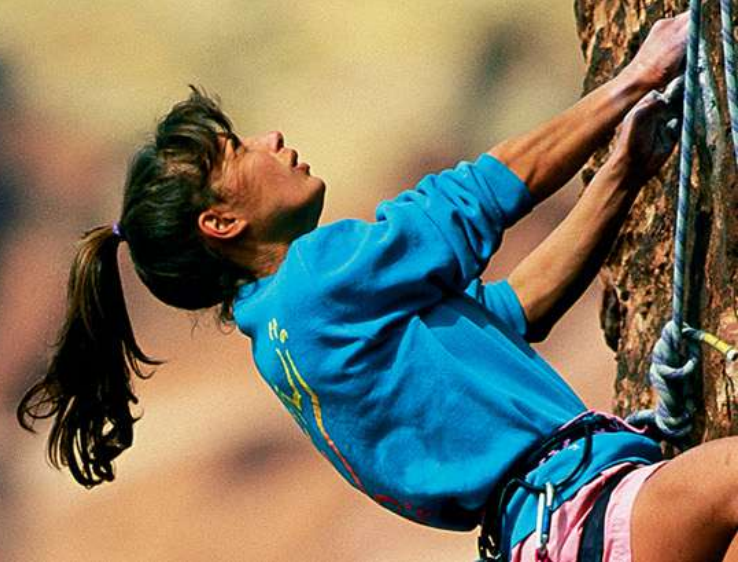


Essentials of Anatomy & Physiology, 4th Edition
Martini / Bartholomew

7 The Muscular System



PowerPoint® Lecture Outlines
prepared by Alan Magid, Duke University

Slides 1 to 110

Overview of Muscular System

What are the Three Types of Muscle Tissue?

Under voluntary control

Skeletal muscles

The muscular system

Under involuntary control

Cardiac muscle

Heart wall

Smooth muscle

Visceral organs

Overview of Muscular System

Skeletal muscles attach to bones directly or indirectly

What are the five functions?

- Produce movement of skeleton

- Maintain posture and body position

- Support soft tissues

- Guard entrances and exits

- Maintain body temperature

Anatomy of Skeletal Muscles

What Is The Gross Anatomy?

Connective tissue organization

Epimysium

Fibrous covering of whole muscle

Perimysium

Fibrous covering of *fascicle*

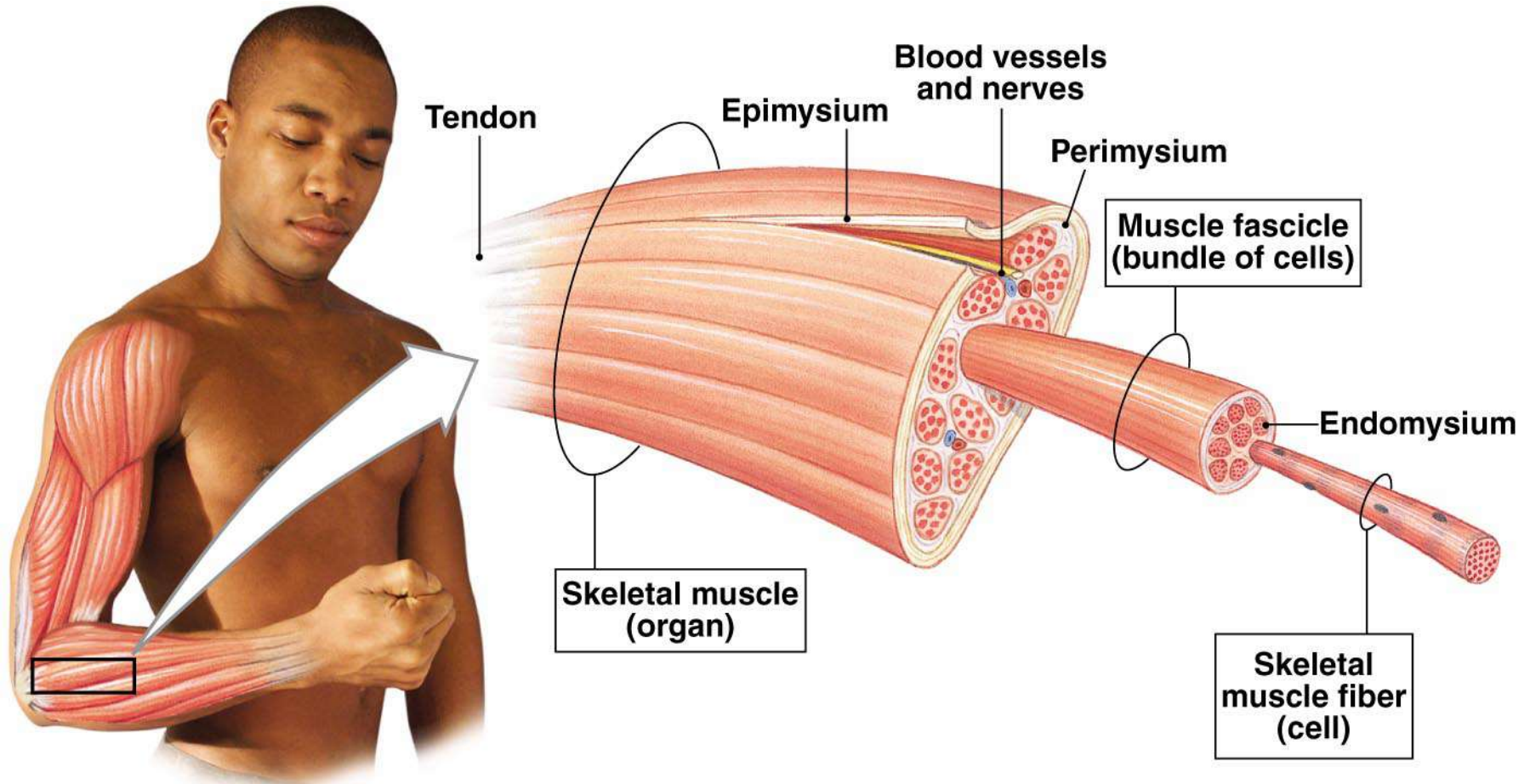
Endomysium

Fibrous covering of a single cell (a muscle *fiber*)

Tendons (or *aponeurosis*)

Anatomy of Skeletal Muscles

The Organization of a Skeletal Muscle



Anatomy of Skeletal Muscles

What is the Microanatomy of a Muscle Fiber?

Sarcolemma

Muscle cell membrane

Sarcoplasm

Muscle cell cytoplasm

Sarcoplasmic reticulum (SR)

Like smooth ER

Transverse tubules (T tubules)

Myofibrils (contraction organelle)

Sarcomeres

Anatomy of Skeletal Muscles

Sarcomere—Repeating structural unit of the myofibril

Parts of a sarcomere

Myofilaments

Thin filaments (actin)

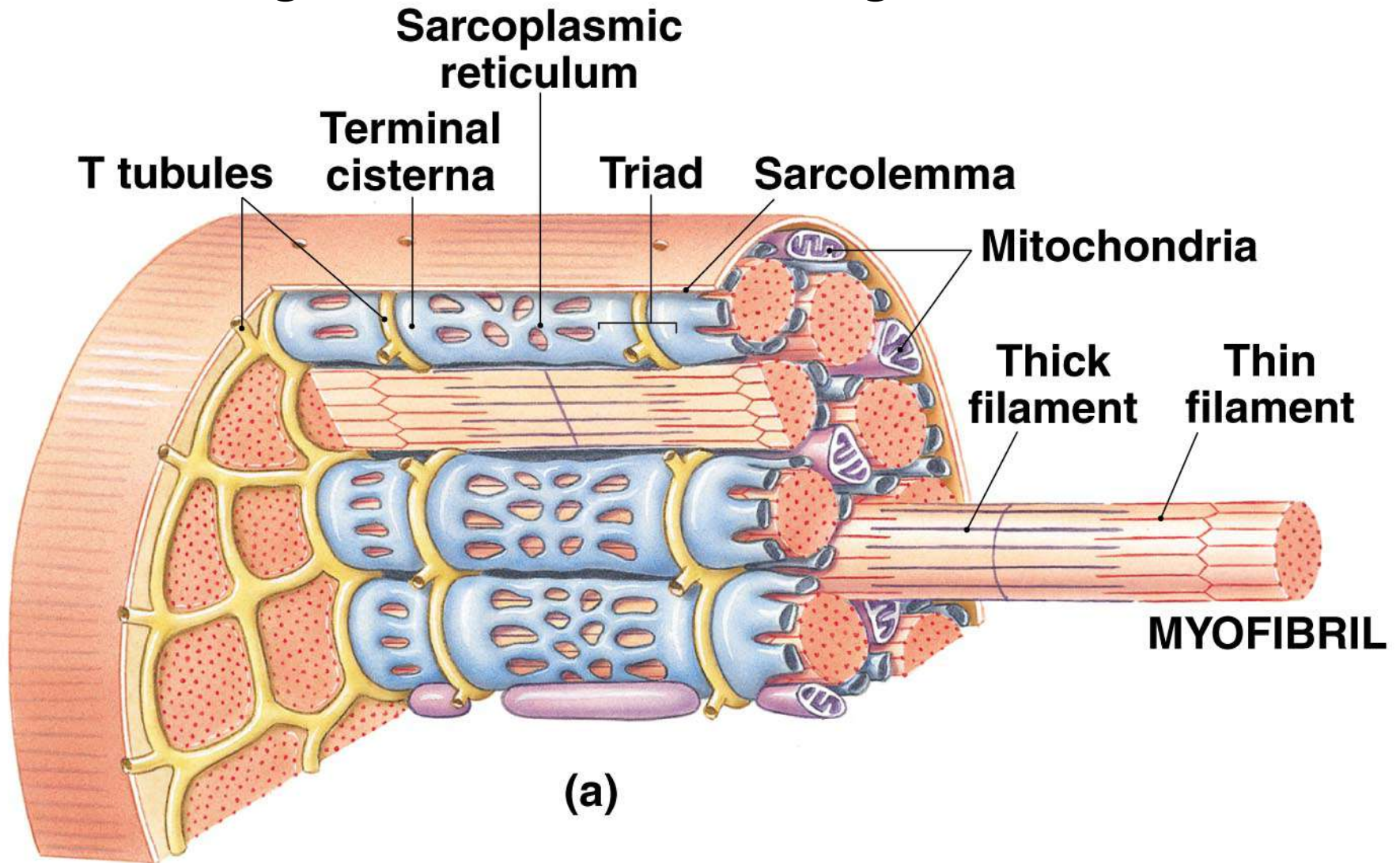
Thick filaments (myosin)

Z lines at each end

Anchor for thin filaments

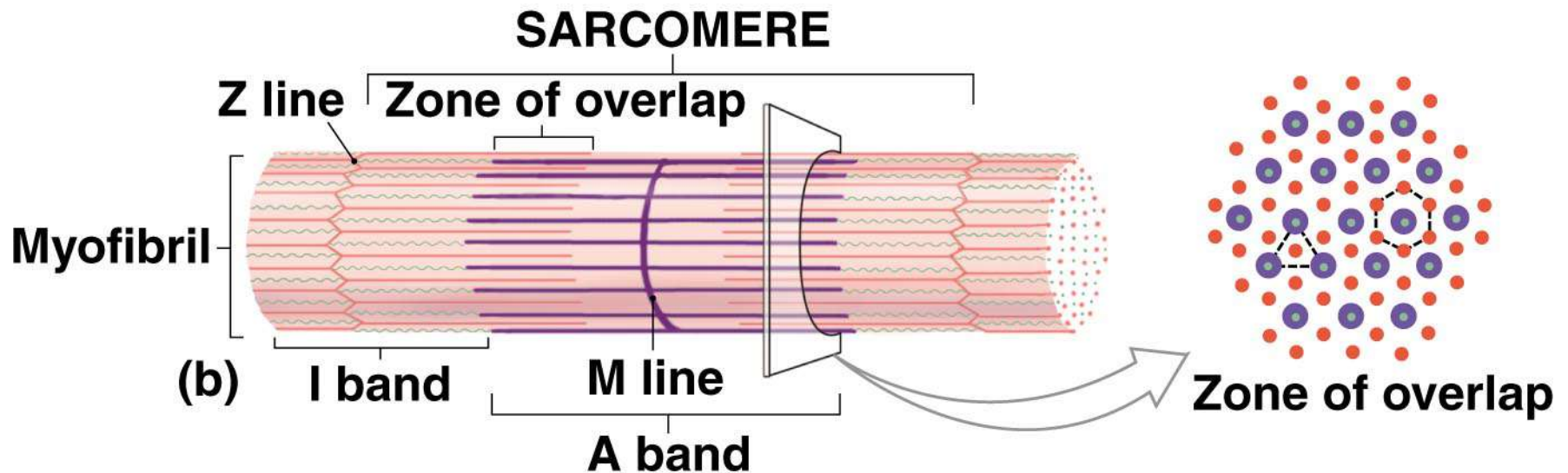
Anatomy of Skeletal Muscles

The Organization of a Single Muscle Fiber



Anatomy of Skeletal Muscles

The Organization of a Single Muscle Fiber

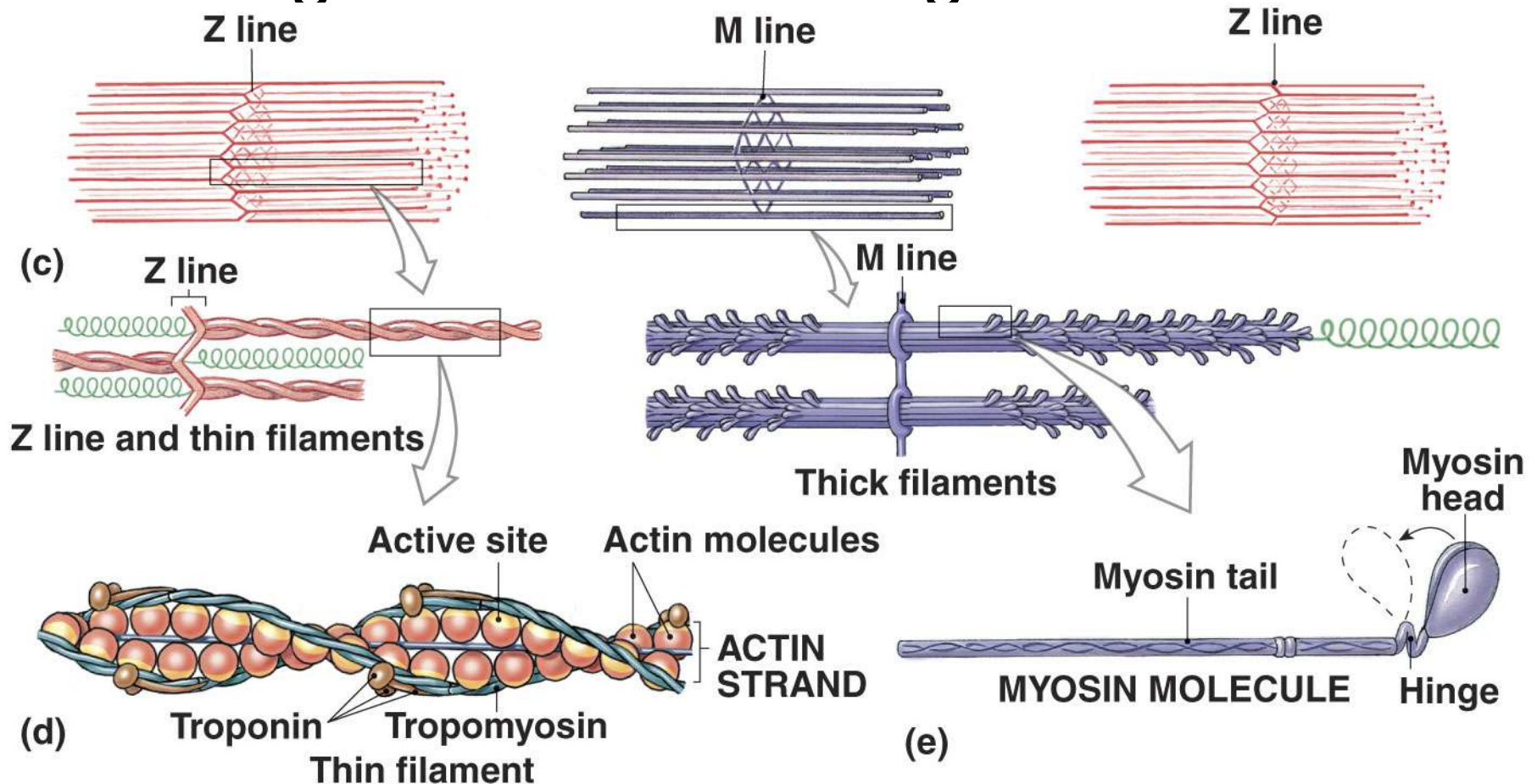


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Figure 7-2(b)

Anatomy of Skeletal Muscles

The Organization of a Single Muscle Fiber



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PLAY

Anatomy of Skeletal Muscles

Figure 7-2(cde)

Anatomy of Skeletal Muscles

Changes in the Appearance of a Sarcomere During Contraction of a Skeletal Muscle Fiber

