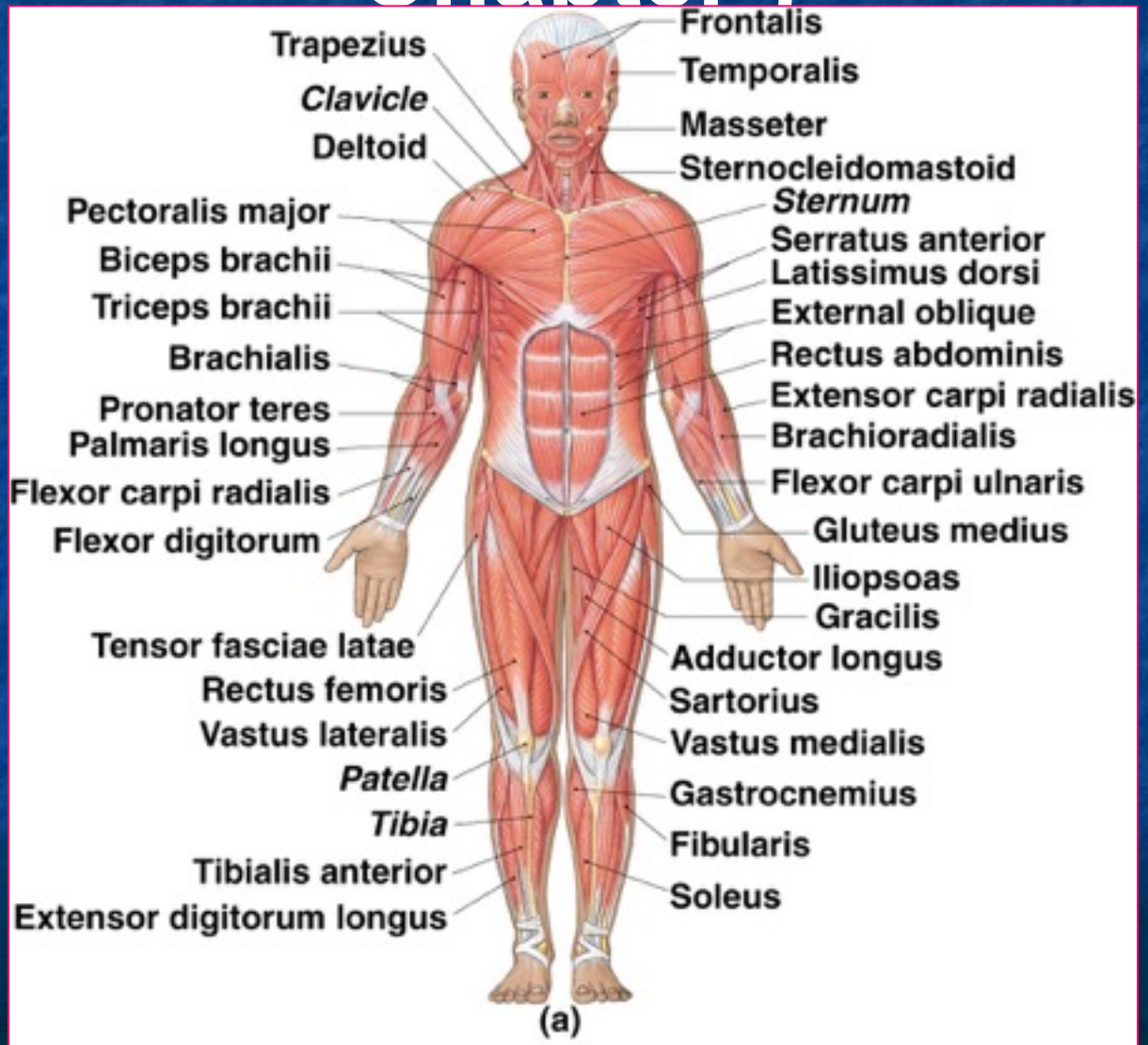
The Muscular System
Chapter 7



There are four characteristics associated with muscle tissue:

- ➢ Excitability - Tissue can receive & respond to stimulation
- ➢ Contractility - Tissue can shorten & thicken
- ➢ Extensibility - Tissue can lengthen
- ➢ Elasticity - After contracting or lengthening, tissue always wants to return to its resting state

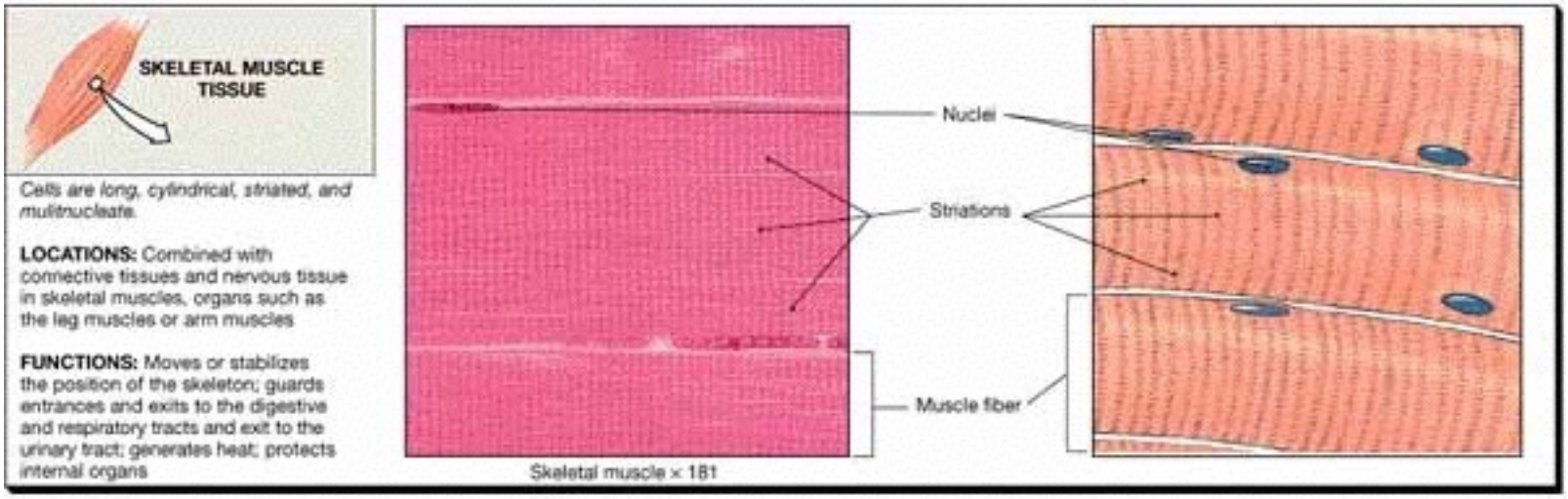
The characteristics of muscle tissue enable it to perform some important functions, including:

- Movement – both voluntary & involuntary
- Maintaining posture
- Supporting soft tissues within body cavities
- Guarding entrances & exits of the body
- Maintaining body temperature

Types of muscle tissue:

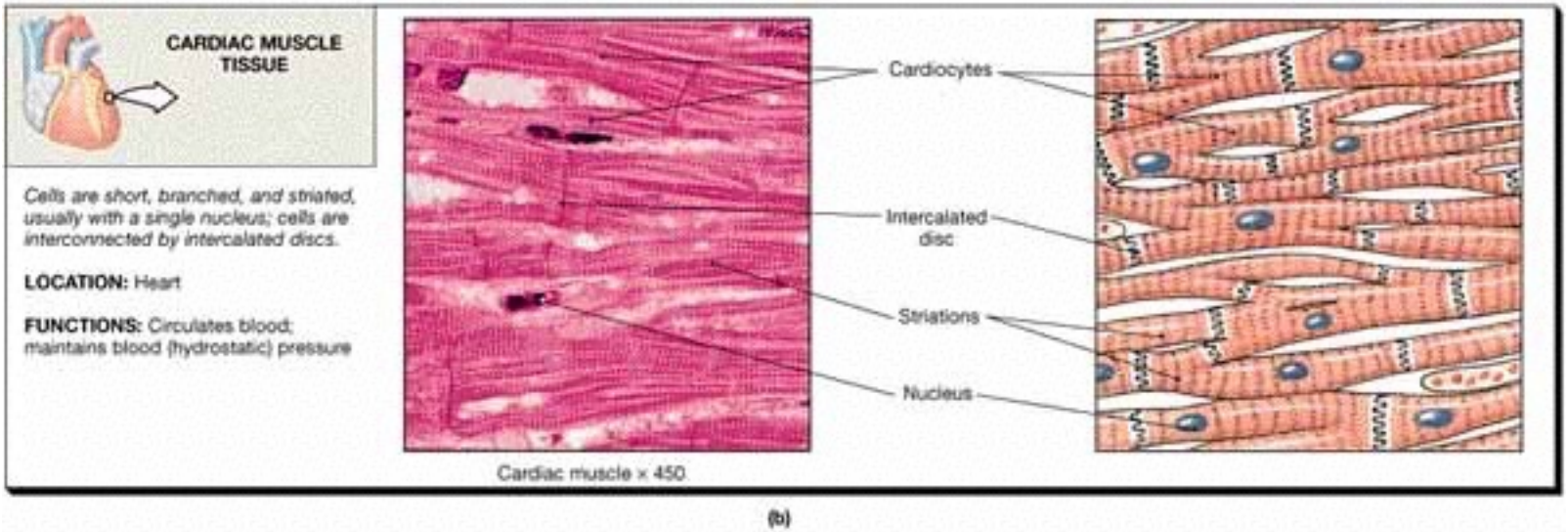
Skeletal muscle tissue

- Associated with & attached to the skeleton
- Under our conscious (*voluntary*) control
- Microscopically the tissue appears *striated*
- Cells are long, cylindrical & multinucleate



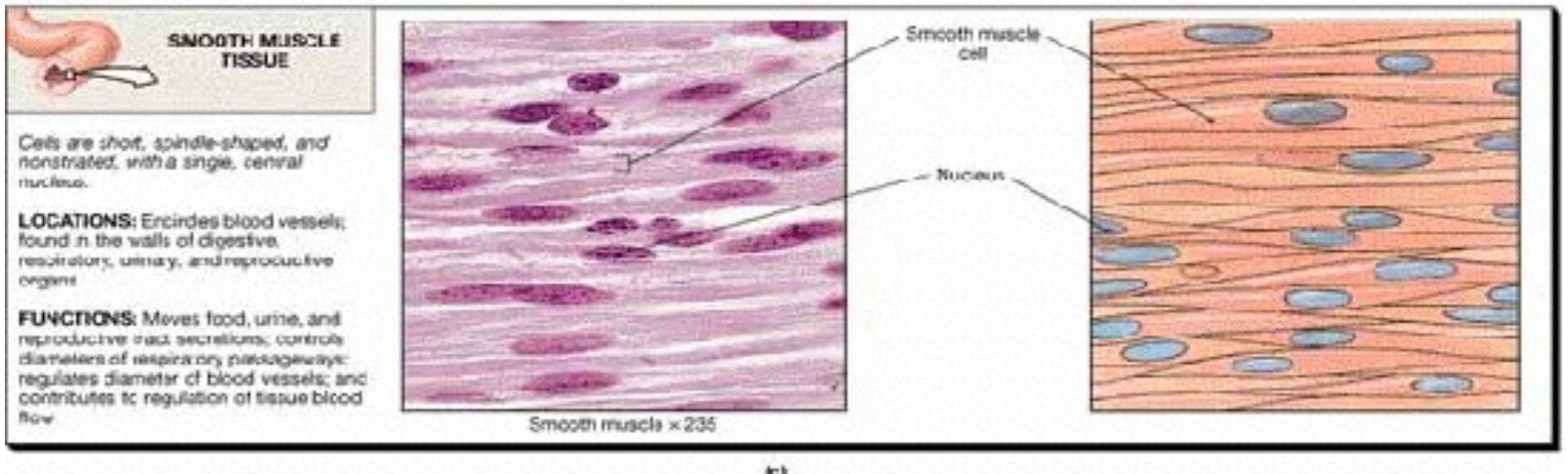
Cardiac muscle tissue

- Makes up myocardium of heart
- Unconsciously (*involuntarily*) controlled
- Microscopically appears *striated*
- Cells are short, branching & have a single nucleus
- Cells connect to each other at *intercalated discs*

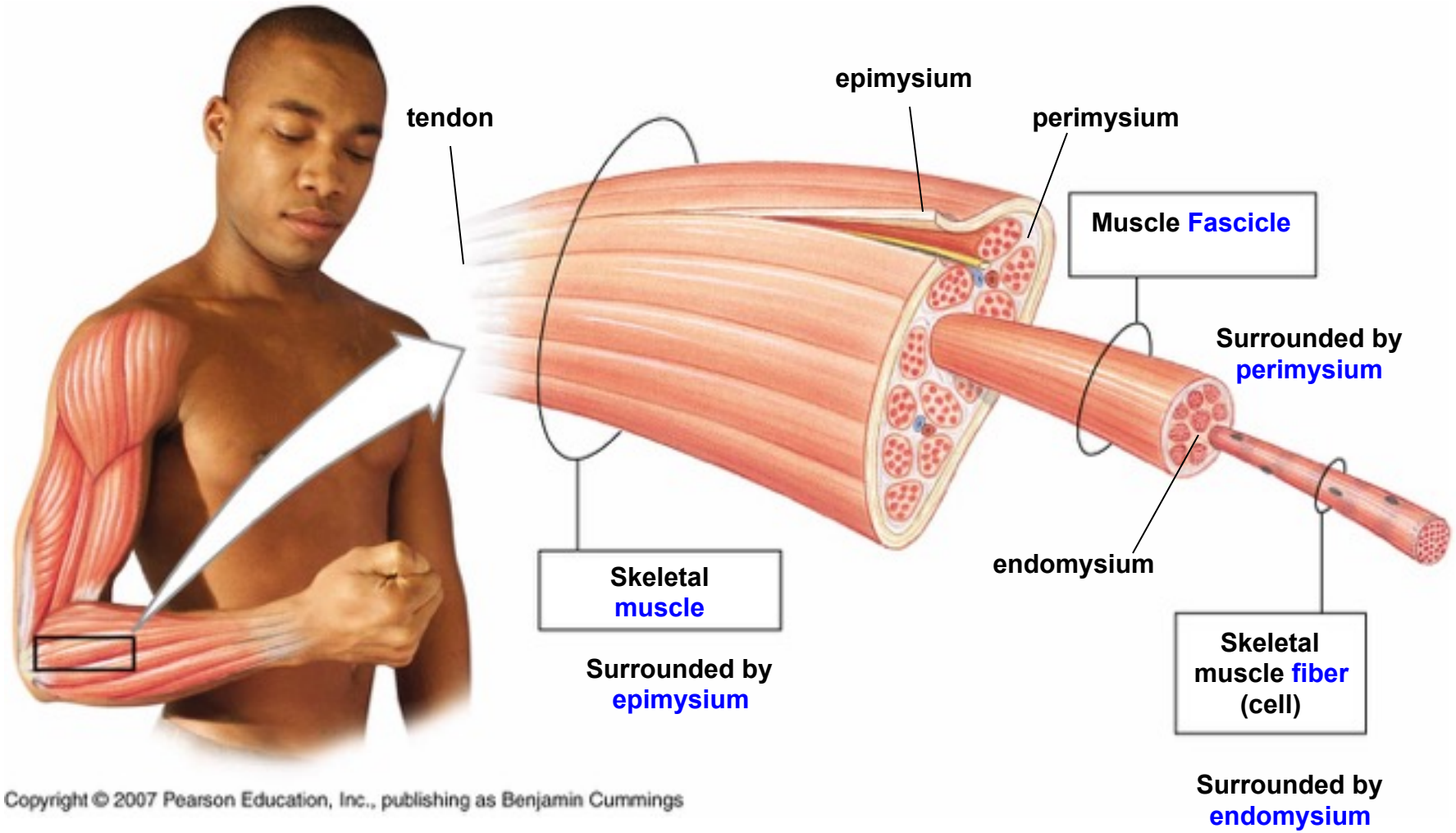


Smooth (visceral) muscle tissue

- Makes up walls of organs & blood vessels
- Tissue is *non-striated* & *involuntary*
- Cells are short, spindle-shaped & have a single nucleus
- Tissue is extremely extensible, while still retaining ability to contract

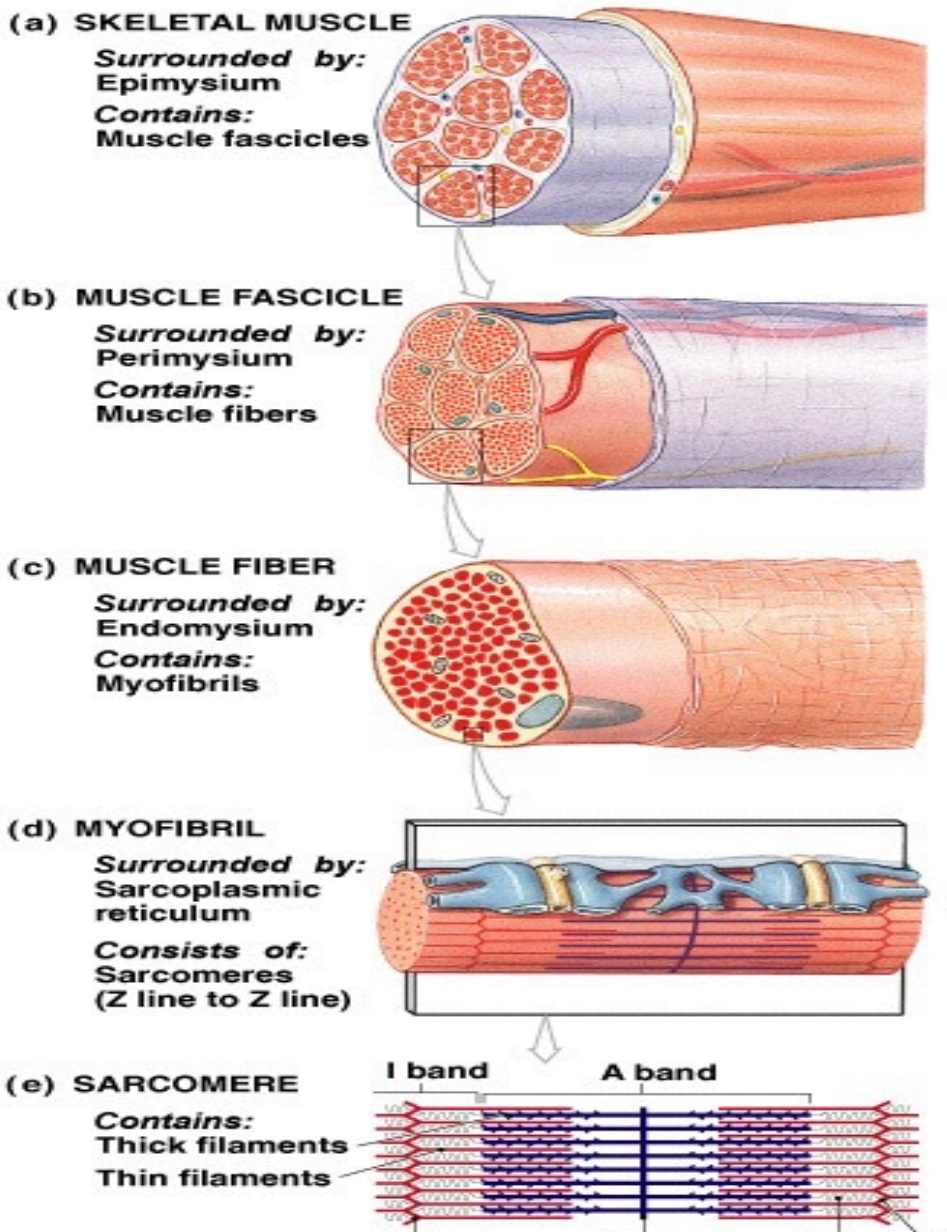


Anatomy of skeletal muscles

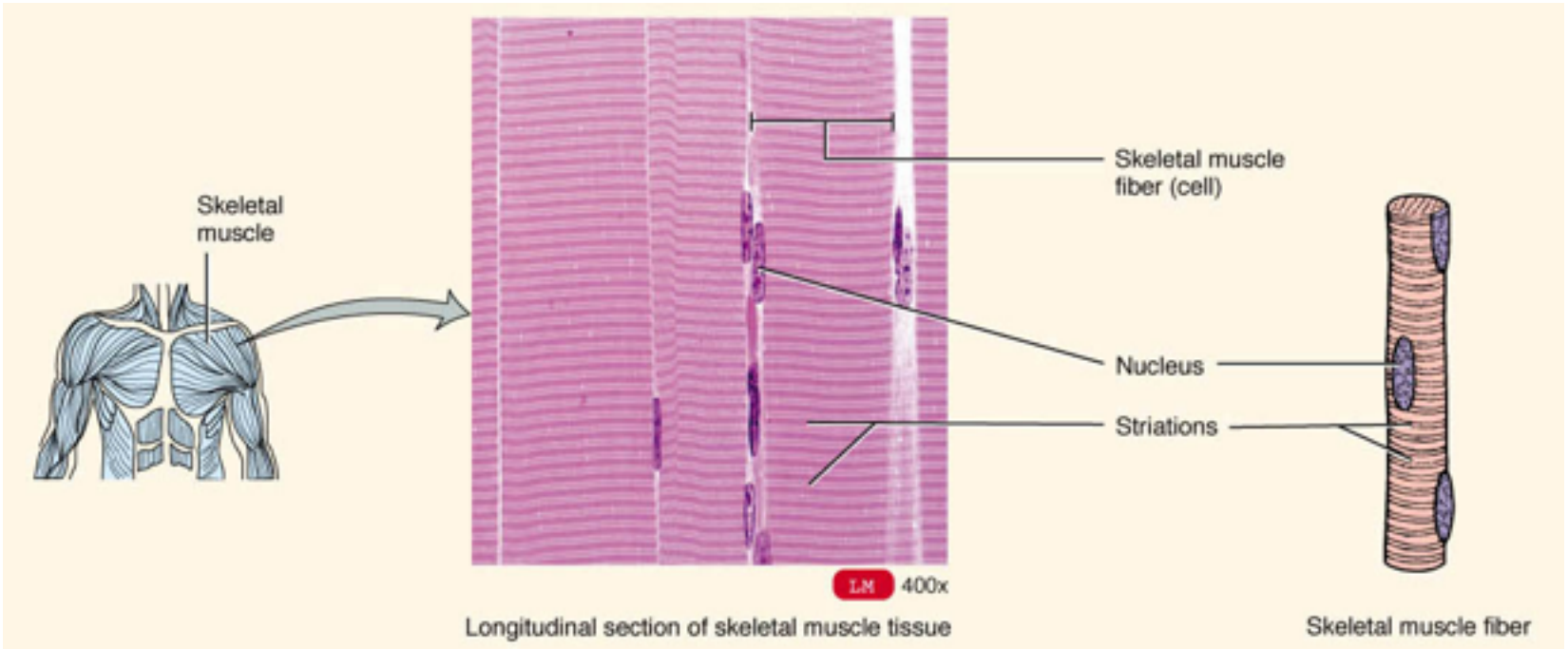


Play IP Anatomy of Skeletal muscles (IP p. 4-6)

