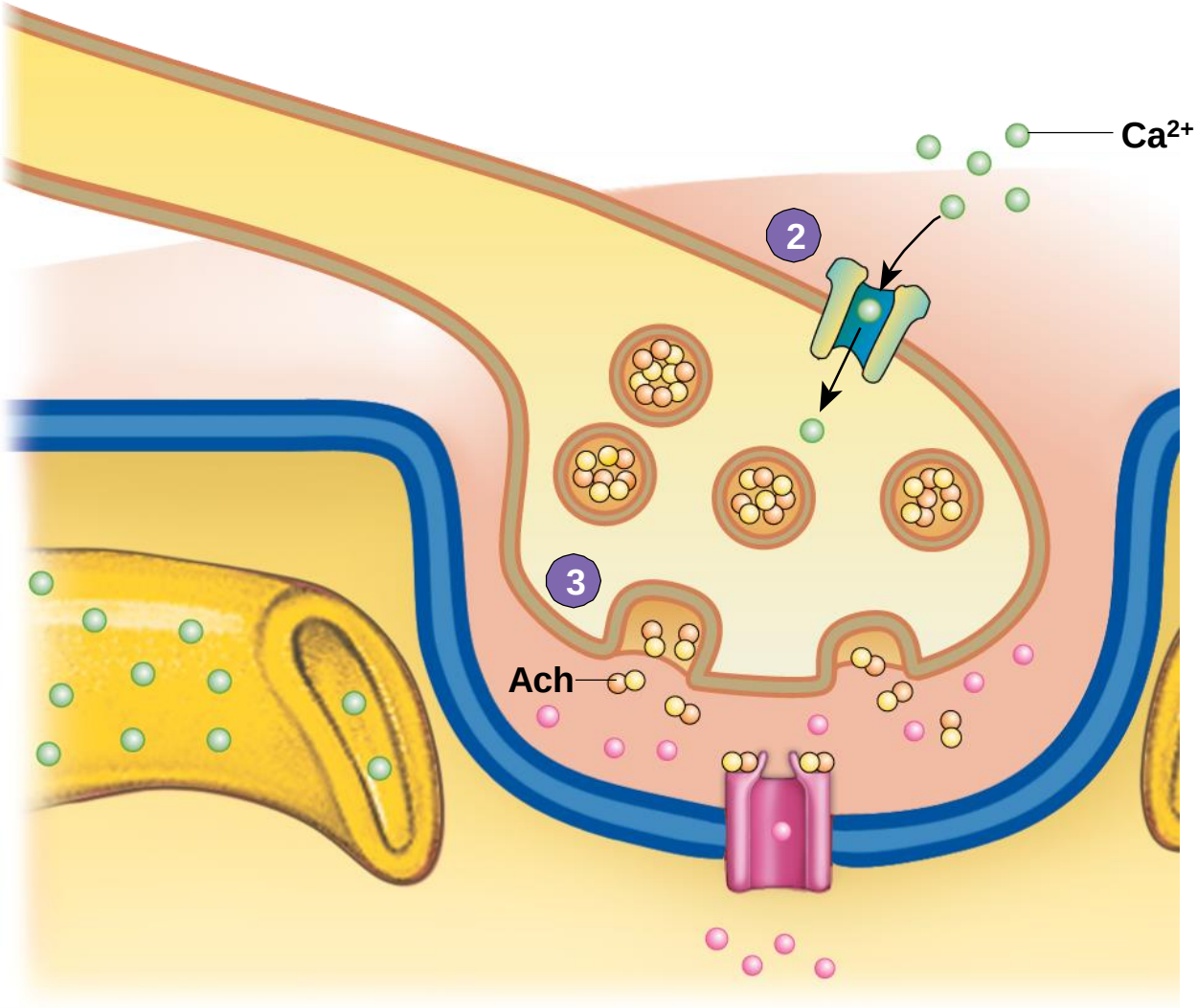
8. ATP is released from myosin heads and heads bend toward center of sarcomere.

9. Bending forces actin to slide over myosin.

10. Acetylcholinesterase (enzyme breaks down acetylcholine) is released, Na^+ channels close, and muscle contraction stops.

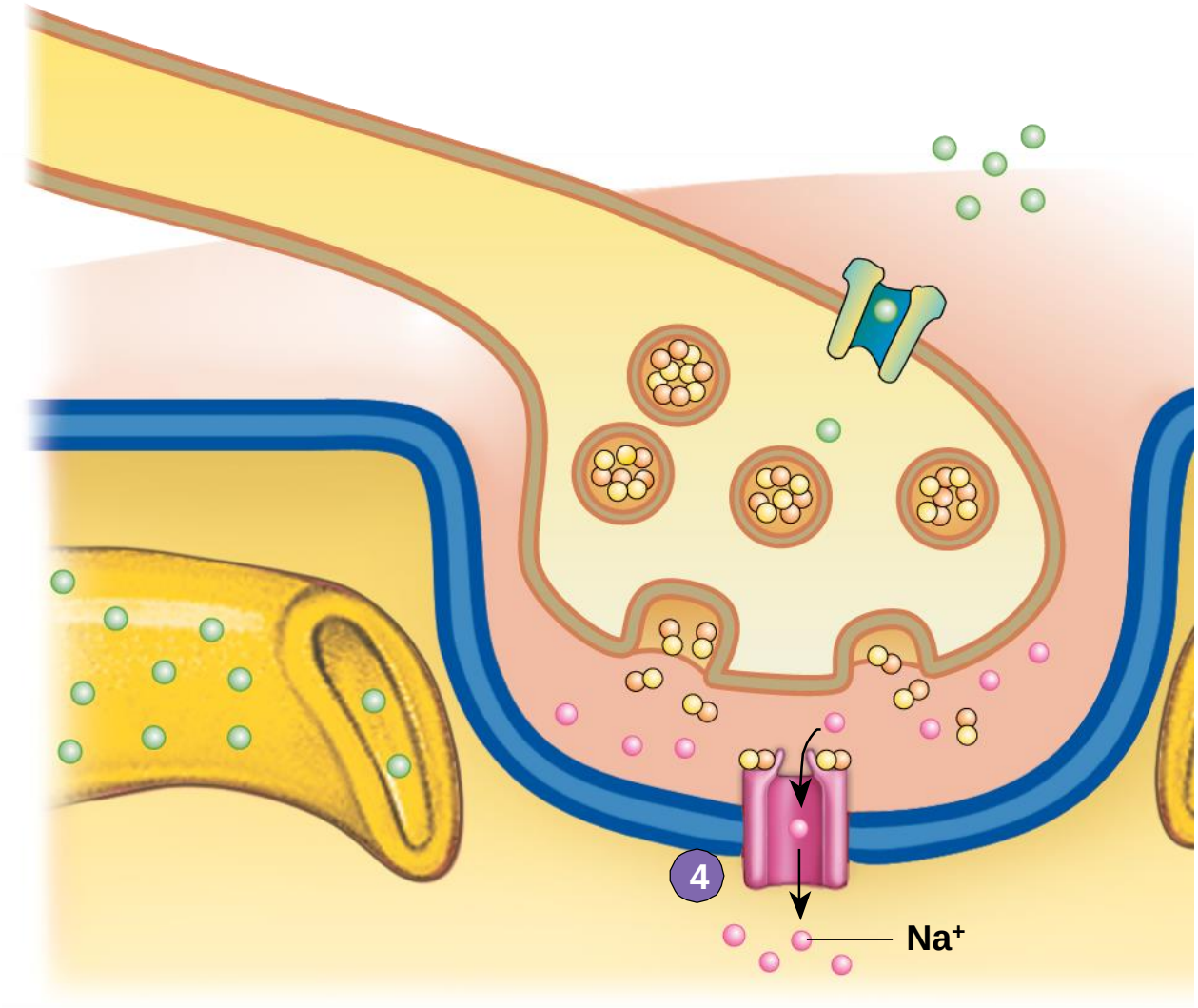


1 **An action potential travels along an axon membrane to a neuromuscular junction.**