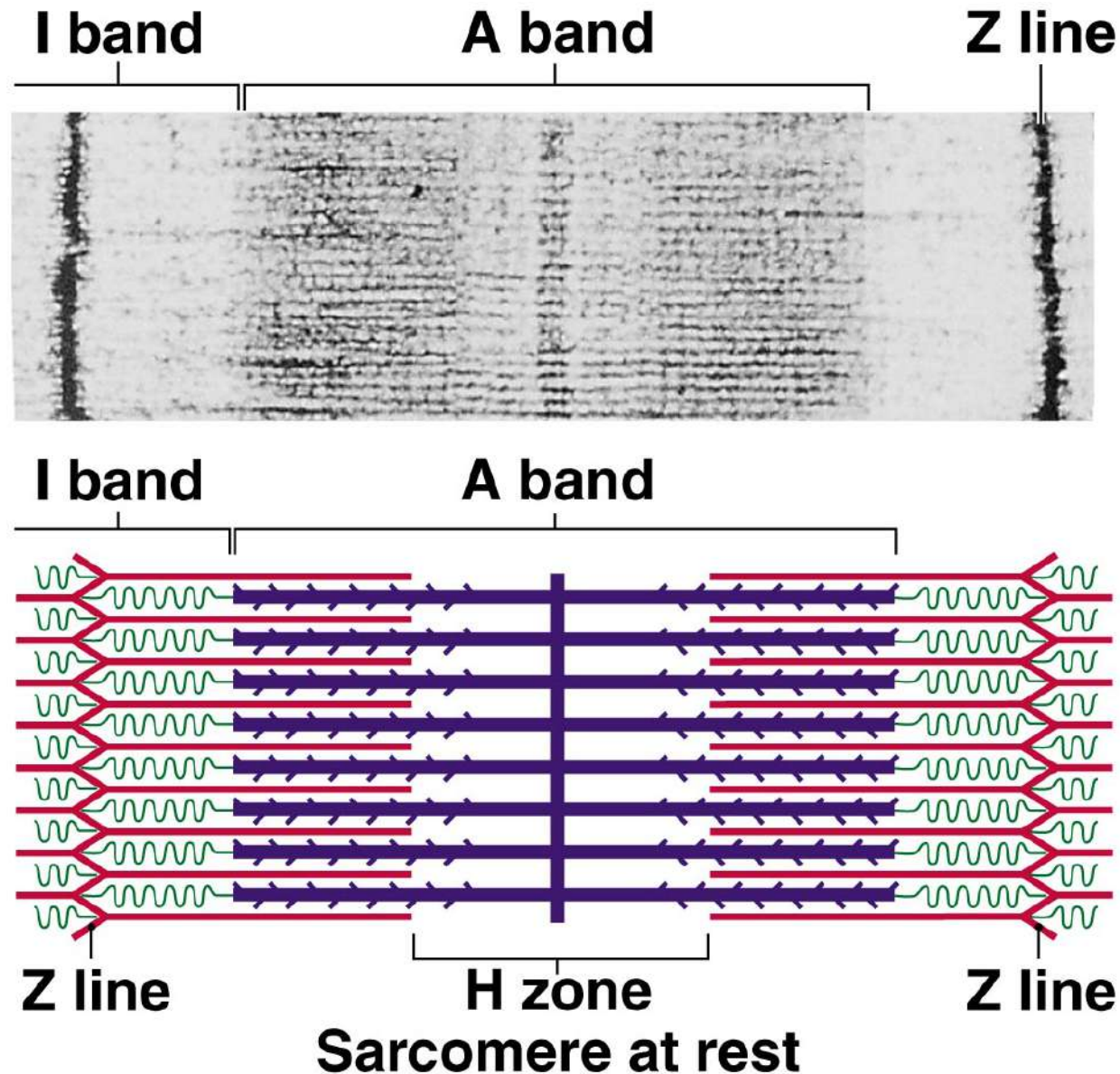


Figure 7-3 (1 of 2)

Anatomy of Skeletal Muscles

Changes in the
Appearance of
a Sarcomere
During
Contraction of
a Skeletal
Muscle Fiber

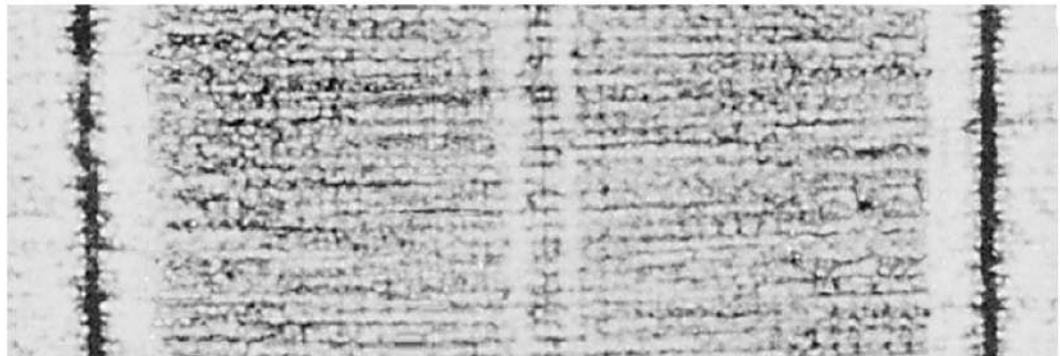
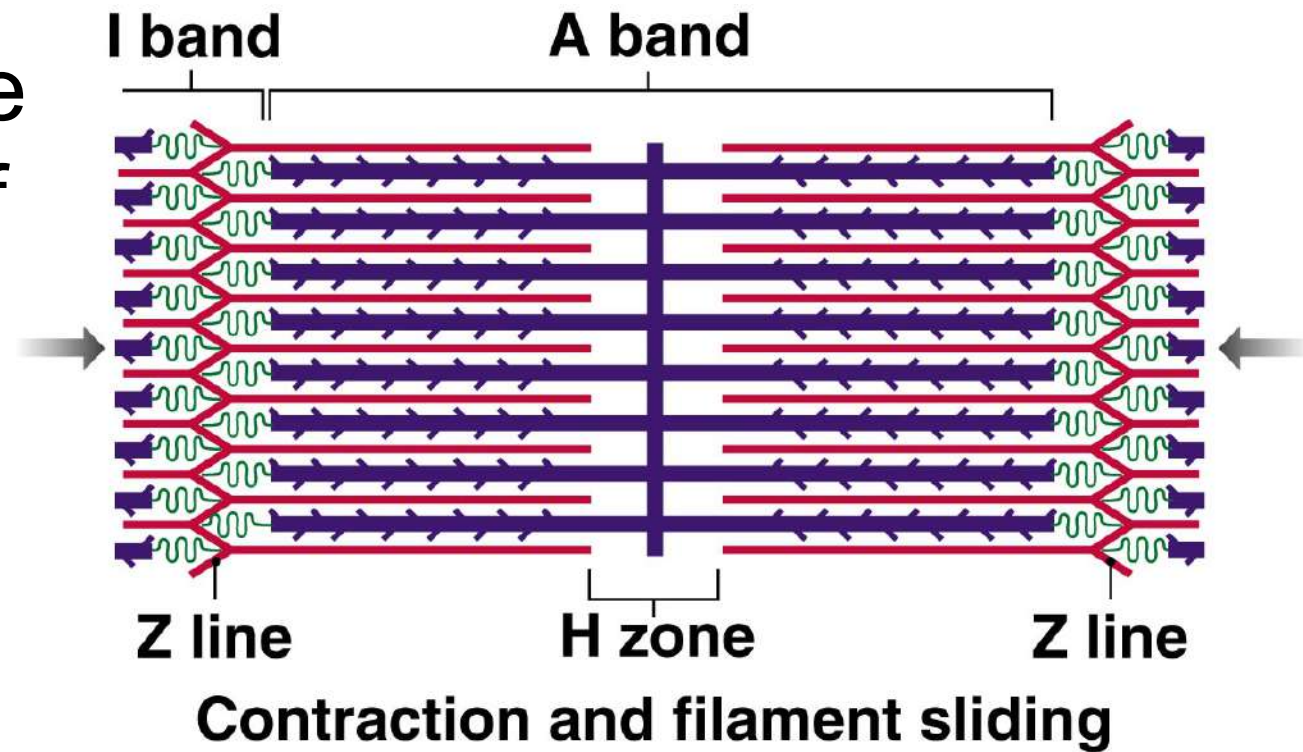
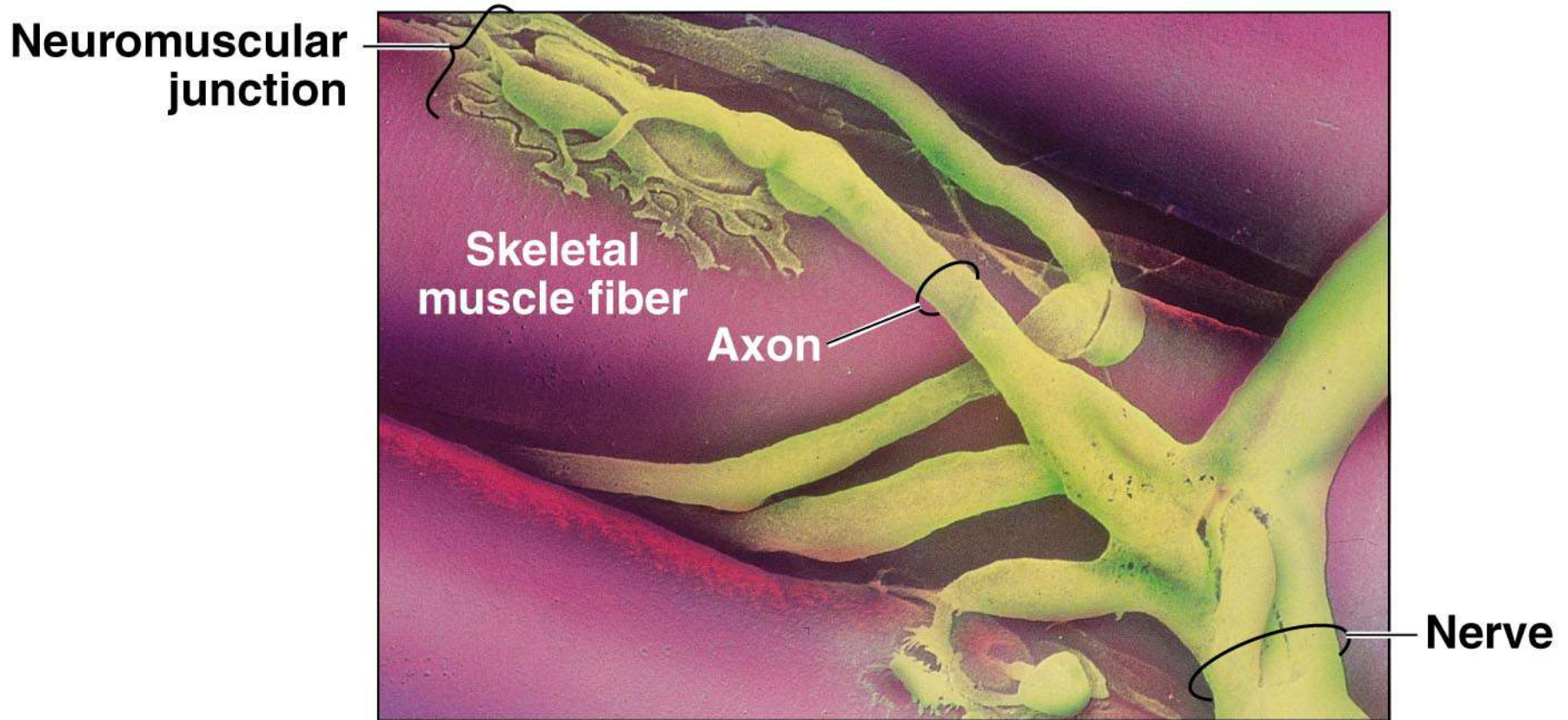


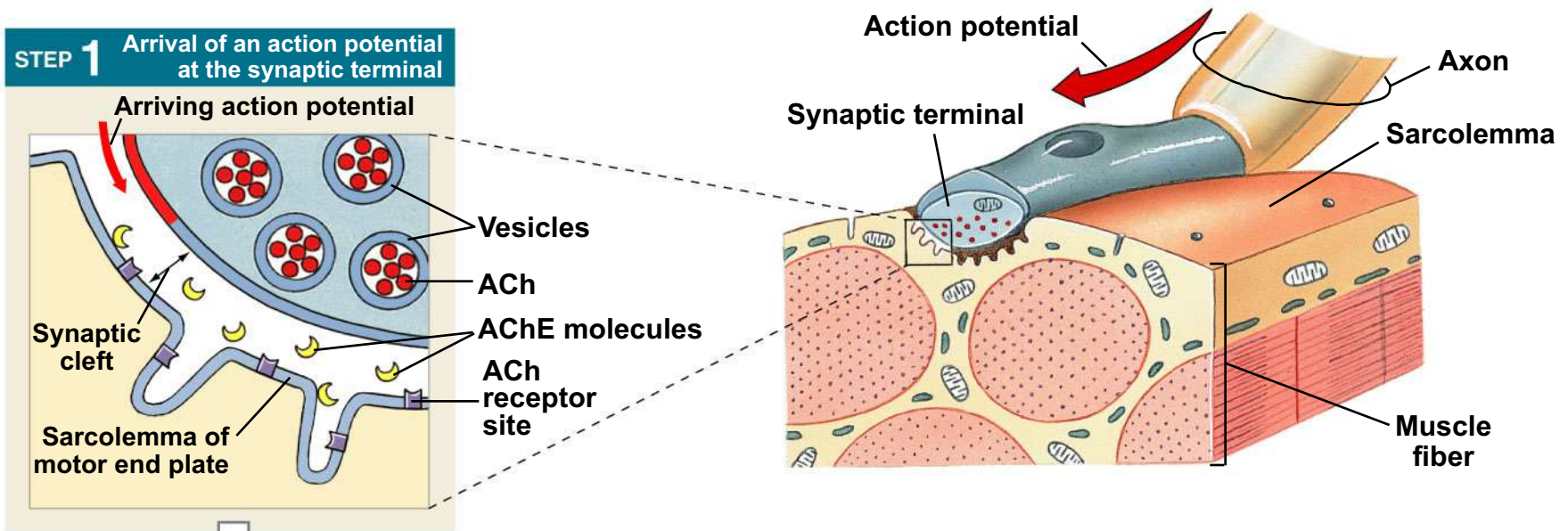
Figure 7-3 (2 of 2)

Control of Muscle Contraction

The Structure and Function of the Neuromuscular Junction

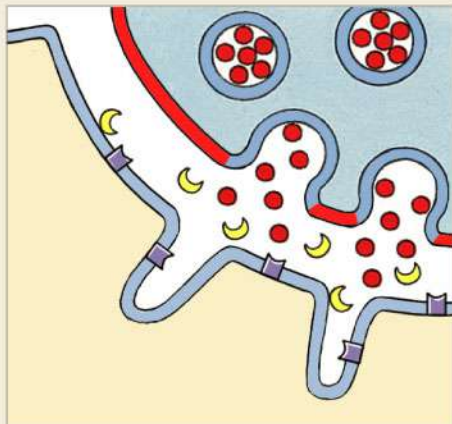


(a)



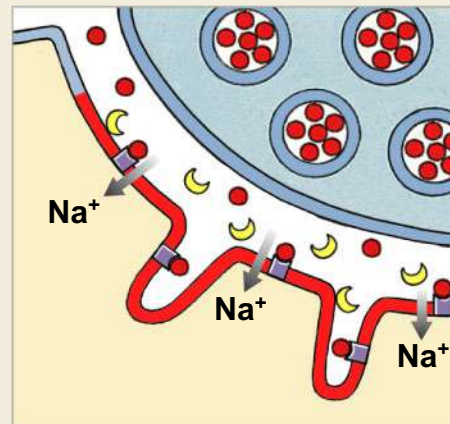
STEP 2 Release of acetylcholine

Vesicles in the synaptic terminal fuse with the neuronal membrane and dump their contents into the synaptic cleft.



STEP 3 ACh binding at the motor end plate

The binding of ACh to the receptors increases the membrane permeability to sodium ions. Sodium ions then rush into the cell.



STEP 4 Appearance of an action potential in the sarcolemma

An action potential spreads across the surface of the sarcolemma. While this occurs, AChE removes the ACh.

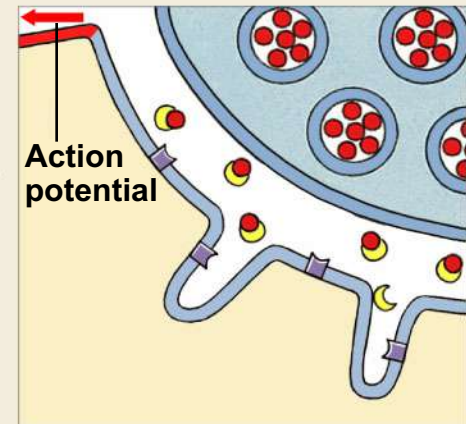
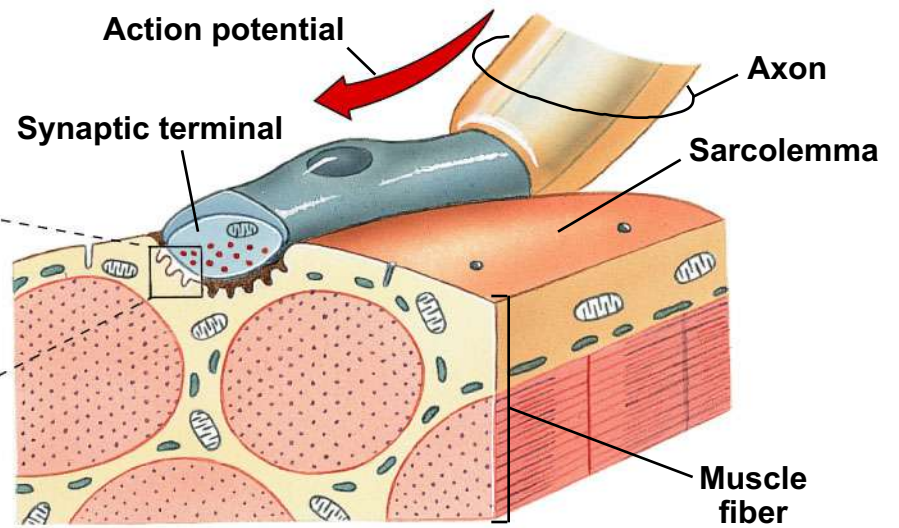
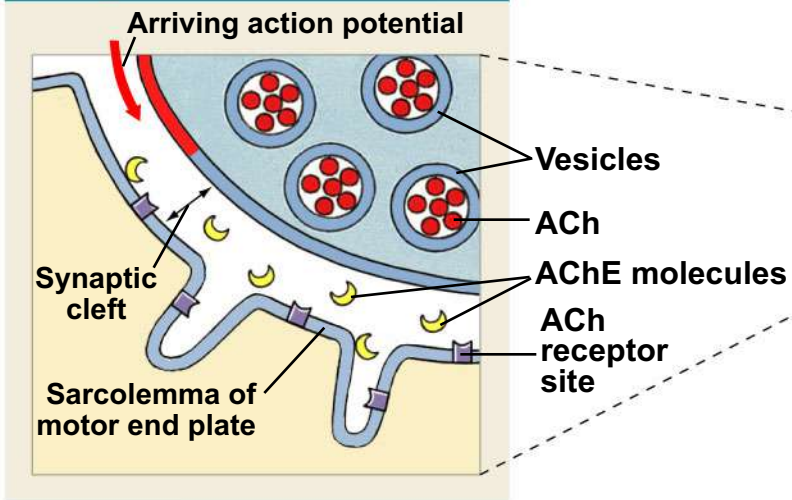
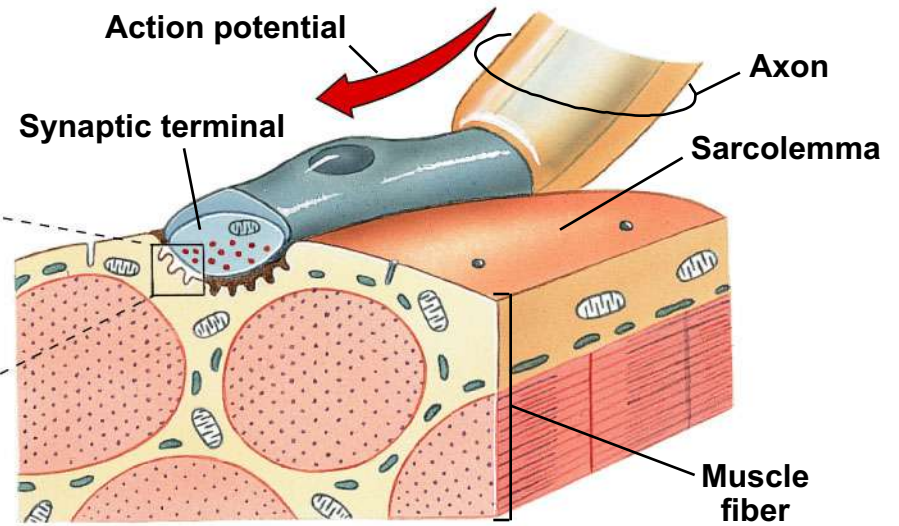
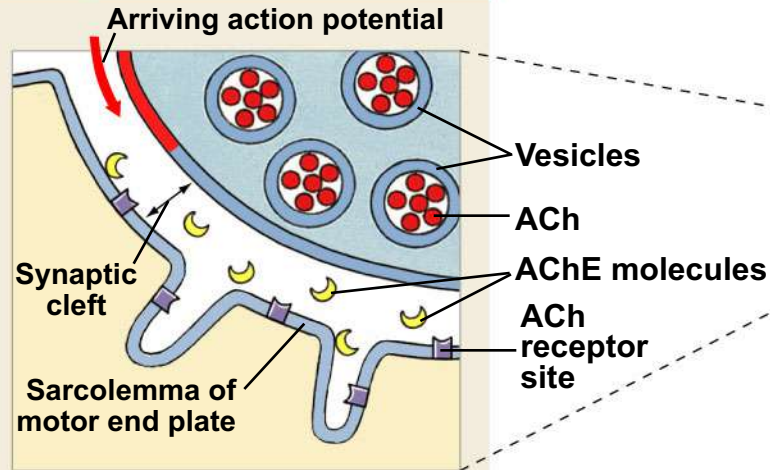


Figure 7-4(b-c)
1 of 5

STEP 1 Arrival of an action potential at the synaptic terminal



STEP 1 Arrival of an action potential at the synaptic terminal



STEP 2 Release of acetylcholine

Vesicles in the synaptic terminal fuse with the neuronal membrane and dump their contents into the synaptic cleft.