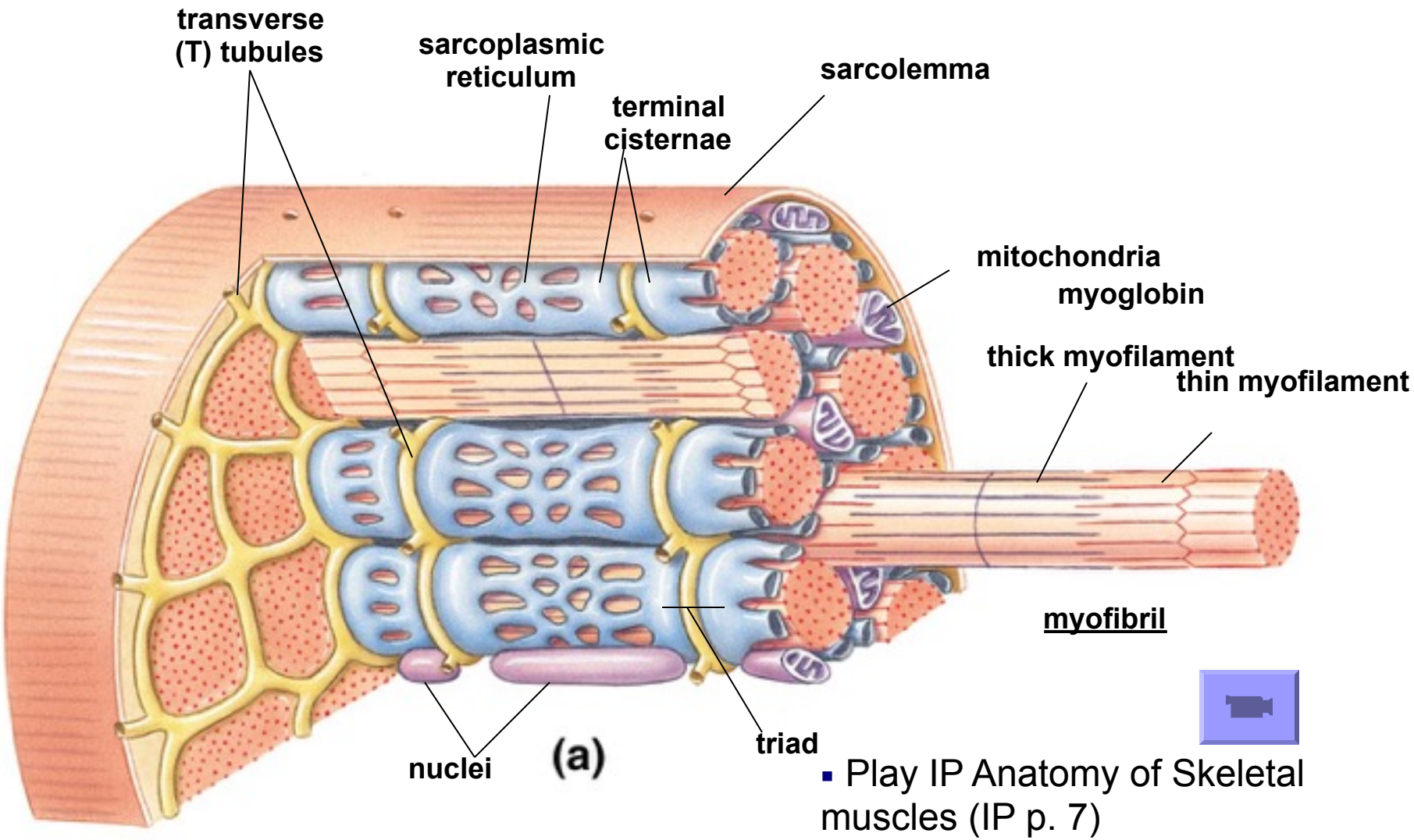
Organization of Skeletal Muscles



Microanatomy of a Muscle Fiber

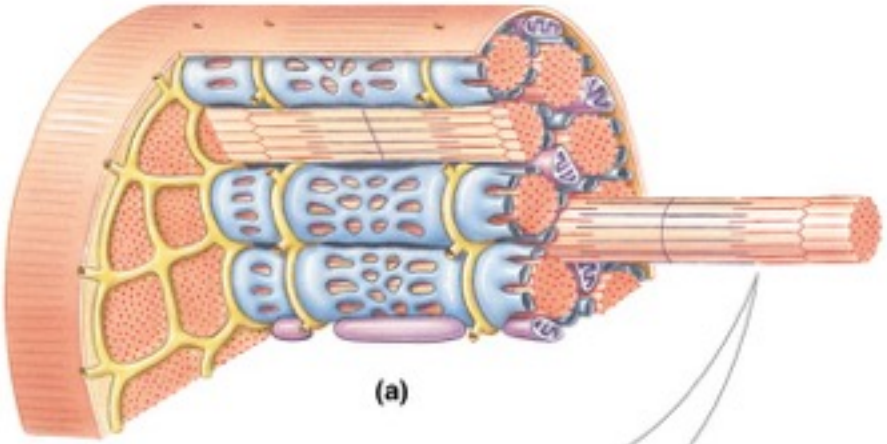


Microanatomy of a Muscle Fiber (Cell)



- Play IP Anatomy of Skeletal muscles (IP p. 7)

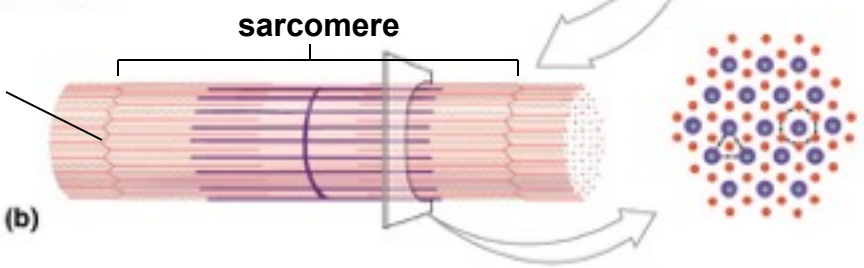
Muscle fiber



sarcomere

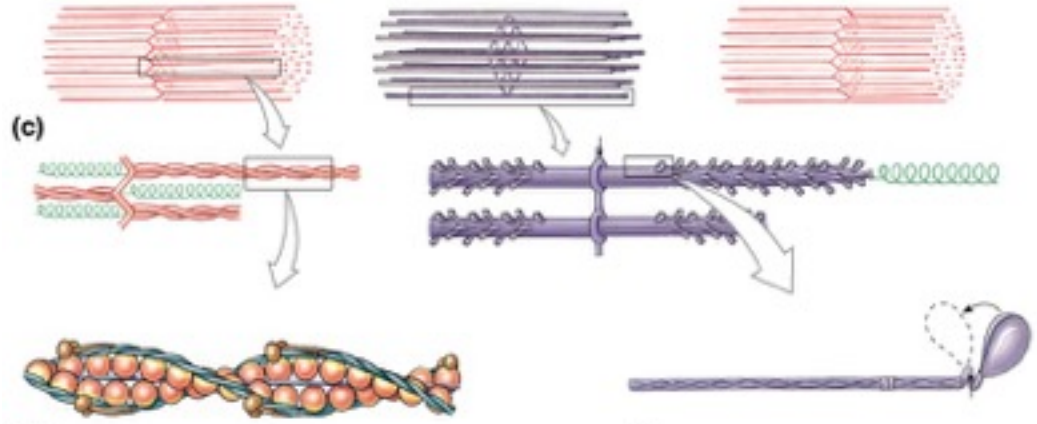
Z-line

myofibril



Thin filaments

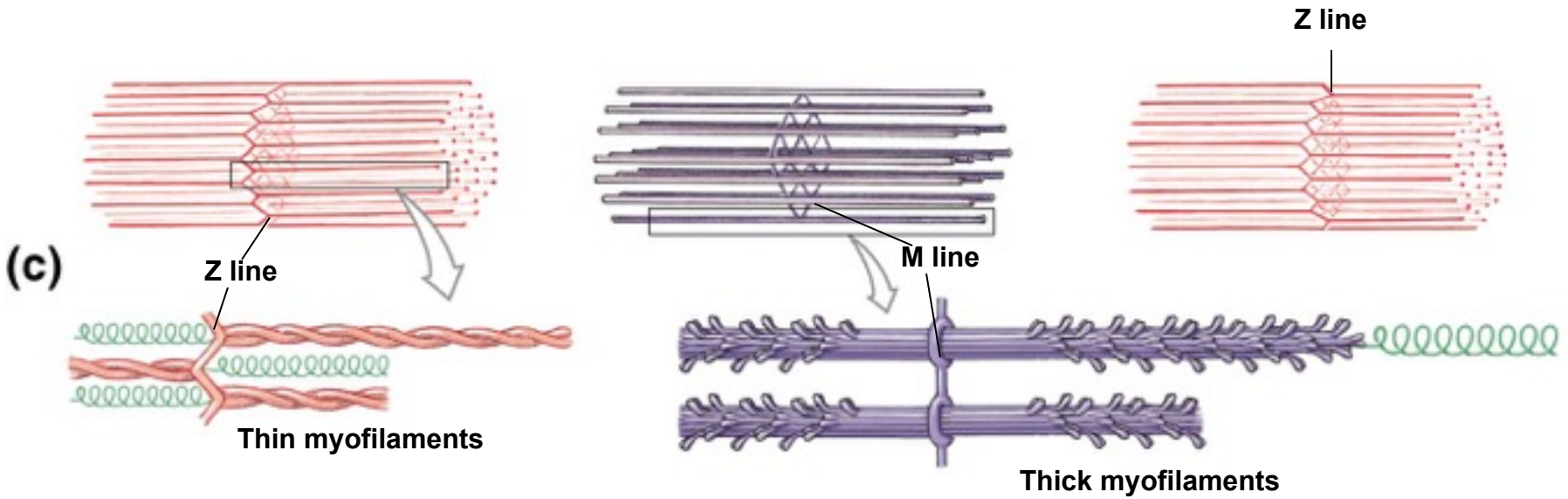
Thick filaments



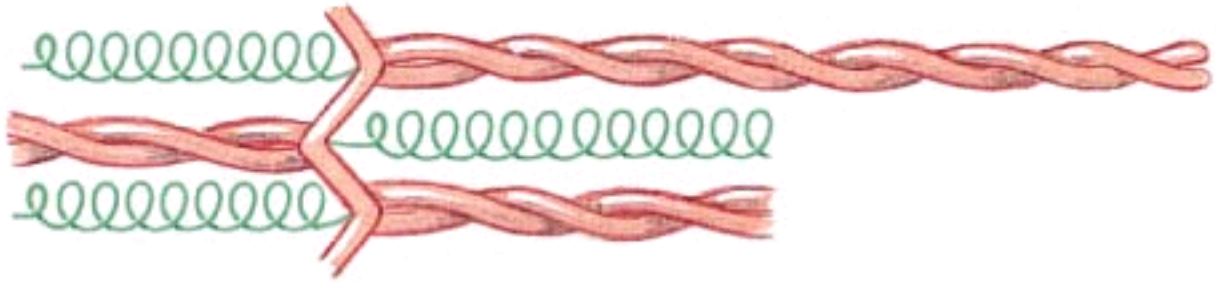
Thin myofilament

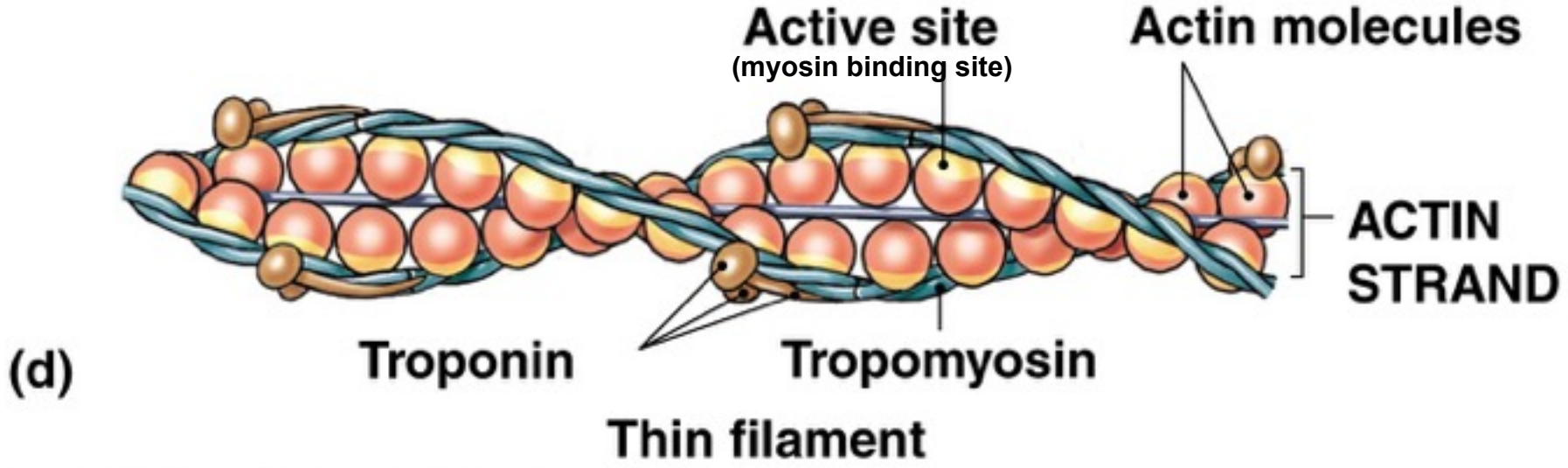
Myosin molecule of thick myofilament

Myofilaments of sarcomere

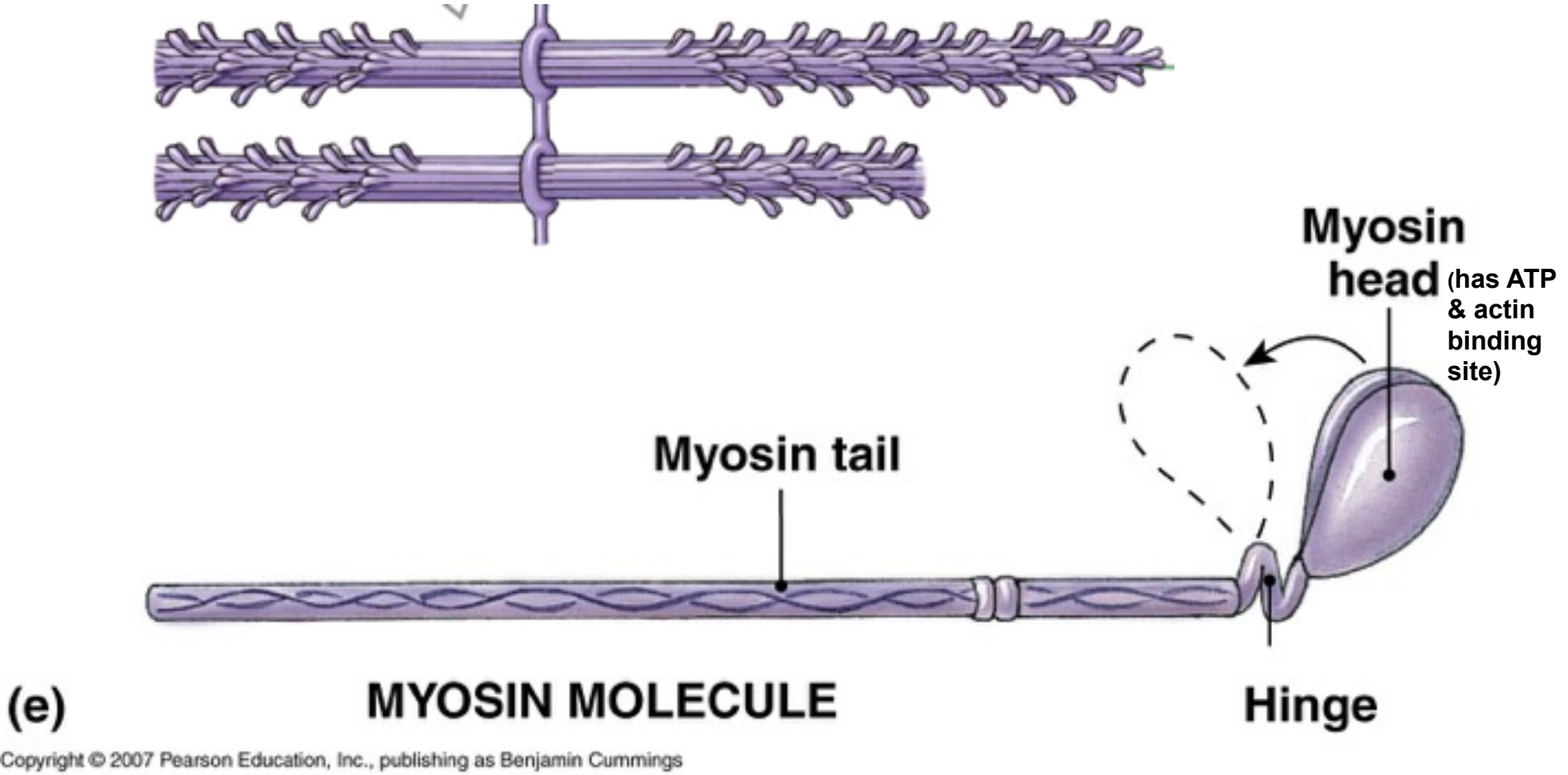


Thin Myofilament



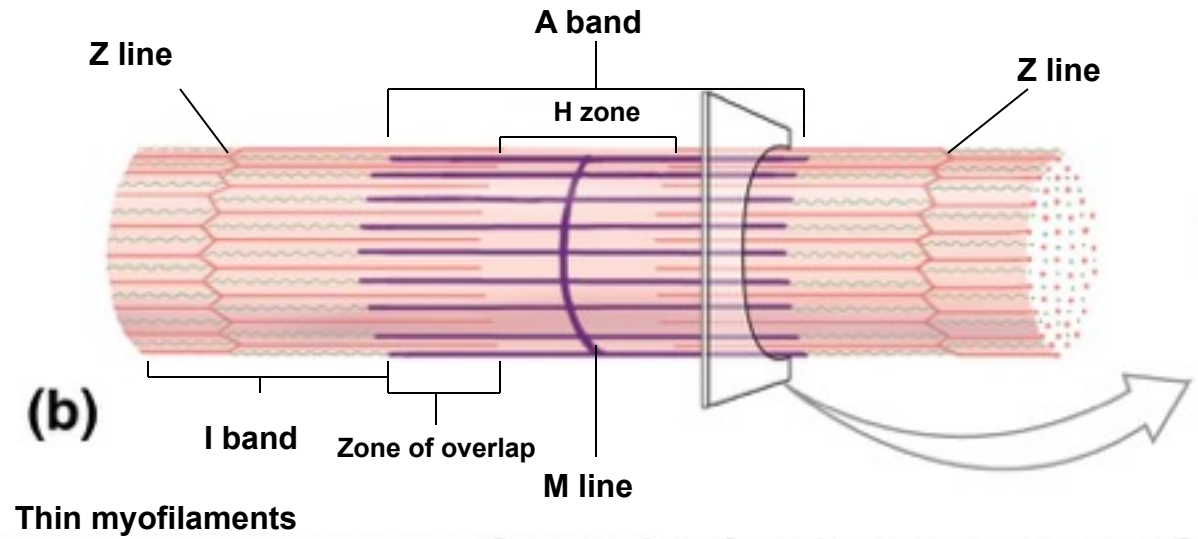


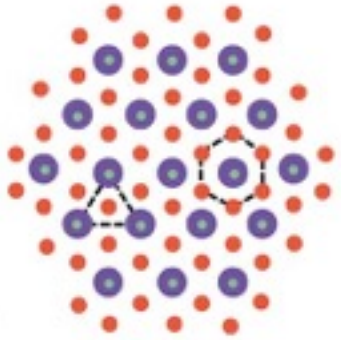
Thick myofilament



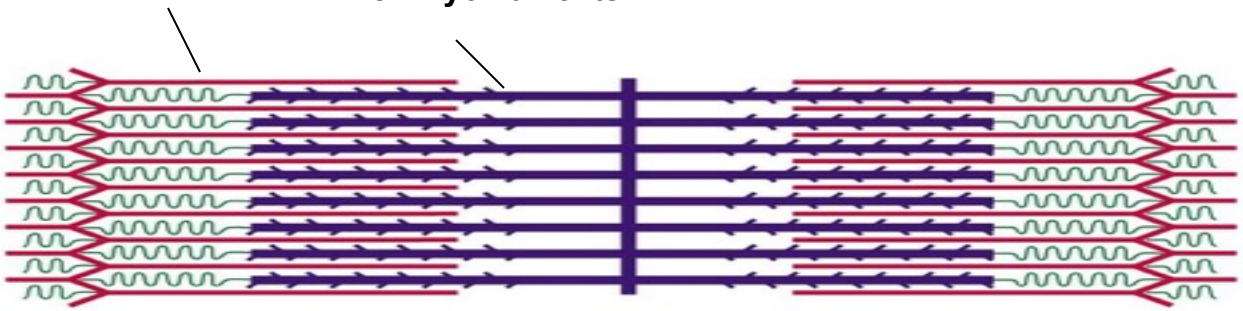
*Play IP sliding filament theory p.5-14 for overview of thin & thick filaments

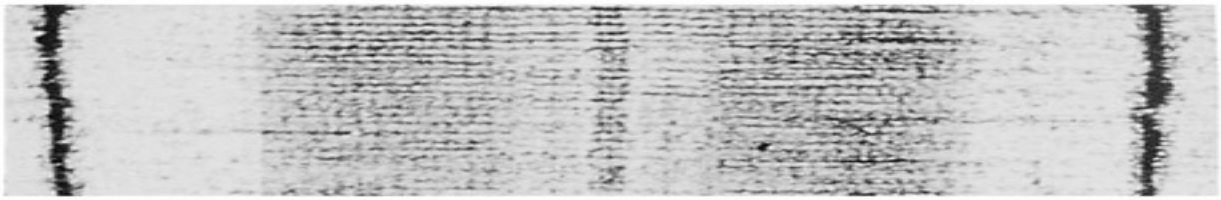
Sarcomere





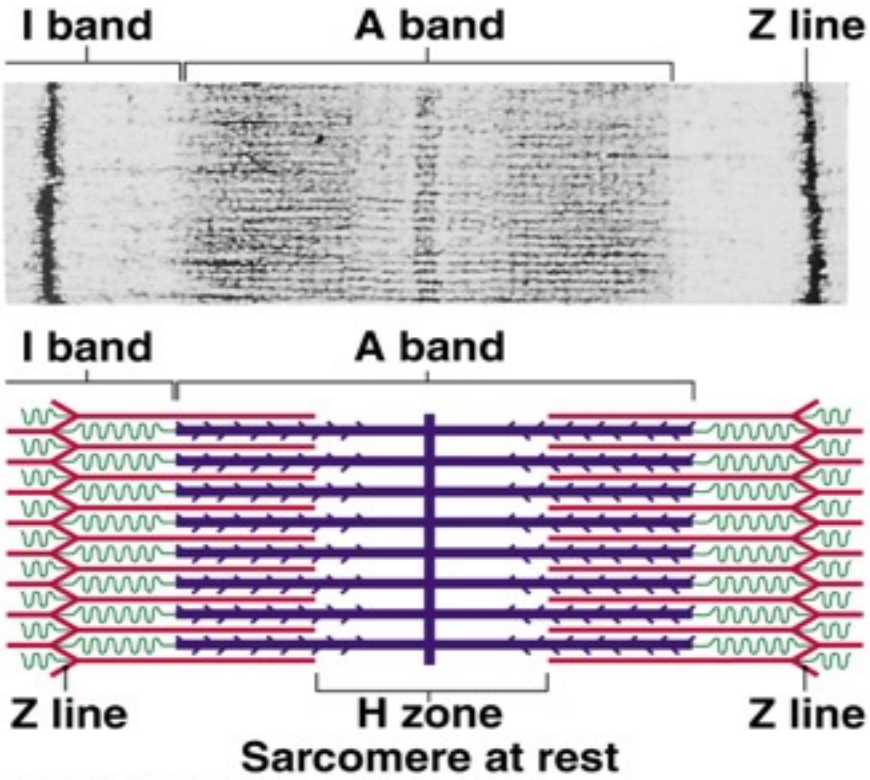
Zone of overlap

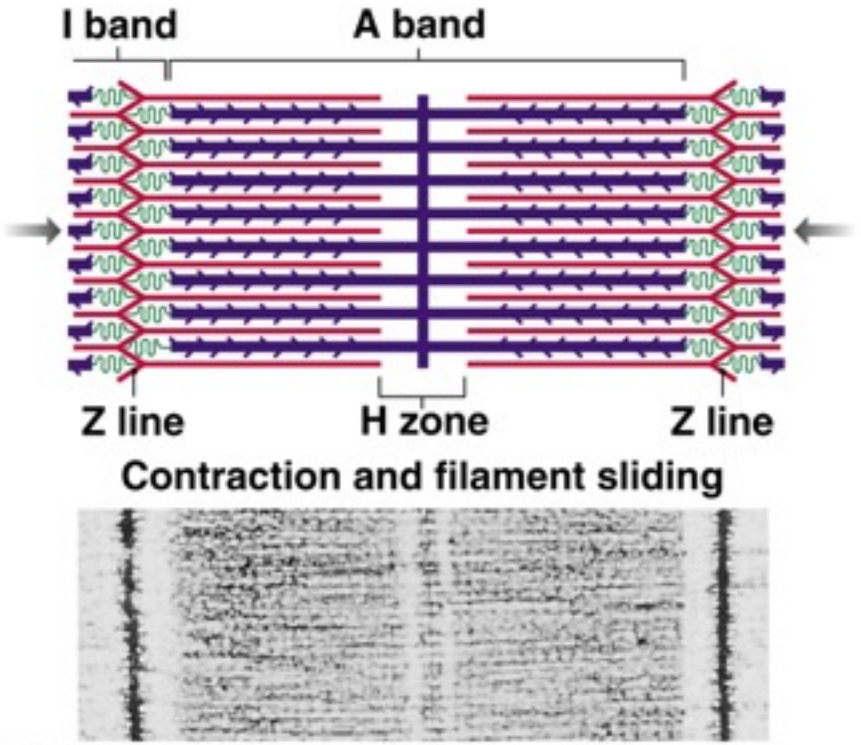


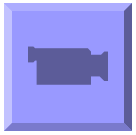


Sliding Filament Theory

- Myosin heads attach to actin molecules (at binding (active) site)
- Myosin "pulls" on actin, causing thin myofilaments to slide across thick myofilaments, towards the center of the sarcomere
- Sarcomere shortens, I bands get smaller, H zone gets smaller, & zone of overlap increases