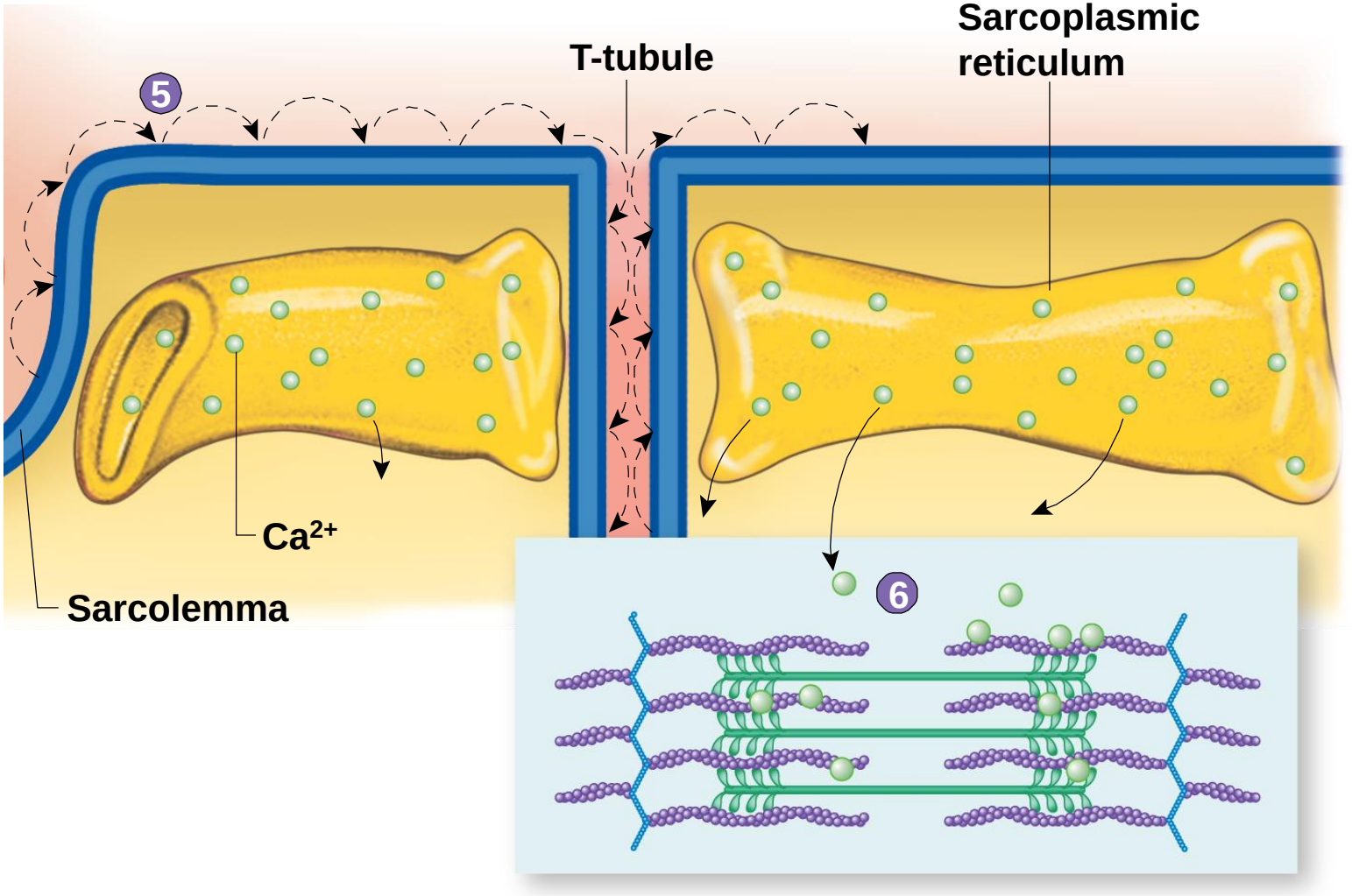


2 Ca^{2+} channels open and Ca^{2+} enters the presynaptic terminal.

3 Acetylcholine is released from presynaptic vesicles.

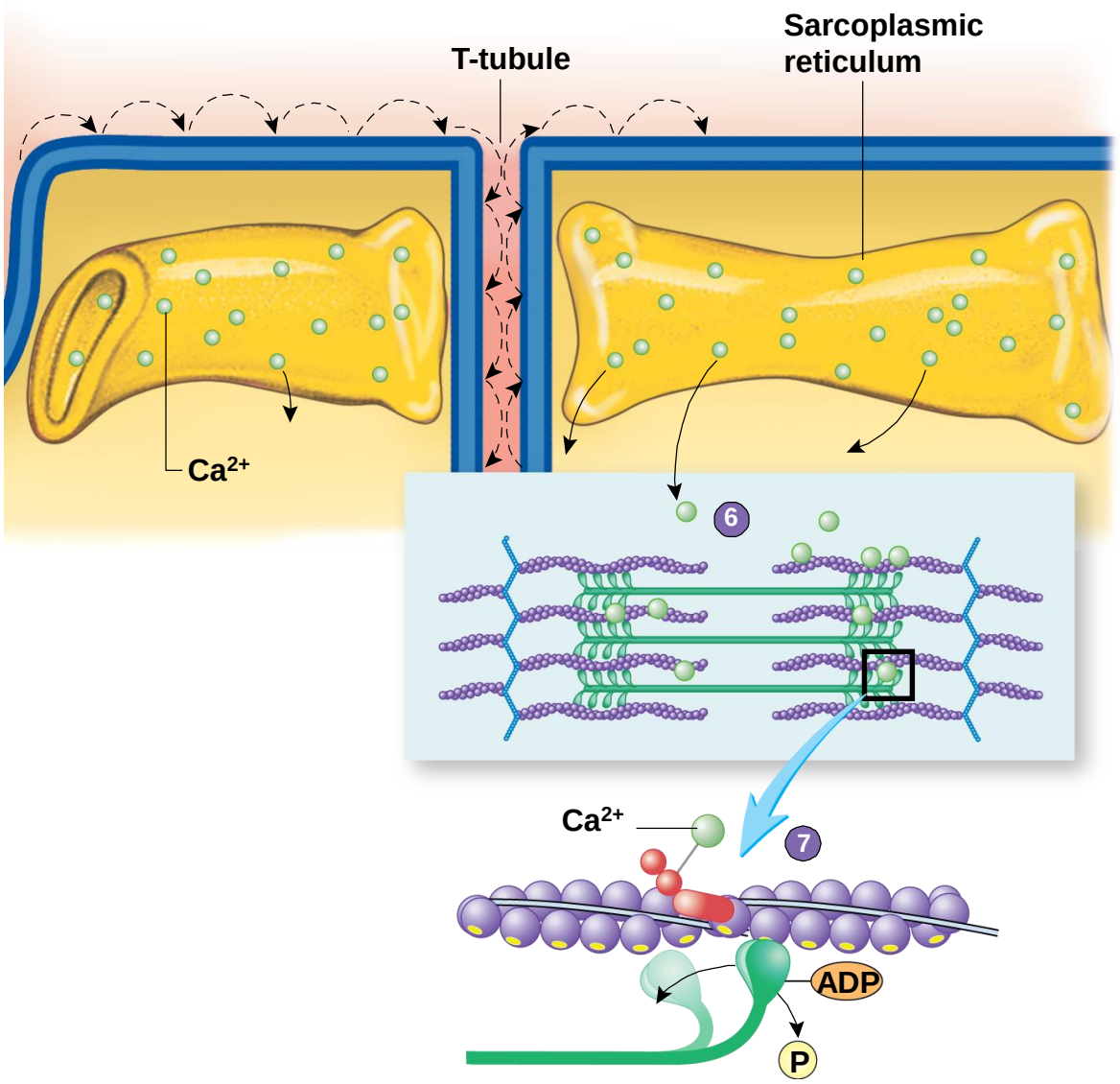


4 Acetylcholine stimulates Na^+ channels on the postsynaptic membrane to open.



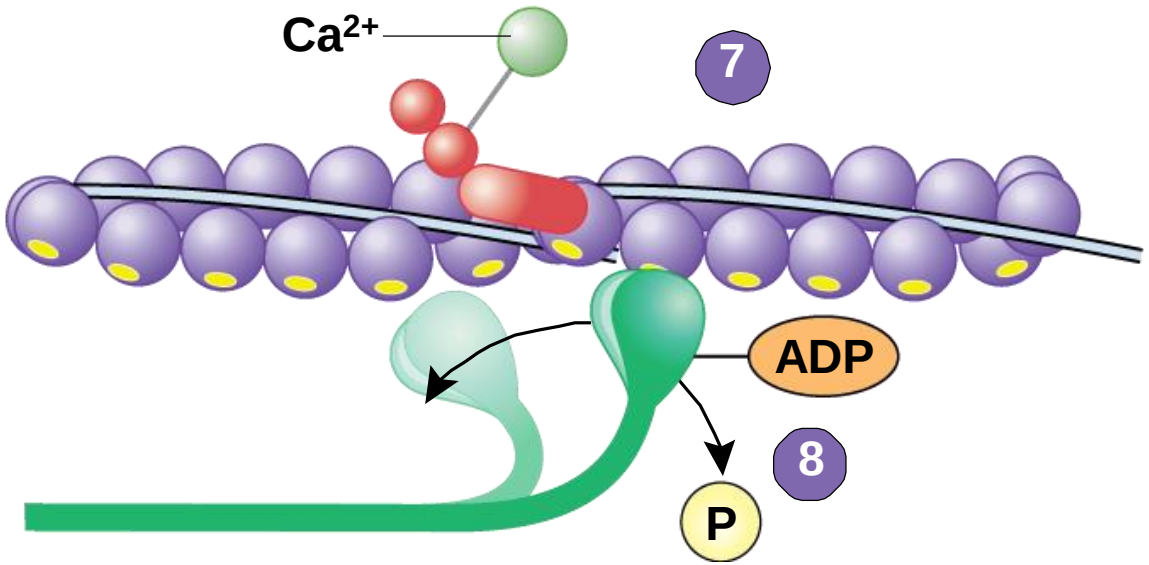
5 Na^+ diffuses into the muscle fiber, initiating an action potential that travels along the sarcolemma and T-tubule membranes.

6 Action potentials in the T-tubules cause the sarcoplasmic reticulum to release Ca^{2+}.



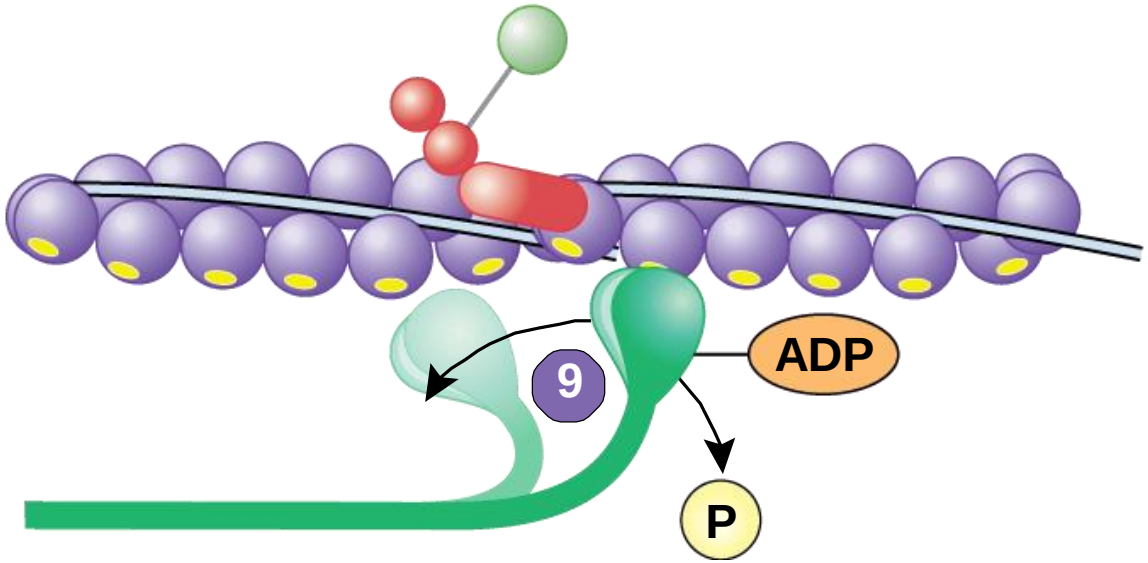
6 **Action potentials in the T-tubules cause the sarcoplasmic reticulum to release Ca^{2+}.**

7 **On the actin, Ca^{2+} binds to troponin, which moves tropomyosin and exposes myosin attachment sites.**



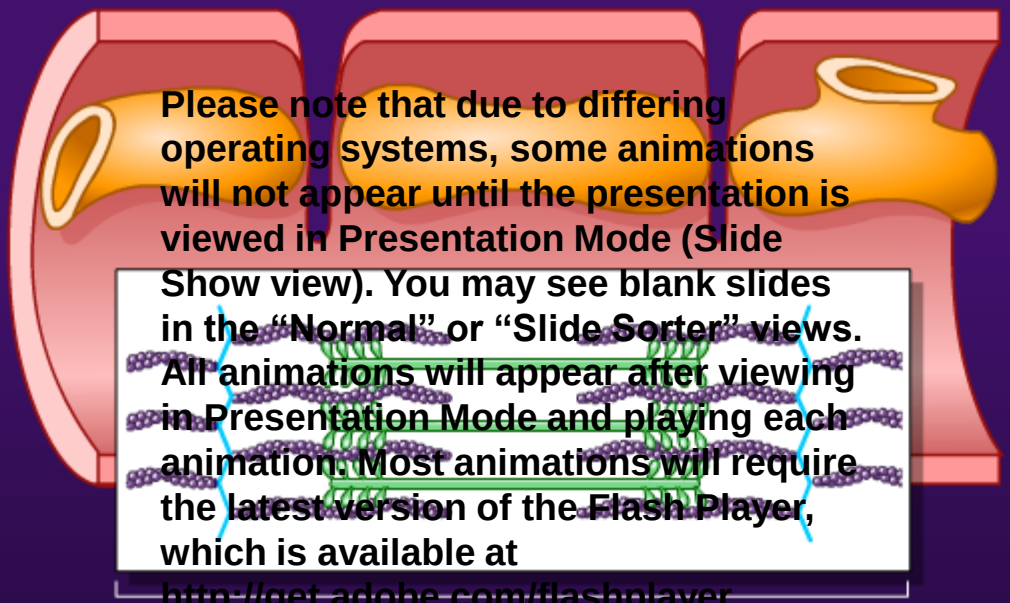
7 **On the actin, Ca^{2+} binds to troponin, which moves tropomyosin and exposes myosin attachment sites.**

8 **ATP molecules are broken down to ADP and P, which releases energy needed to move the myosin heads.**



9 **The heads of the myosin myofilaments bend, causing the actin to slide past the myosin. As long as Ca^{2+} is present, the cycle repeats.**