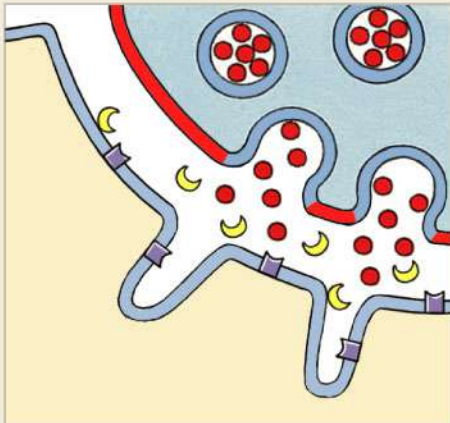
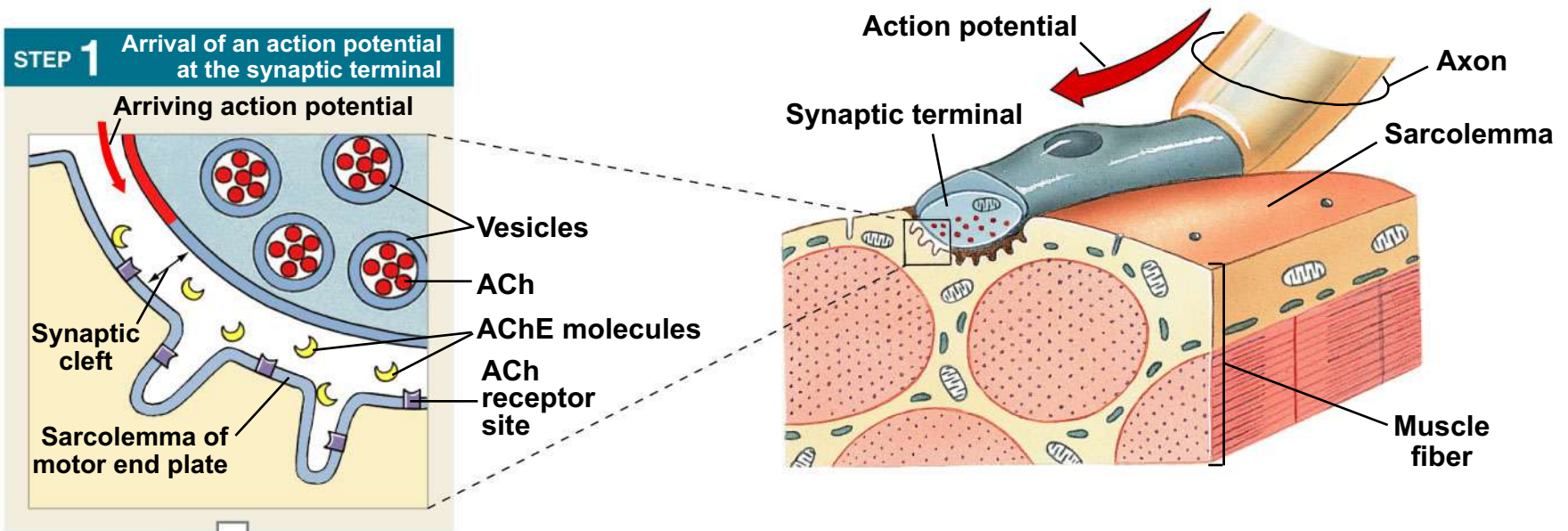
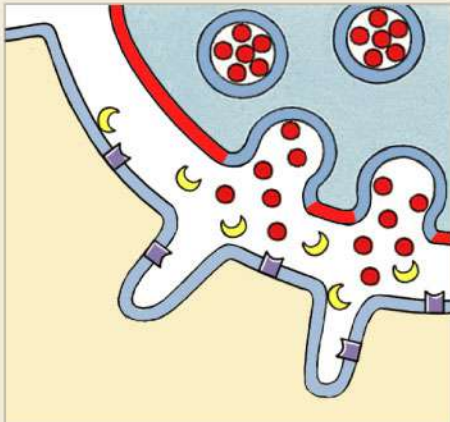


Figure 7-4(b-c)
3 of 5



STEP 2 Release of acetylcholine

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STEP 3 ACh binding at the motor end plate

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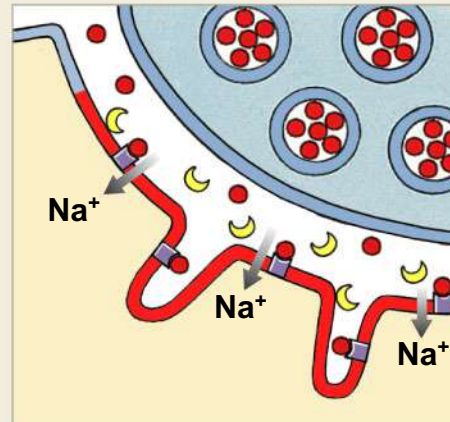
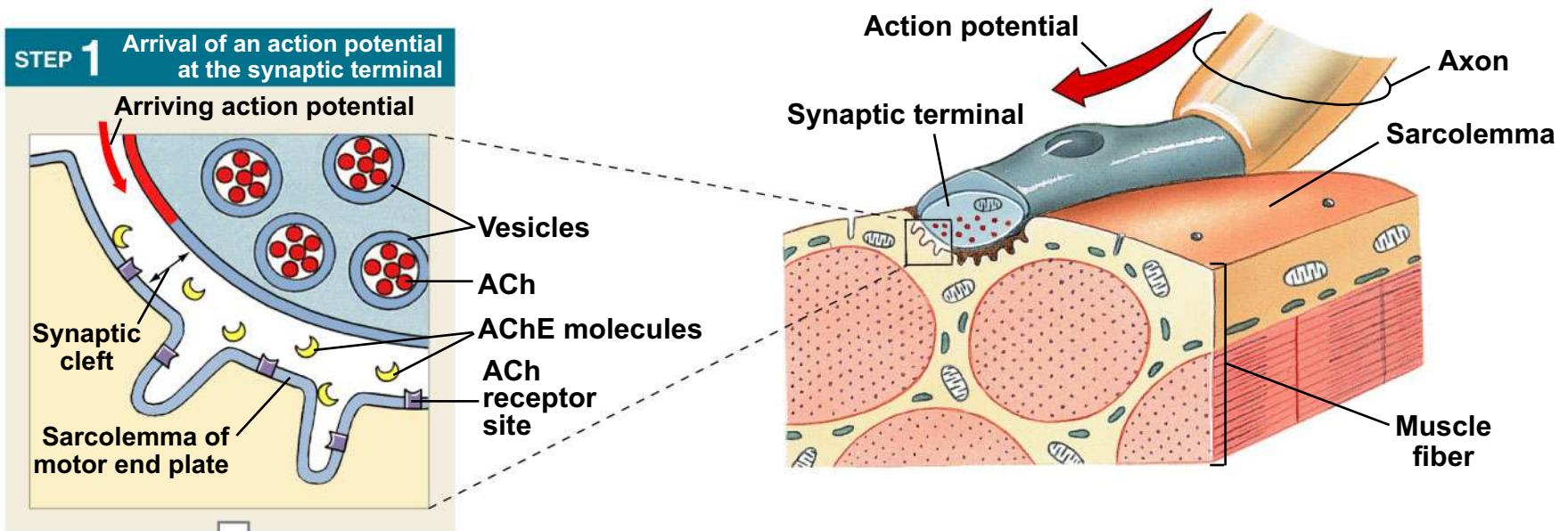
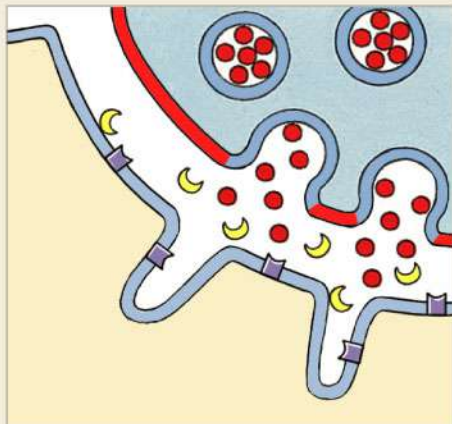


Figure 7-4(b-c)
4 of 5



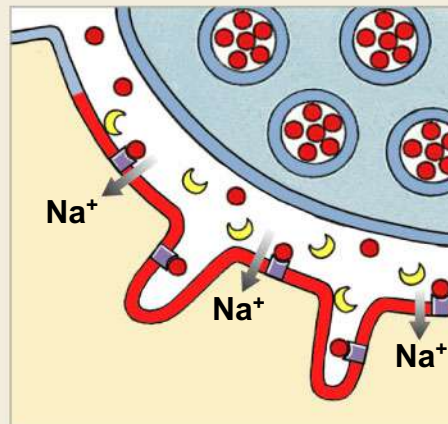
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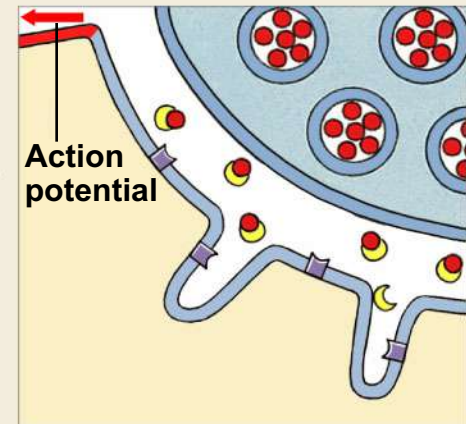


Figure 7-4(b-c)
5 of 5

Anatomy of Skeletal Muscles

What is the Contraction Process?

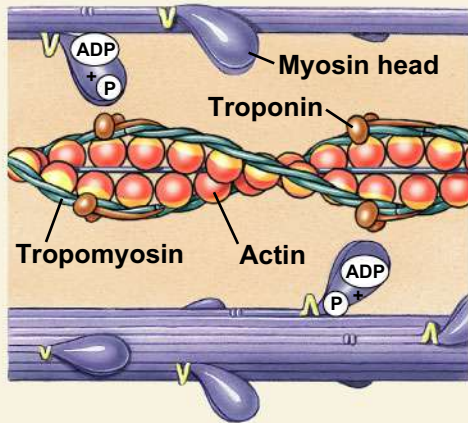
Actin *active sites* and myosin *cross-bridges* interact

Thin filaments *slide* past thick filaments

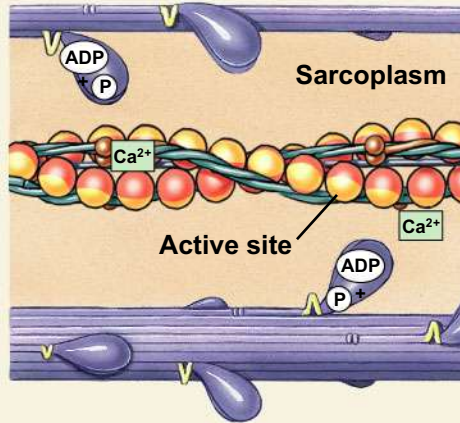
Cross-bridges undergo a cycle of movement