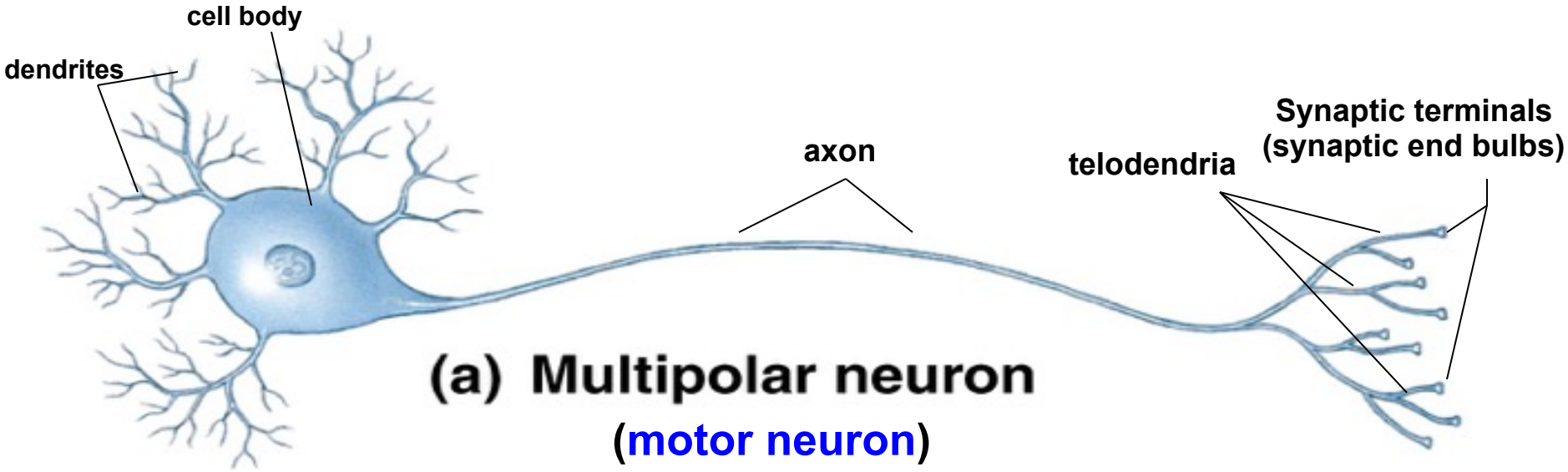


Play IP sliding filament theory p. 28

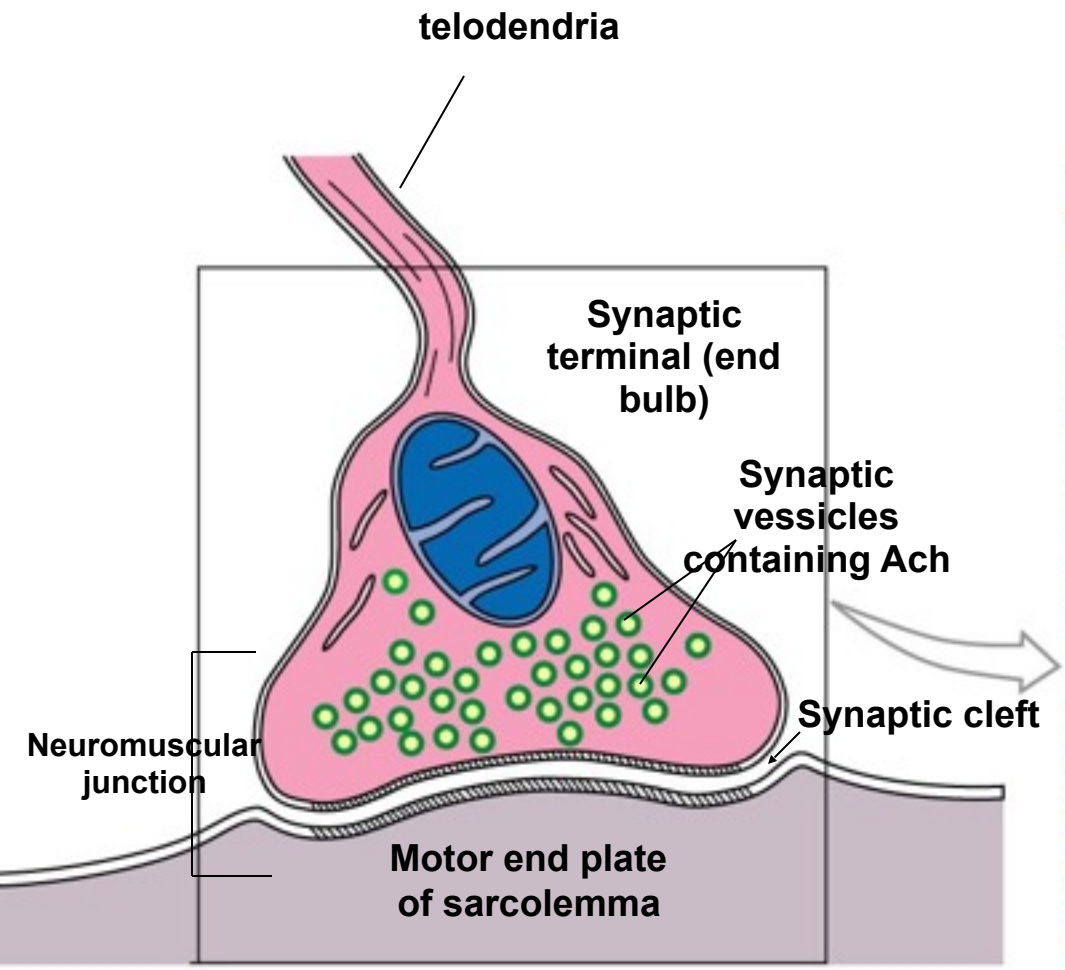
- As sarcomeres shorten, myofibril shortens. As myofibrils shorten, so does muscle fiber
- Once a muscle *fiber* begins to contract, it will contract maximally
- This is known as the “all or none” principle

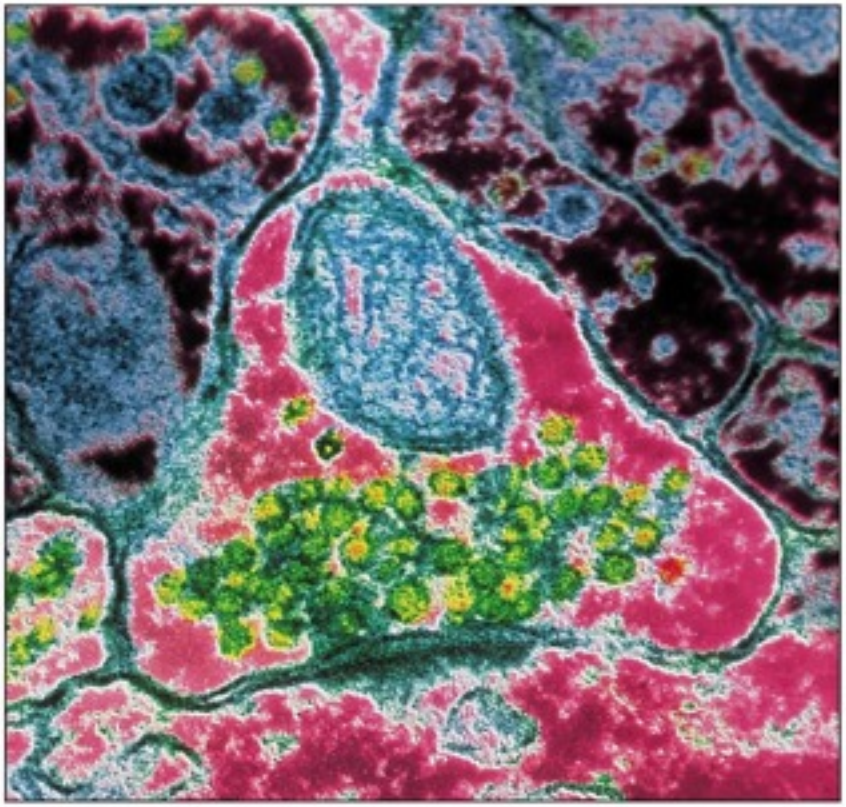
Physiology of skeletal muscle contraction

- Skeletal muscles require stimulation from the nervous system in order to contract
- *Motor neurons* are the cells that cause muscle fibers to contract



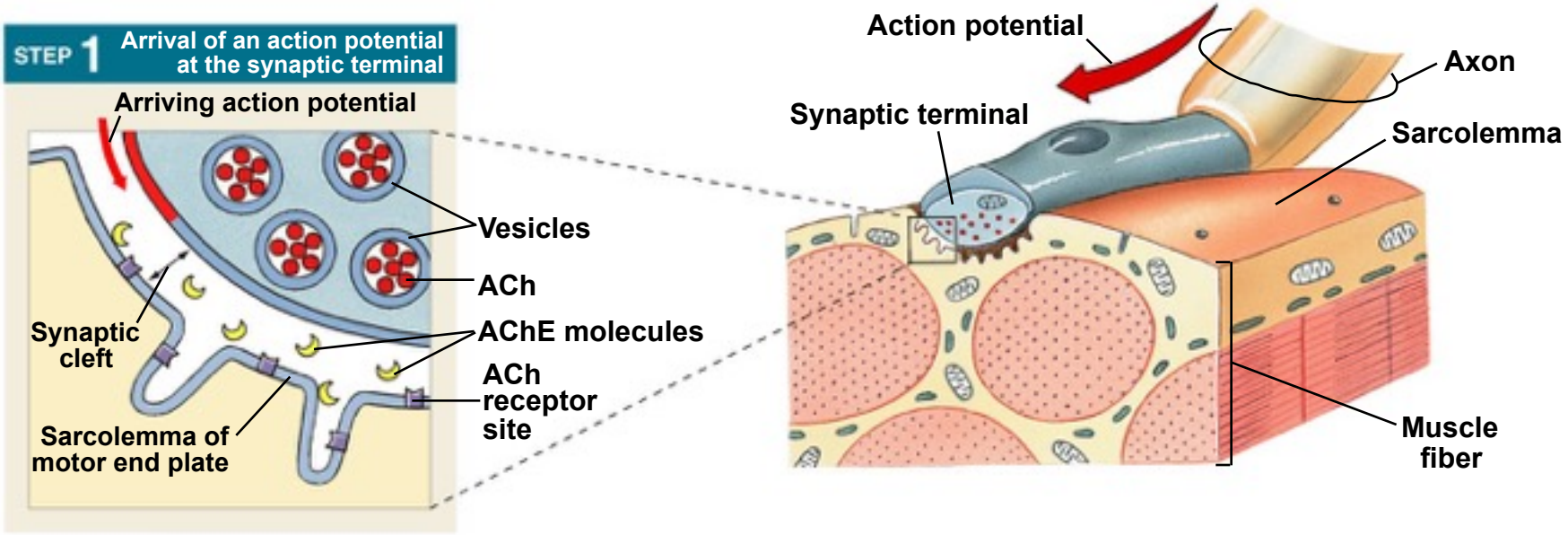
Neuromuscular junction





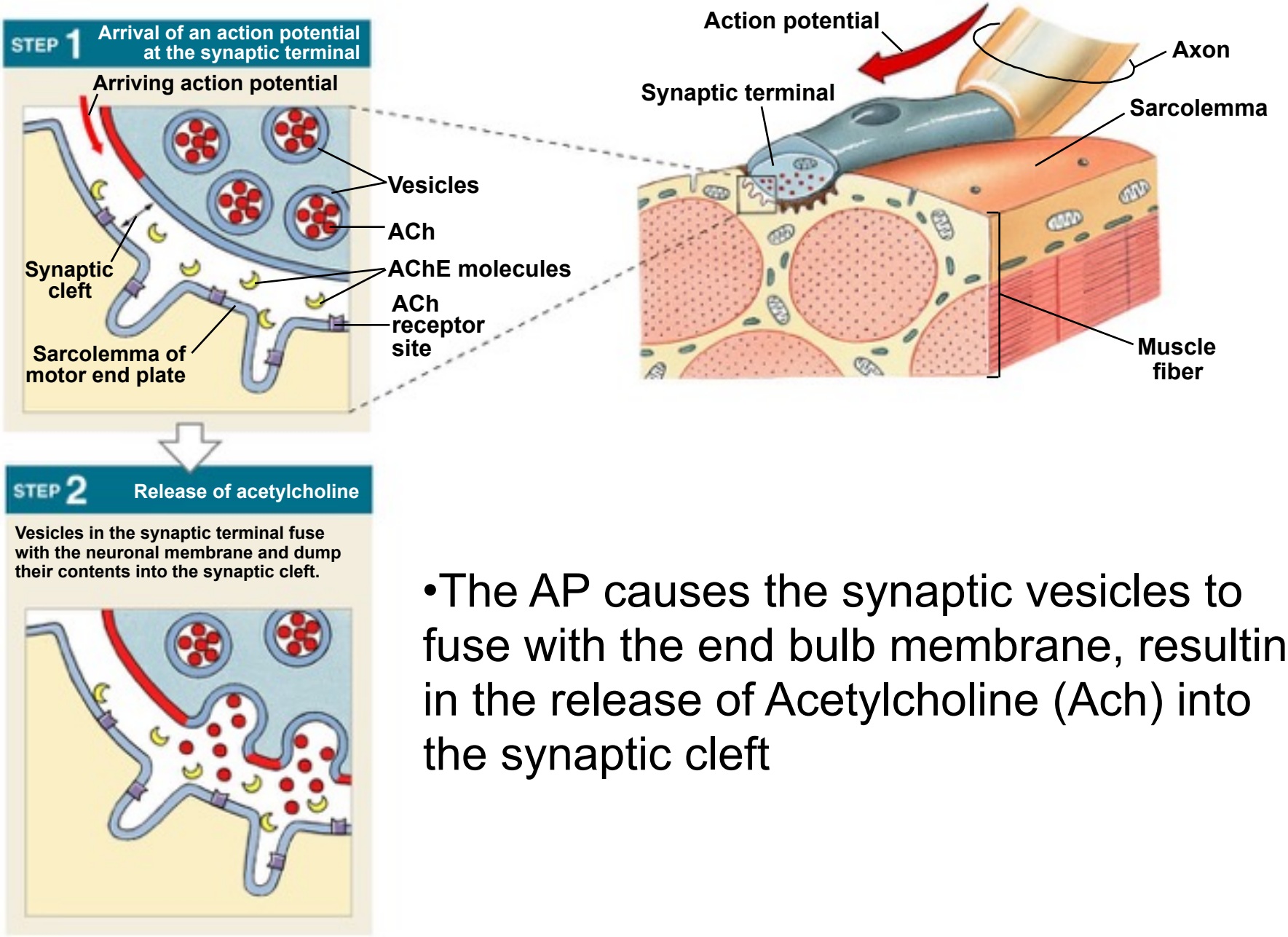
Overview of Events at the neuromuscular junction

- An *action potential (AP)*, an electrical impulse, travels down the axon of the motor neuron to the end bulbs (synaptic terminals)
- The AP causes the synaptic vesicles to fuse with the end bulb membrane, resulting in the release of Acetylcholine (Ach) into the synaptic cleft
- Ach diffuses across the synaptic cleft & binds to Ach receptors on the motor end plate
- The binding of Ach to its receptors causes a new AP to be generated along the muscle cell membrane
- Immediately after it binds to its receptors, Ach will be broken down by Acetylcholinesterase (AchE) – an enzyme present in the synaptic cleft



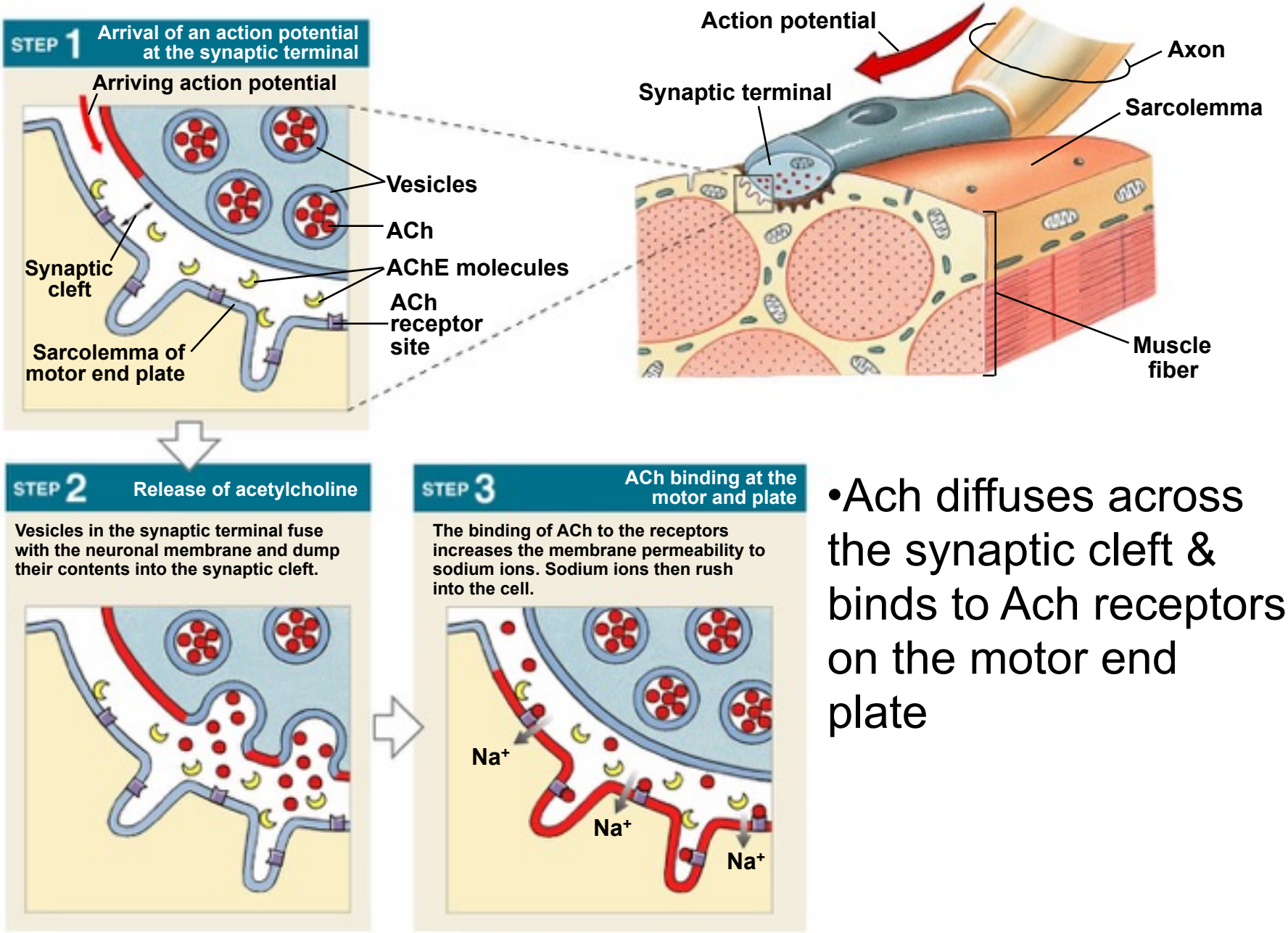
• An *action potential (AP)*, an electrical impulse, travels down the axon of the motor neuron to the end bulbs (synaptic terminals)

Figure 7-4(b-c)
2 of 5



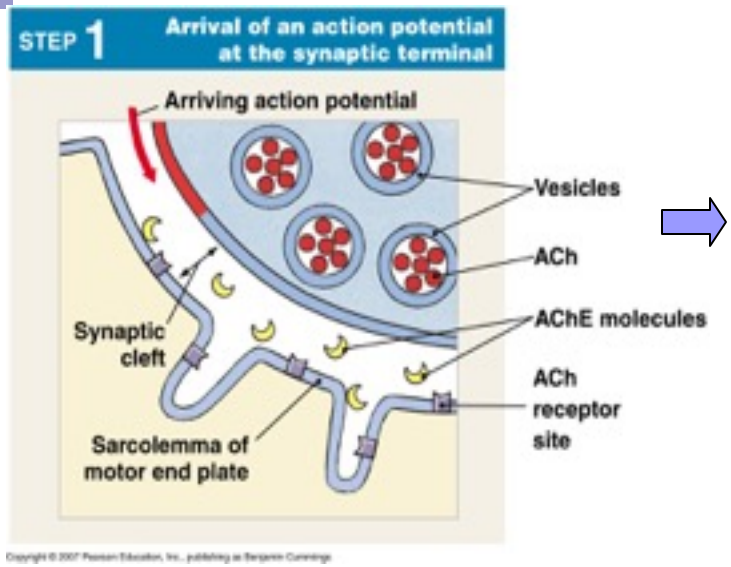
•The AP causes the synaptic vesicles to fuse with the end bulb membrane, resulting in the release of Acetylcholine (Ach) into the synaptic cleft

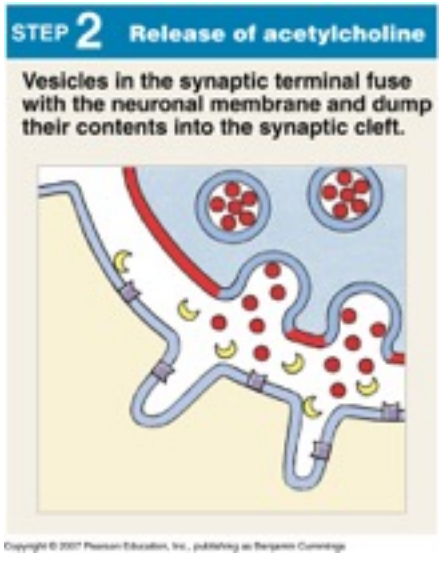
Figure 7-4(b-c)
3 of 5

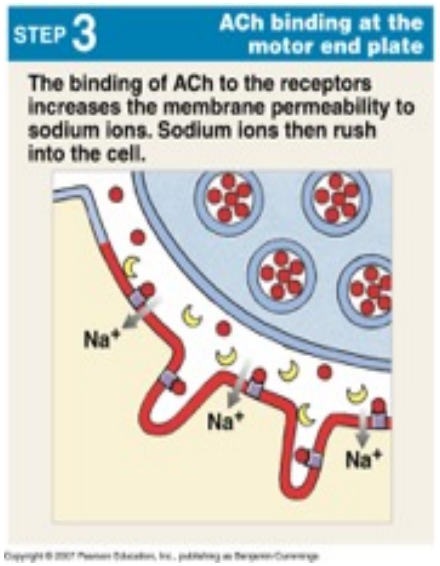


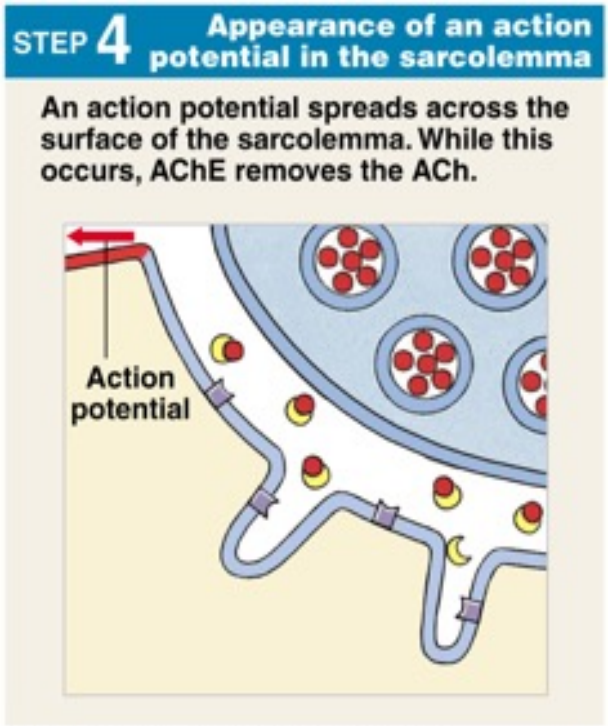
•Ach diffuses across the synaptic cleft & binds to Ach receptors on the motor end plate