Action Potentials and Muscle Contraction



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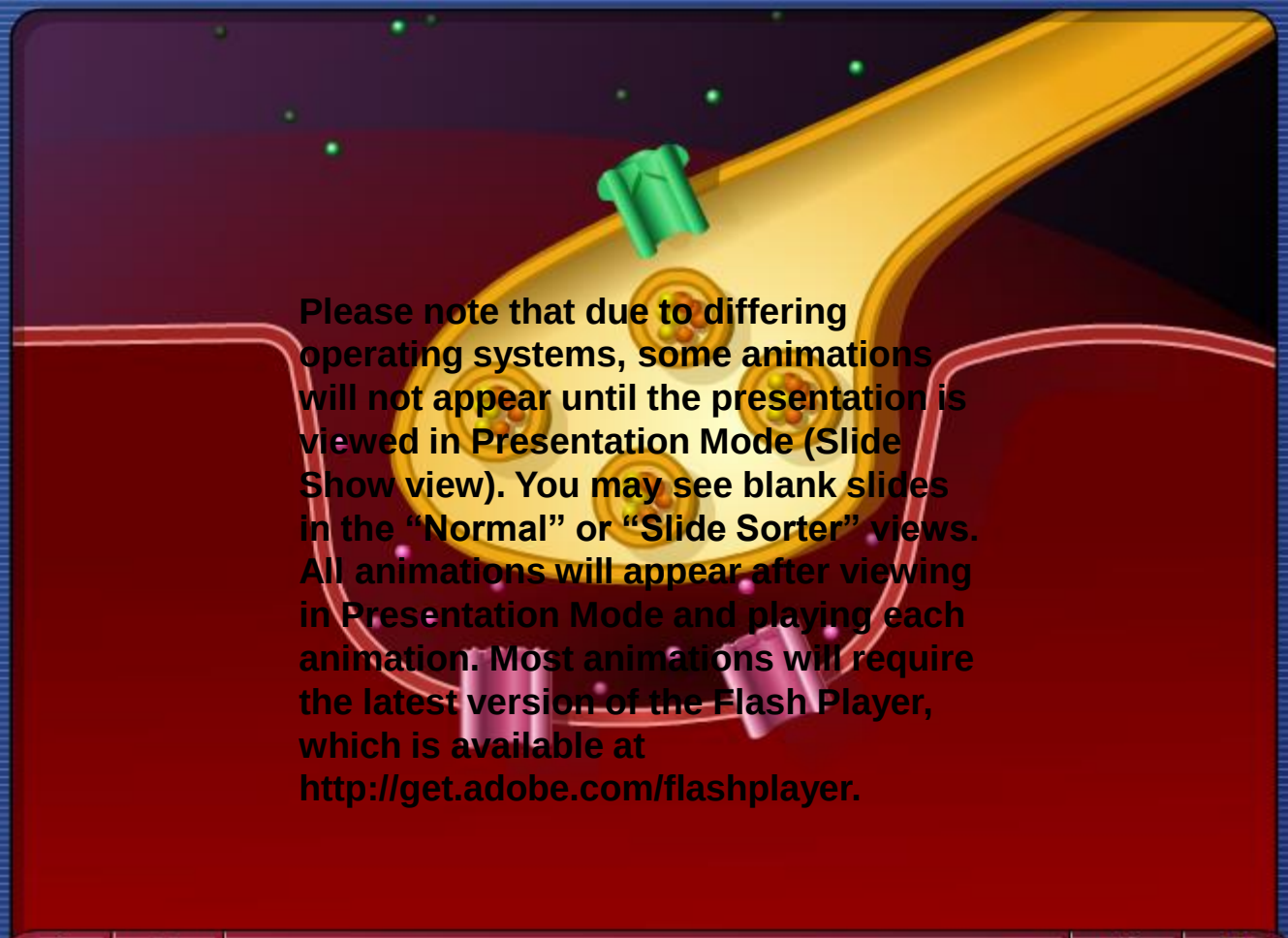
An action potential introduced at the neuromuscular junction is propagated along the sarcolemma of the skeletal muscle.

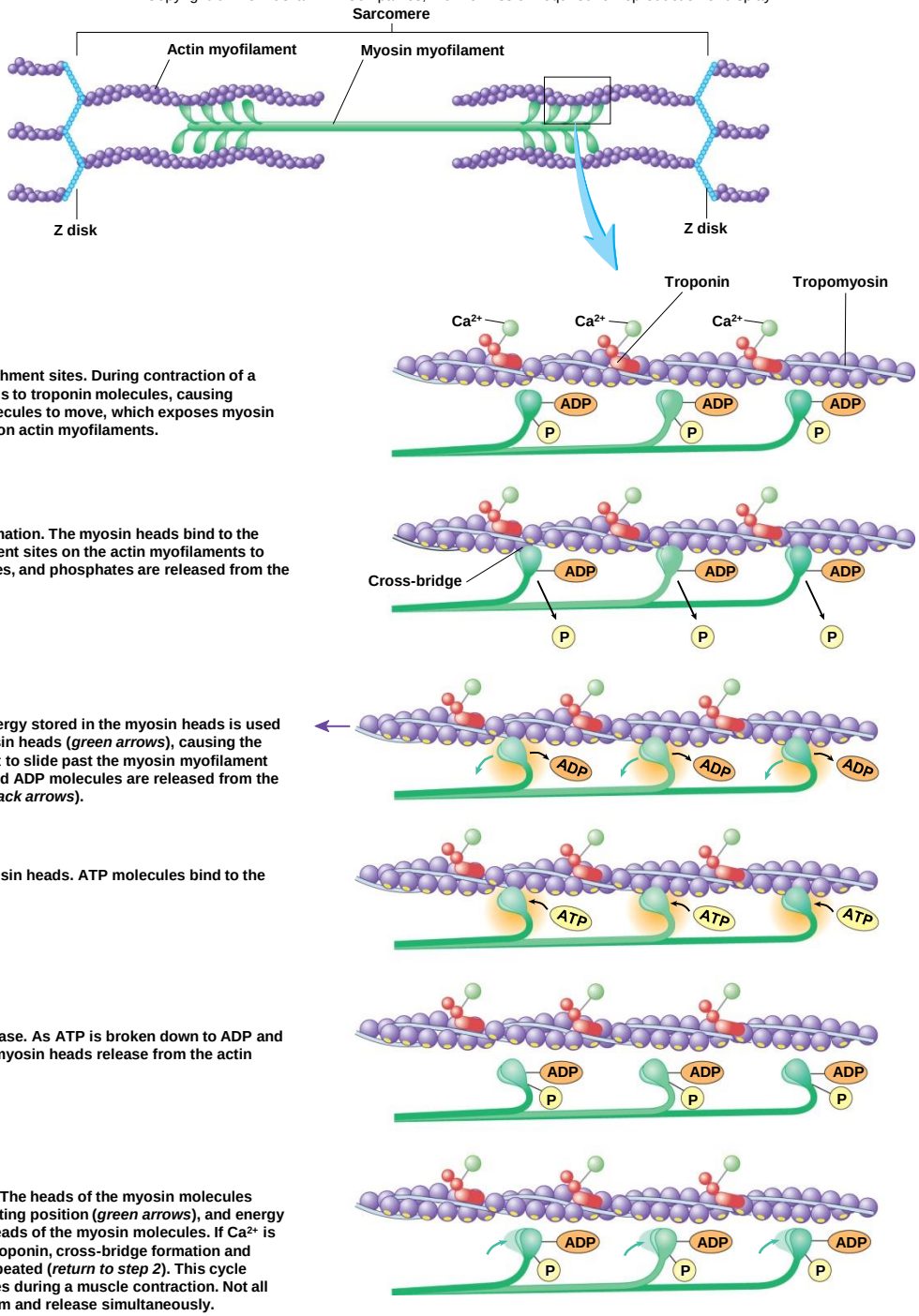
Function of the Neuromuscular Junction



ATP and Muscle Contractions

- Energy for muscle contractions supplied by ATP
- Energy is released as ATP → ADP + P
- ATP is stored in myosin heads
- ATP help form cross-bridge formation between myosin and actin
- New ATP must bind to myosin before cross-bridge is released
- **Rigor mortis:**

  person dies and no ATP is available to release cross-bridges



1. **Exposure of attachment sites. During contraction of a muscle, Ca^{2+} binds to troponin molecules, causing tropomyosin molecules to move, which exposes myosin attachment sites on actin myofilaments.**

2. **Cross-bridge formation. The myosin heads bind to the exposed attachment sites on the actin myofilaments to form cross-bridges, and phosphates are released from the myosin heads.**

3. **Power stroke. Energy stored in the myosin heads is used to move the myosin heads (*green arrows*), causing the actin myofilament to slide past the myosin myofilament (*purple arrow*), and ADP molecules are released from the myosin heads (*black arrows*).**

4. **ATP binds to myosin heads. ATP molecules bind to the myosin heads.**

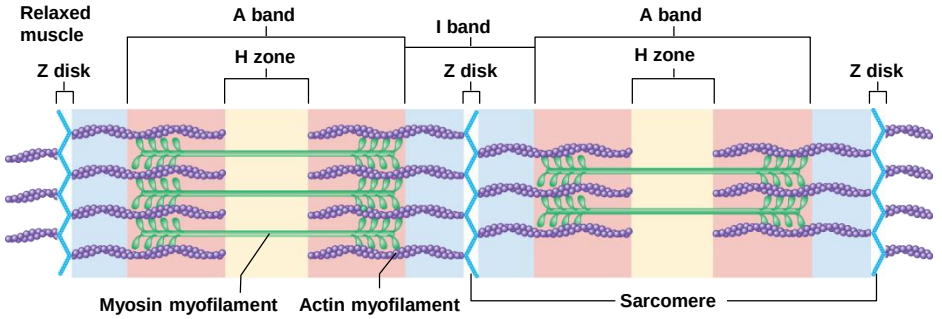
5. **Cross-bridge release. As ATP is broken down to ADP and phosphates, the myosin heads release from the actin attachment sites.**

6. **Recovery stroke. The heads of the myosin molecules return to their resting position (*green arrows*), and energy is stored in the heads of the myosin molecules. If Ca^{2+} is still attached to troponin, cross-bridge formation and movement are repeated (*return to step 2*). This cycle occurs many times during a muscle contraction. Not all cross-bridges form and release simultaneously.**

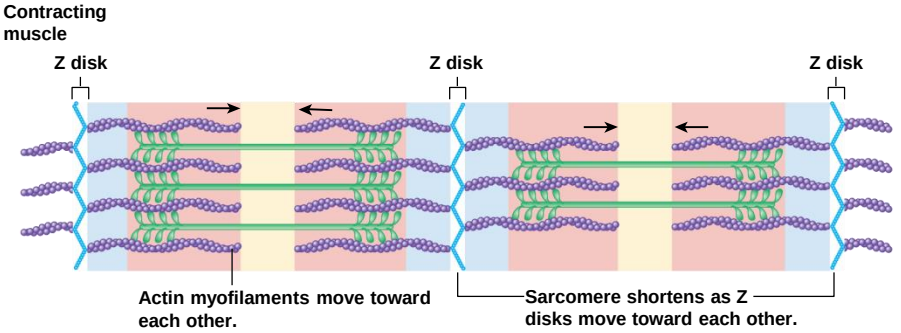
Other Information

- ATP is made in mitochondria from aerobic or anaerobic respiration.
- During a muscle contraction, H zone and I band shorten but A band stays the same.
- Striations of skeletal and cardiac muscle are due to sarcomeres (actin and myosin).