Attach, pivot, detach, return

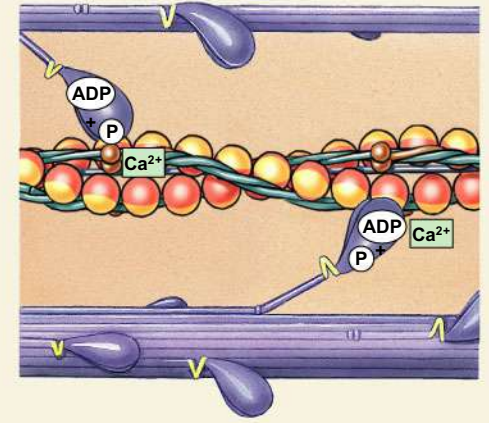
Resting sarcomere



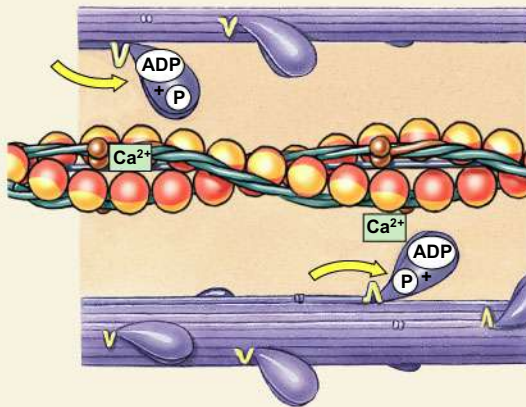
STEP 1 Active-site exposure



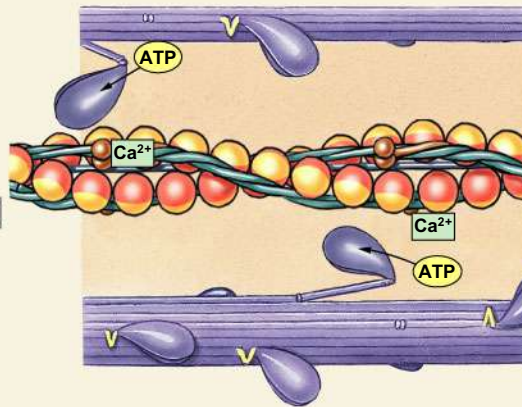
STEP 2 Cross-bridge formation



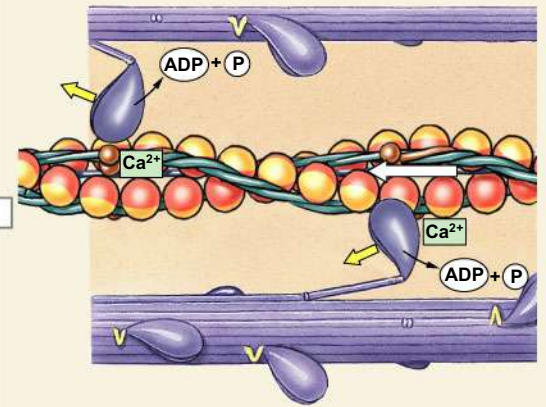
STEP 5 Myosin reactivation



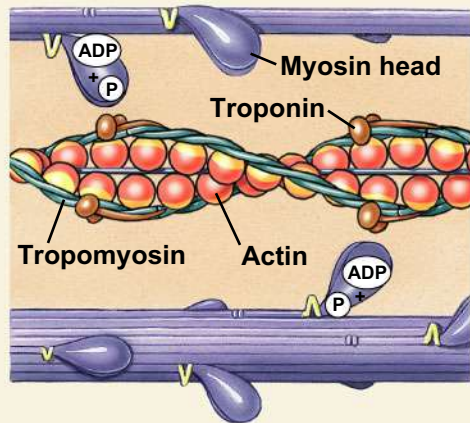
STEP 4 Cross bridge detachment

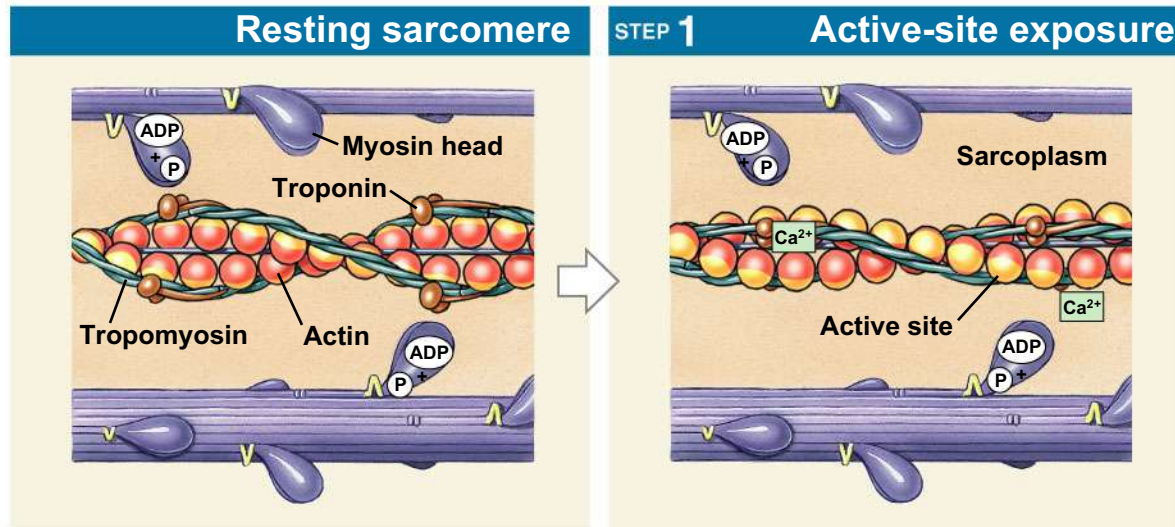


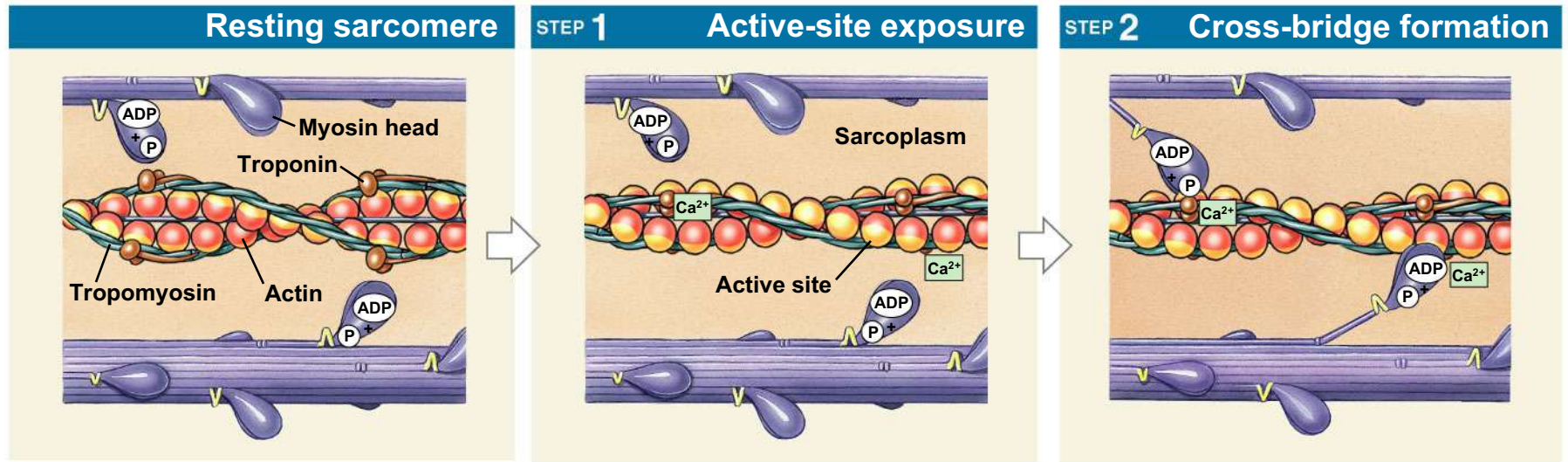
STEP 3 Pivoting of myosin head



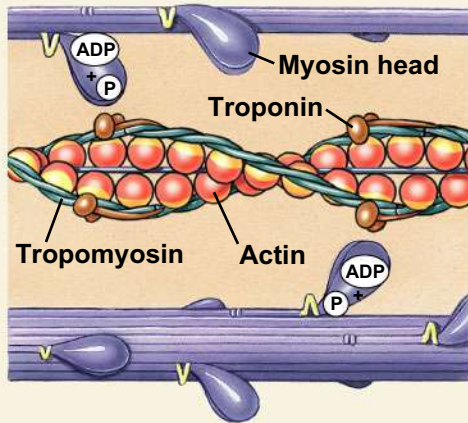
Resting sarcomere



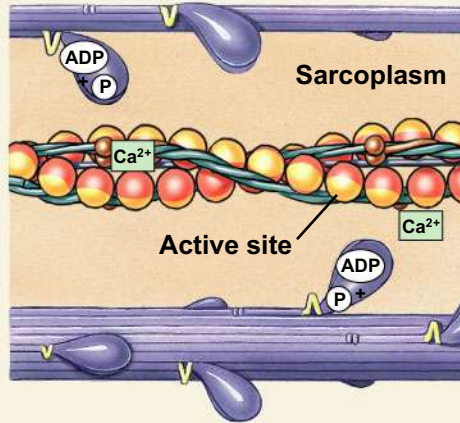




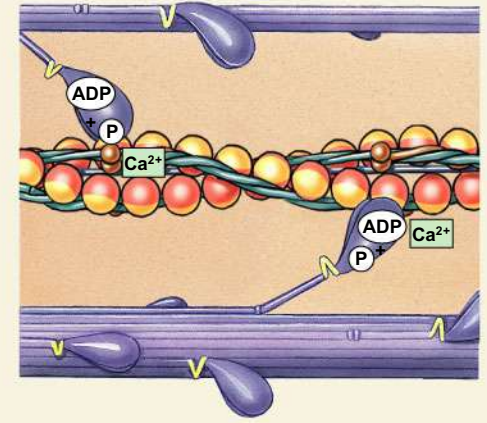
Resting sarcomere



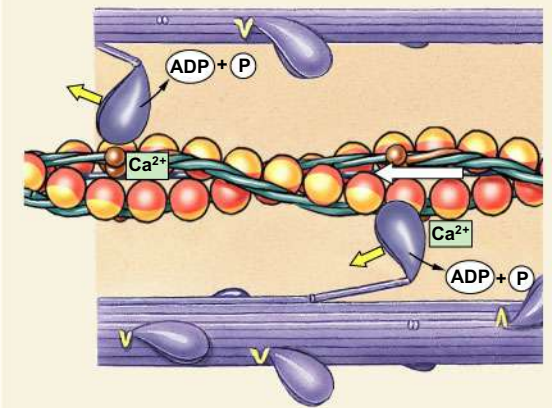
STEP 1 Active-site exposure

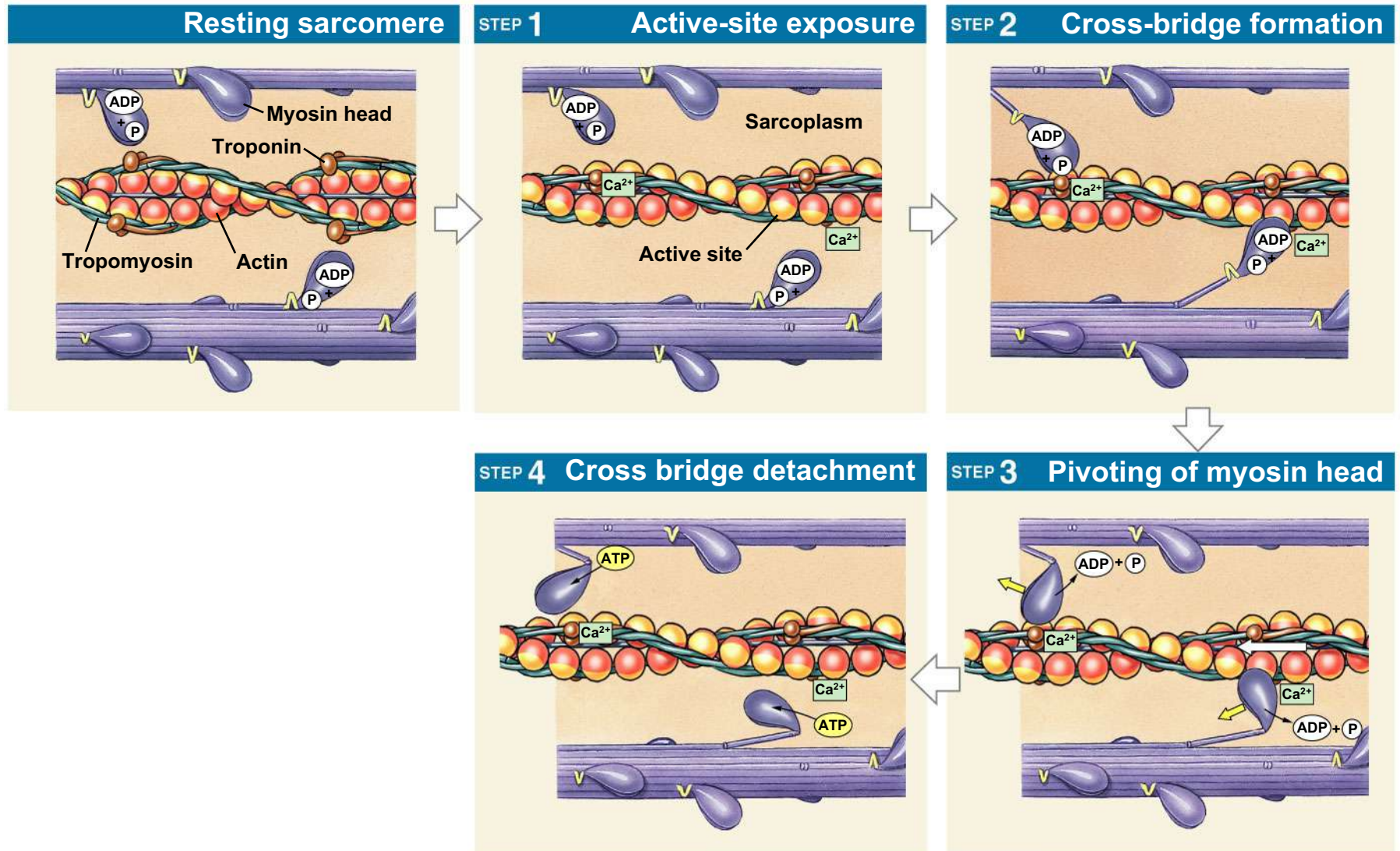


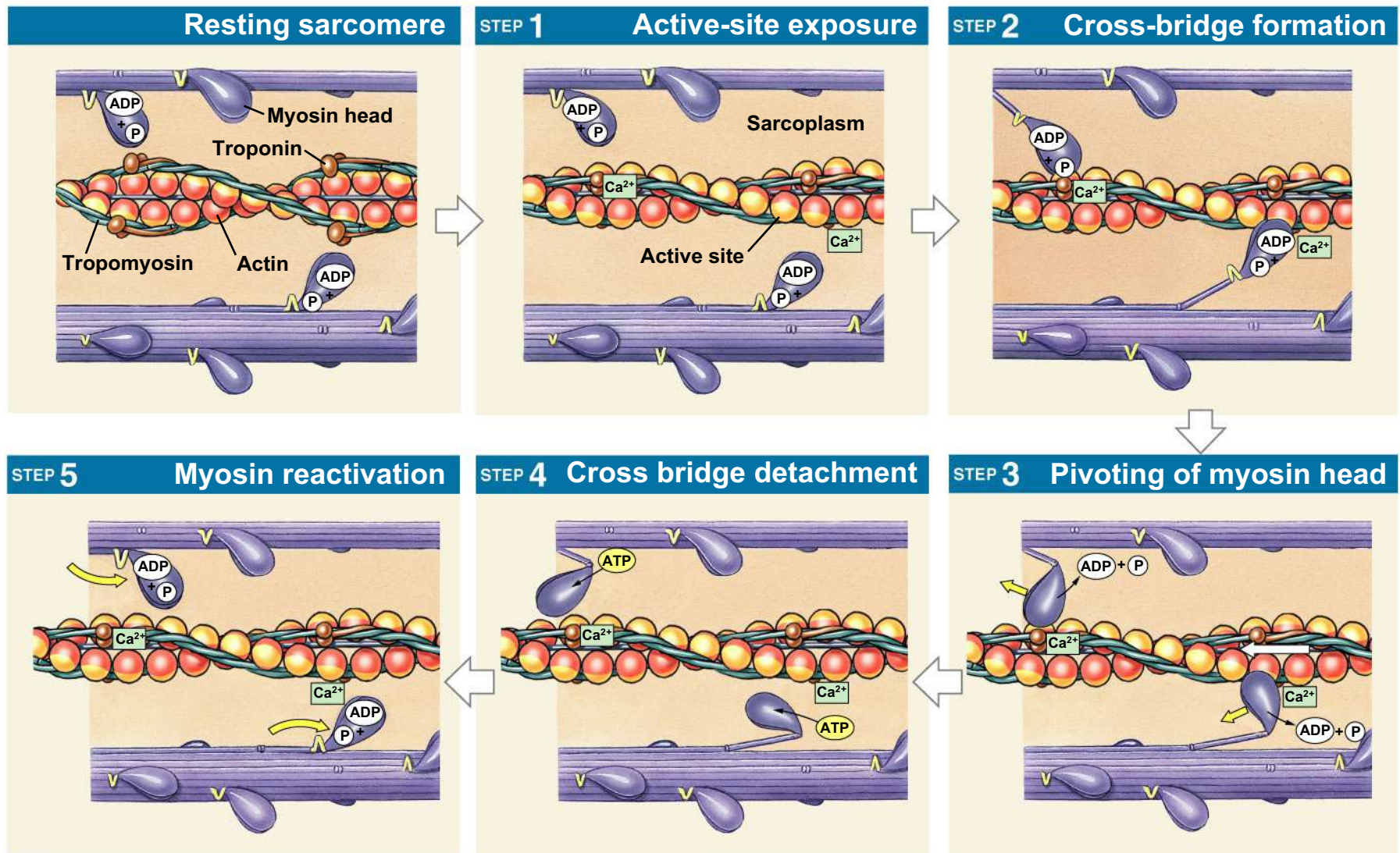
STEP 2 Cross-bridge formation



STEP 3 Pivoting of myosin head





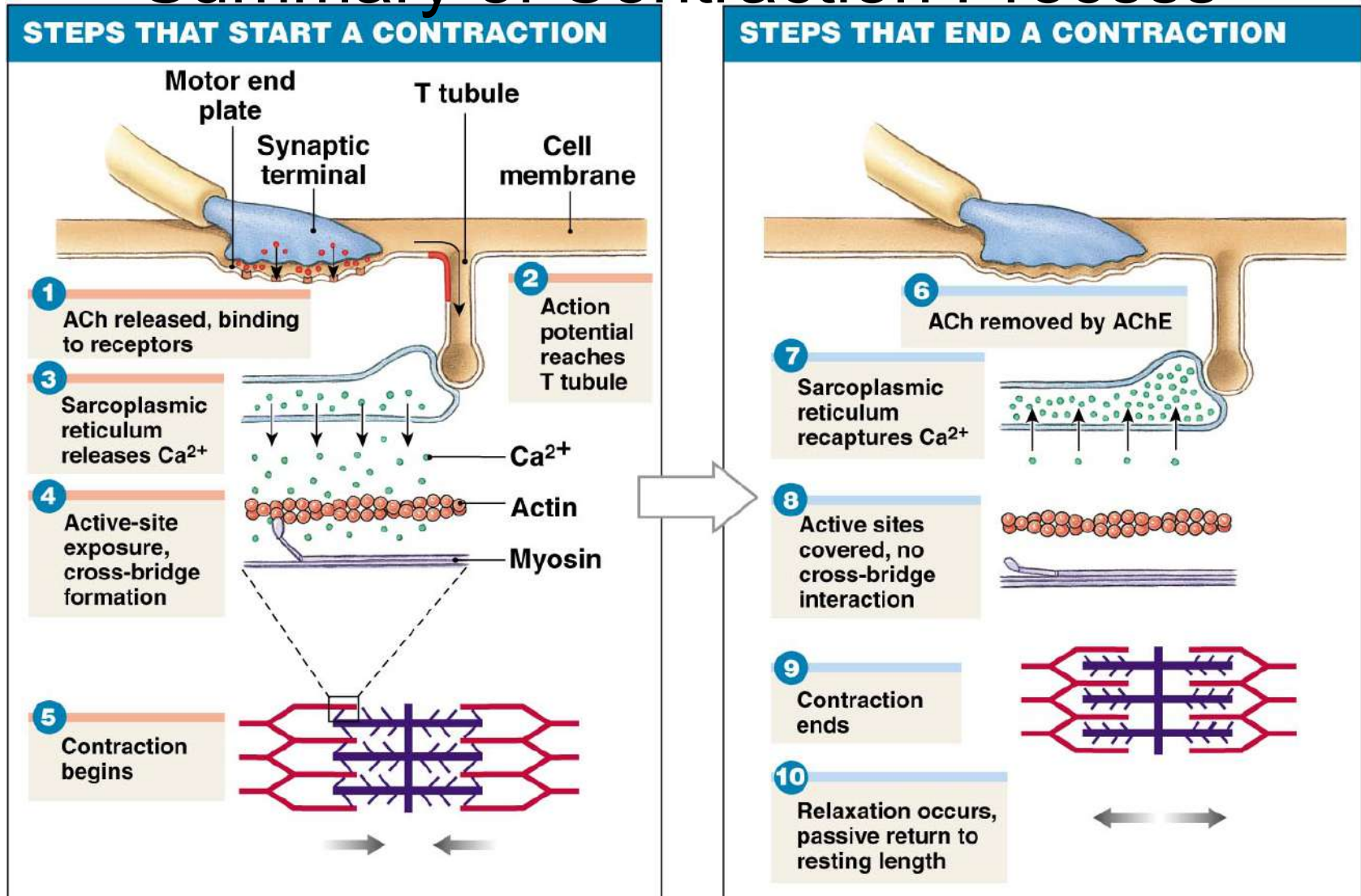


PLAY

Control of Muscle Fiber Contraction

Control of Muscle Contraction

Summary of Contraction Process



Control of Muscle Contraction

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.