Figure 7-4(b-c)
4 of 5



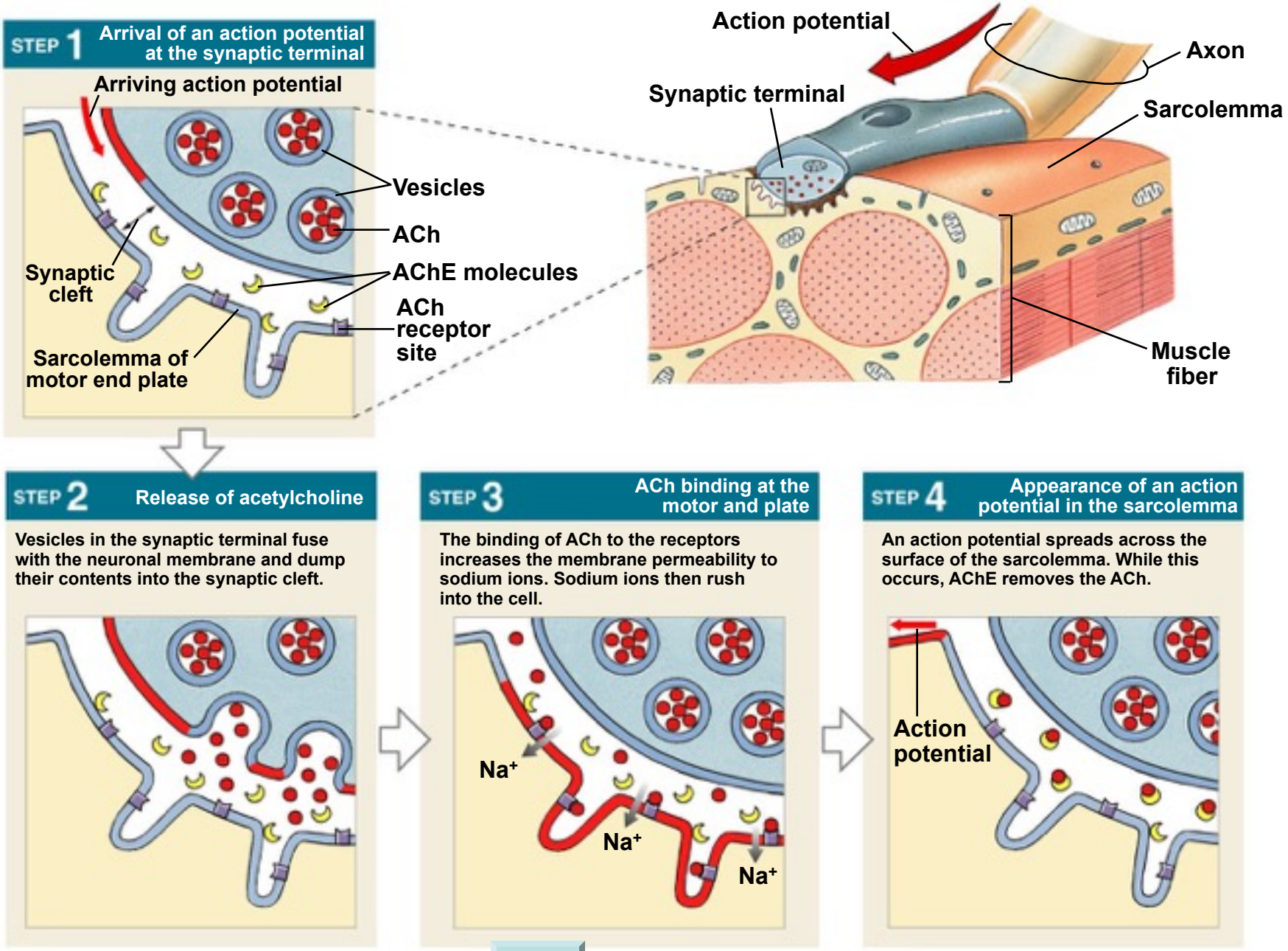






- The binding of Ach to its receptors causes a new AP to be generated along the muscle cell membrane

- Immediately after it binds to its receptors, Ach will be broken down by Acetylcholinesterase (AchE) – an enzyme present in the synaptic cleft



- Play IP neuromuscular junction p. 14

Physiology of Skeletal Muscle Contraction

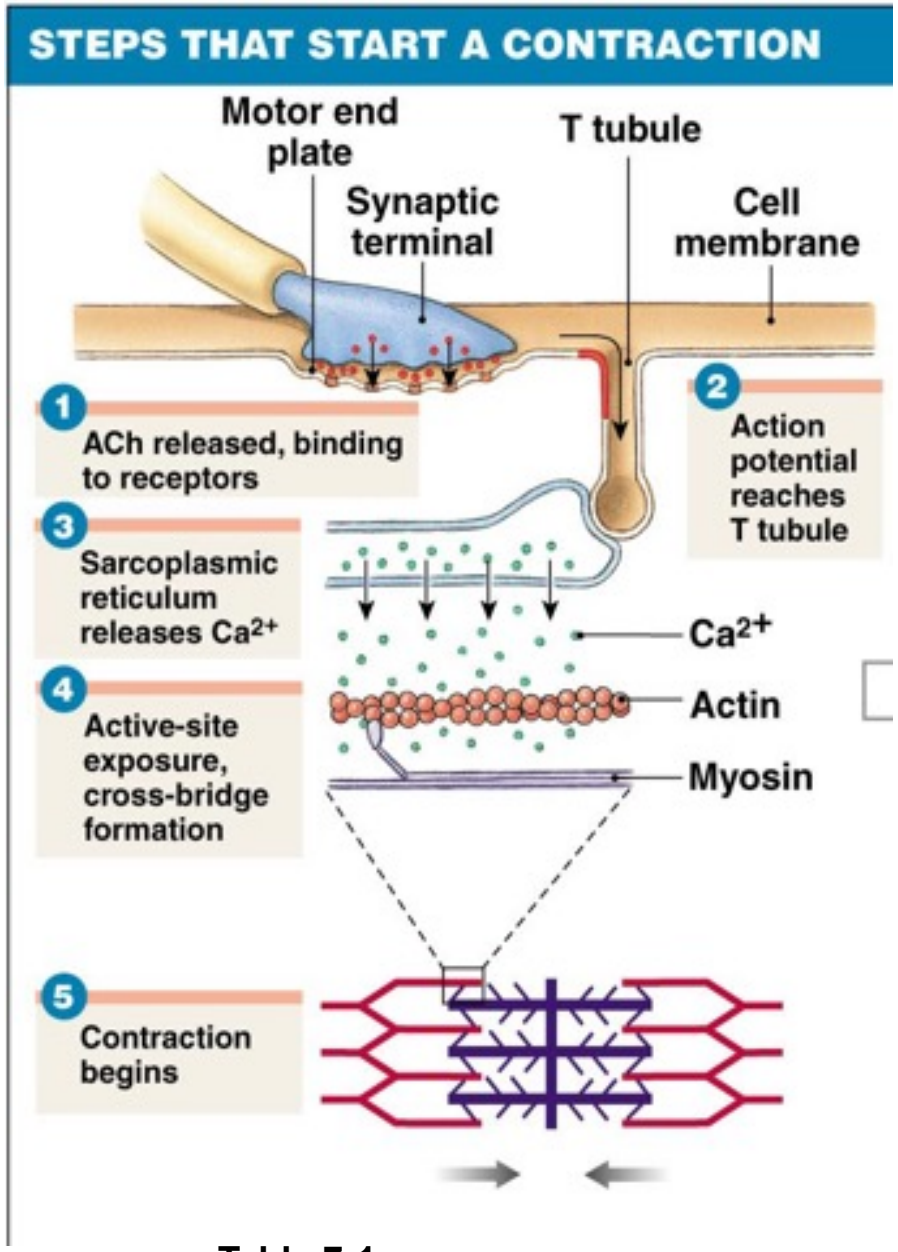


Table 7-1

•Once an action potential (AP) is generated at the motor end plate it will spread like an electrical current along the sarcolemma of the muscle fiber

- The AP will also spread into the T-tubules, exciting the terminal cisternae of the sarcoplasmic reticula

•This will cause Calcium (Ca^{+2}) gates in the SR to open, allowing Ca^{+2} to diffuse into the sarcoplasm

•Calcium will bind to troponin (on the thin myofilament), causing it to change its shape. This then pulls tropomyosin away from the active sites of actin molecules.

•The exposure of the active sites allow the sliding of the filaments

Physiology of skeletal muscle contraction – events at the myofilaments

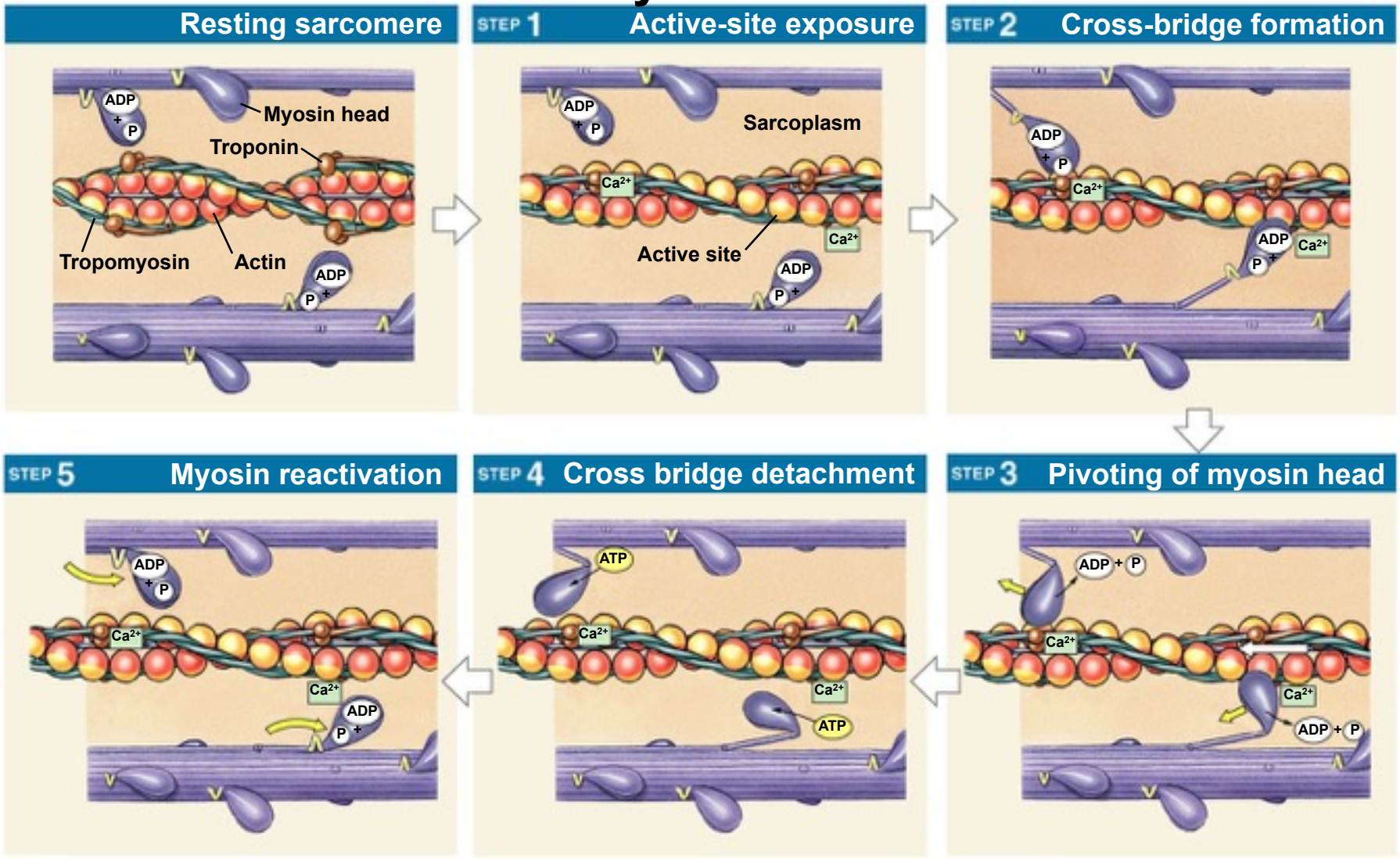


Figure 7-5
1 of 7

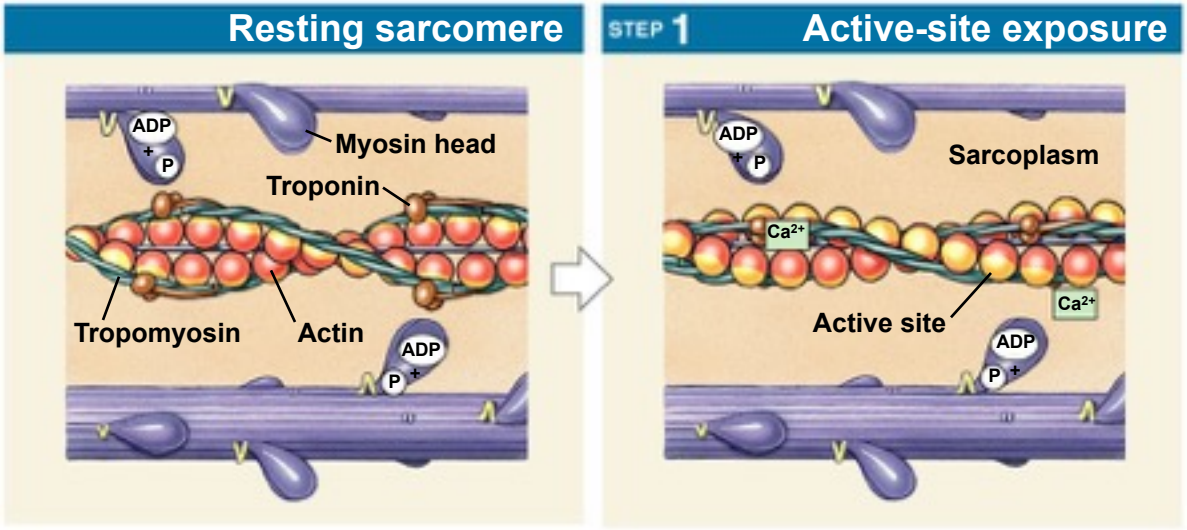


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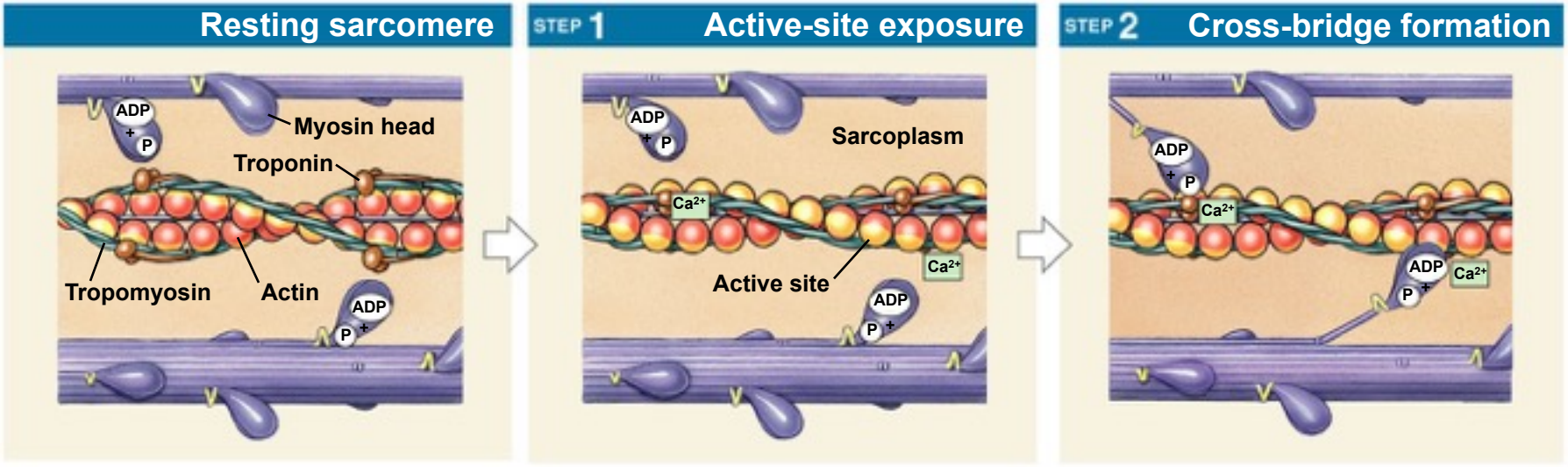
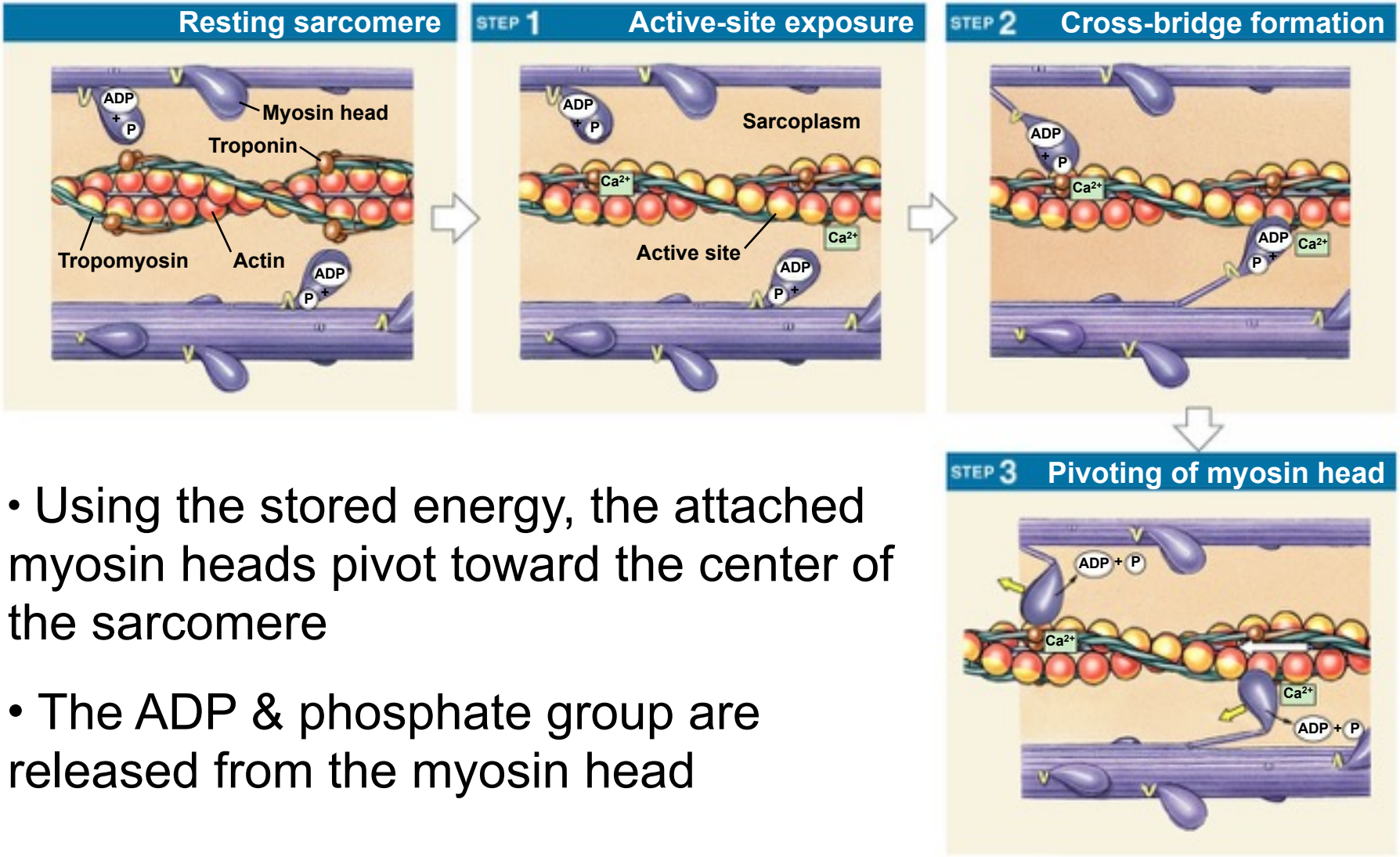
Figure 7-5
3 of 7



- Myosin heads are *"energized"* by the presence of ADP + PO_4^{3-} at the ATP binding site (energy is released as phosphate bond of ATP breaks)

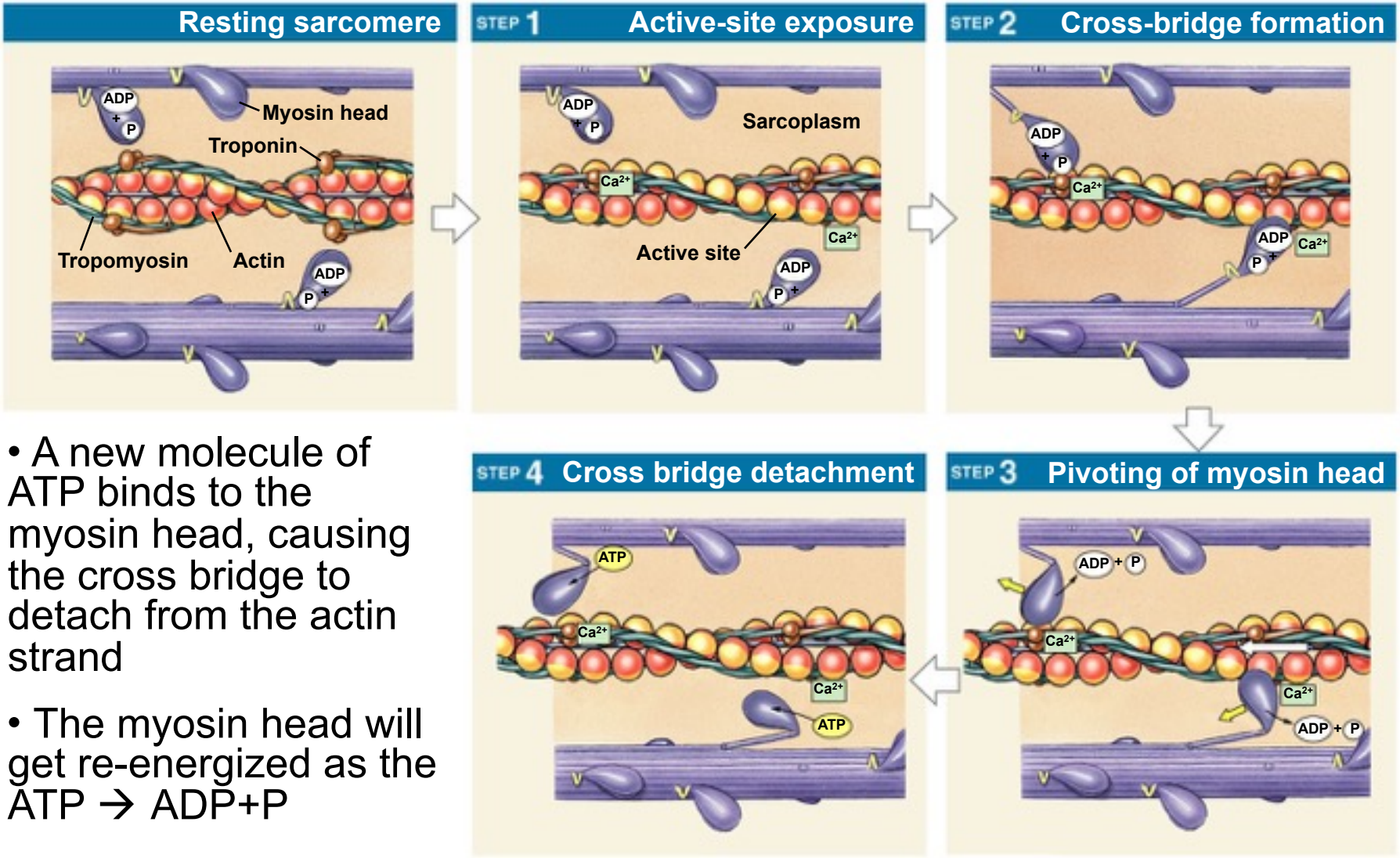
- Once the active sites are exposed, the energized myosin heads hook into actin molecules forming *cross-bridges*

Figure 7-5
4 of 7



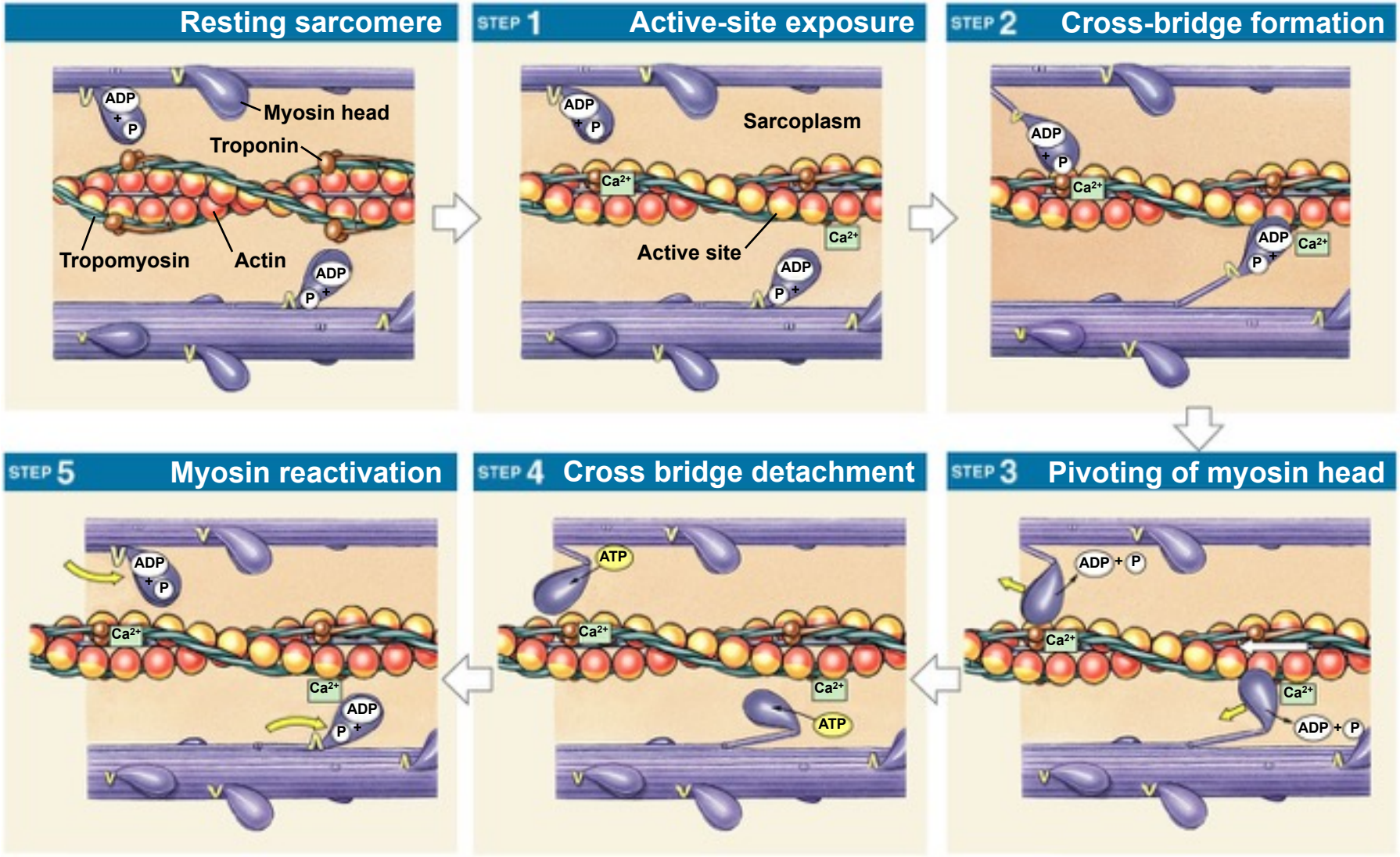
- Using the stored energy, the attached myosin heads pivot toward the center of the sarcomere
- The ADP & phosphate group are released from the myosin head