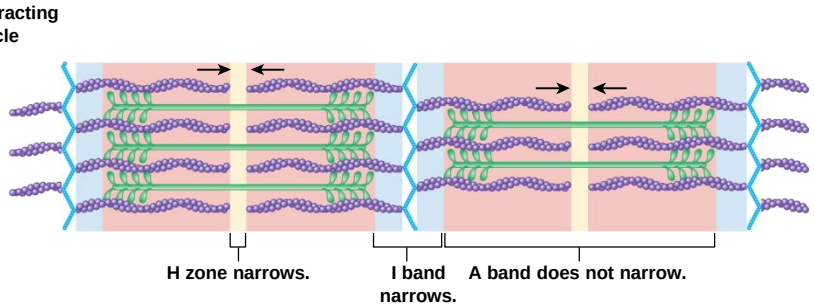
1. Actin and myosin myofilaments in a relaxed muscle (*right*) and a contracted muscle (*#4 below*) are the same length. Myofilaments do not change length during muscle contraction.



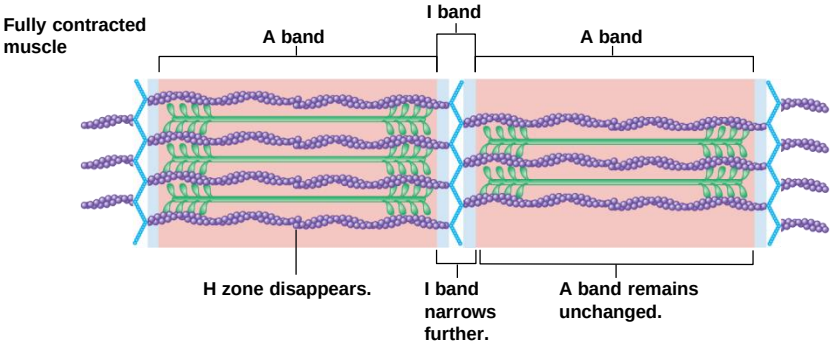
2. During contraction, actin myofilaments at each end of the sarcomere slide past the myosin myofilaments toward each other. As a result, the Z disks are brought closer together, and the sarcomere shortens.



3. As the actin myofilaments slide over the myosin myofilaments, the H zones (*yellow*) and the I bands (*blue*) narrow. The A bands, which are equal to the length of the myosin myofilaments, do not narrow, because the length of the myosin myofilaments does not change.

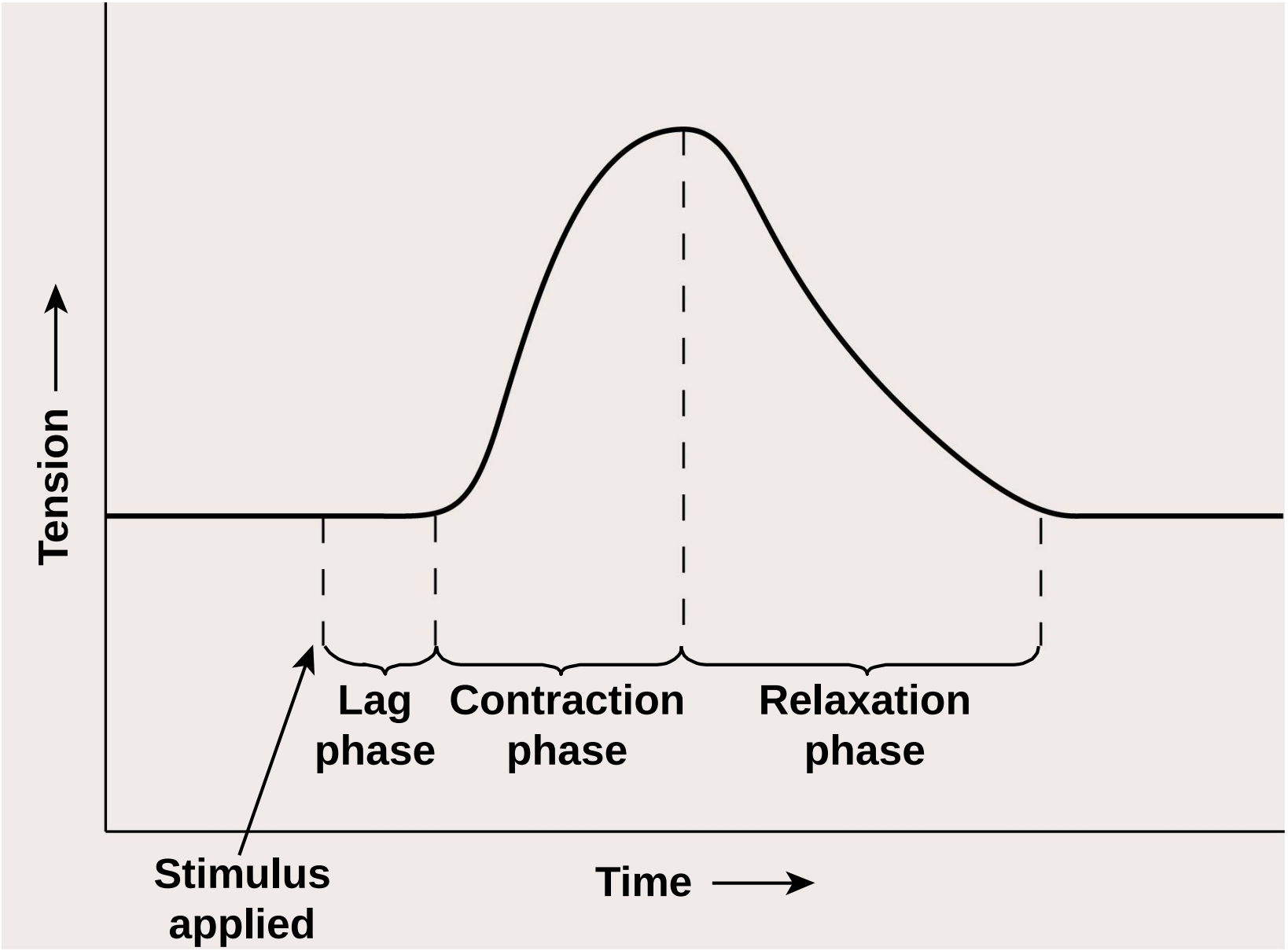


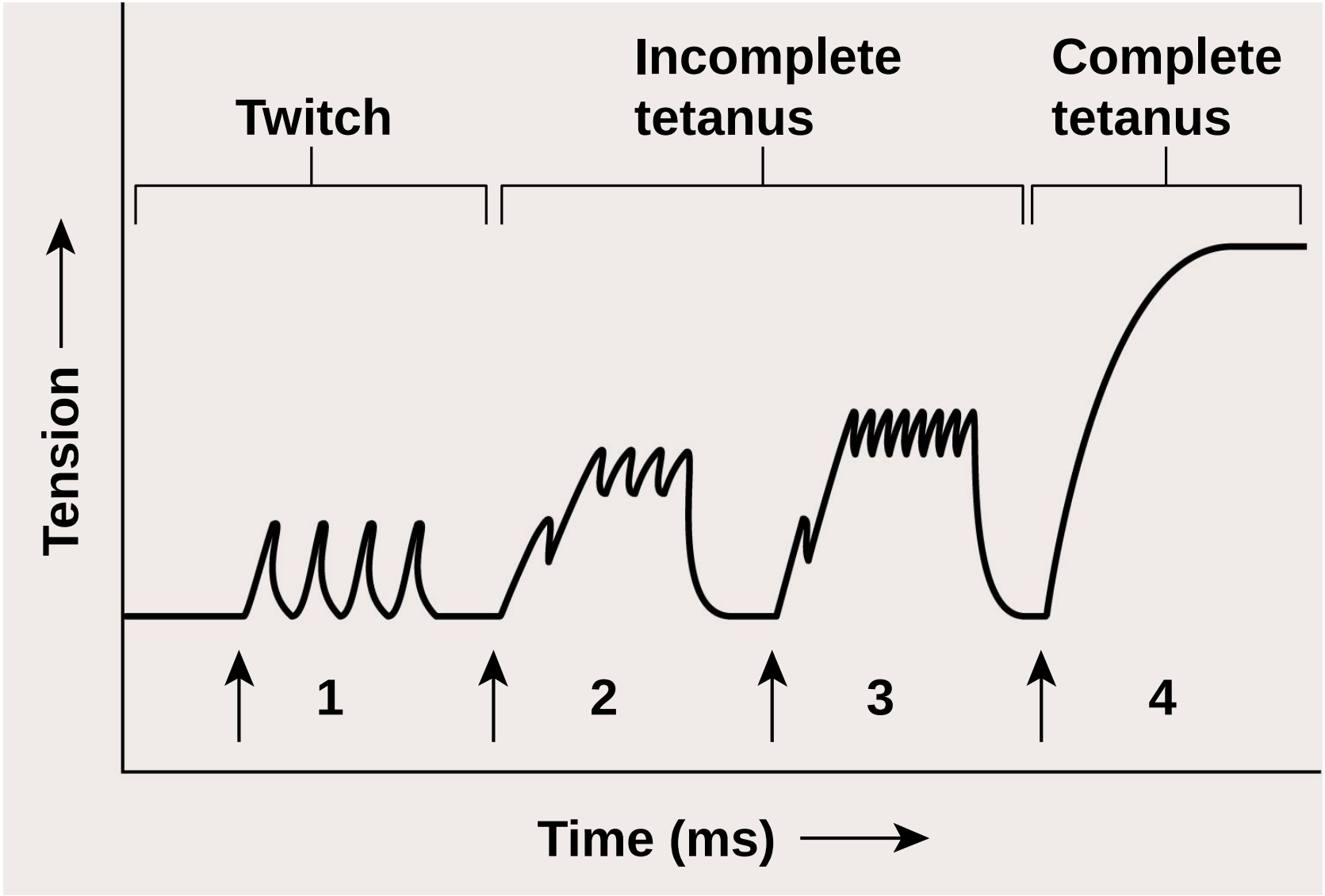
4. In a fully contracted muscle, the ends of the actin myofilaments overlap, and the H zone disappears.



Terms

- **Threshold:**
  weakest stimulus needed to produce a response
- **All or None Law:**
  muscle contracts or doesn't (no in between)
- **Twitch:**
  rapid contraction and relaxation of a muscle
- **Tetanus:**
  muscle remains contracted





- **Isometric:**
  amount of tension increases (weight)

- **Isotonic:**
  amount of repetitions increases

- **Tone:**
  constant tension over a long period of time

Slow and Fast Twitch Fibers

Slow Twitch Fibers

- Contract slowly
- Fatigue slowly
- Long distance runners
- Use aerobic respiration
- Energy from fat
- Dark meat
- Red or dark because of myoglobin
- **Myoglobin**: helps O_2 bind in muscle

Fast Twitch Fibers

- Contract quickly
- Fatigue quickly
- Sprinters
- Use anaerobic respiration
- Energy from glycogen
- White meat