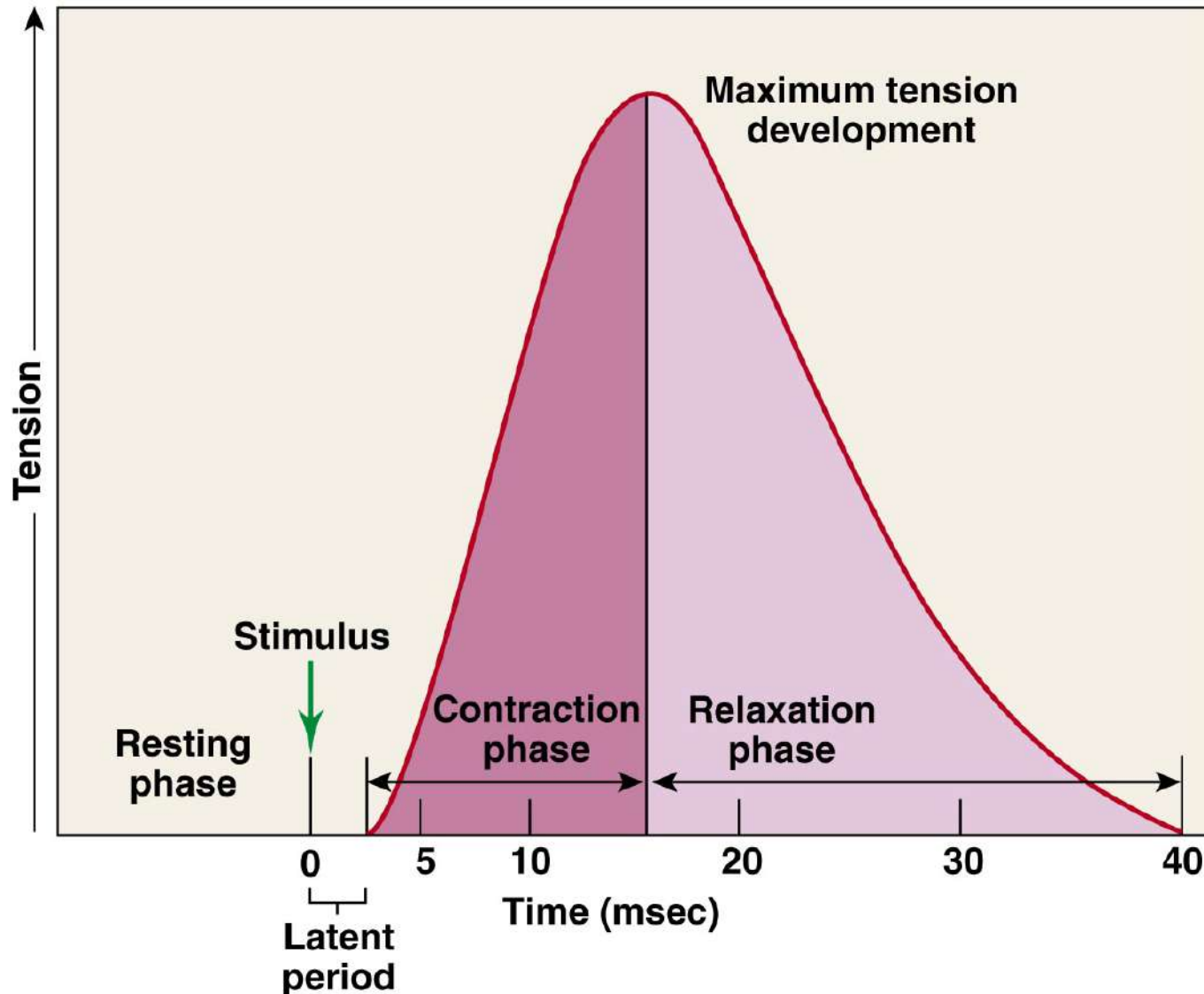
Muscle Mechanics

What are Some Basic Muscle Definitions?

- *Muscle tension*—The pulling *force* on the tendons that muscle cells generate when *contracting*
- *Muscle twitch*—A brief contraction-relaxation response to a single action potential

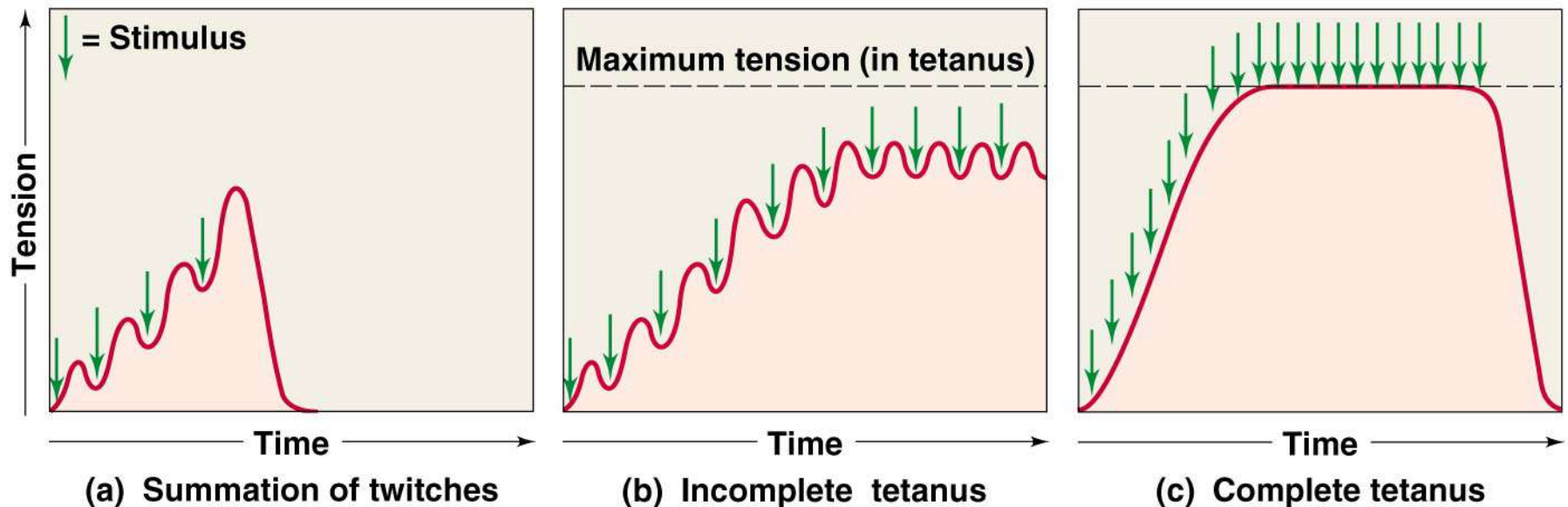
Muscle Mechanics

The Twitch and Development of Tension



Muscle Mechanics

The Effects of Repeated Stimulations



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Figure 7-7

Muscle Mechanics

What are Motor Units?

Motor Unit —A motor neuron and all the muscle cells it controls

Recruitment—To increase muscle tension by activating more motor units

Muscle Mechanics

Motor Units

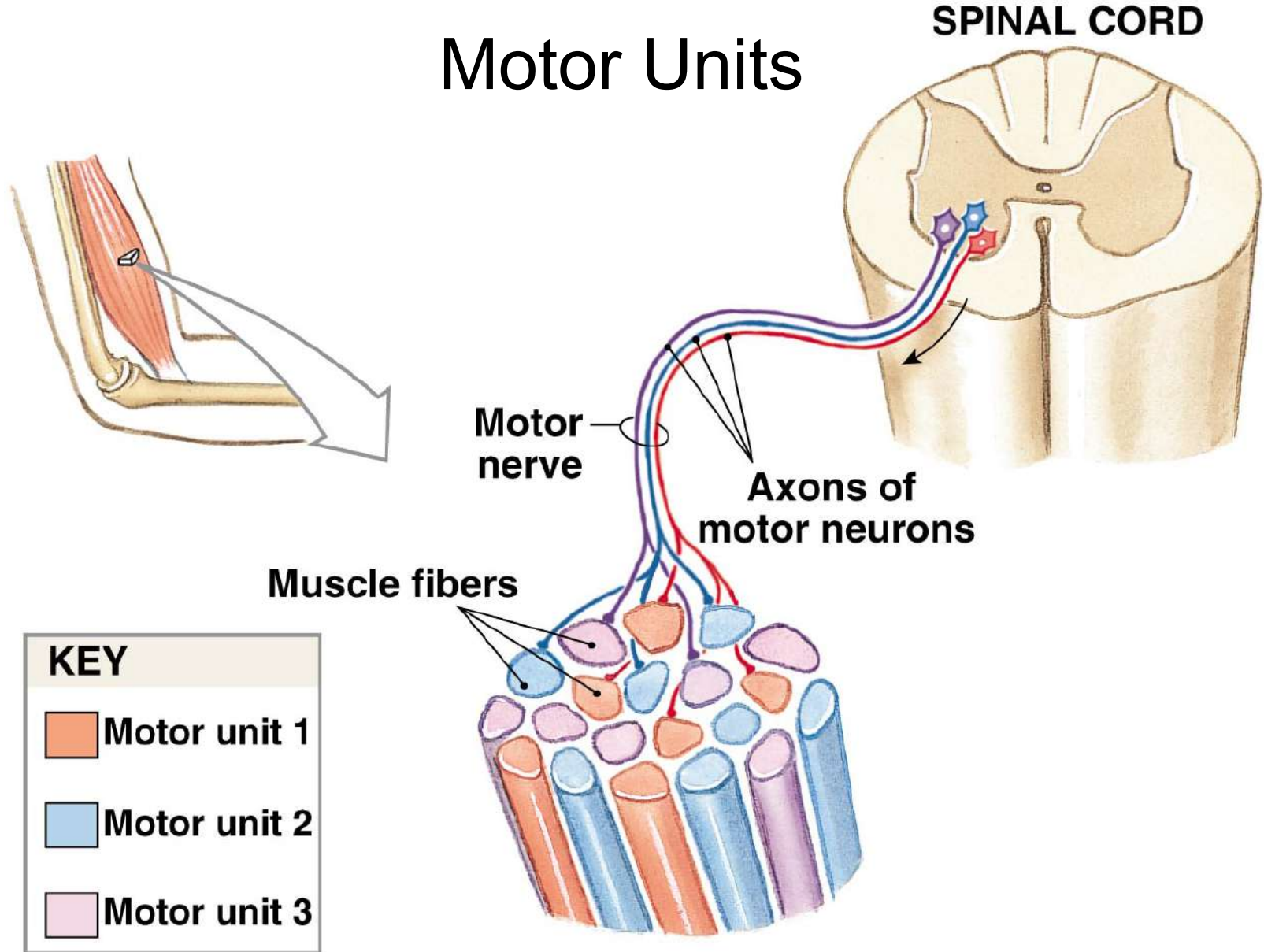


Figure 7-8

Muscle Mechanics

Key Note

All voluntary (intentional) movements involve the sustained, sub-tetanic contractions of skeletal muscle fibers organized into distinct motor units. The force generated can be increased by increasing the frequency of action potentials or by recruiting additional motor units.

Muscle Mechanics

What are the Two Types of Contractions?

Isotonic contraction

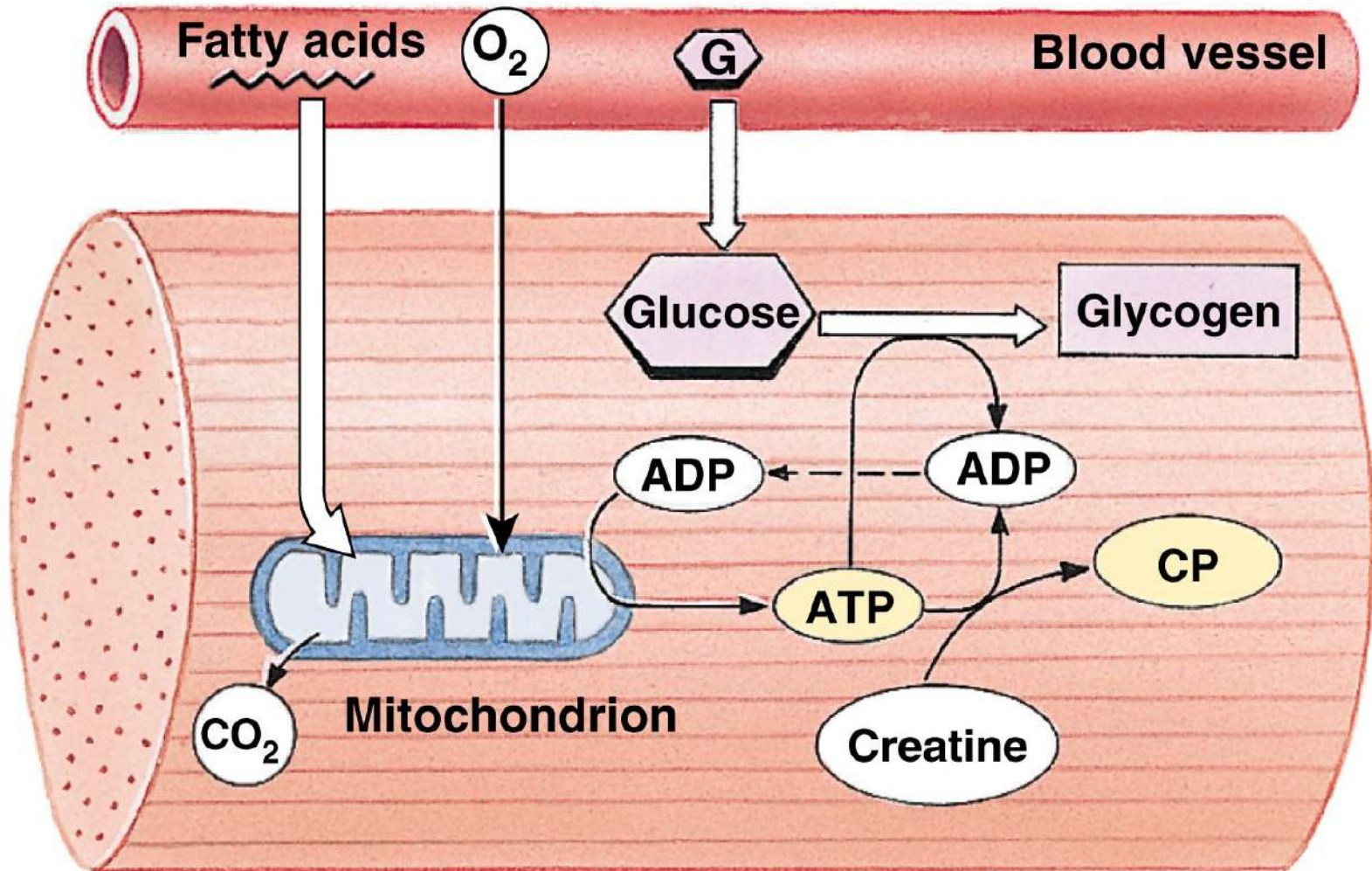
The tension (load) on a muscle stays constant (*iso* = same, *tonic* = tension) during a movement. (Example: lifting a baby)

Isometric contraction

The length of a muscle stays constant (*iso* = same, *metric* = length) during a “*contraction*” (Example: holding a baby at arms length)

Energetics of Muscle Contraction

Muscle Metabolism

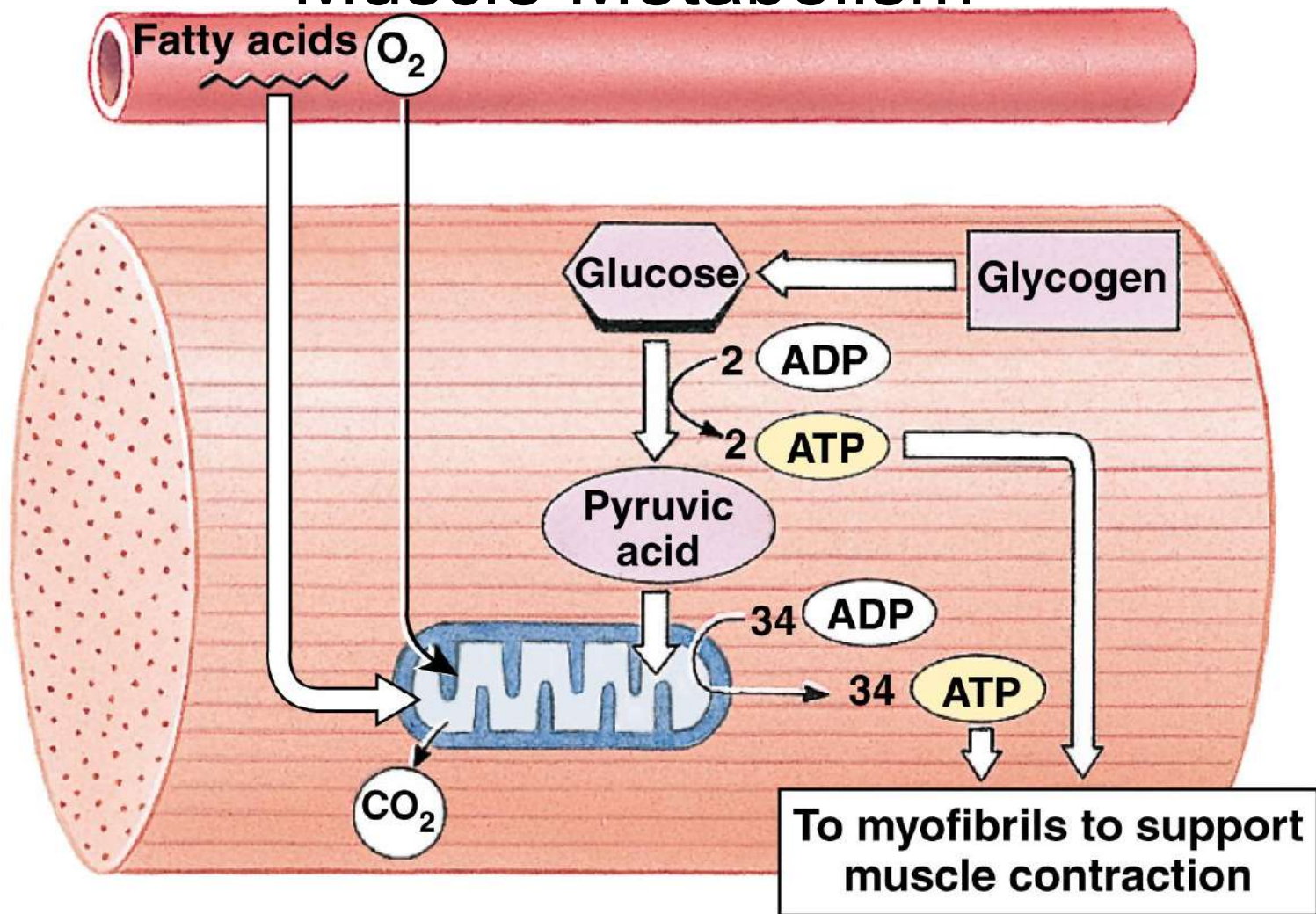


(a) Resting muscle

Figure 7-9(a)