Figure 7-5



- A new molecule of ATP binds to the myosin head, causing the cross bridge to detach from the actin strand
- The myosin head will get re-energized as the ATP → ADP+P

- As long as the active sites are still exposed, the myosin head can bind again to the next active site



PLAY

IP Sliding filament theory – p. 17-24 single cross bridge; p. 27 multiple cross bridges

Figure 7-5
7 of 7

Physiology of Skeletal Muscle Contraction

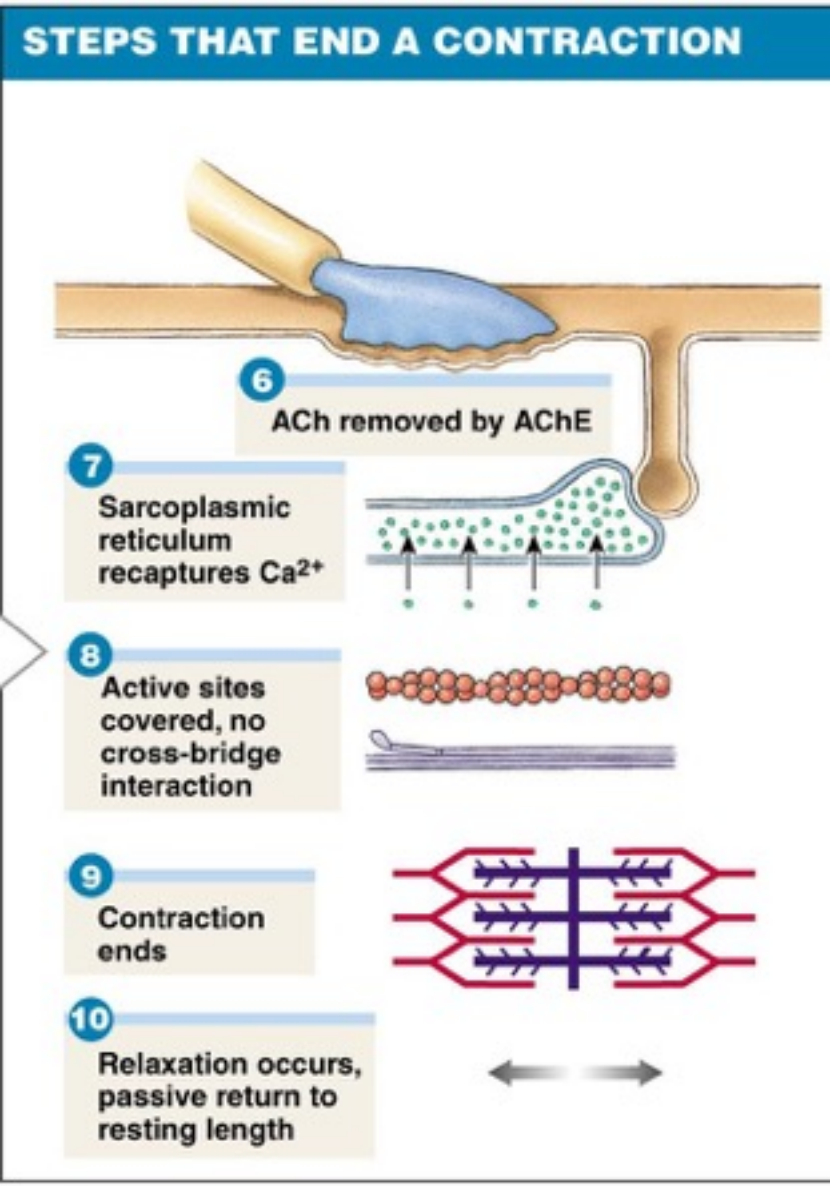


Table 7-1

- If there are no longer APs generated on the motor neuron, no more Ach will be released
- AchE will remove Ach from the motor end plate, and AP transmission on the muscle fiber will end
- Ca^{+2} gates in the SR will close & Ca^{+2} will be actively transported back into the SR
- With Ca^{+2} removed from the sarcoplasm (& from troponin), tropomyosin will re-cover the active sites of actin
- No more cross-bridge interactions can form
- Thin myofilaments slide back to their resting state

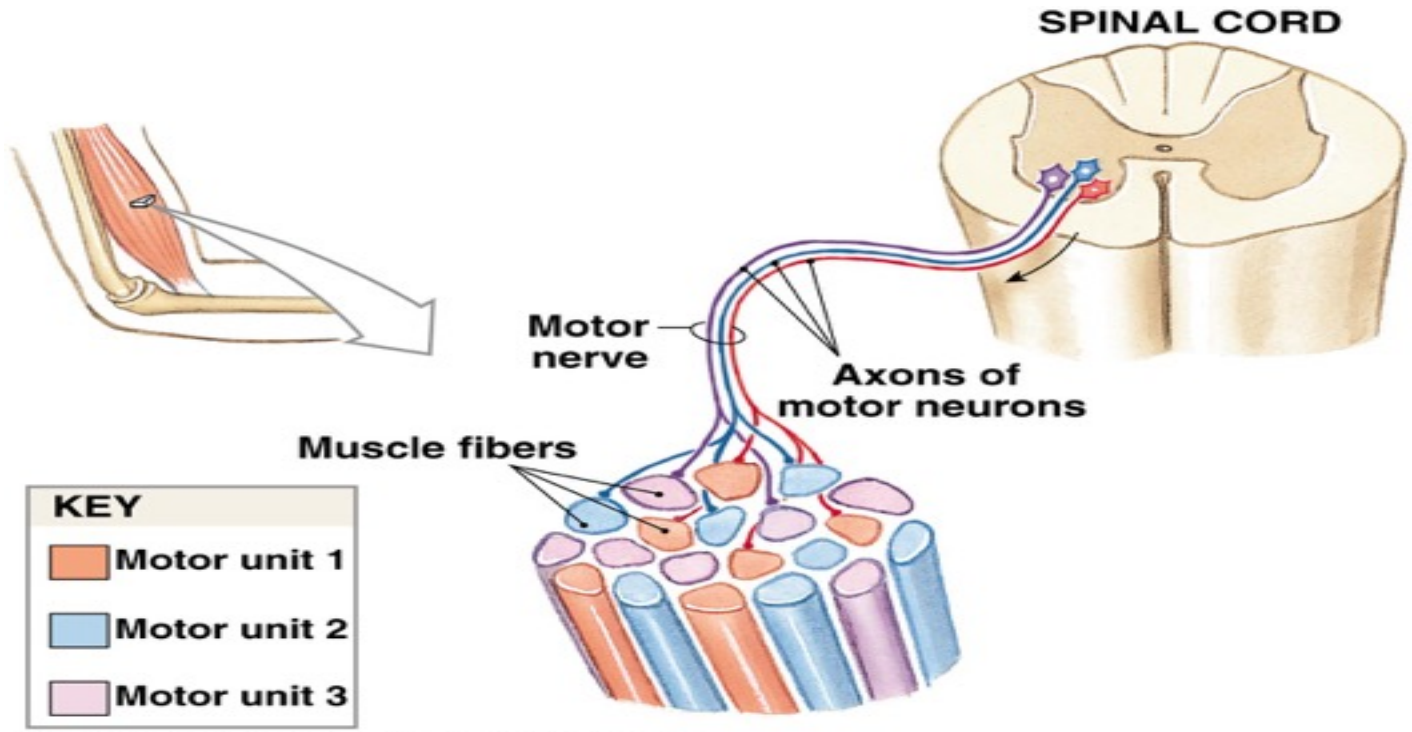
Key Note

Skeletal muscle fibers shorten as thin filaments interact with thick filaments and sliding occurs. The trigger for contraction is the calcium ions released by the SR when the muscle fiber is stimulated by its motor neuron. Contraction is an active process; relaxation and the return to resting length is entirely passive.

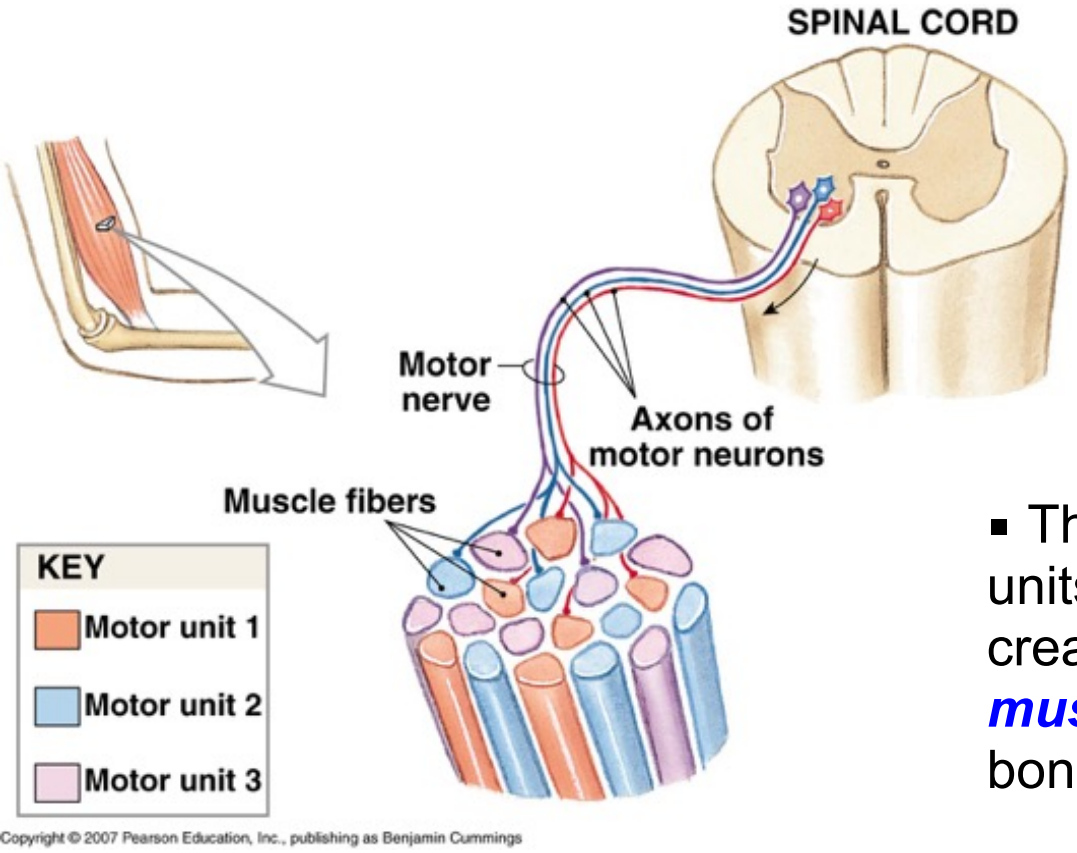
These physiological processes describe what happen at the cellular level – how skeletal muscle *fibers* contract

But what about at the organ level? How do skeletal *muscles* (like your biceps brachii) contract to create useful movement?

- Skeletal muscles are made up of thousands of muscle fibers
- A single motor neuron may directly control a few fibers within a muscle, or hundreds to thousands of muscle fibers
- All of the muscle fibers controlled by a single motor neuron constitute a ***motor unit***



- The size of the motor unit determines how fine the control of movement can be –
  - small motor units → precise control (e.g. eye muscles
  - large motor units →gross control (e.g. leg muscles)



- ***Recruitment*** is the ability to activate more motor units as more force (tension) needs to be generated

- There are always some motor units active, even when at rest. This creates a resting tension known as ***muscle tone,*** which helps stabilize bones & joints, & prevents atrophy

PLAY Play IP Contraction of motor units p. 3-7

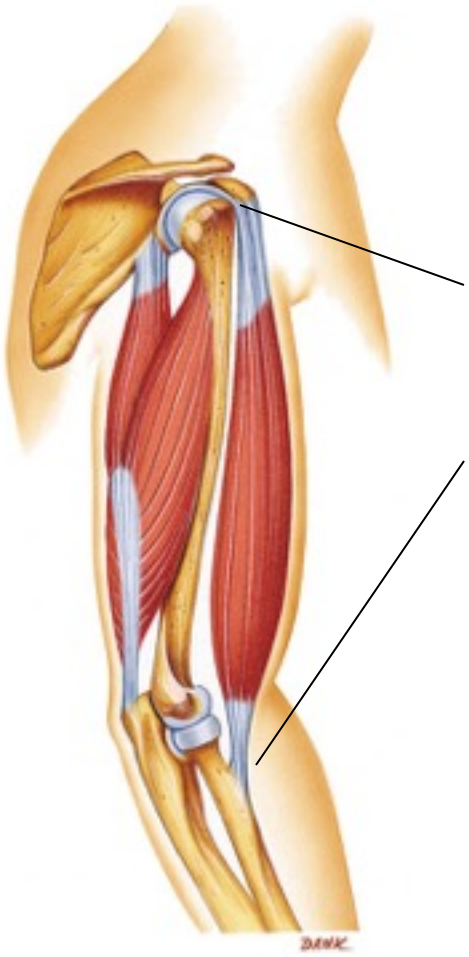
When skeletal muscles contract, they may produce two types of contractions:

- Isotonic contraction
- Isometric contraction

Isotonic contraction – as tension increases (more motor units recruited), length of muscle changes usually resulting in movement of a joint. The tension (load) on a muscle stays constant (*iso* = same, *tonic* = tension) during a movement. (Example: lifting a baby, picking up object, walking, etc.)

Isometric contraction – no change in length of muscle even as tension increases. The length of a muscle stays constant (*iso* = same, *metric* = length) during a "*contraction*" (Example: holding a baby at arms length, pushing against a closed door.) Necessary in everyday life to counteract effects of gravity (e.g. postural muscles keeping head up)

Anatomy of the Muscular System



- *Origin*
  Muscle attachment that remains fixed
- *Insertion*
  Muscle attachment that moves
- *Action*
  What joint movement a muscle produces
  i.e. flexion, extension, abduction, etc.

- For muscles to create a movement, they can *only* ***pull***, not push
- Muscles in the body rarely work alone, & are usually arranged in groups surrounding a joint
- A muscle that contracts to create the desired action is known as an ***agonist*** or ***prime mover***
- A muscle that helps the agonist is a ***synergist***
- A muscle that opposes the action of the agonist, therefore undoing the desired action is an ***antagonist***

Skeletal muscle movements

Flexion/extension

Abduction/adduction

Rotation – left/right; internal(medial)/external(lateral)

pronation/supination

Elevation/depression

Protraction/retraction

Dorsiflexion/plantarflexion

Inversion/eversion

TABLE 7-3 *Muscle Terminology*

TERMS INDICATING POSITION, DIRECTION, OR MUSCLE FIBER ORIENTATION	TERMS INDICATING SPECIFIC REGIONS OF THE BODY*	TERMS INDICATING STRUCTURAL CHARACTERISTICS OF THE MUSCLE	TERMS INDICATING ACTIONS
Anterior (front)	Abdominis (abdomen)	**Origin**	**General**
Externus (superficial)	Anconeus (elbow)	Biceps (two heads)	Abductor
Extrinsic (outside)	Auricularis (auricle of ear)	Triceps (three heads)	Adductor
Inferioris (inferior)	Brachialis (brachium)	Quadriceps (four heads)	Depressor
Internus (deep,internal)	Capitis (head)		Extensor
Intrinsic (inside)	Carpi (wrist)	**Shape**	Flexor
Lateralis (lateral)	Cervicis (neck)	Deltoid (triangle)	Levator
Medialis/medius (medial, middle)	Cleido/clavius (clavicle)	Orbicularis (circle)	Pronator
	Coccygeus (coccyx)	Pectinate (comblike)	Rotator
Obliquus (oblique)	Costalis (ribs)	Piriformis (pear-shaped)	Supinator
Posterior (back)	Cutaneous (skin)	Platys- (flat)	Tensor
Profundus (deep)	Femoris (femur)	Pyramidal (pyramid)	
Rectus (straight, parallel)	Genio- (chin)	Rhomboid	**Specific**
Superficialis (superficial)	Glosso/glossal (tongue)	Serratus (serrated)	Buccinator (trumpeter)
Superioris (superior)	Hallucis (great toe)	Splenius (bandage)	Risorius (laugher)
Transversus (transverse)	Ilio- (ilium)	Teres (long and round)	Sartorius (like a tailor)
	Inguinal (groin)	Trapezius (trapezoid)	
	Lumborum (lumbar region)		

TABLE 7-3 *Muscle Terminology*

TERMS INDICATING POSITION, DIRECTION, OR MUSCLE FIBER ORIENTATION	TERMS INDICATING SPECIFIC REGIONS OF THE BODY*	TERMS INDICATING STRUCTURAL CHARACTERISTICS OF THE MUSCLE	TERMS INDICATING ACTIONS
	Nasalis (nose)	**Other Striking Features**	
	Nuchal (back of neck)	Alba (white)	
	Oculo- (eye)	Brevis (short)	
	Oris (mouth)	Gracilis (slender)	
	Palpebrae (eyelid)	Lata (wide)	
	Pollicis (thumb)	Latissimus (widest)	
	Popliteus (behind knee)	Longissimus (longest)	
	Psoas (loin)	Longus (long)	
	Radialis (radius)	Magnus (large)	
	Scapularis (scapula)	Major (larger)	
	Temporalis (temples)	Maximus (largest)	
	Thoracis (thoracic region)	Minimus (smallest)	
	Tibialis (tibia)	Minor (smaller)	
	Ulnaris (ulna)	-tendinosus (tendinous)	
	Uro- (urinary)	Vastus (great)	

*For other regional terms, refer to Figure 1-6, p.17, which shows anatomical landmarks.

- An Overview of the Major Skeletal Muscles

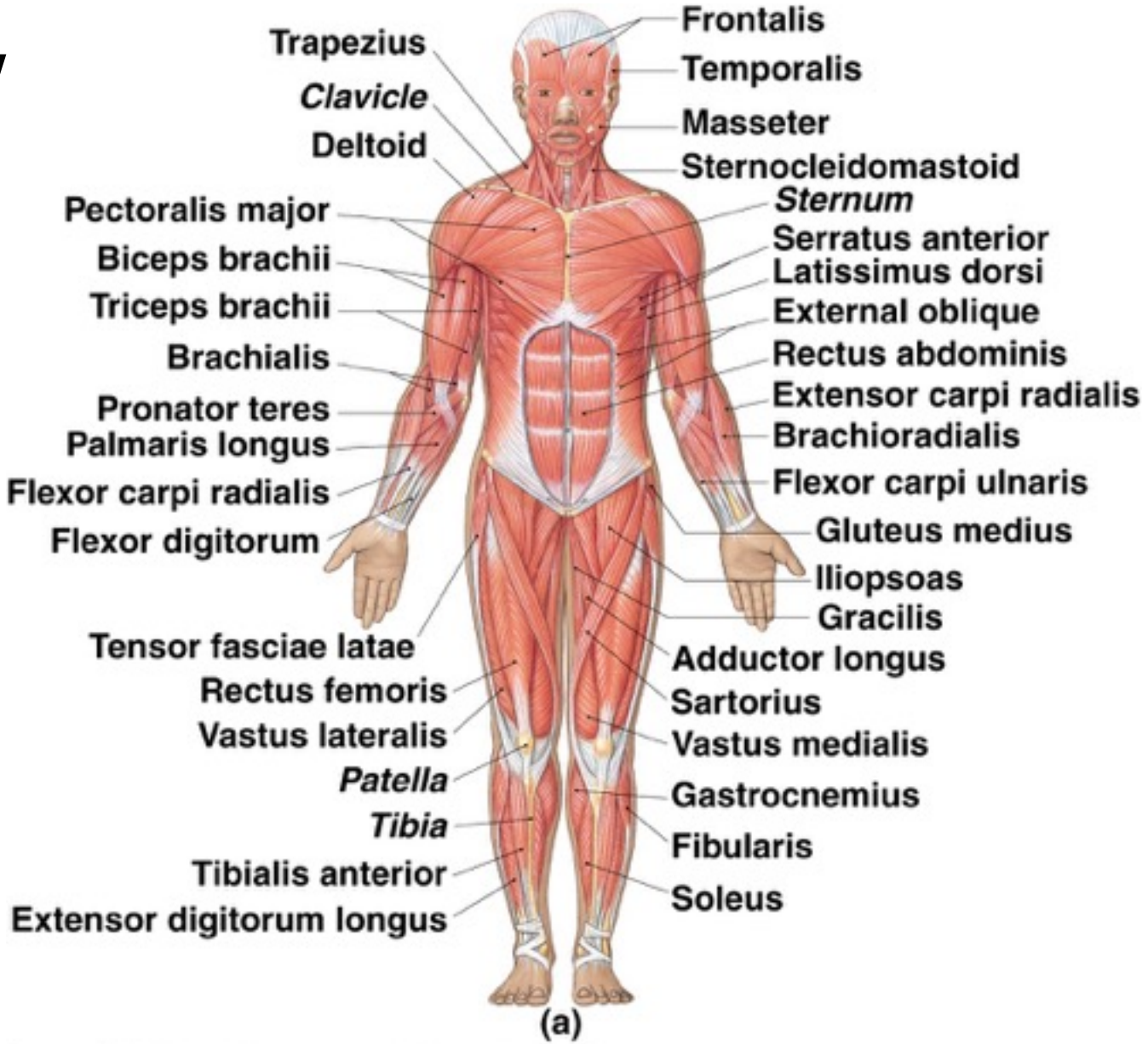


Figure 7-11(a)

- An Overview of the Major Skeletal Muscles

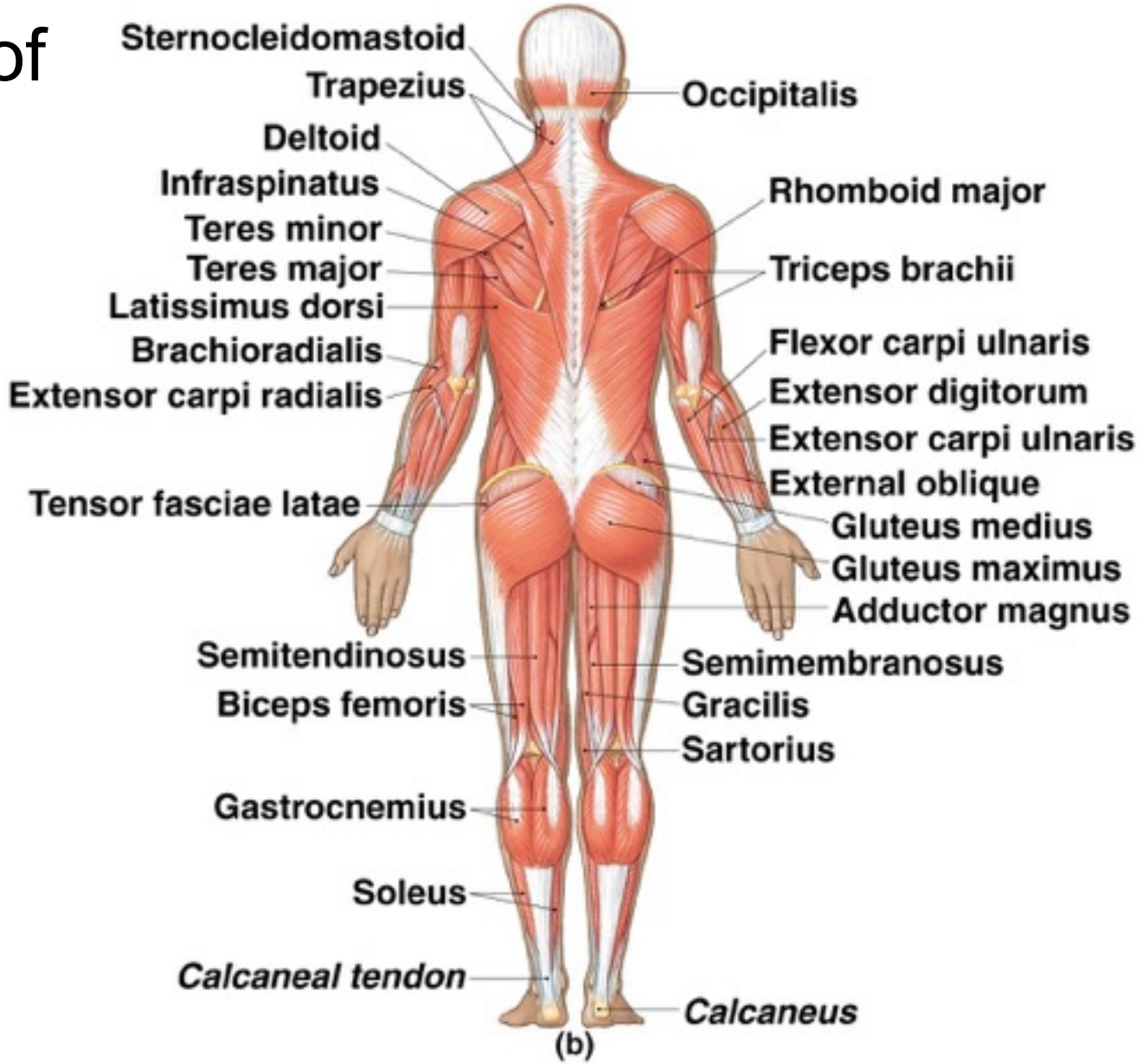


Figure 7-11(b)