Other Facts about Twitch Fibers

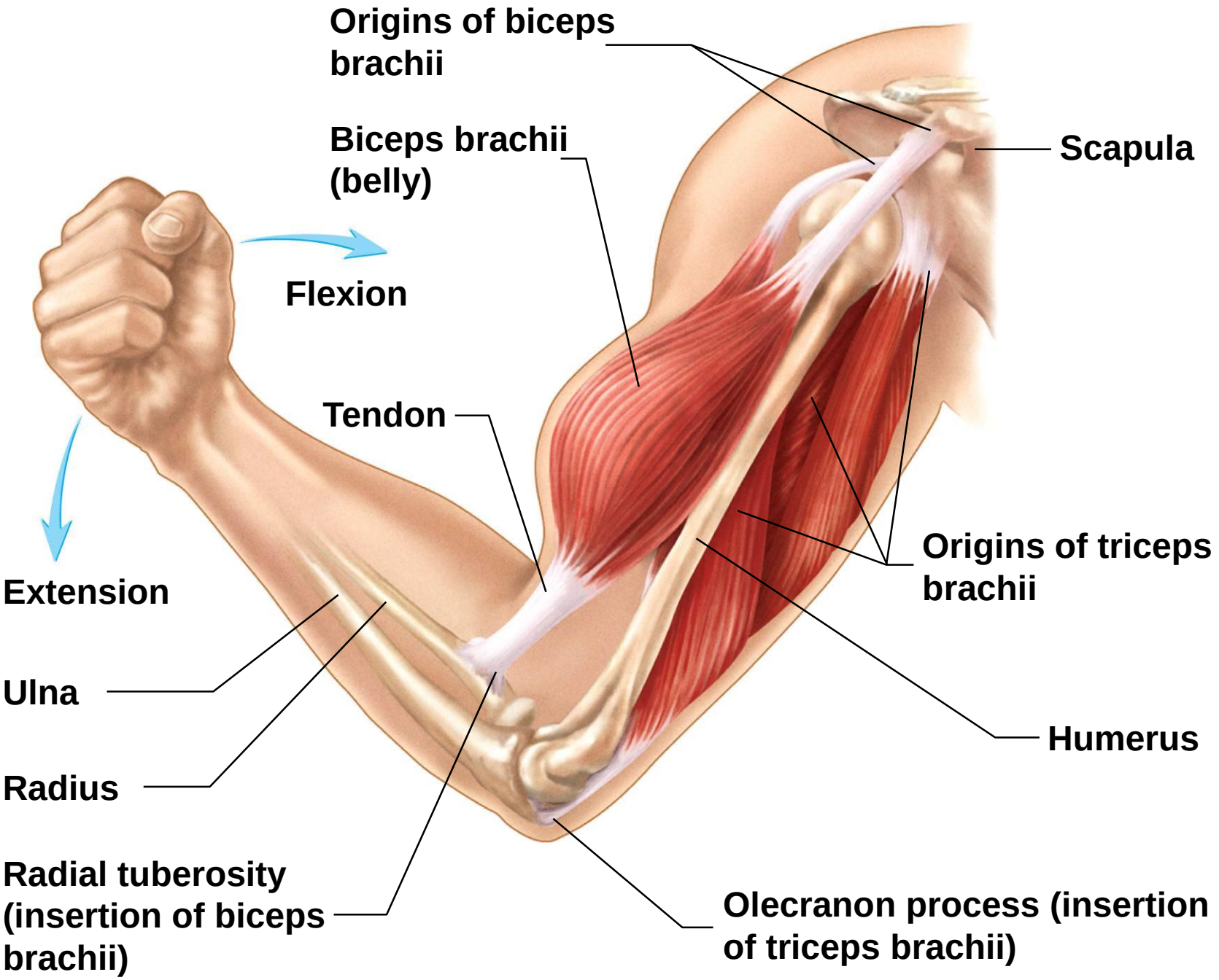
- Humans have both types of fibers
- Distribution of fibers is genetically determined
- Neither type can be converted but capacity can be increased through intense exercise

TABLE 7.1 Characteristics of Skeletal Muscle Fiber Types

	Slow-Twitch (Type I)	Fast-Twitch (Type IIa)	Fast-Twitch (Type IIb)
Fiber Diameter	Smallest	Intermediate	Largest
Myoglobin Content	High	High	Low
Mitochondria	Many	Many	Few
Metabolism	High aerobic capacity	High anaerobic capacity; intermediate aerobic capacity	Highest anaerobic capacity
Fatigue Resistance	High	Intermediate	Low
Myosin Head Activity	Slow	Fast	Fast
Glycogen Concentration	Low	High	High
Functions	Maintenance of posture; endurance activities	Endurance activities in endurance-trained muscles	Rapid, intense movement of short duration (sprinting)

Skeletal Muscle Anatomy

- **Origin:**
  nonmovable end
- **Insertion:**
  movable end
- **Belly:**
  middle
- **Synergists:**
  muscles that work together
- **Antagonist:**
  muscles that oppose each other



Nomenclature

Muscles are named according to

- **Location:**

  Ex. tibialis anterior

- **Origin/insertion:**

  Ex. sternocleidomastoid

- **Size:**

  Ex. gluteus maximus

- **Shape:**

  Ex. deltoid (triangular)

- **Function:**

  Ex. masseter

Muscles of Head and Neck

- **Occipitofrontalis:**
  raises eyebrows (forehead)

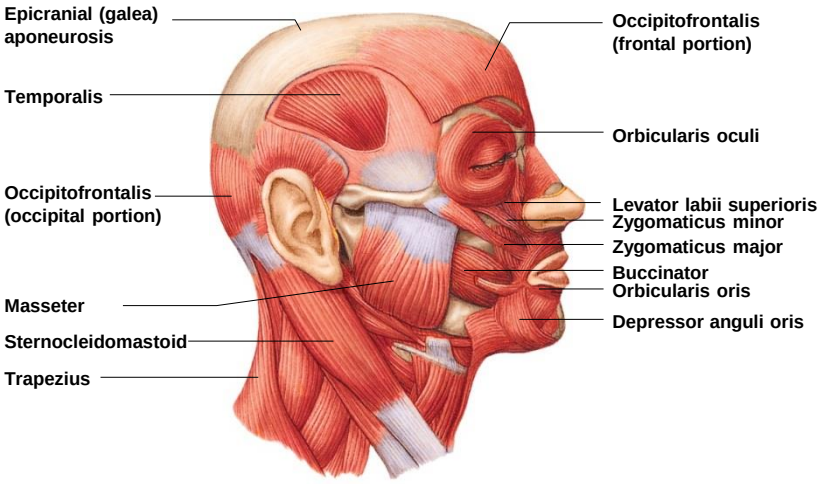
- **Orbicularis oculi:**
  allows blinking (eyes)

- **Orbicularis oris:**
  kissing muscle (mouth)

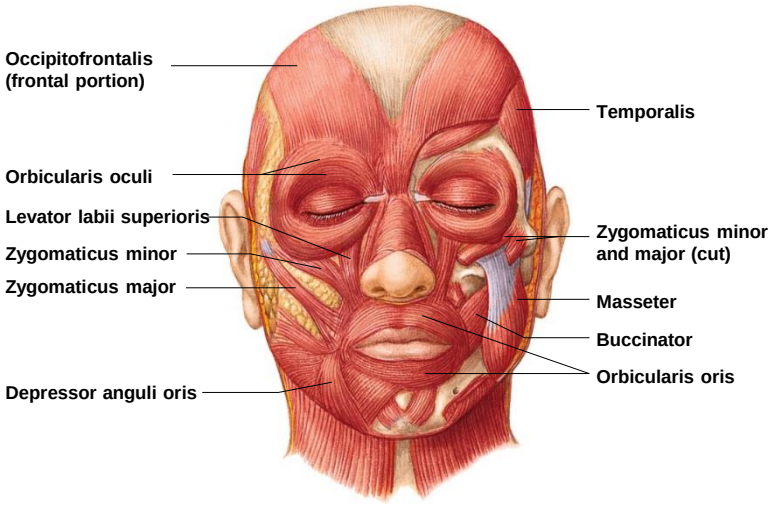
- **Zygomaticus:**
  smiling muscle (cheek)