Energetics of Muscle Contraction

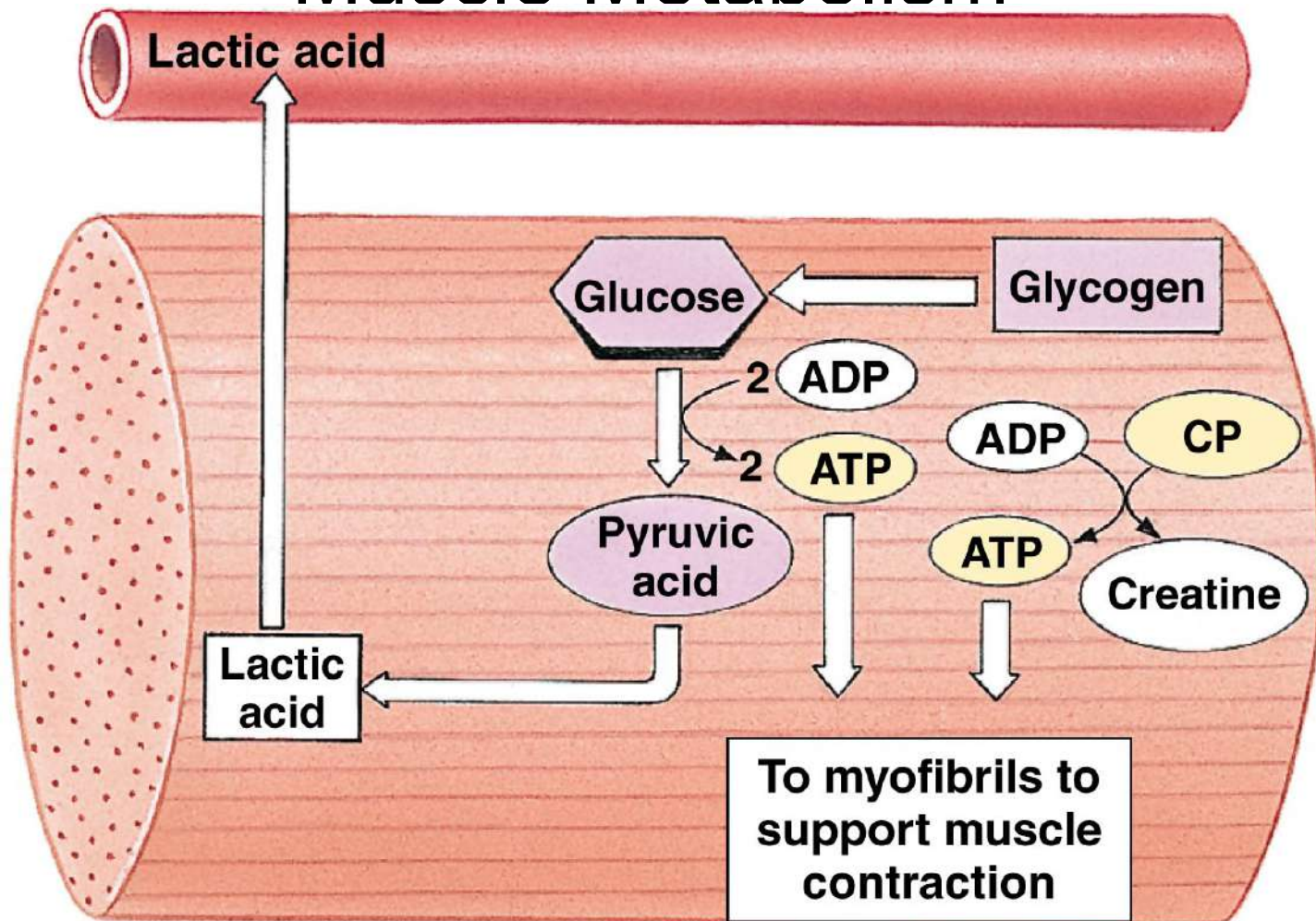
Muscle Metabolism



(b) Moderate activity

Energetics of Muscle Contraction

Muscle Metabolism



(c) Peak activity

Energetics of Muscle Contraction

Muscle Fatigue—When a muscle loses ability to contract due to a low pH (*lactic acid* buildup), low ATP levels, or other problems

Energetics of Muscle Contraction

Key Note

Skeletal muscles at rest metabolize fatty acids and store glycogen. During light activity, muscles can generate ATP through the aerobic breakdown of carbohydrates, lipids, or amino acids. At peak levels of activity, most of the energy is provided by anaerobic reactions that generate lactic acid.

Muscle Performance

Physical Conditioning

Hypertrophy

Increase in muscle bulk. Can result from anaerobic training.

Muscle Performance

Key Note

What you don't use, you lose. When motor units are inactive for days or weeks, muscle fibers break down their contractile proteins and grow smaller and weaker. If inactive for long periods, muscle fibers may be replaced by fibrous tissue.

Cardiac and Smooth Muscle

Cardiac Muscle Tissue

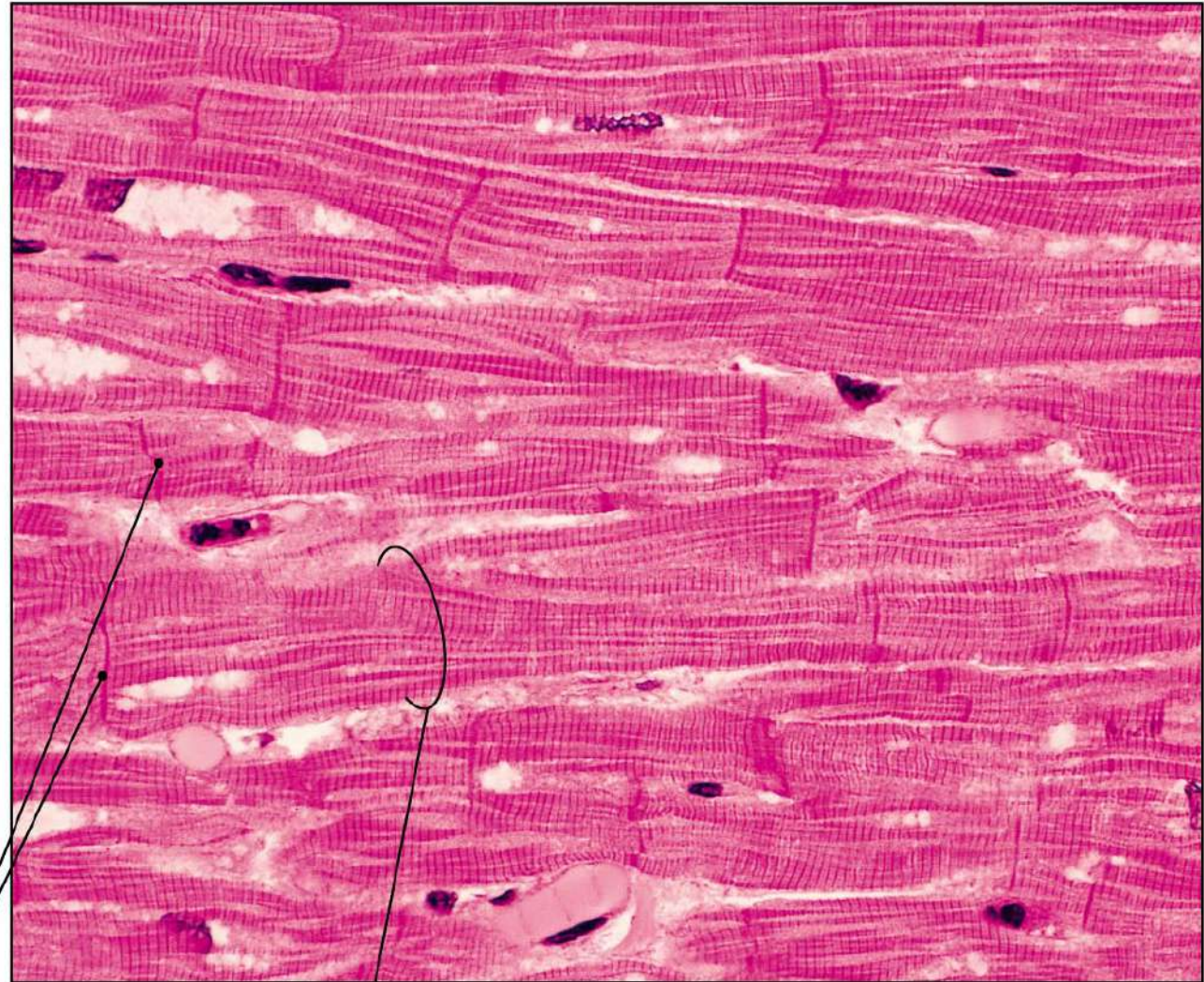


Figure 7-10(a)

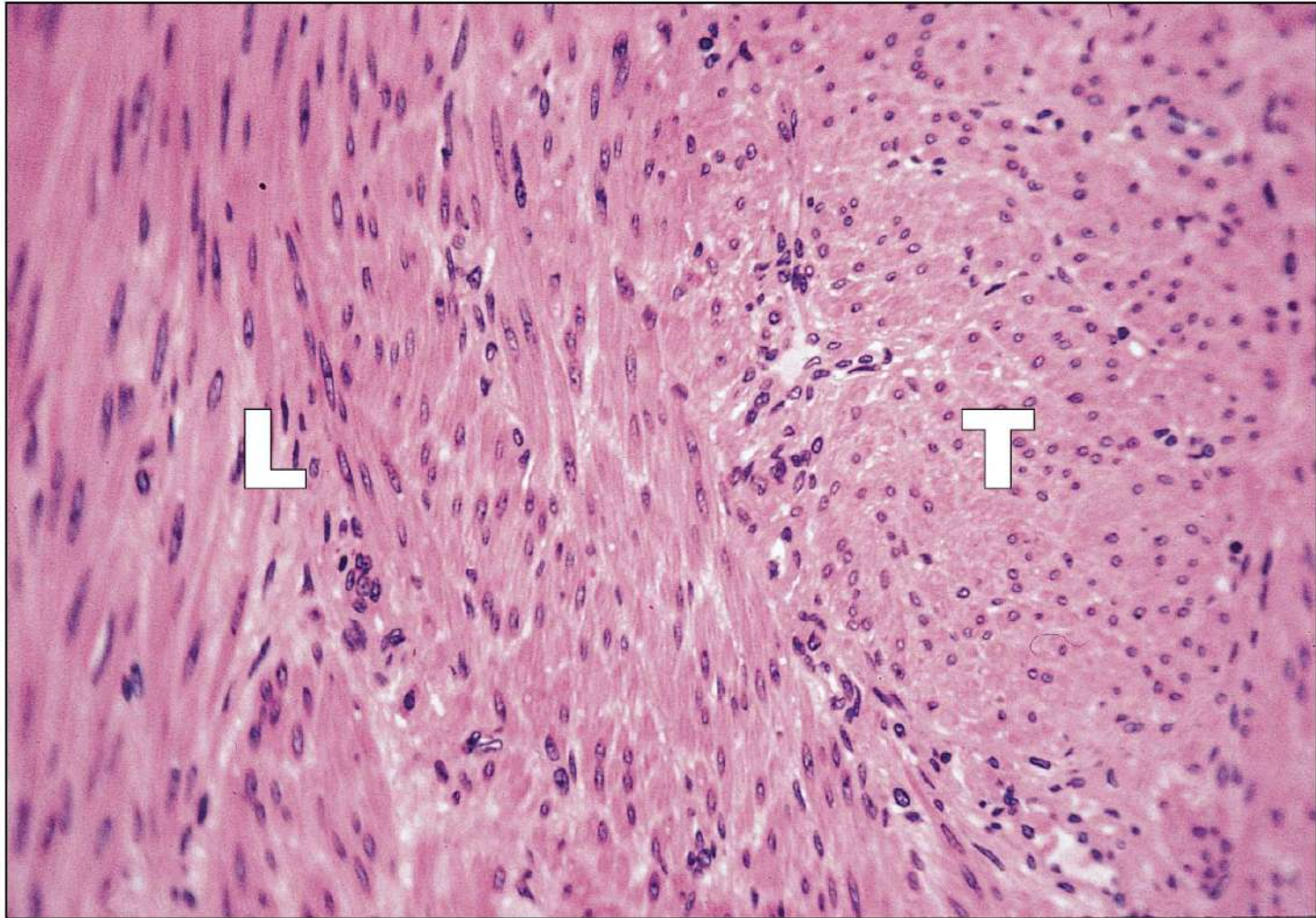
**Intercalated
discs**

**Cardiac
muscle cell**

(a)

Cardiac and Smooth Muscle

Smooth Muscle Tissue



(b)

Cardiac and Smooth Muscle

TABLE 7 - 2 *A Comparison of Skeletal, Cardiac, and Smooth Muscle Tissues*

PROPERTY	SKELETAL MUSCLE FIBER	CARDIAC MUSCLE CELL	SMOOTH MUSCLE CELL
Fiber dimensions (diameter × length)	100 μm × up to 60 cm	10–20 μm × 50–100 μm	5–10 μm × 30–200 μm
Nuclei	Multiple, near sarcolemma	Usually single, centrally located	Single, centrally located
Filament organization	In sarcomeres along myofibrils	In sarcomeres along myofibrils	Scattered throughout sarcoplasm
Control mechanism	Neural, at single neuromuscular junction	Automaticity (pacemaker cells)	Automaticity (pacesetter cells), neural or hormonal control
Ca²⁺ source	Release from sarcoplasmic reticulum	Extracellular fluid and release from sarcoplasmic reticulum	Extracellular fluid and release from sarcoplasmic reticulum
Contraction	Rapid onset; tetanus can occur; rapid fatigue	Slower onset; tetanus cannot occur; resistant to fatigue	Slow onset; tetanus can occur; resistant to fatigue
Energy source	Aerobic metabolism at moderate levels of activity; glycolysis (anaerobic) during peak activity	Aerobic metabolism, usually lipid or carbohydrate substrates	Primarily aerobic metabolism

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Anatomy of the Muscular System

An Overview of the Major Skeletal Muscles

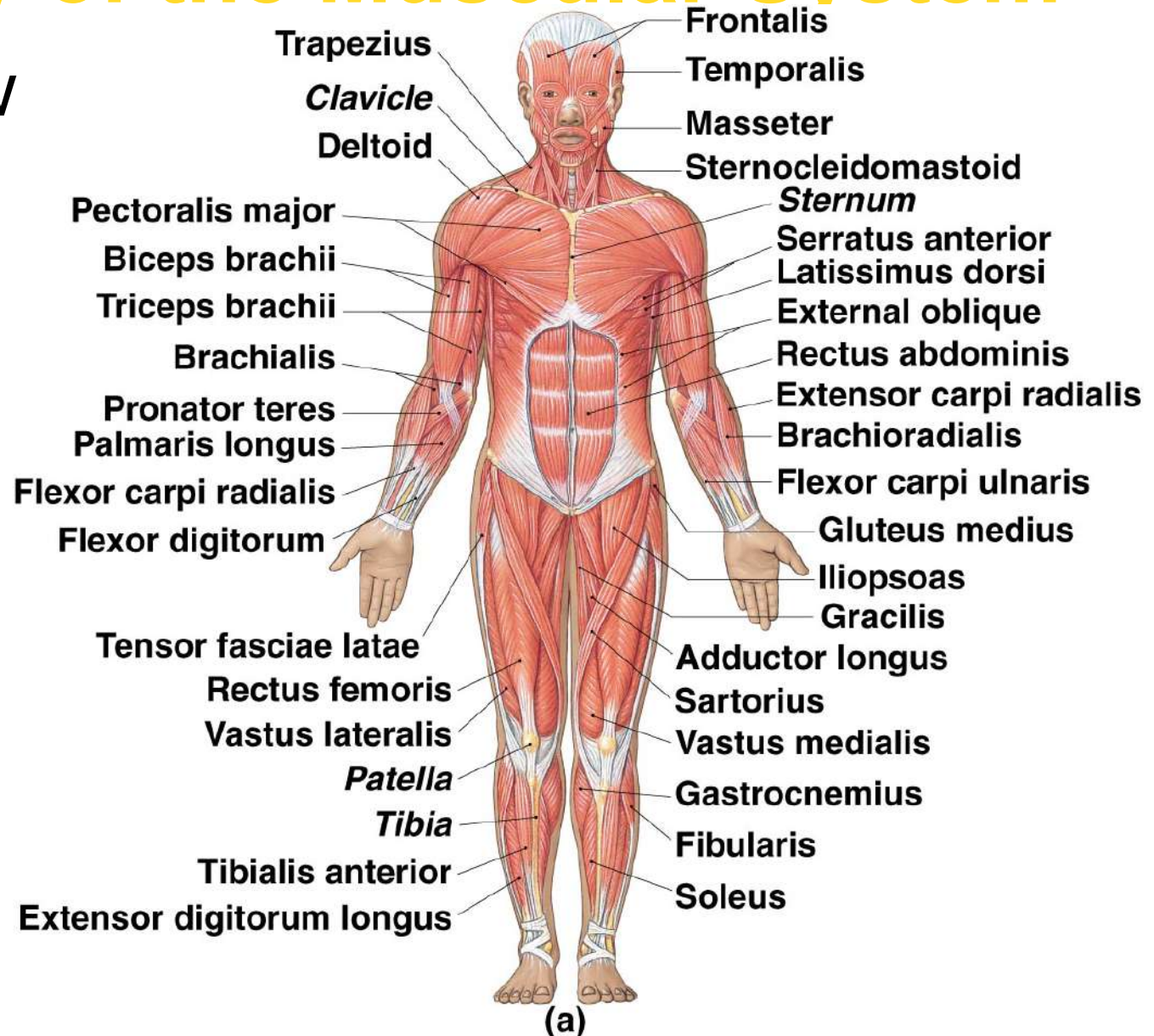


Figure 7-11(a)

Anatomy of the Muscular System

An Overview of the Major Skeletal Muscles

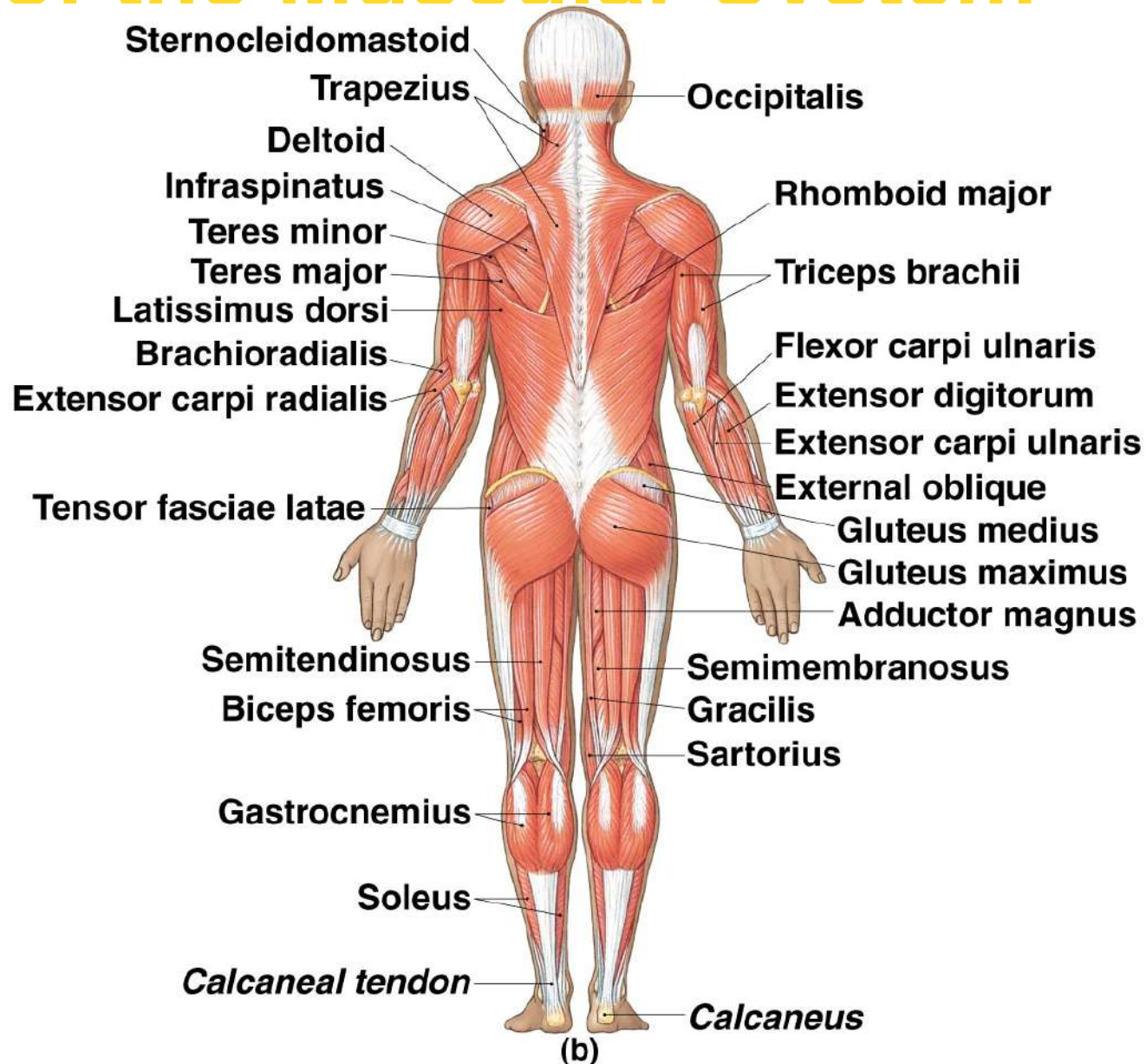


Figure 7-11(b)

Anatomy of the Muscular System

What Are the Origins, Insertions, and Actions?