Anatomy of the Muscular System

Muscles of the Head and Neck

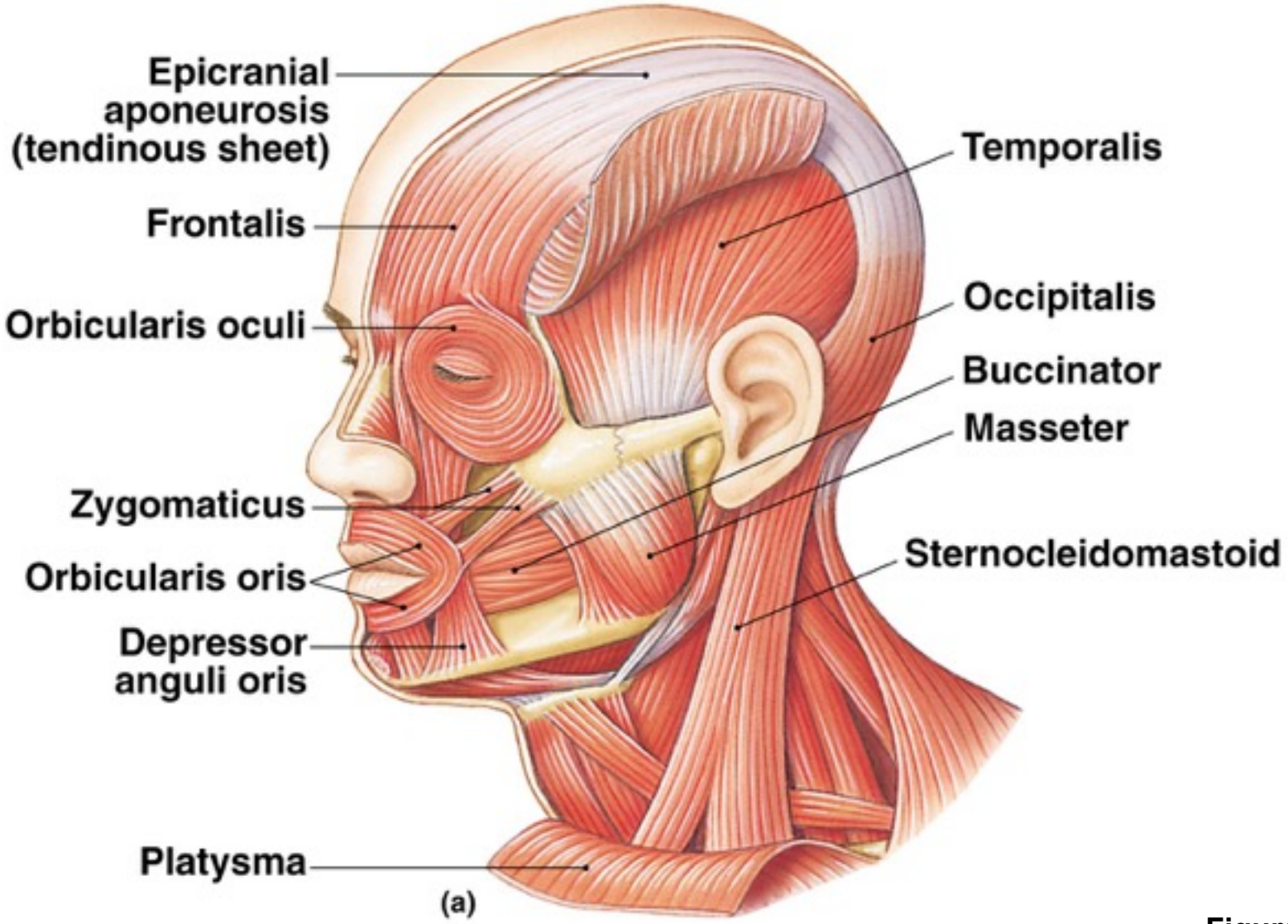


Figure 7-12(a)

Anatomy of the Muscular System

Muscles of the Head and Neck

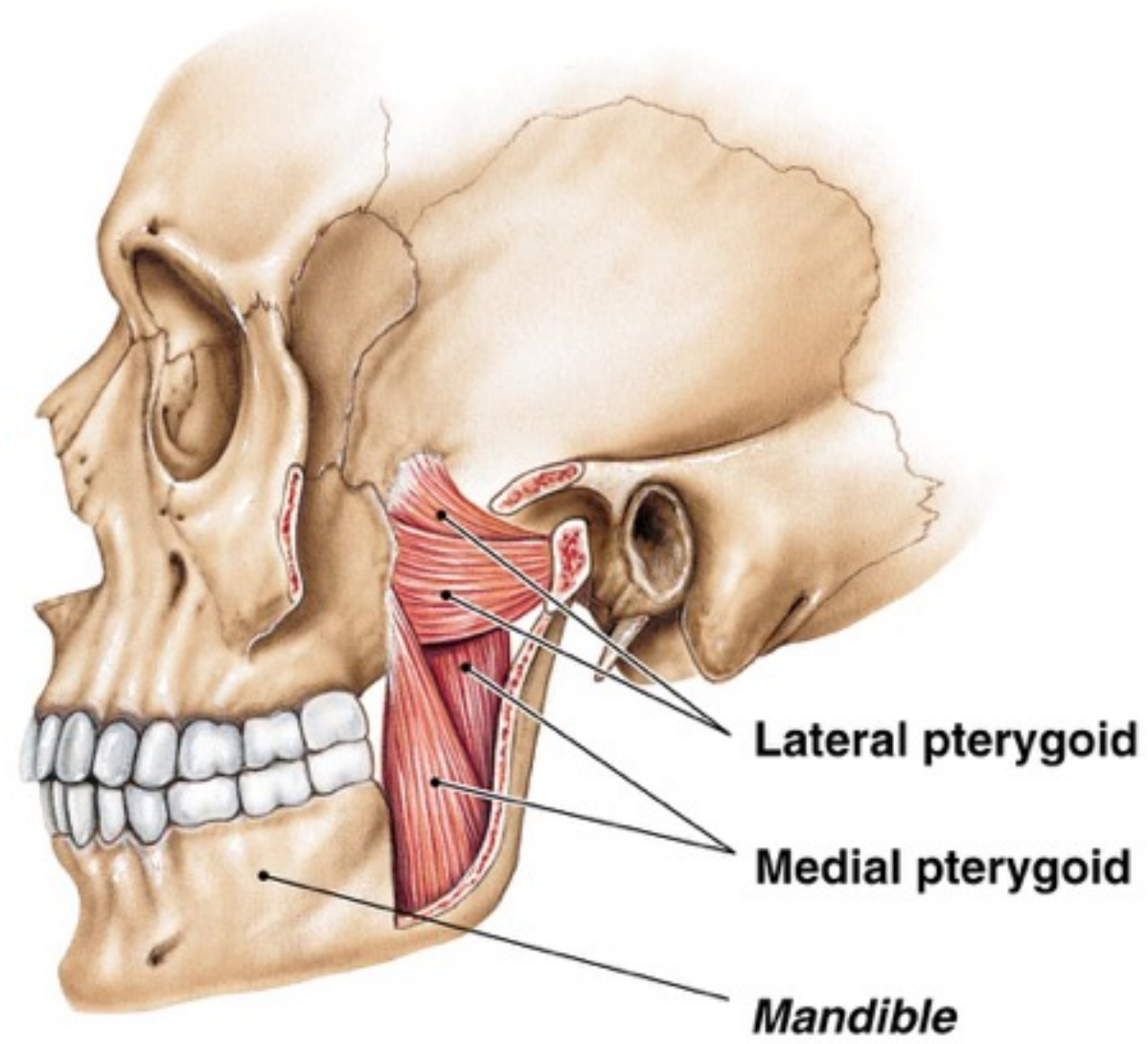


Figure 7-12(b)

(b) Lateral view, pterygoid muscles exposed

Anatomy of the Muscular System

Muscles of the Head and Neck

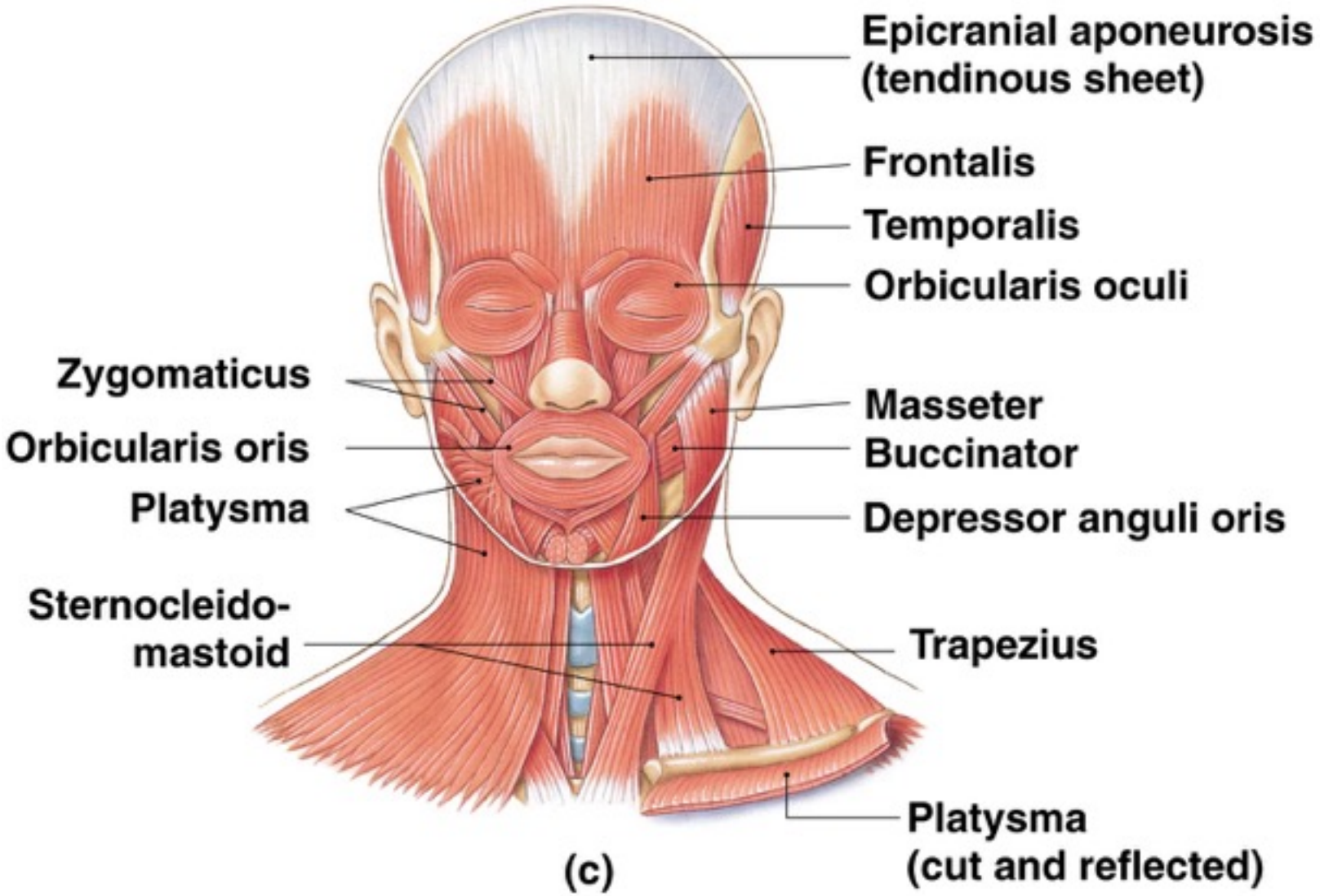


Figure 7-12(c)

Anatomy of the Muscular System

Muscles of the Anterior Neck

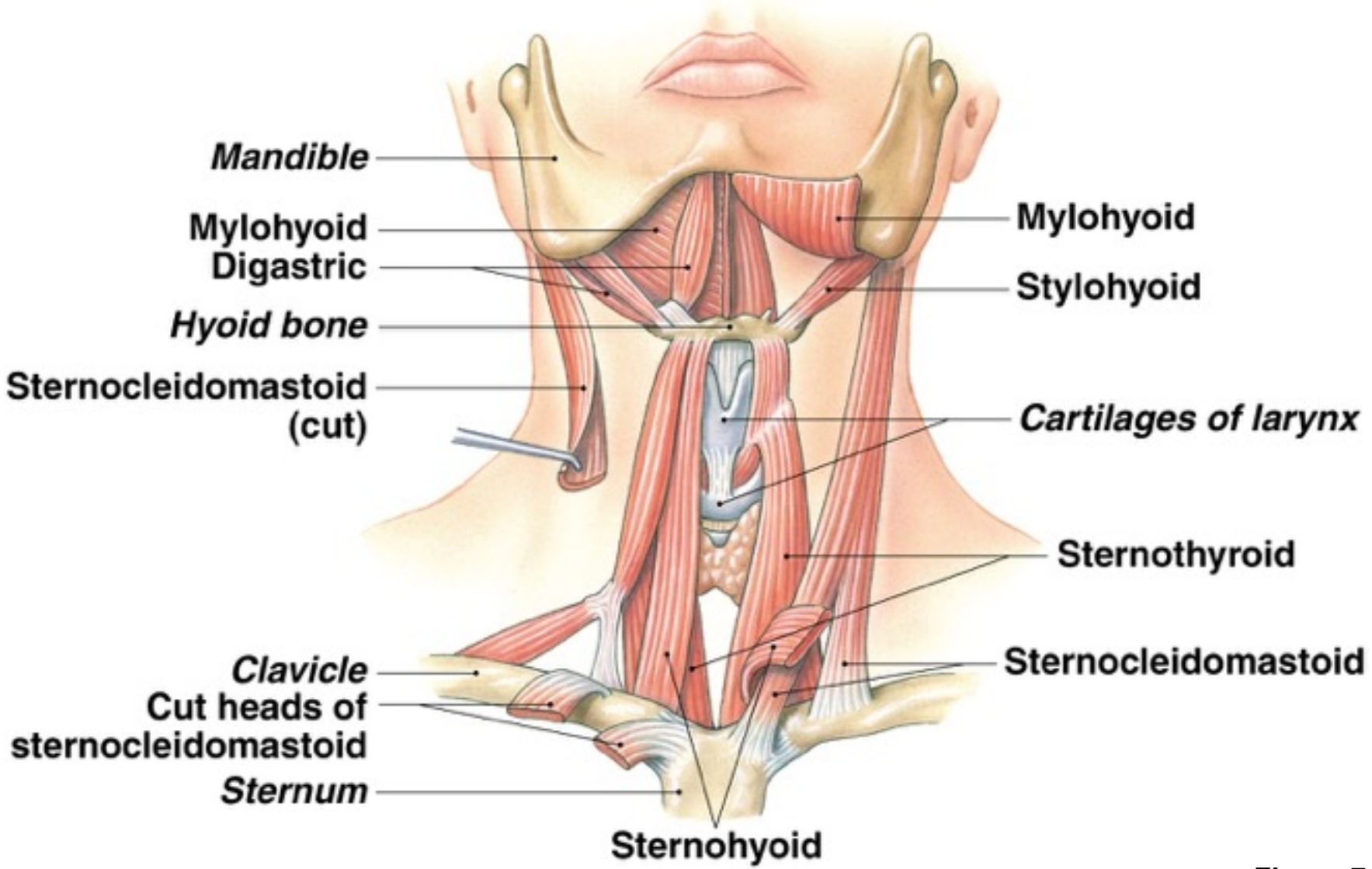


Figure 7-13

Anatomy of the Muscular System

Muscles of the Spine

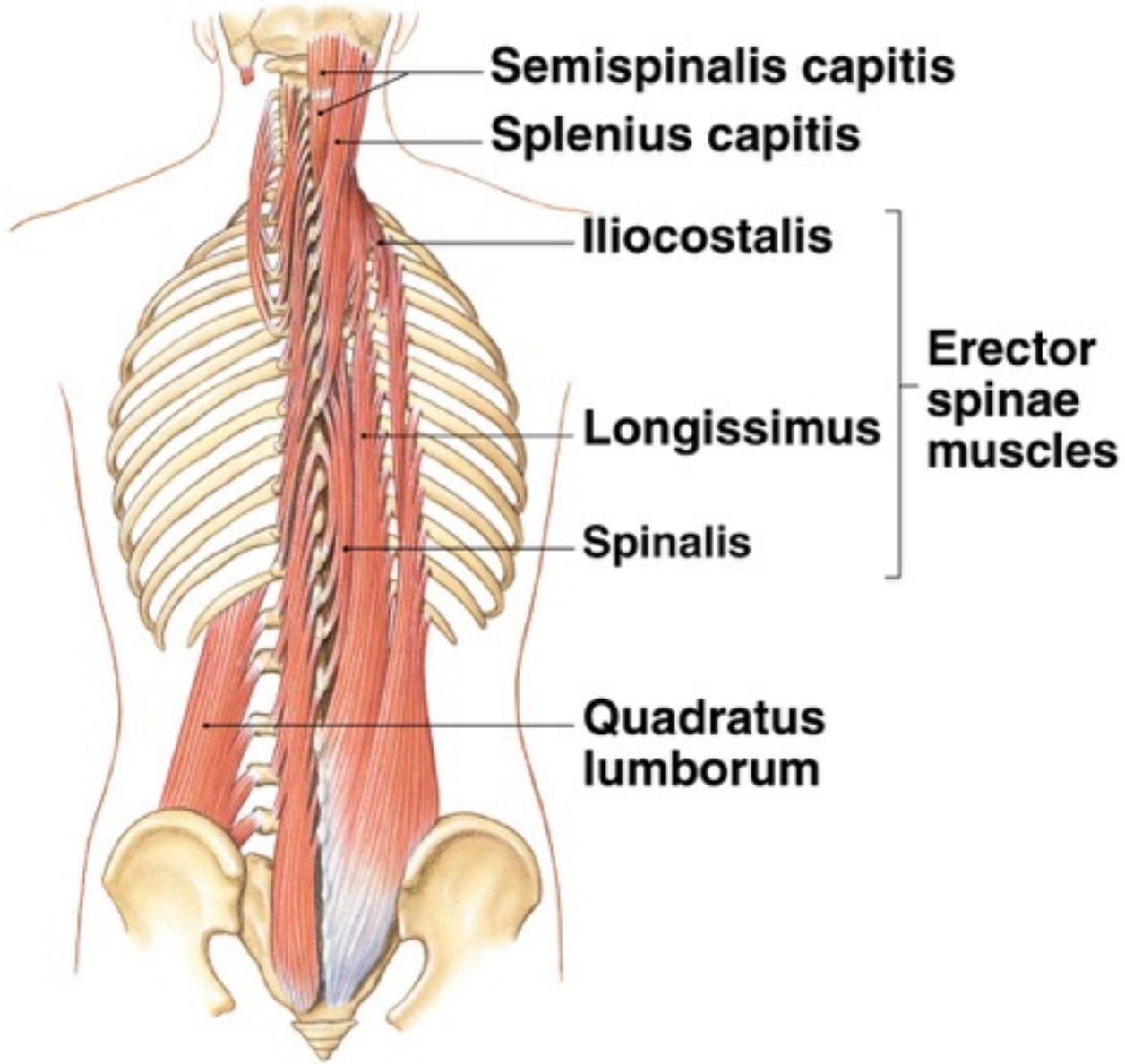
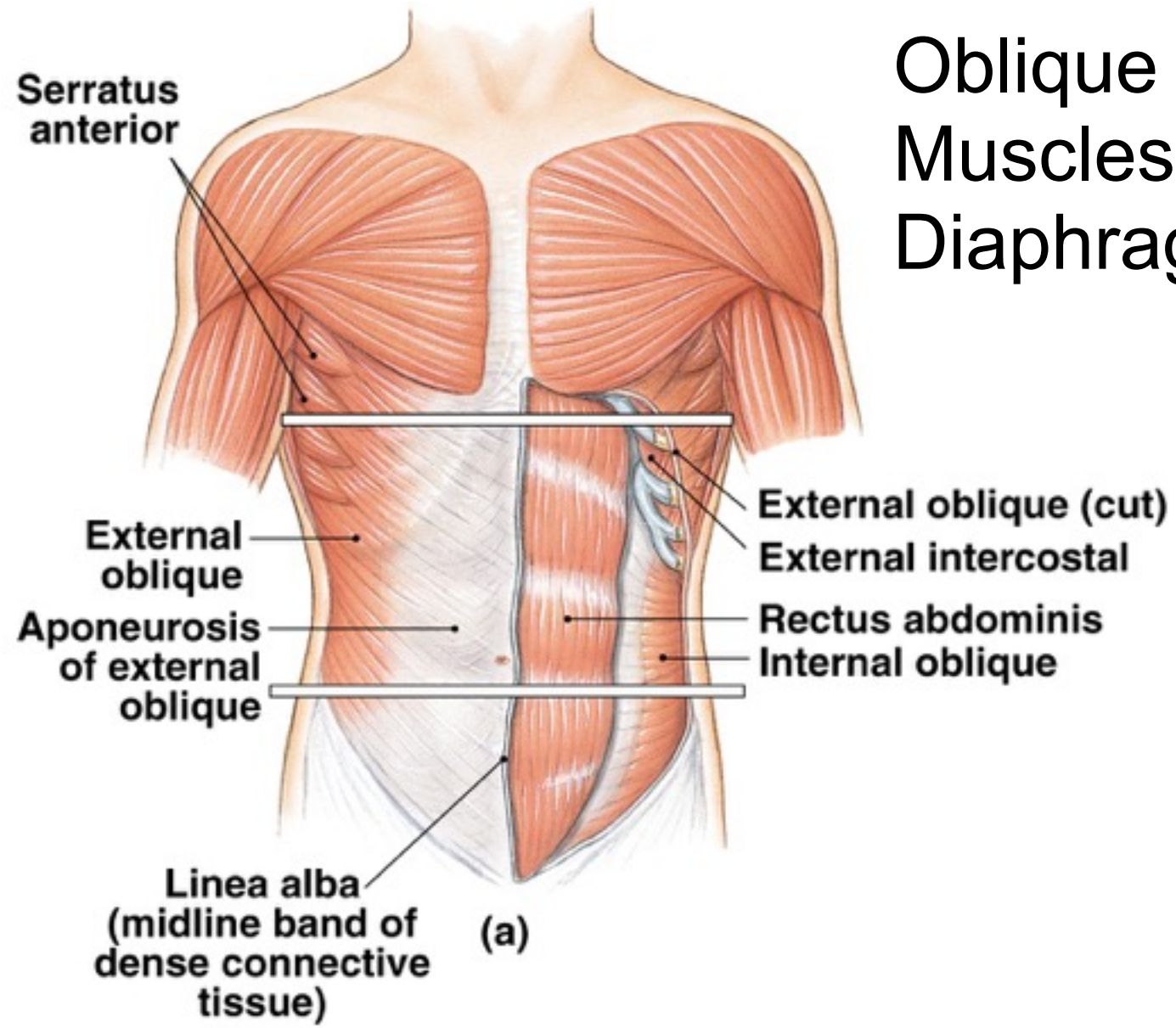


Figure 7-14

Anatomy of the Muscular System



Oblique and Rectus Muscles and the Diaphragm

Figure 7-15(a)