- **Masseter:**
  chewing (mastication) muscle

Muscles of Facial Expression & Mastication



(a) Lateral view



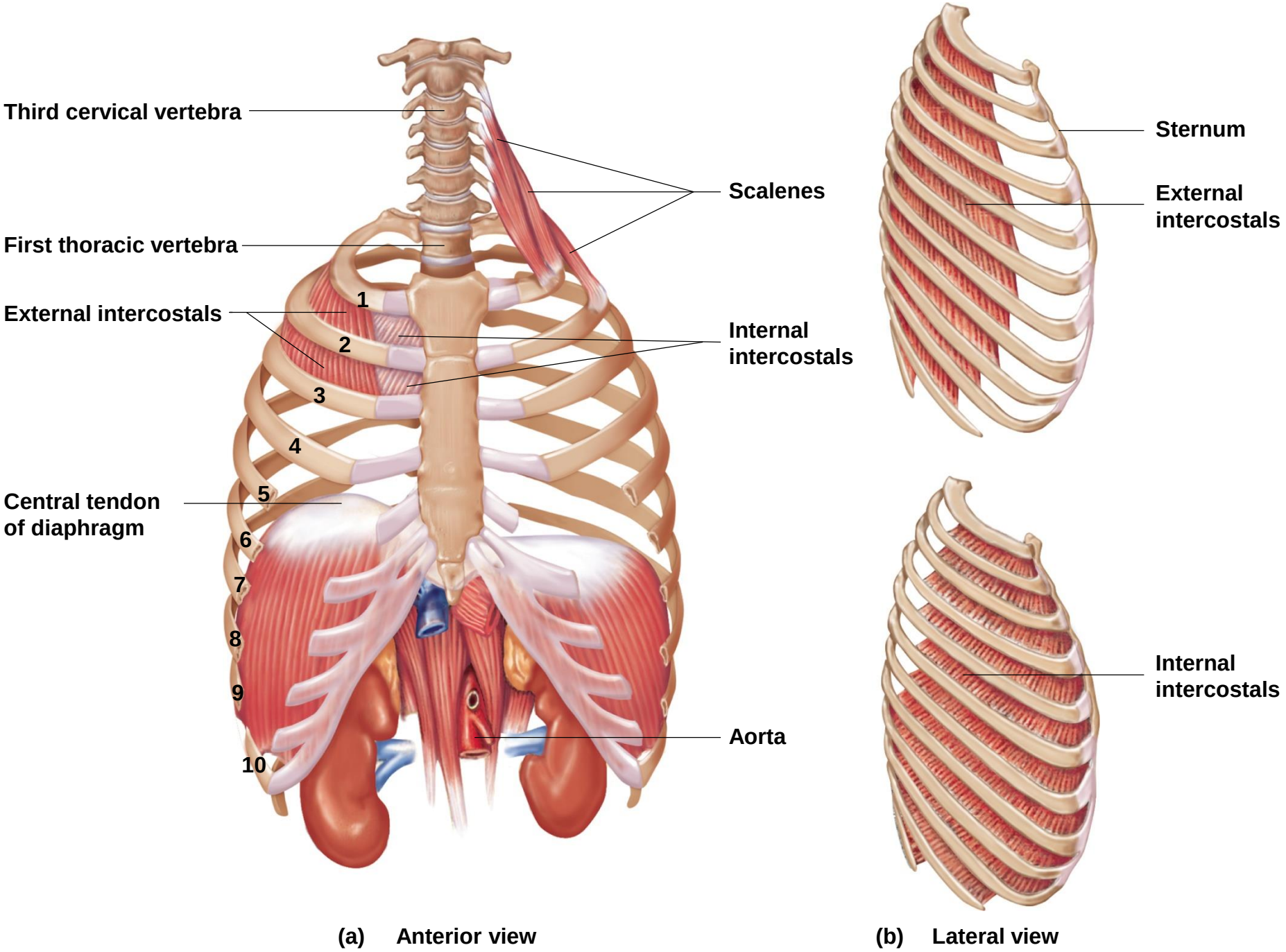
(b) Anterior view

Thoracic Muscles

- **External intercostals:**
  elevate ribs for inspiration

- **Internal intercostals:**
  depress ribs during forced expiration

- **Diaphragm:**
  moves during quiet breathing



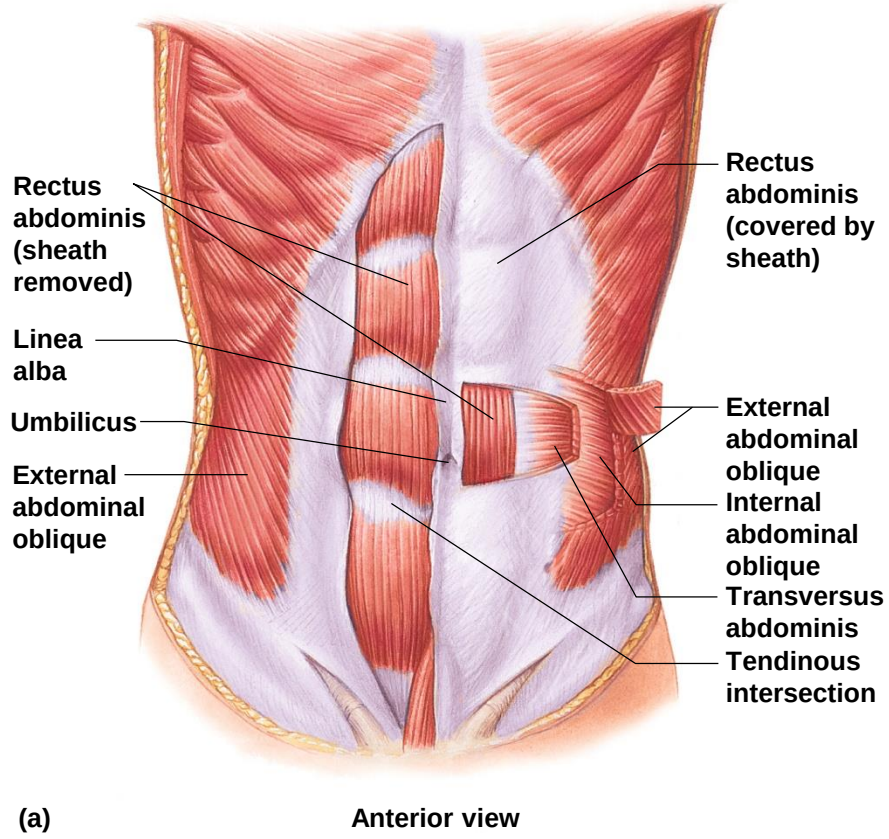
Abdominal Wall Muscles

- **Rectus abdominis:**
  - center of abdomen
  - compresses abdomen

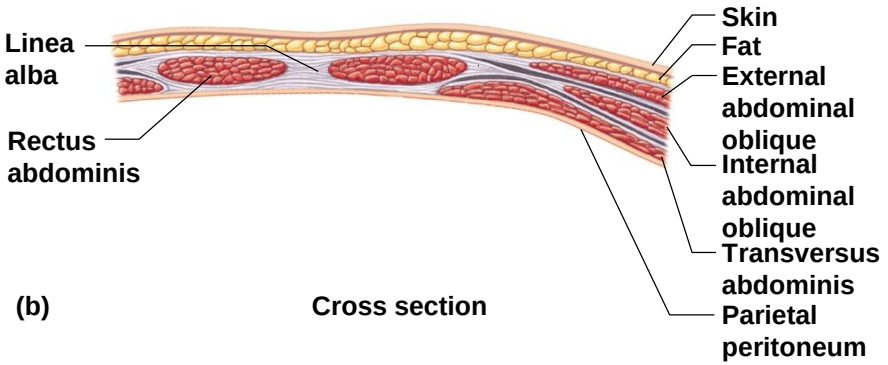
- **External abdominal oblique:**
  - sides of abdomen
  - compresses abdomen

- **Internal abdominal oblique:** compresses abdomen

- **Transverse abdominis:** compresses abdomen



(a) Anterior view



(b) Cross section

TABLE 7.9 Muscles of the Abdominal Wall (see figures 7.14, 7.20, 7.22)

Muscle	Origin	Insertion	Action
Rectus abdominis (rek'tŭs ab-dom'i-nis)	Pubic crest and pubic symphysis	Xiphoid process and inferior ribs	Flexes vertebral column; compresses abdomen
External abdominal oblique	Ribs 5–12	Iliac crest, inguinal ligament, and fascia of rectus abdominis	Compresses abdomen; flexes and rotates vertebral column
Internal abdominal oblique	Iliac crest, inguinal ligament, and lumbar fascia	Ribs 10–12 and fascia of rectus abdominis	Compresses abdomen; flexes and rotates vertebral column
Transversus abdominis (trans-ver'sŭs ab-dom'in-is)	Costal cartilages 7–12, lumbar fascia, iliac crest, and inguinal ligament	Xiphoid process, fascia of rectus abdominis, and pubic tubercle	Compresses abdomen

Upper Limb Muscles

- **Trapezius:**
  - shoulders and upper back
  - extends neck and head

- **Pectoralis major:**
  - chest
  - elevates ribs

- **Serratus anterior:**
  - between ribs
  - elevates ribs

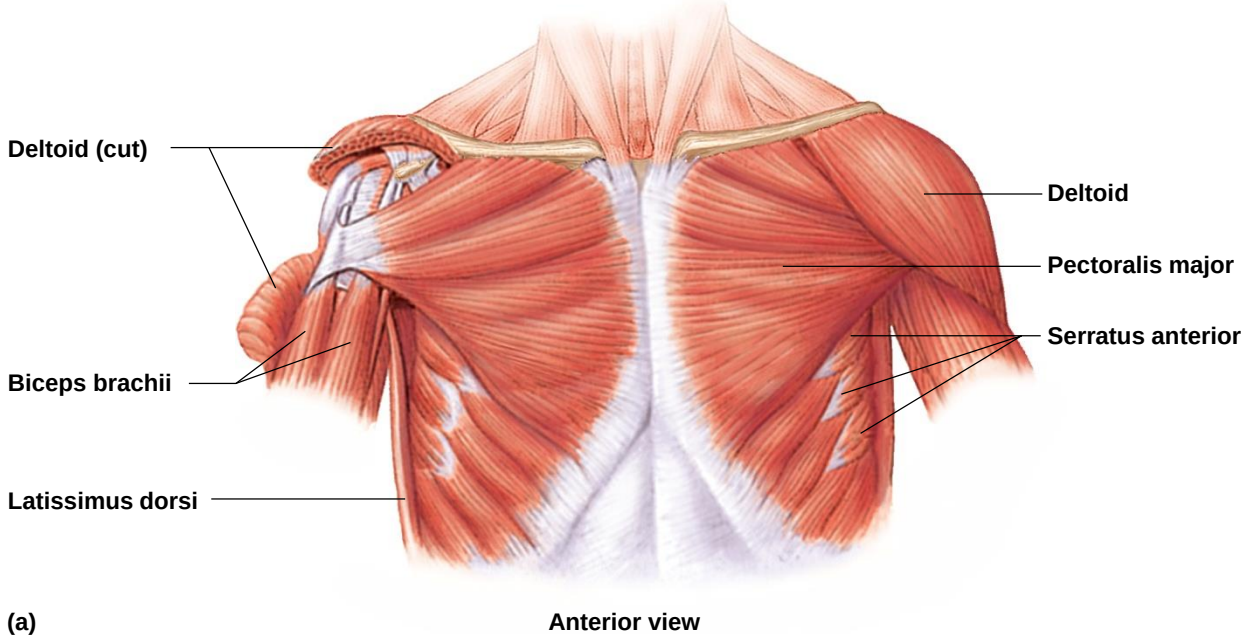
- **Deltoid:**
  - shoulder
  - abductor or upper limbs

- **Triceps brachii:**
  - 3 heads
  - extends elbow

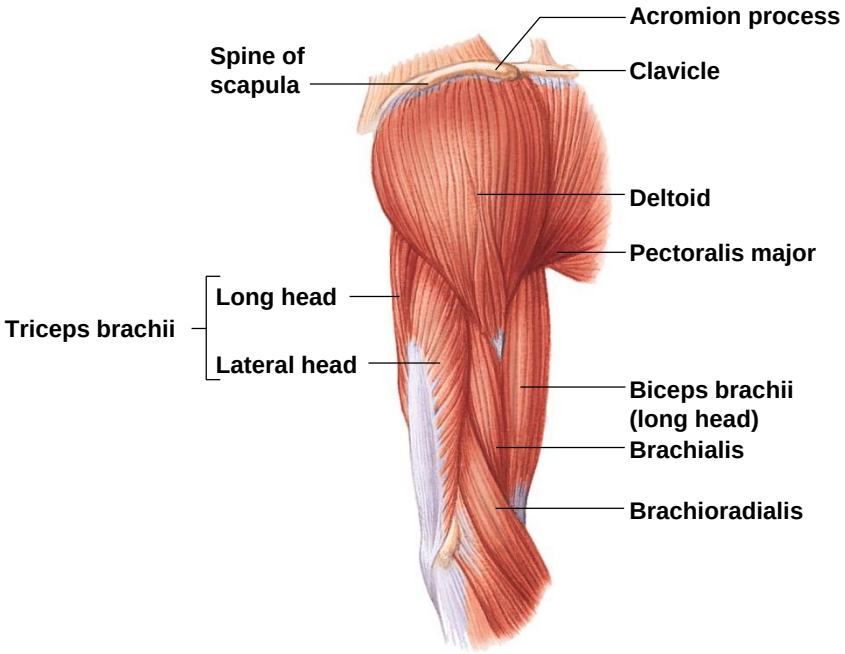
- **Biceps brachii:**
  - “flexing muscle”
  - flexes elbow and shoulder

- **Brachialis:**
  flexes elbow

- **Latissimus dorsi:**
  - lower back
  - extends shoulder



(a) Anterior view



(b) Lateral view

TABLE 7.12 Arm Movements (see figures 7.14, 7.22, 7.23, and 7.25)

Muscle	Origin	Insertion	Action
Deltoid (del′toyd)	Clavicle, acromion process, and scapular spine	Deltoid tuberosity	Flexes and extends shoulder; abducts and medially and laterally rotates arm
Latissimus dorsi (lă-tis′i-mŭs dōr′sī)	Spinous processes of T7–L5, sacrum and iliac crest, and inferior angle of scapula in some people	Medial crest of intertubercular groove	Extends shoulder; adducts and medially rotates arm
Pectoralis major (pek′tō-rā′lis)	Clavicle, sternum, superior six costal cartilages, and abdominal muscles	Lateral crest of intertubercular groove	Flexes shoulder; extends shoulder from flexed position; adducts and medially rotates arm
Teres major (ter′ēz)	Lateral border of scapula	Medial crest of intertubercular groove	Extends shoulder; adducts and medially rotates arm
Rotator Cuff			
Infraspinatus (in′fră-spī-nā′tŭs)	Infraspinous fossa of scapula	Greater tubercle of humerus	Stabilizes and extends shoulder and laterally rotates arm
Subscapularis (sŭb′skap-ū-lār′is)	Subscapular fossa of scapula	Lesser tubercle of humerus	Stabilizes and extends shoulder and medially rotates arm
Supraspinatus (sŭ′pră-spī-nā′tŭs)	Supraspinous fossa of scapula	Greater tubercle of humerus	Stabilizes shoulder and abducts arm
Teres minor (te′rēz)	Lateral border of scapula	Greater tubercle of humerus	Stabilizes and extends shoulder; adducts and laterally rotates arm

TABLE 7.13 Arm Muscles (see figures 7.14, 7.22, 7.23, and 7.25)

Muscle	Origin	Insertion	Action
Biceps brachii (bī′seps brā′kē-ī)	Long head—supraglenoid tubercle Short head—coracoid process	Radial tuberosity and aponeurosis of biceps brachii	Flexes elbow; supinates forearm; flexes shoulder
Brachialis (brā′kē-al′is)	Anterior surface of humerus	Coronoid process of ulna	Flexes elbow
Triceps brachii (trī′seps brā′kē-ī)	Long head—lateral border of scapula Lateral head—lateral and posterior surface of humerus Medial head—posterior humerus	Olecranon process of ulna	Extends elbow; extends shoulder; adducts arm