Origin

Muscle attachment that remains fixed

Insertion

Muscle attachment that moves

Action

What joint movement a muscle produces

Anatomy of the Muscular System

What are the Primary Action Categories?

Prime mover (agonist)

Main muscle in an action

Synergist

Helper muscle in an action

Antagonist

Opposed muscle to an action

Anatomy of the Muscular System

What are the Selected Muscles
of the Head?

Frontalis

Orbicularis oris

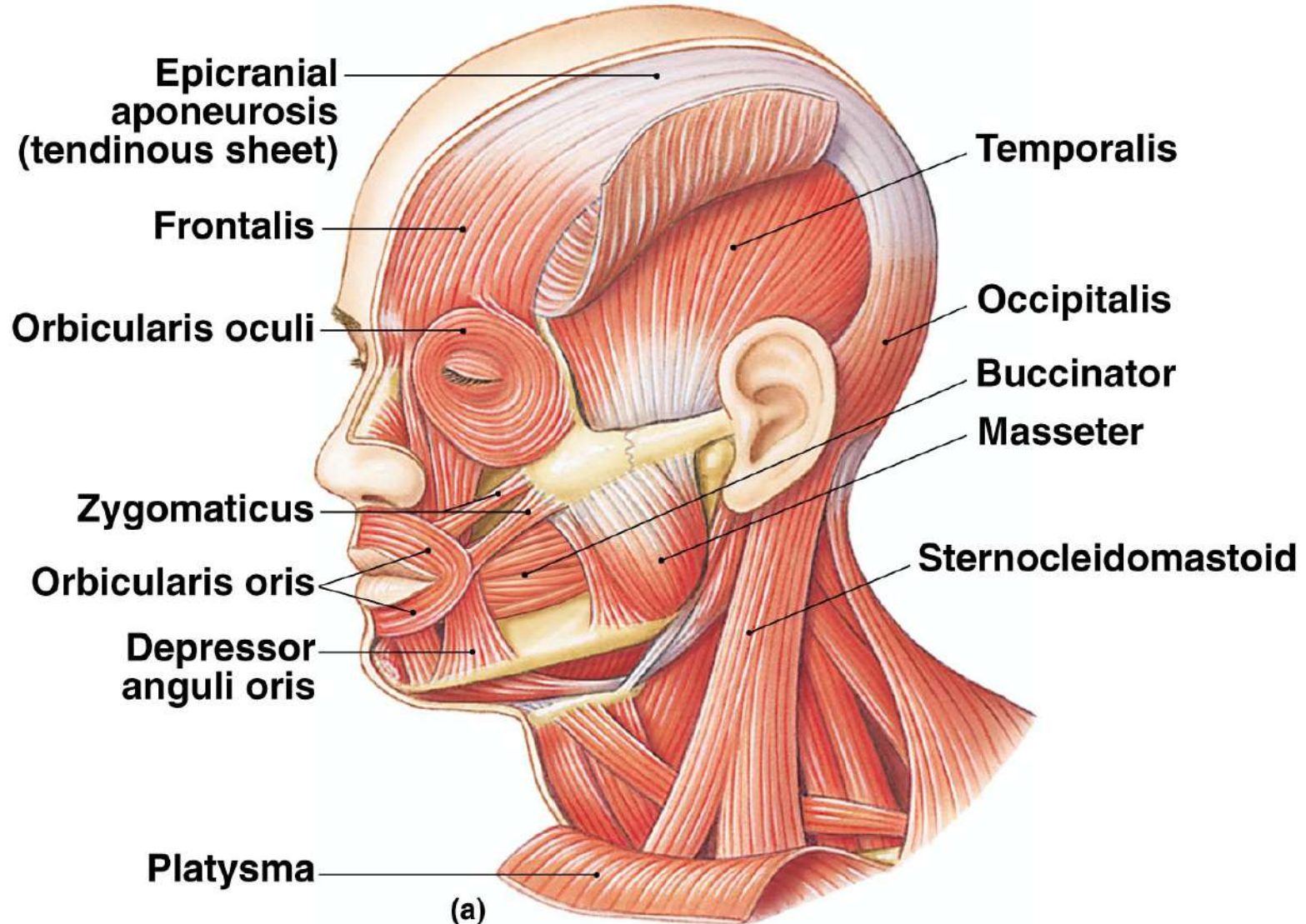
Buccinator

Masseter

Temporalis

Anatomy of the Muscular System

Muscles of the Head and Neck



Anatomy of the Muscular System

Muscles of the Head and Neck

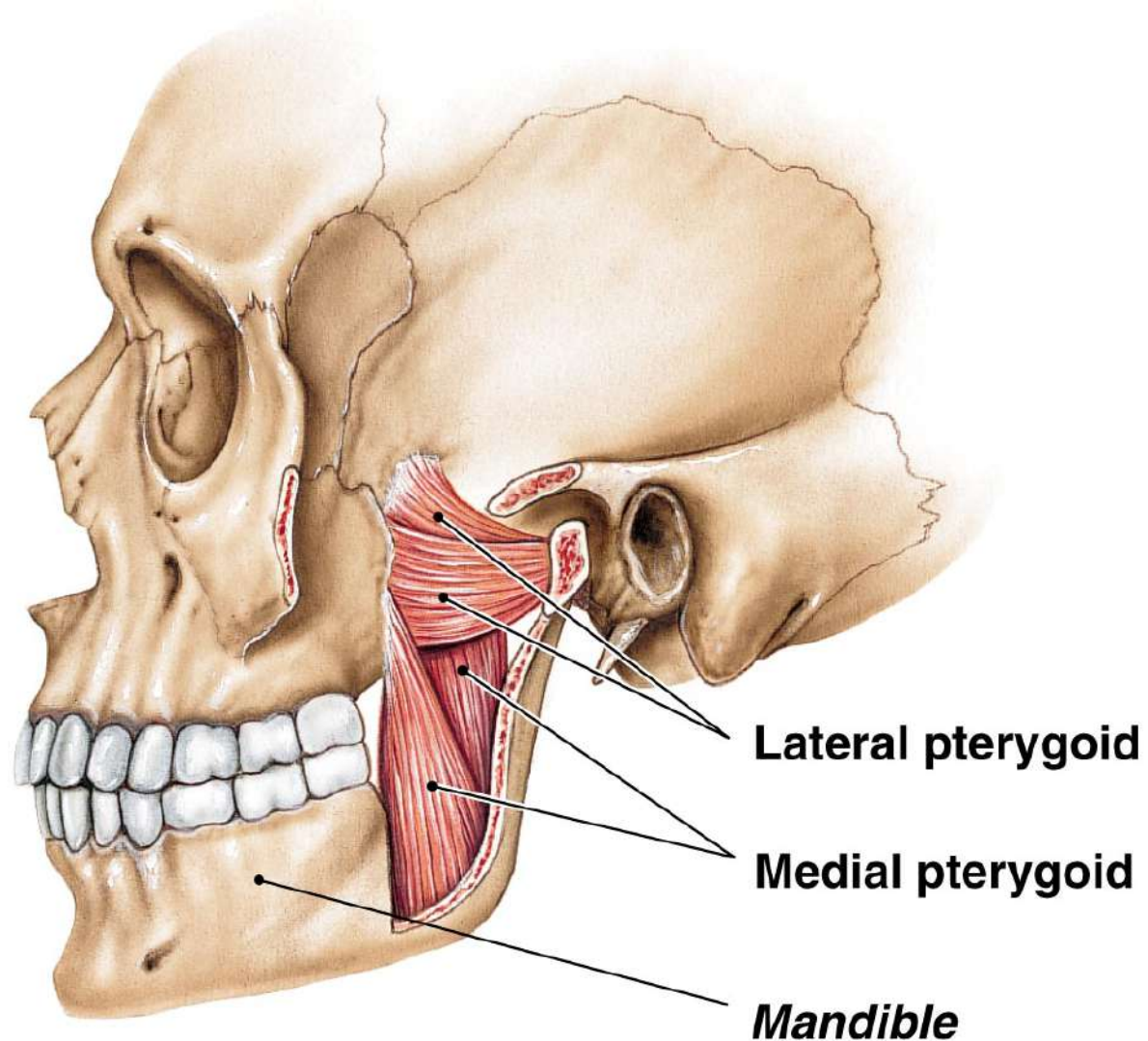
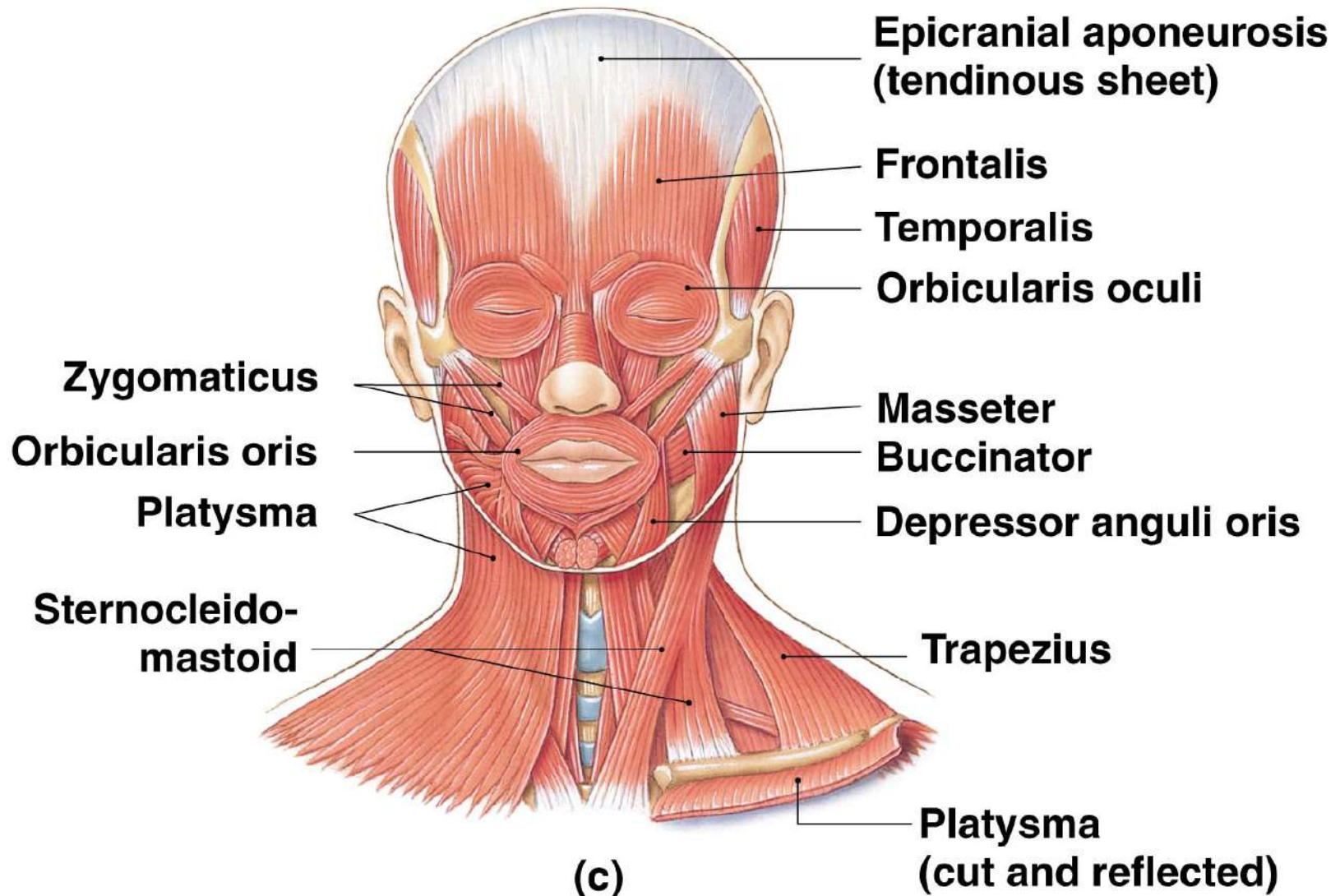


Figure 7-12(b)