Anatomy of the Muscular System

Oblique and Rectus Muscles and the Diaphragm

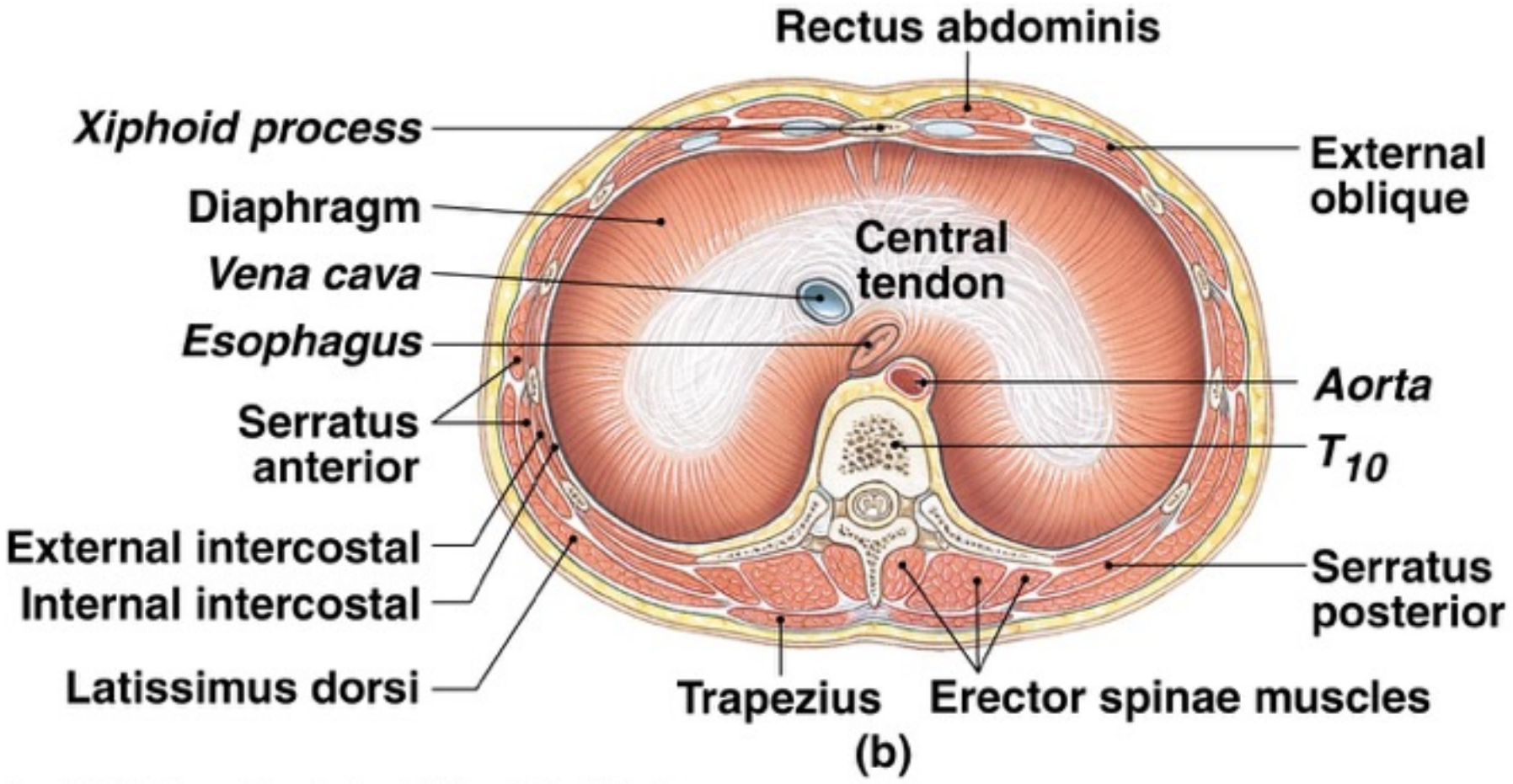


Figure 7-15(b)

Anatomy of the Muscular System

Oblique and Rectus Muscles and the Diaphragm

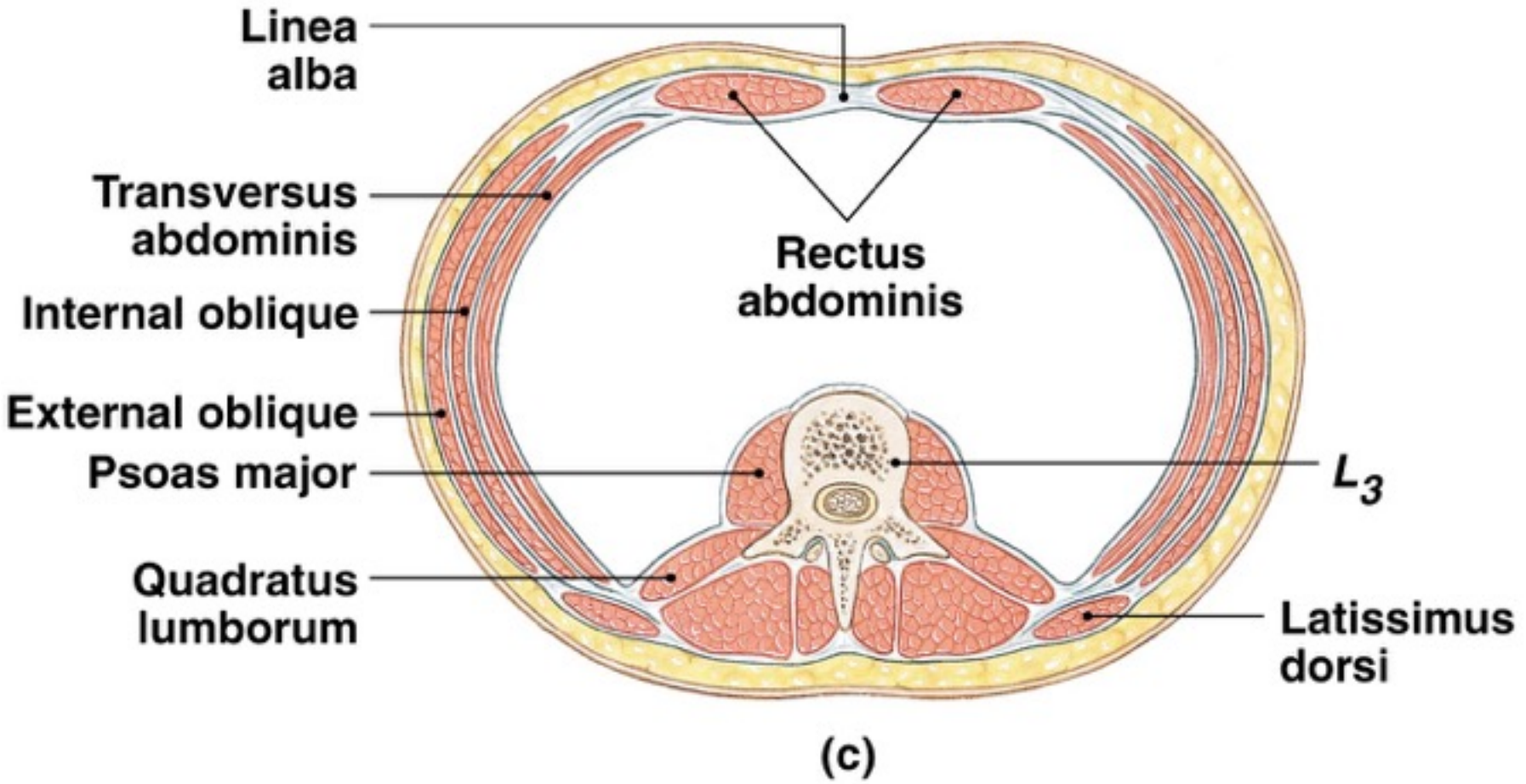
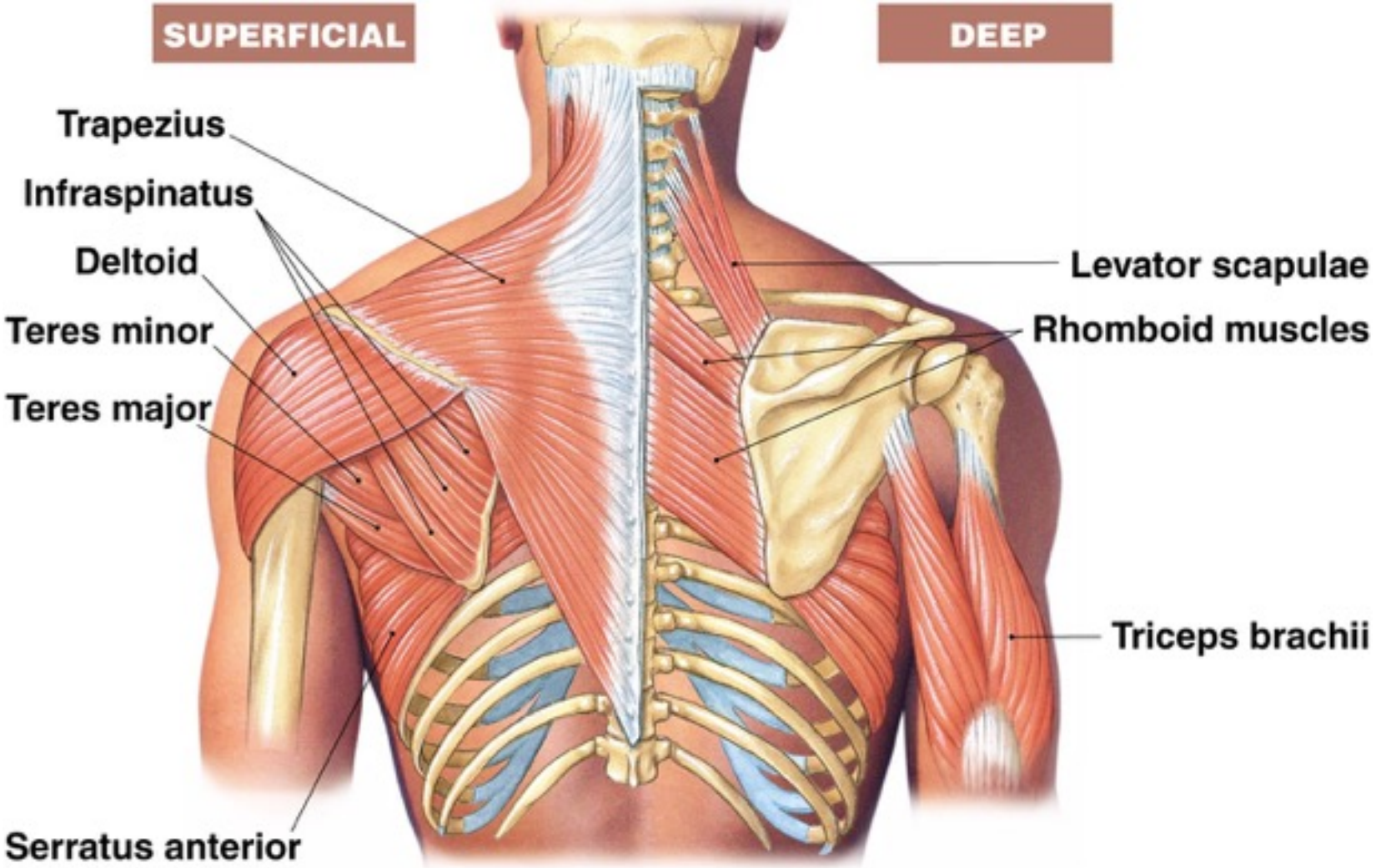


Figure 7-15(c)

Anatomy of the Muscular System

Muscles of the Shoulder

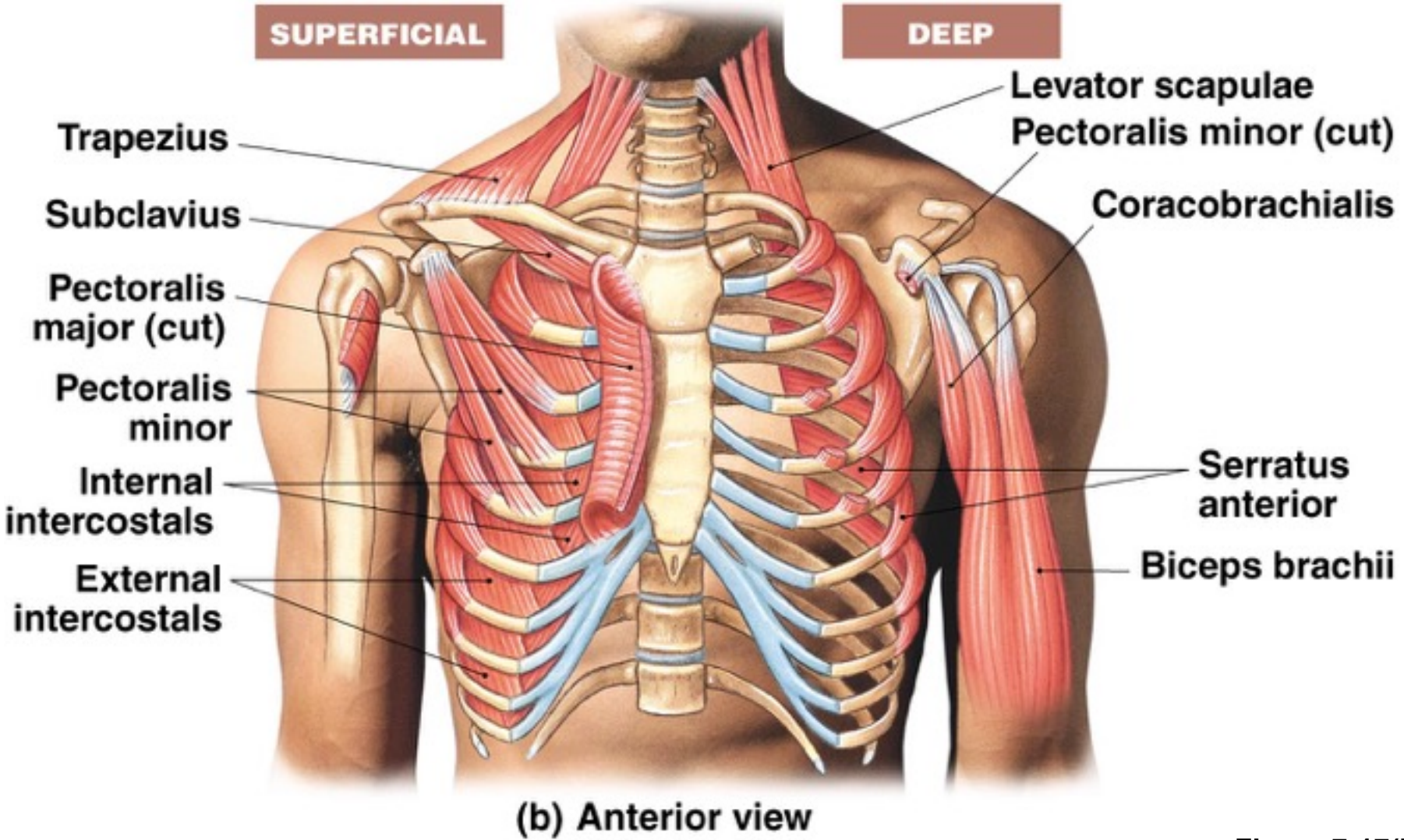


(a) Posterior view

Figure 7-17(a)

Anatomy of the Muscular System

Muscles of the Shoulder

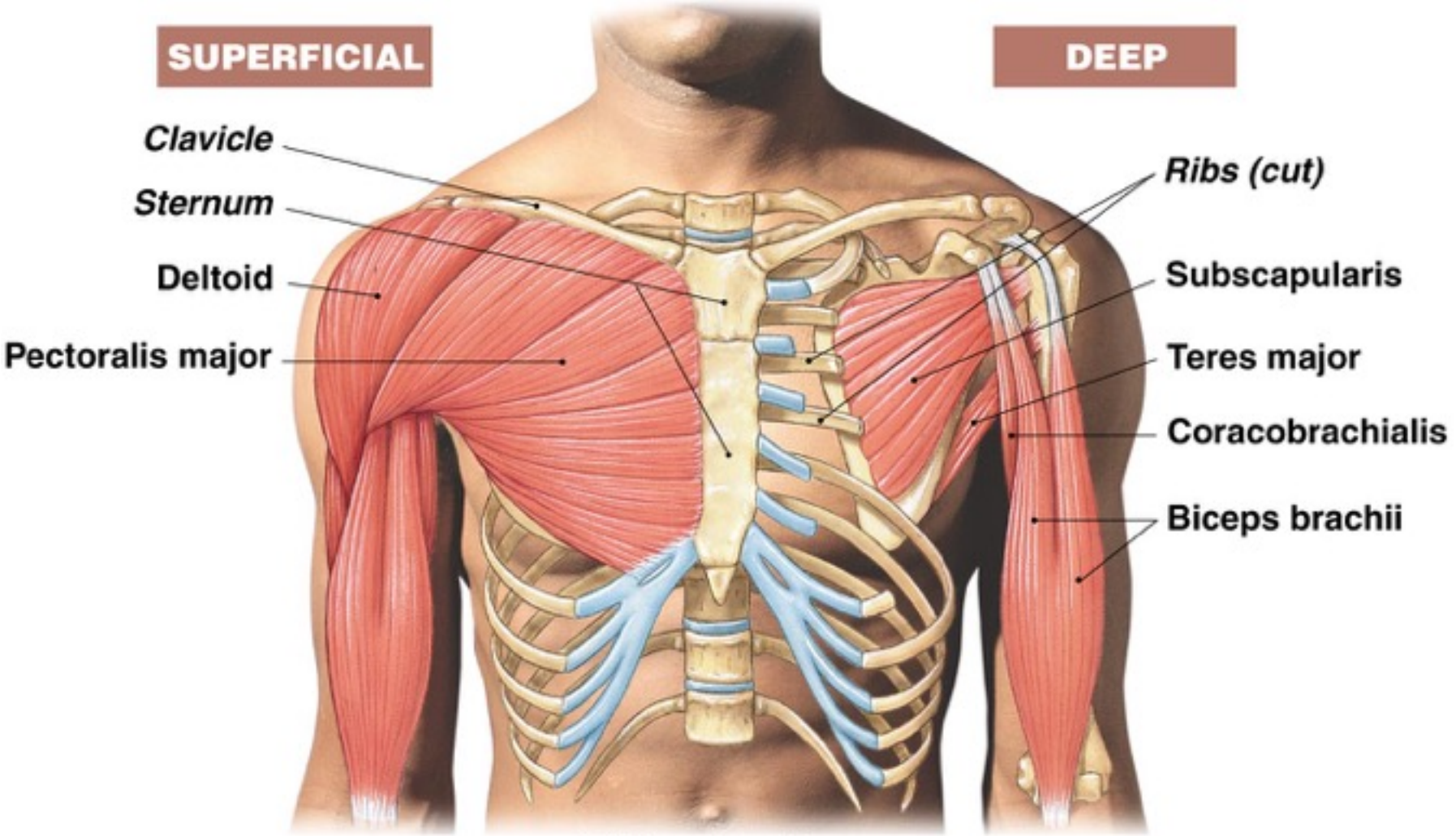


(b) Anterior view

Figure 7-17(b)

Anatomy of the Muscular System

Muscles that Move the Arm



(a) Anterior view

Figure 7-18(a)

Anatomy of the Muscular System

Muscles that Move the Arm

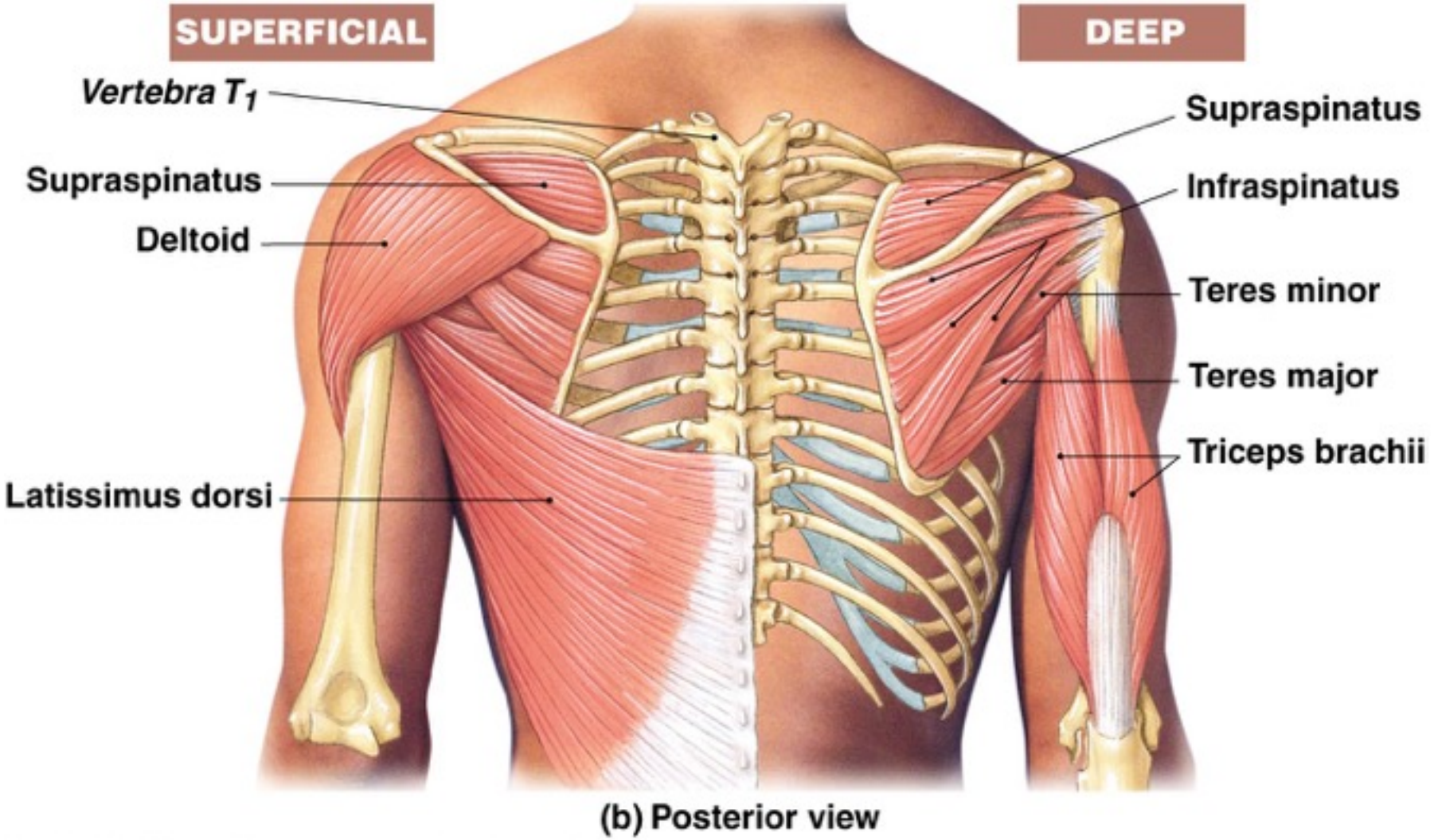


Figure 7-18(b)