Muscles of Hips and Thighs

- **Iliopsoas:**

  flexes hip
- **Gluteus maximus:**
  - buttocks
  - extends hip and abducts thigh
- **Gluteus medius:**
  - hip
  - abducts and rotates thigh

TABLE 7.15 Muscles Moving the Thigh (see figure 7.26)

Muscle	Origin	Insertion	Action
Iliopsoas (il′ē-ō-sō′ŭs)	Iliac fossa and vertebrae T12–L5	Lesser trochanter of femur and hip capsule	Flexes hip
Gluteus maximus (glū′tē-ŭs mak′si-mŭs)	Posterior surface of ilium, sacrum, and coccyx	Gluteal tuberosity of femur and iliotibial tract	Extends hip; abducts and laterally rotates thigh
Gluteus medius (glū′tē-ŭs mē′dē-ŭs)	Posterior surface of ilium	Greater trochanter of femur	Abducts and medially rotates thigh
Gluteus minimus (glū′tē-ŭs min′i-mŭs) (not shown)	Posterior surface of ilium	Greater trochanter of femur	Abducts and medially rotates thigh
Tensor fasciae latae (ten′sōr fa′shē-ē lā′tē)	Anterior superior iliac spine	Through lateral fascia of thigh to lateral condyle of tibia	Steadies femur on tibia through iliotibial tract when standing; flexes hip; medially rotates and abducts thigh

Muscles of Upper Leg

Quadriceps femoris

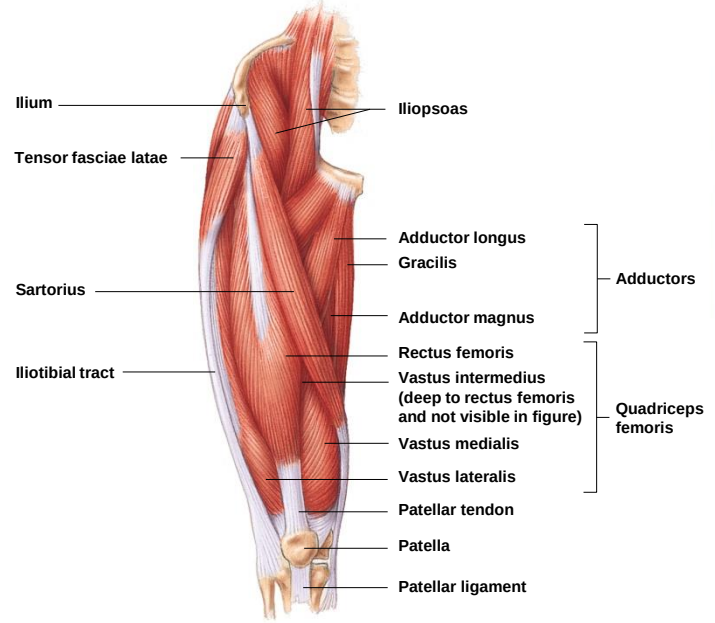
4 thigh muscles

- **Rectus femoris:**
  - front of thigh
  - extends knee and flexes hip
- **Vastus lateralis:**
  extends knee
- **Vastus medialis:**
  extends knee
- **Vastus intermedius:**
  extends knee

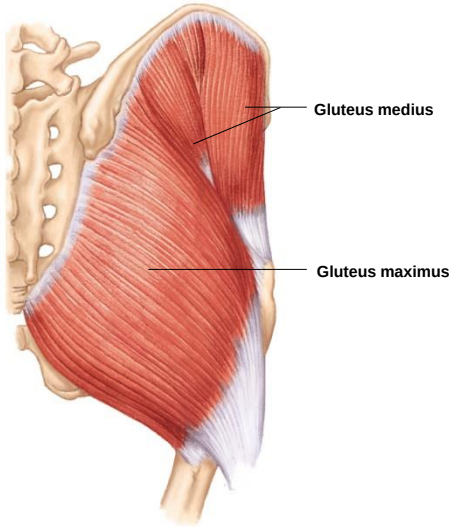
- **Gracilis:**

  adducts thigh and flexes knee

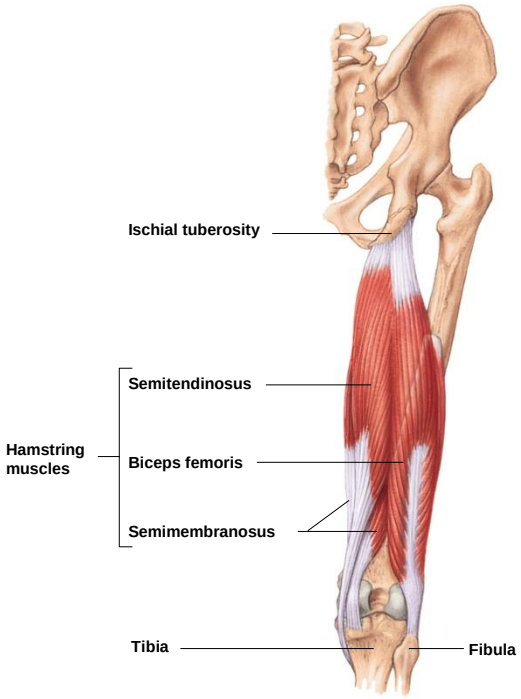
- **Biceps femoris, semimembranosus, semitendinosus:**
  - hamstring
  - back of thigh
  - flexes knee, rotates leg, extends hip



(a) Anterior view



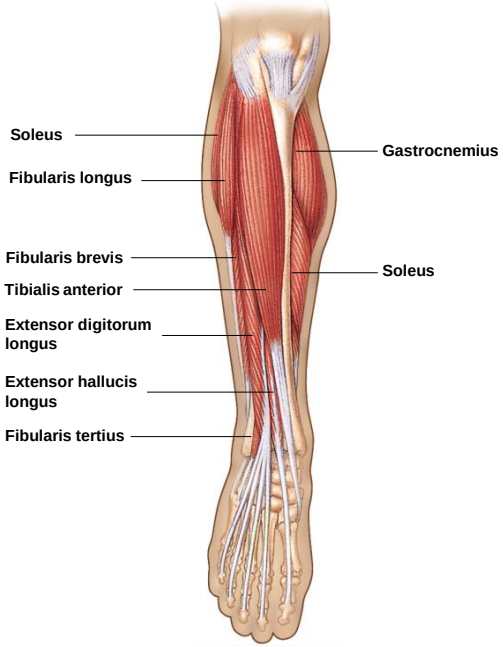
(b) Posterior view



(c) Posterior view

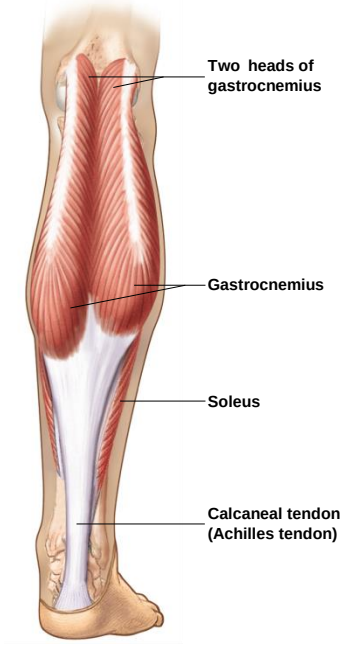
Muscles of Lower Leg

- **Tibialis anterior:**
  - front of lower leg
  - inverts foot
- **Gastrocnemius:**
  - calf
  - flexes foot and leg
- **Soleus:**
  - attaches to ankle
  - flexes foot



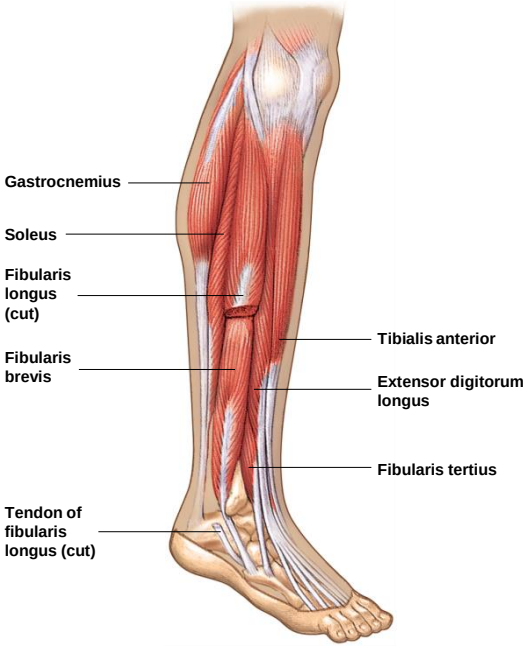
Anterior view

(a)



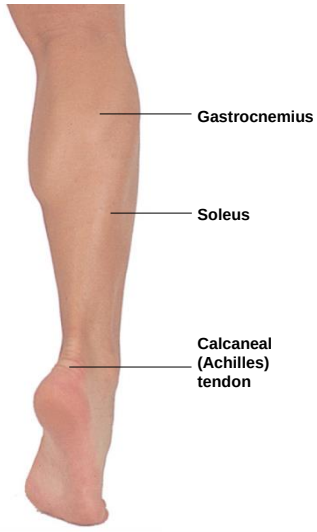
Posterior view

(b)