Anatomy of the Muscular System

Muscles That Move the Forearm and Wrist

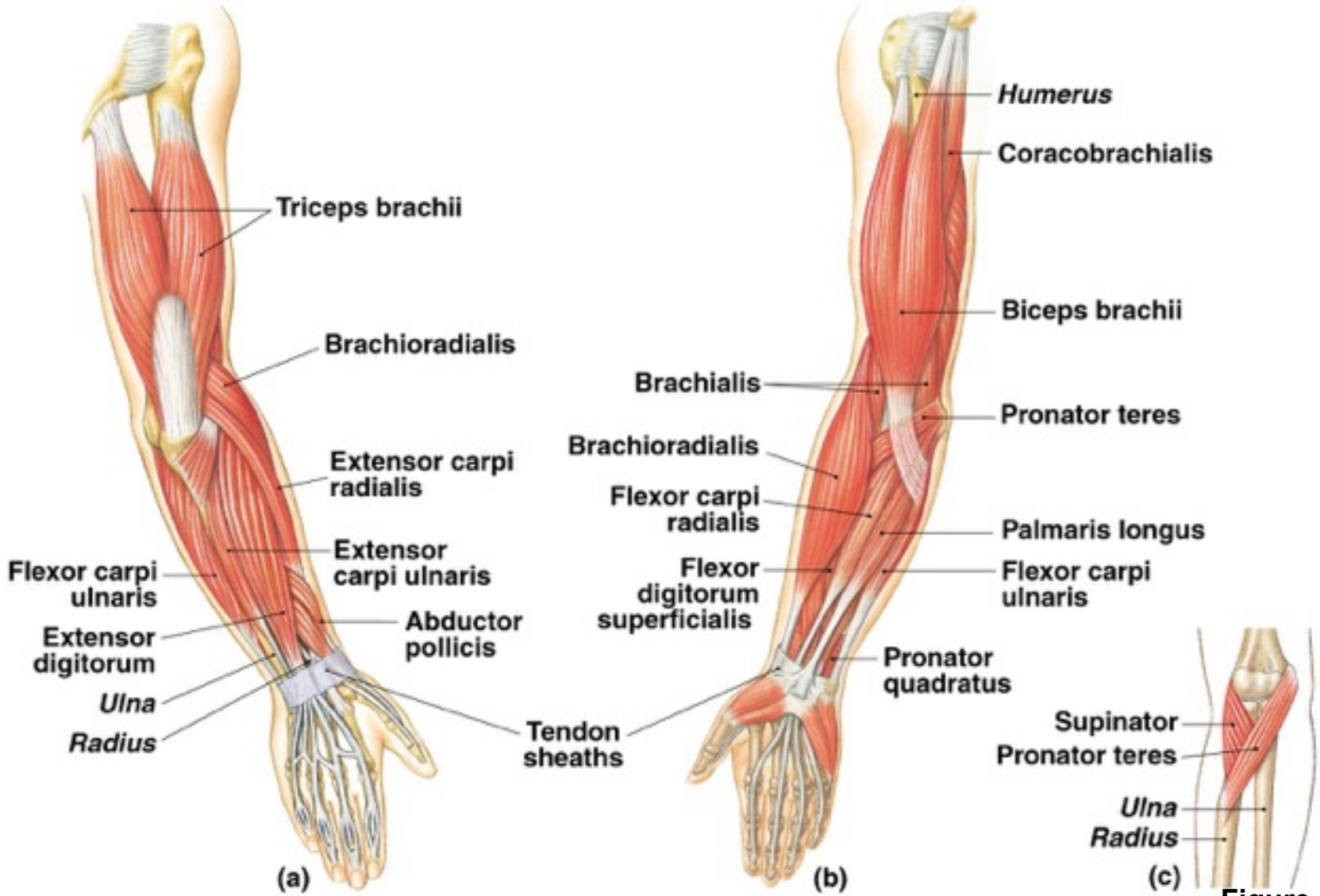


Figure 7-19

Anatomy of the Muscular System

Muscles That Move the Thigh

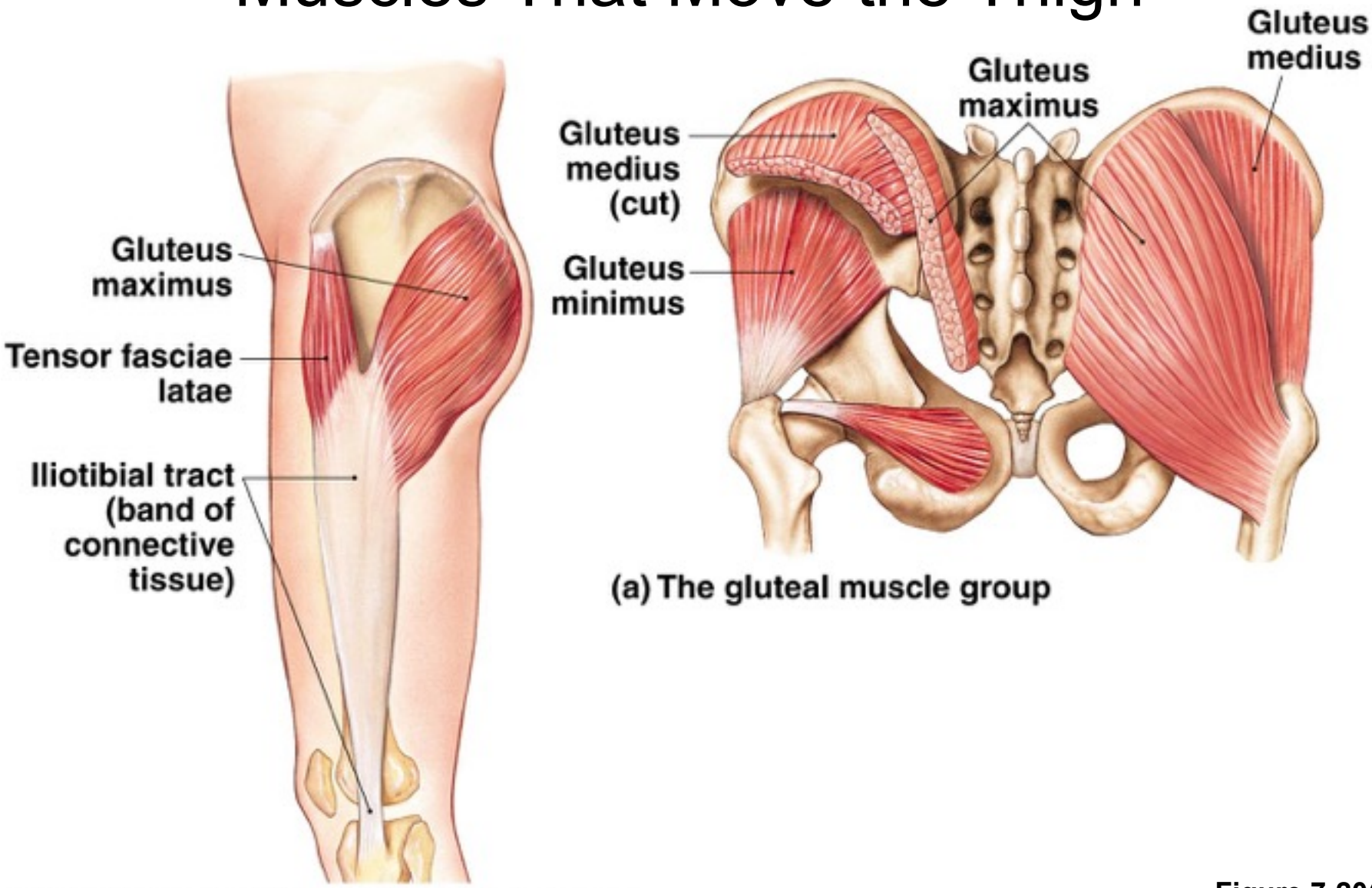
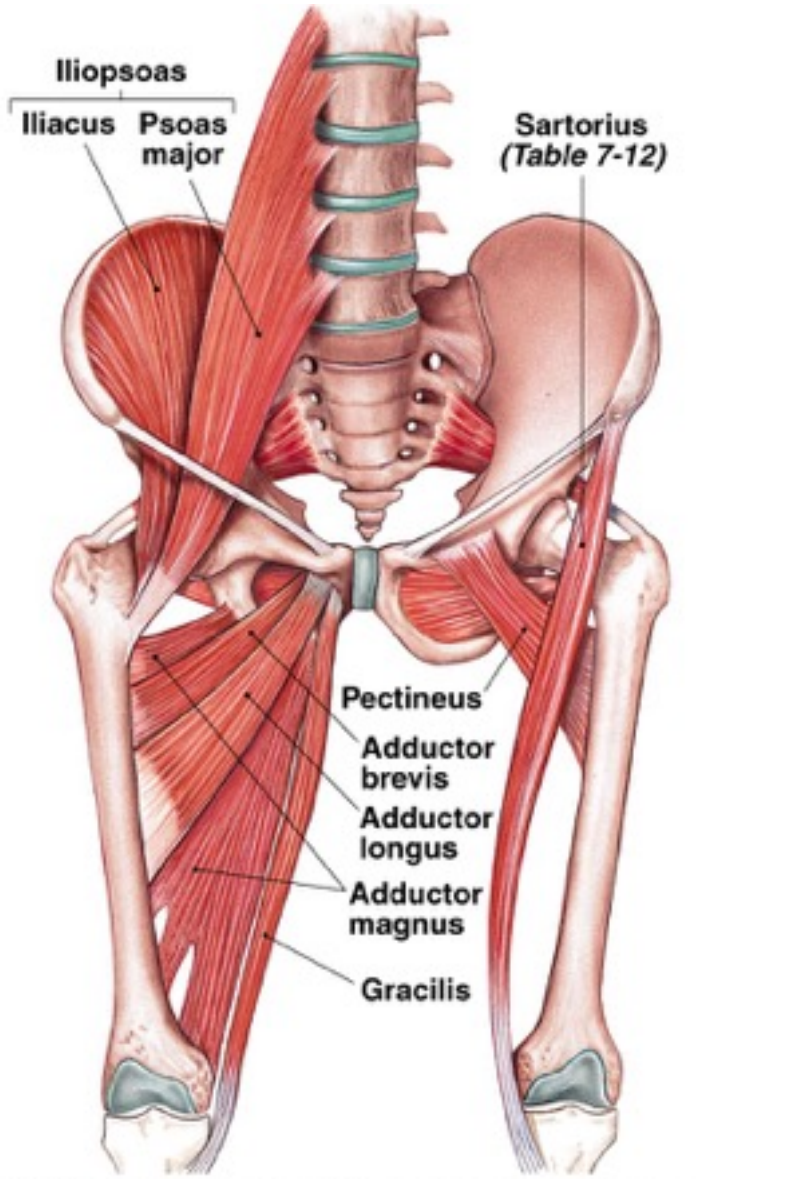


Figure 7-20(a)

Anatomy of the Muscular System

Muscles That Move the Thigh



(b) The iliopsoas muscle and the adductor group

Figure 7-20(b)

Anatomy of the Muscular System

Muscles That Move the Leg

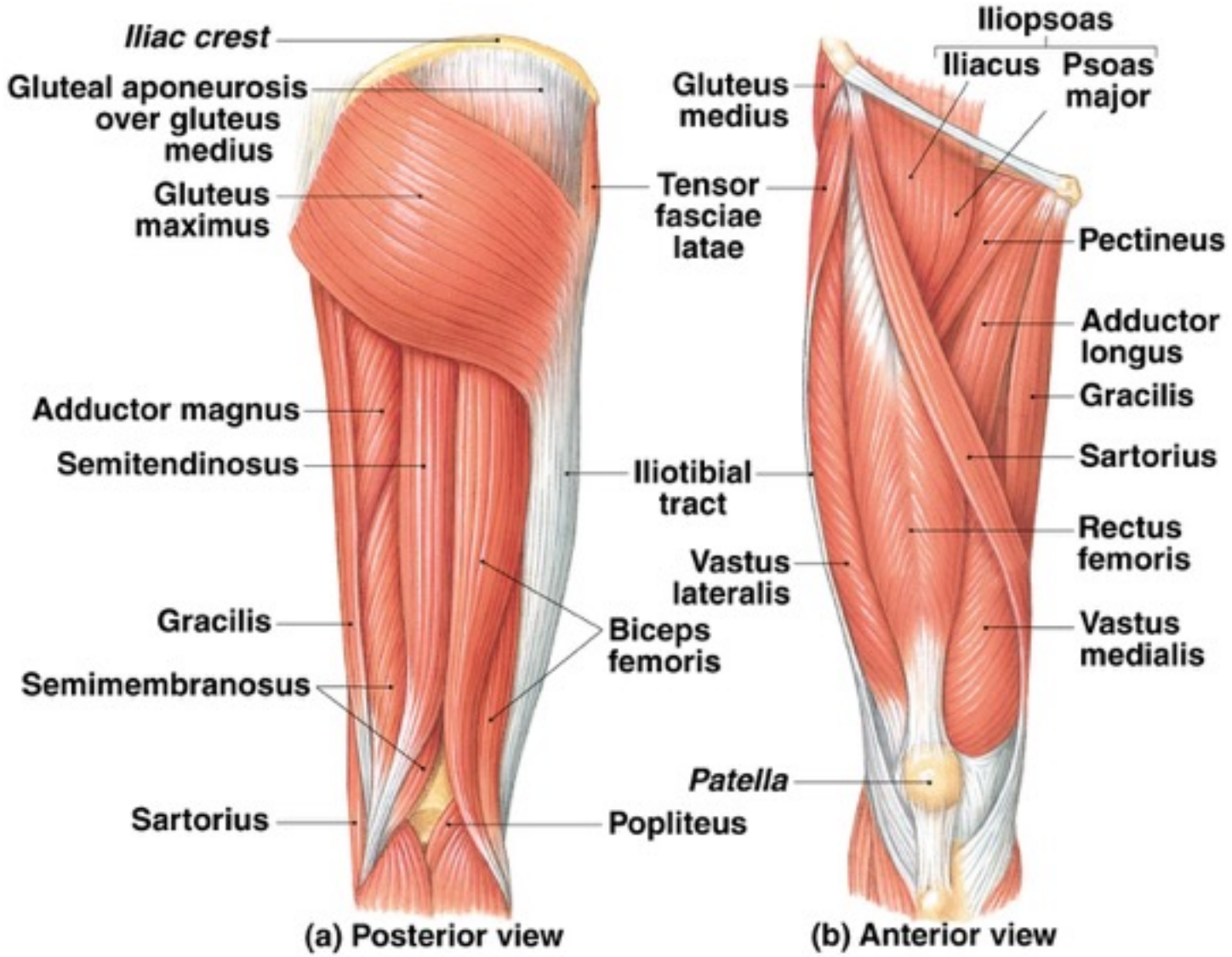


Figure 7-21

Anatomy of the Muscular System

Muscles That Move the Foot and Toes

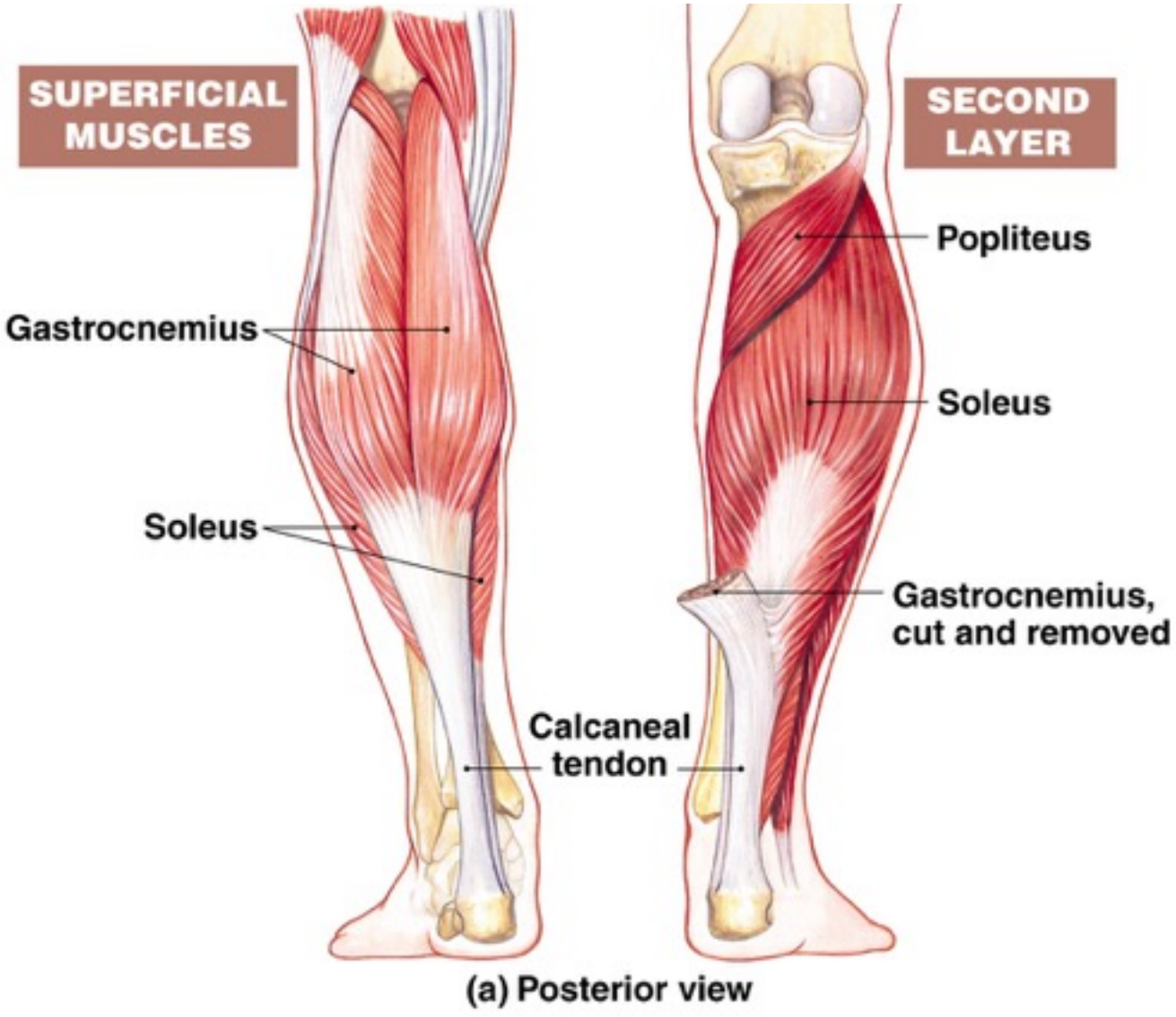


Figure 7-22(a)

Anatomy of the Muscular System

Muscles That Move the Foot and Toes

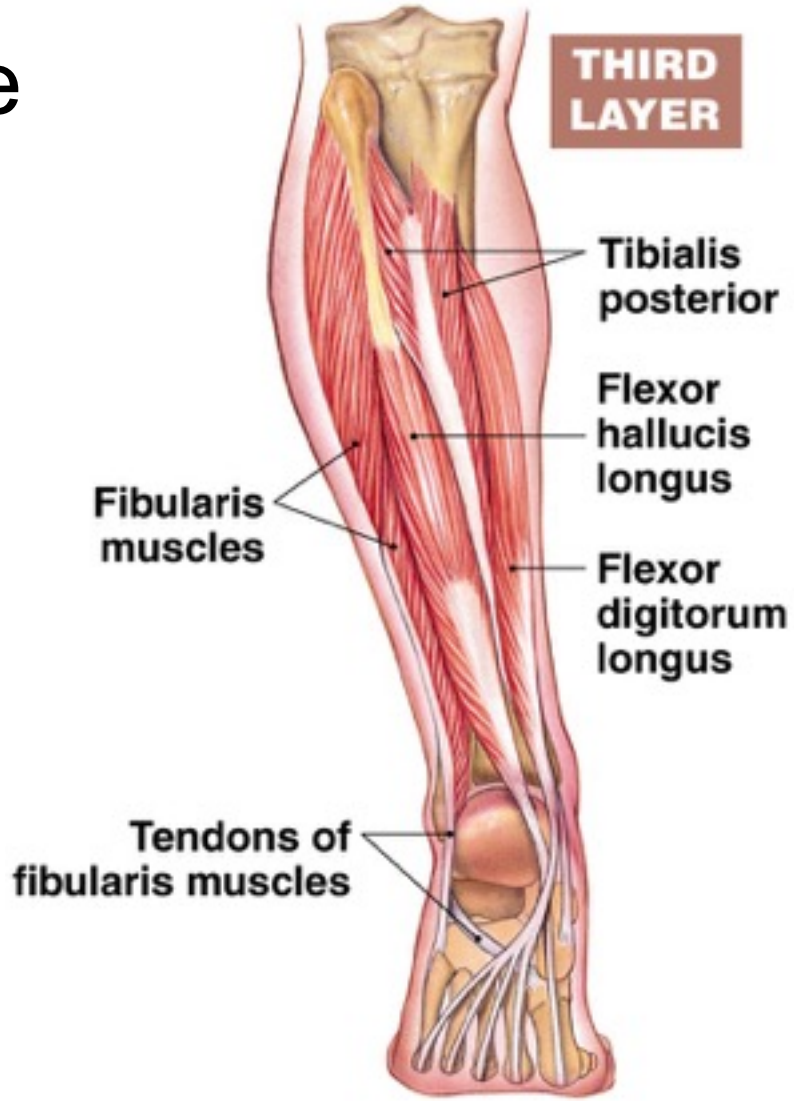
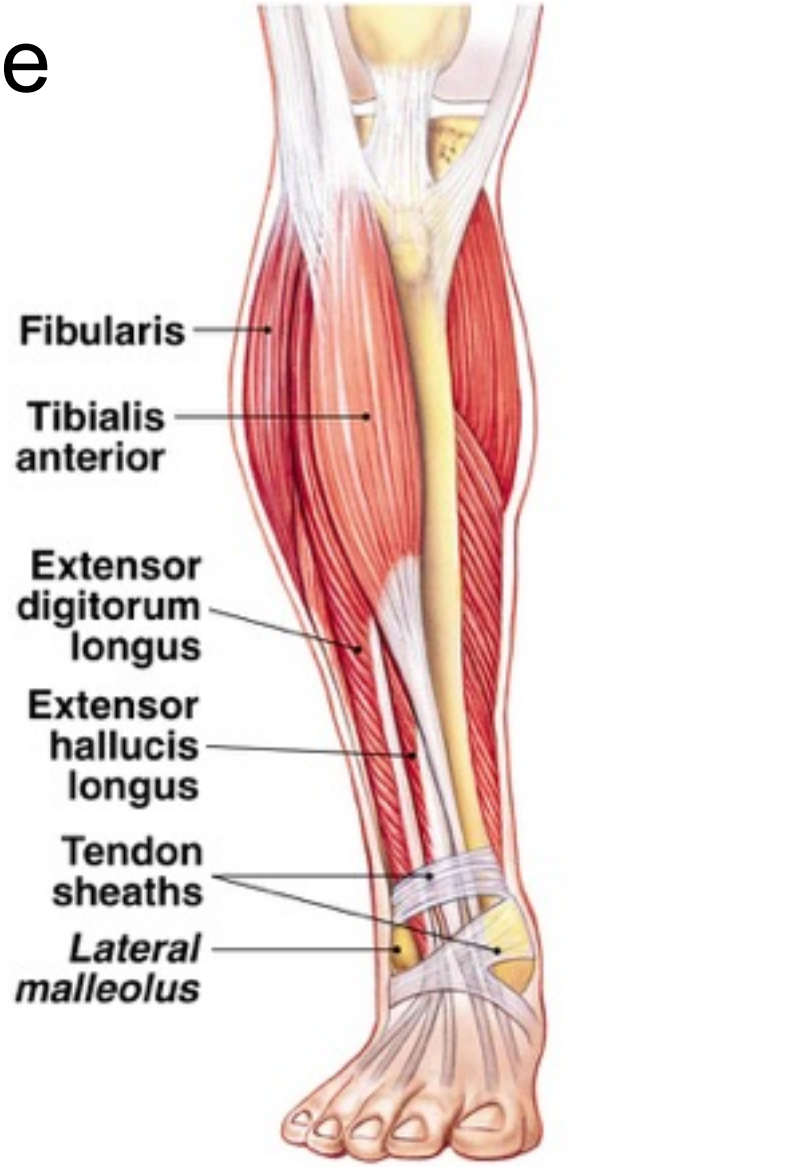


Figure 7-22(b)

Anatomy of the Muscular System

Muscles That Move the Foot and Toes

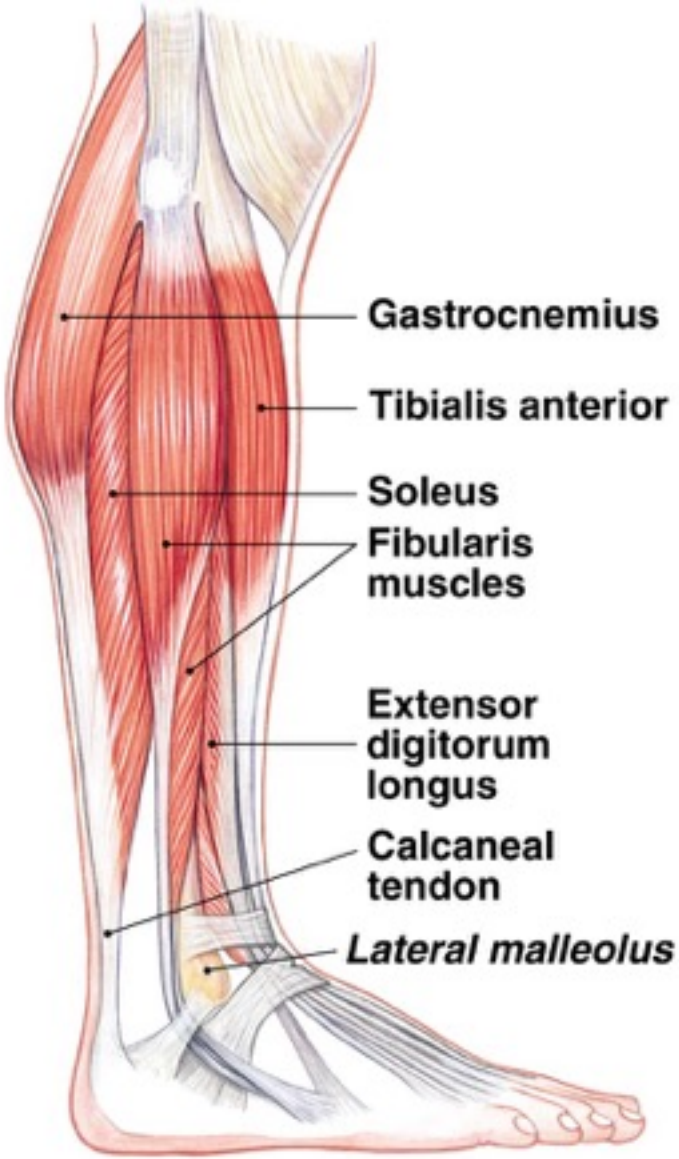


(c) Anterior view, right leg

Figure 7-22(c)

Anatomy of the Muscular System

Muscles That Move the Foot and Toes



(d) Lateral view

Figure 7-22(d)