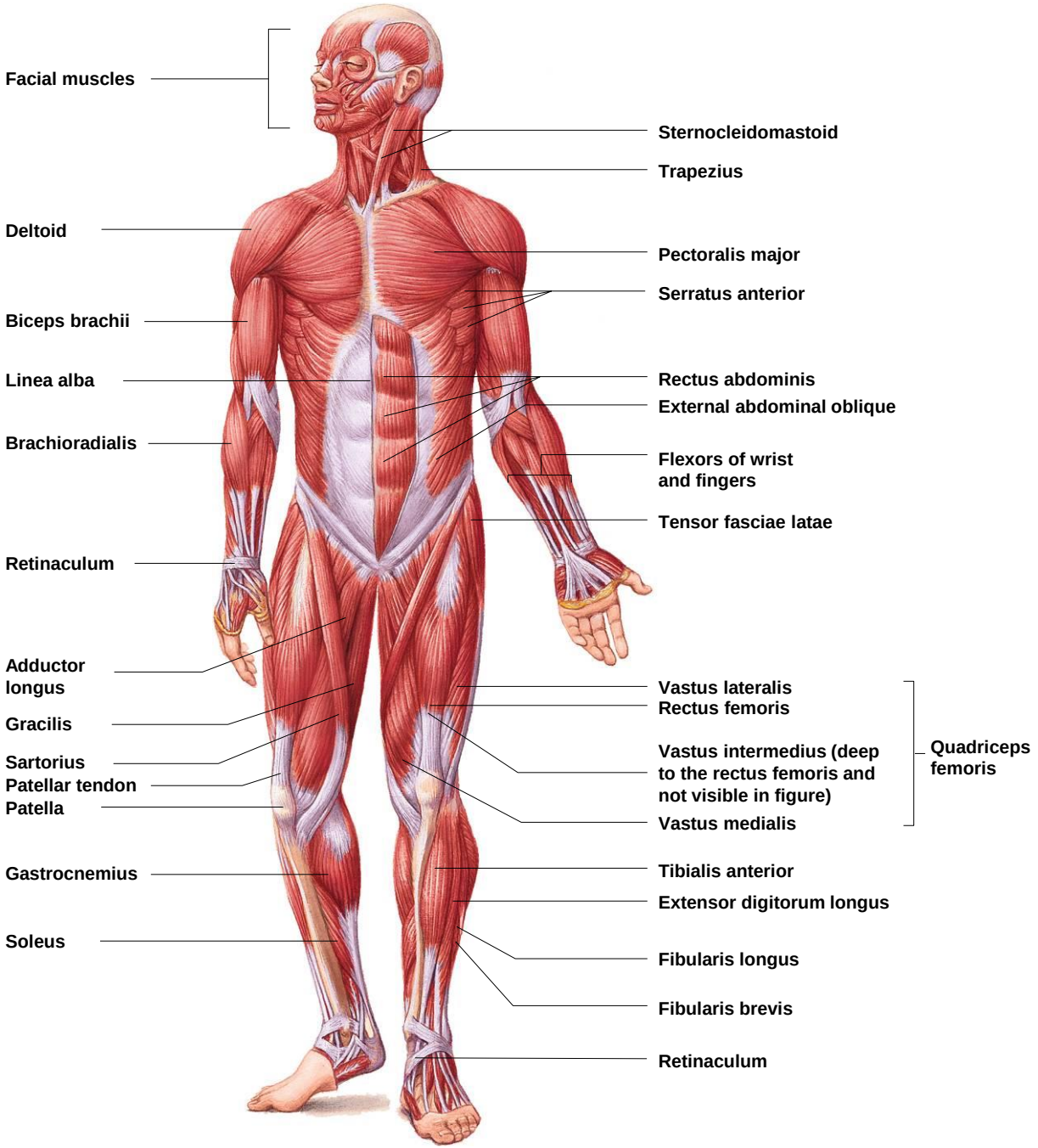
Lateral view

(c)

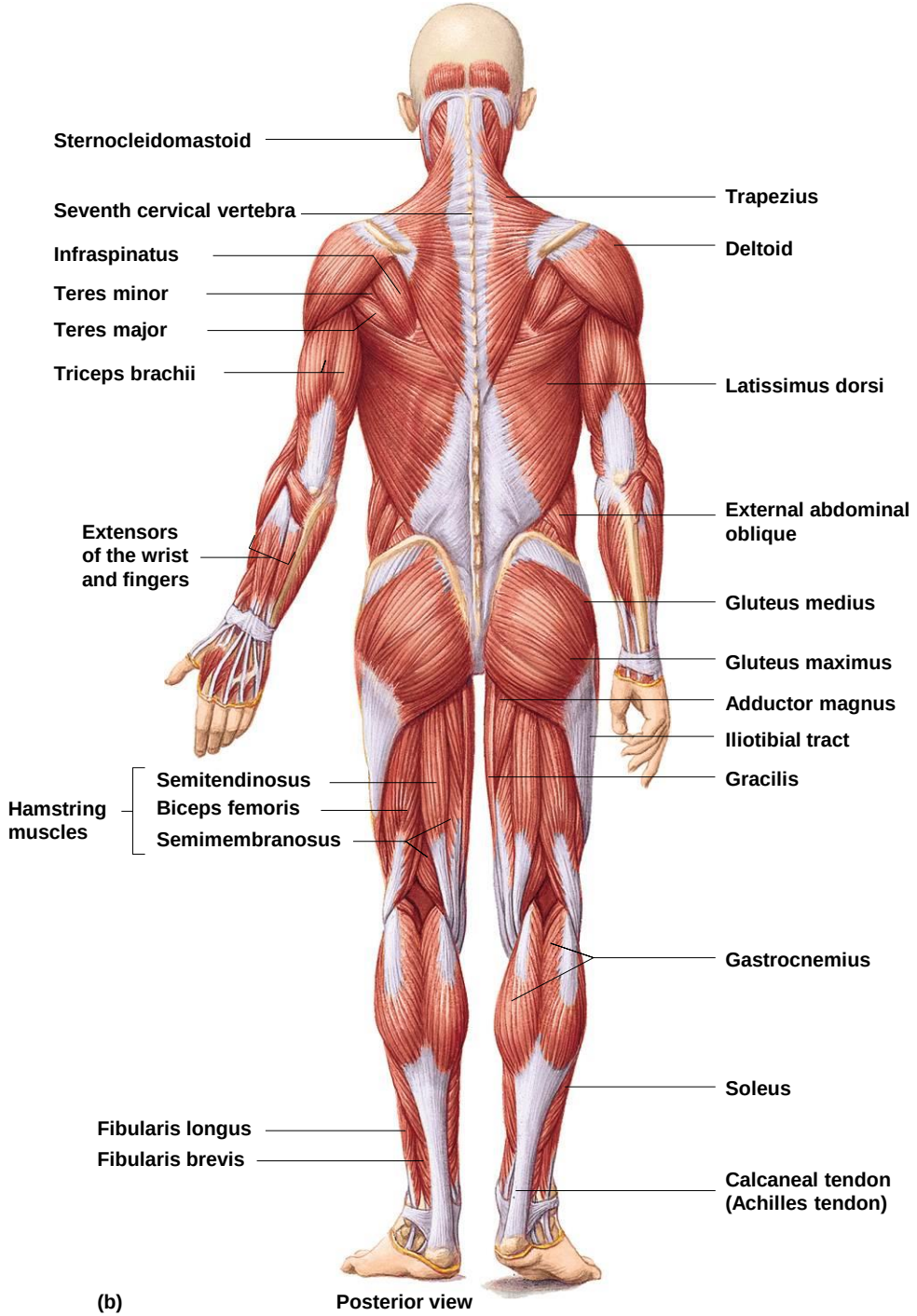


Posterior view

(d)

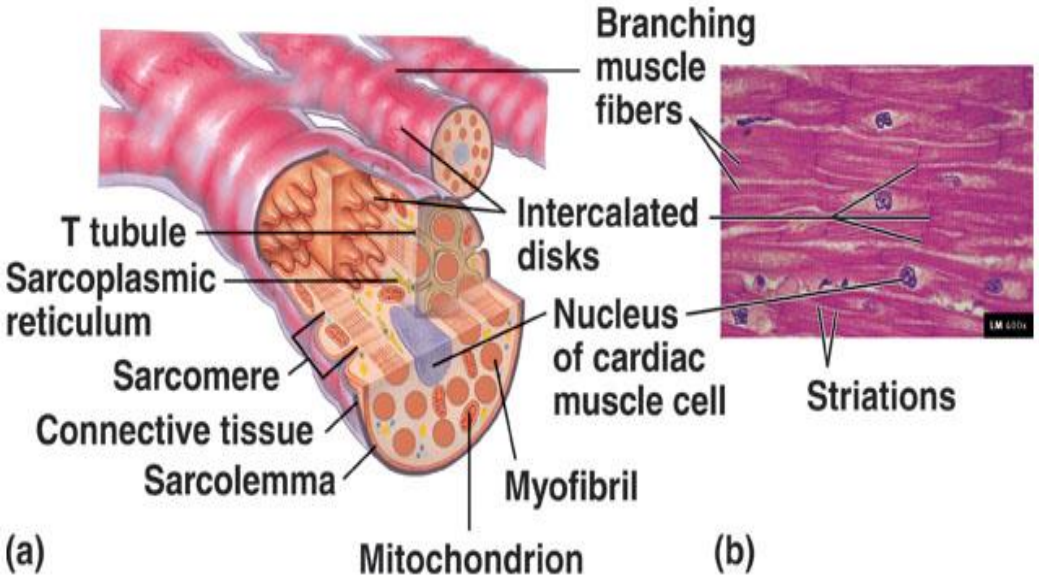


(a) Anterior view



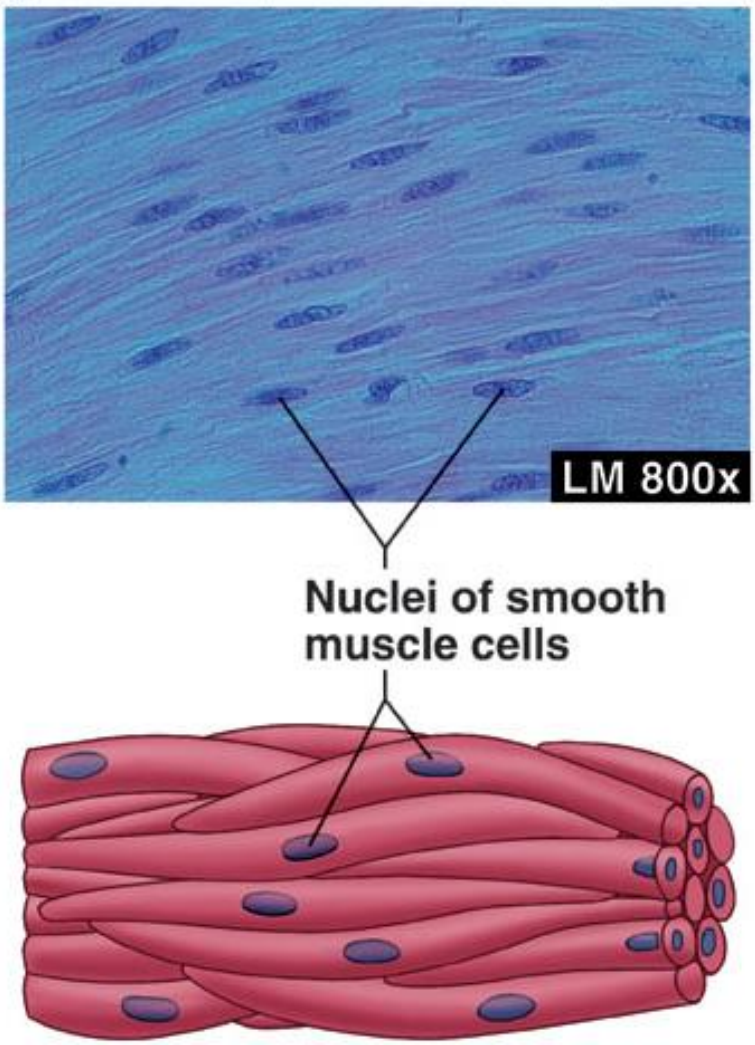
(b) Posterior view

Cardiac Muscle Characteristics



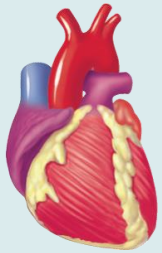
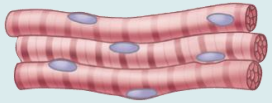
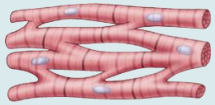
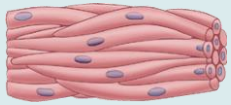
- Heart
- 1 centrally located nucleus/cell
- Striated
- Rich in mitochondria
- **Intercalated disks:** special cell junctions that allow cells to act as a unit

Smooth Muscle Characteristics



- Found on organs
- 1 centrally located nucleus/cell
- Not striated
- Less actin and myosin
- Under involuntary control

TABLE 7.2 Comparison of Muscle Types AP|R

	Skeletal Muscle	Cardiac Muscle	Smooth Muscle
			
Location	Attached to bone	Heart	Walls or hollow organs, blood vessels, and glands
Appearance			
Cell Shape	Long, cylindrical	Branched	Spindle-shaped
Nucleus	Multiple, peripheral	Usually single, central	Single, central
Special Features	———	Intercalated disks	Cell-to-cell attachments
Striations	Yes	Yes	No
Autorhythmic	No	Yes	Yes
Control	Voluntary	Involuntary	Involuntary
Function	Move the whole body	Contract heart to propel blood through the body	Compress organs, ducts, tubes, and so on