(b) Lateral view, pterygoid muscles exposed

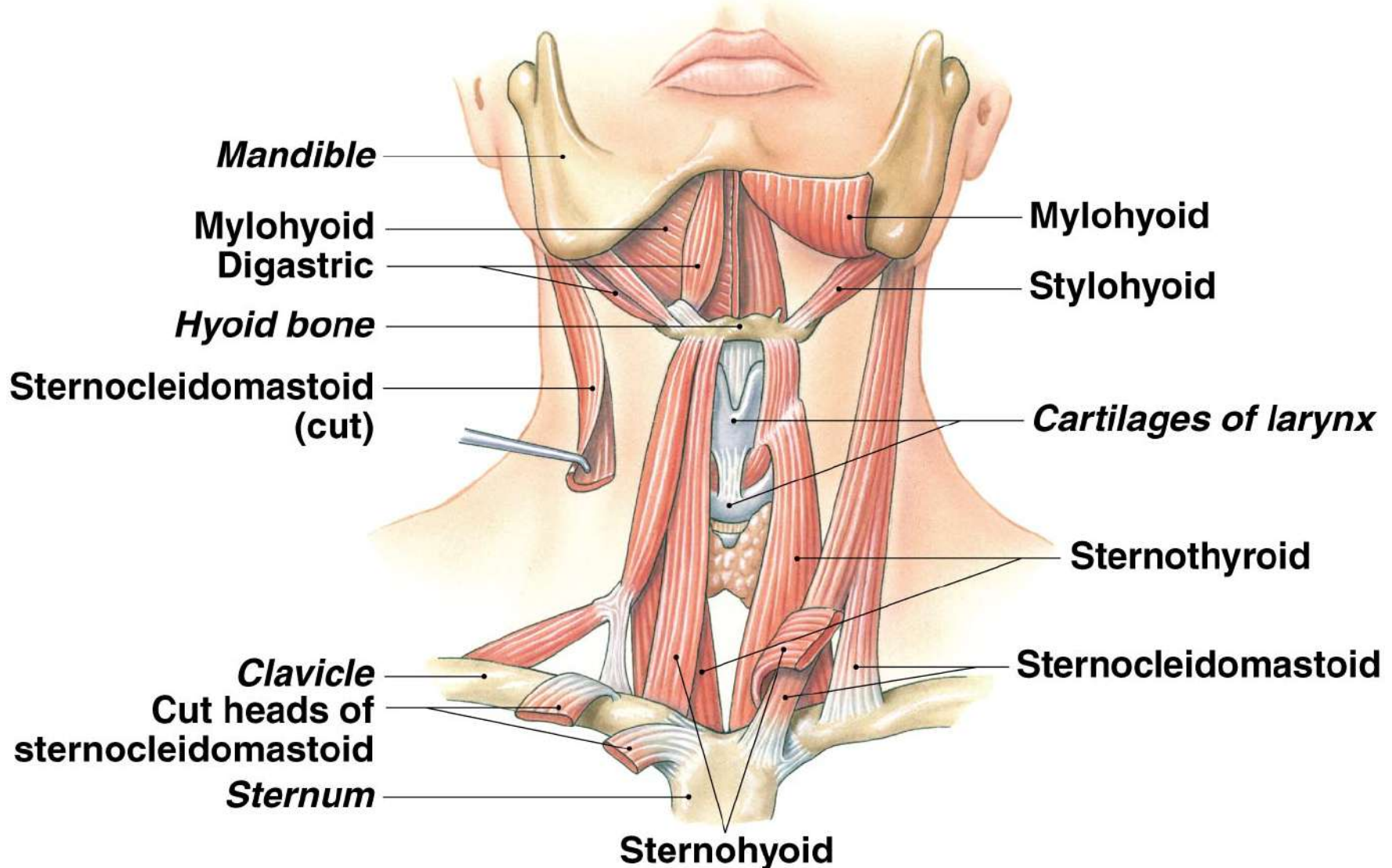
Anatomy of the Muscular System

Muscles of the Head and Neck



Anatomy of the Muscular System

Muscles of the Anterior Neck



Anatomy of the Muscular System

Muscles of the Spine

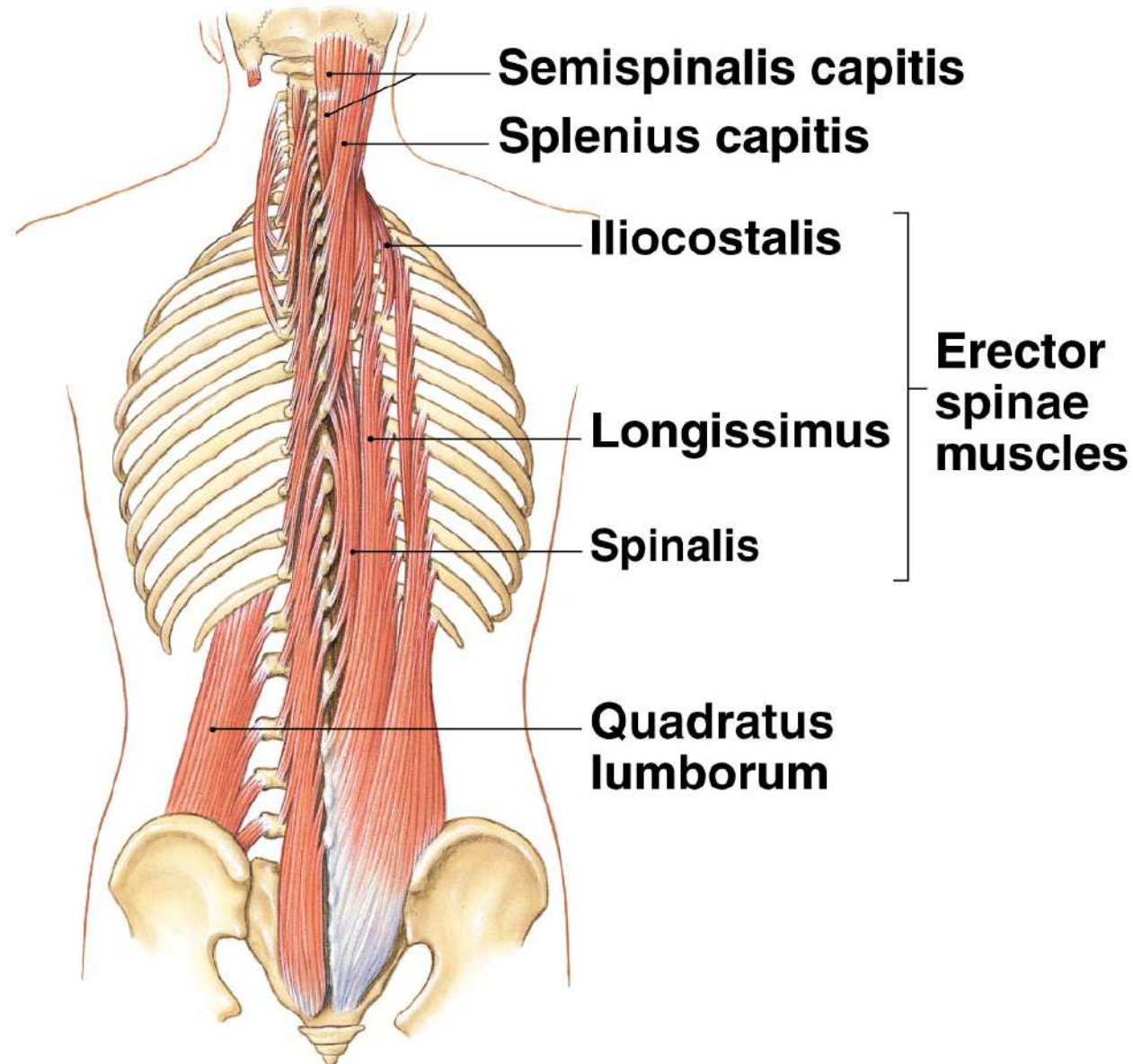


Figure 7-14

Anatomy of the Muscular System

What are the Axial Muscles
of the Trunk?

Abdominal region

Rectus abdominis

External oblique

Internal oblique

Transversus abdominis

Anatomy of the Muscular System

Oblique and Rectus Muscles and the Diaphragm

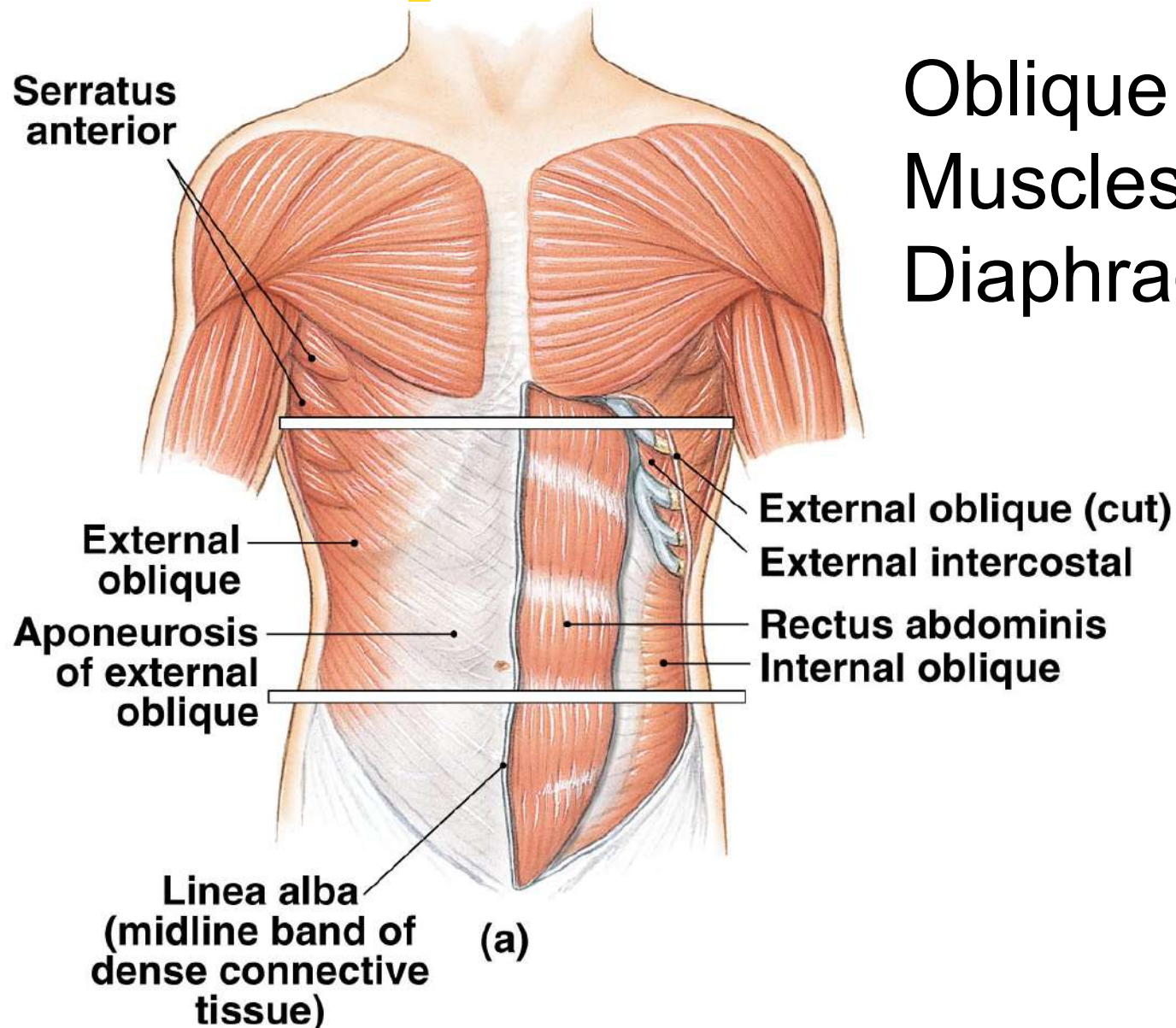
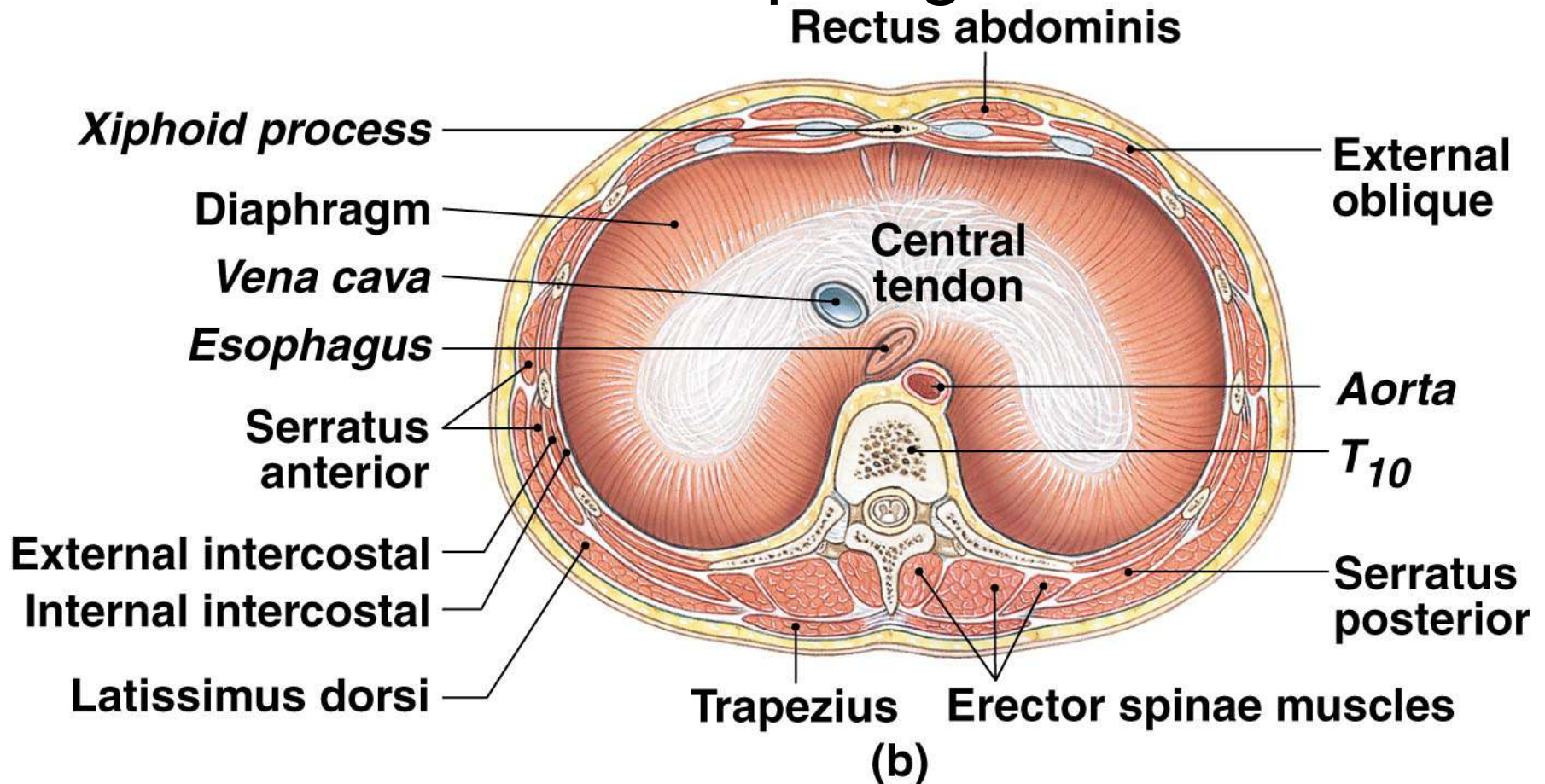


Figure 7-15(a)

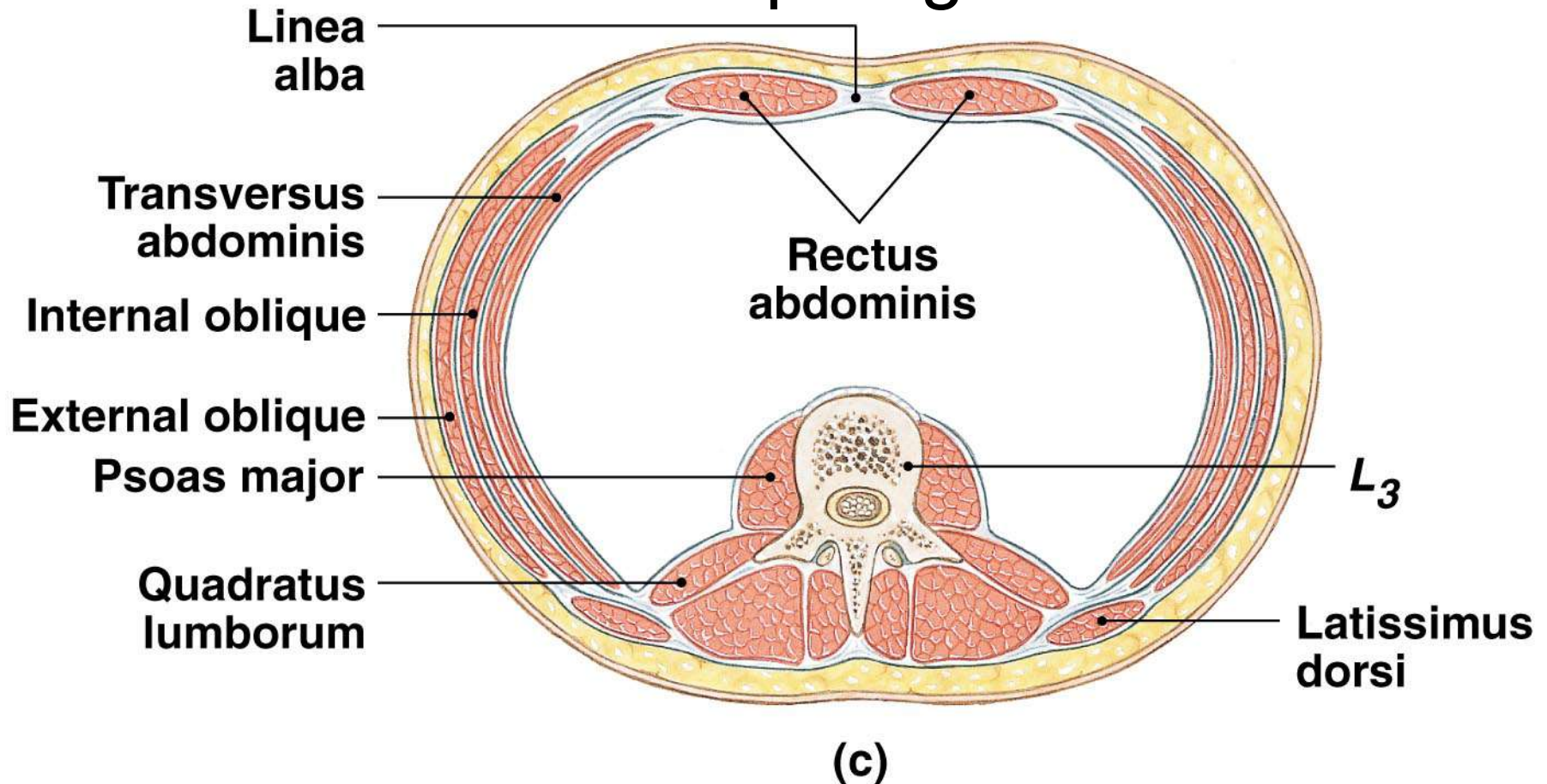
Anatomy of the Muscular System

Oblique and Rectus Muscles and the Diaphragm



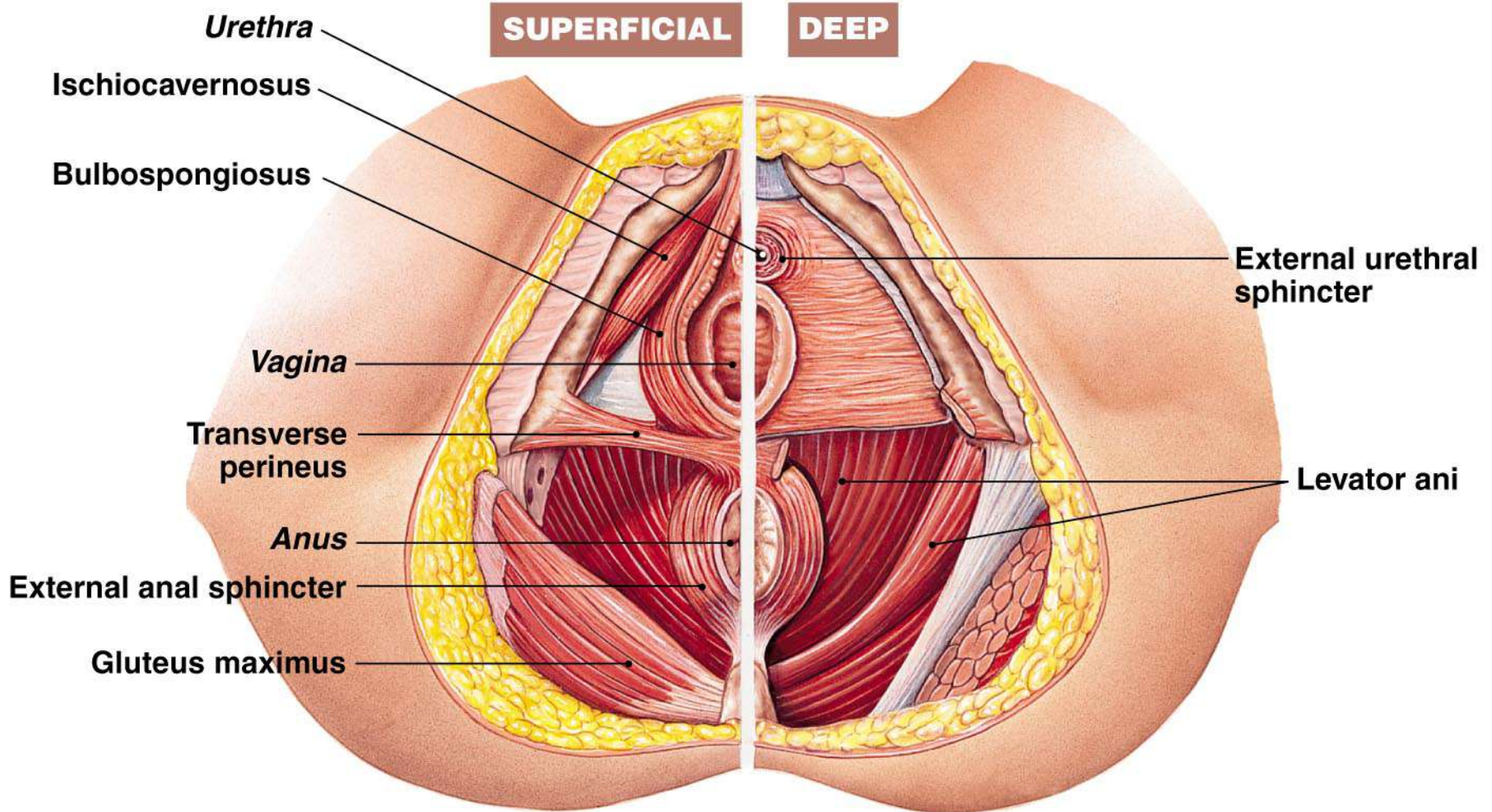
Anatomy of the Muscular System

Oblique and Rectus Muscles and the Diaphragm



Anatomy of the Muscular System

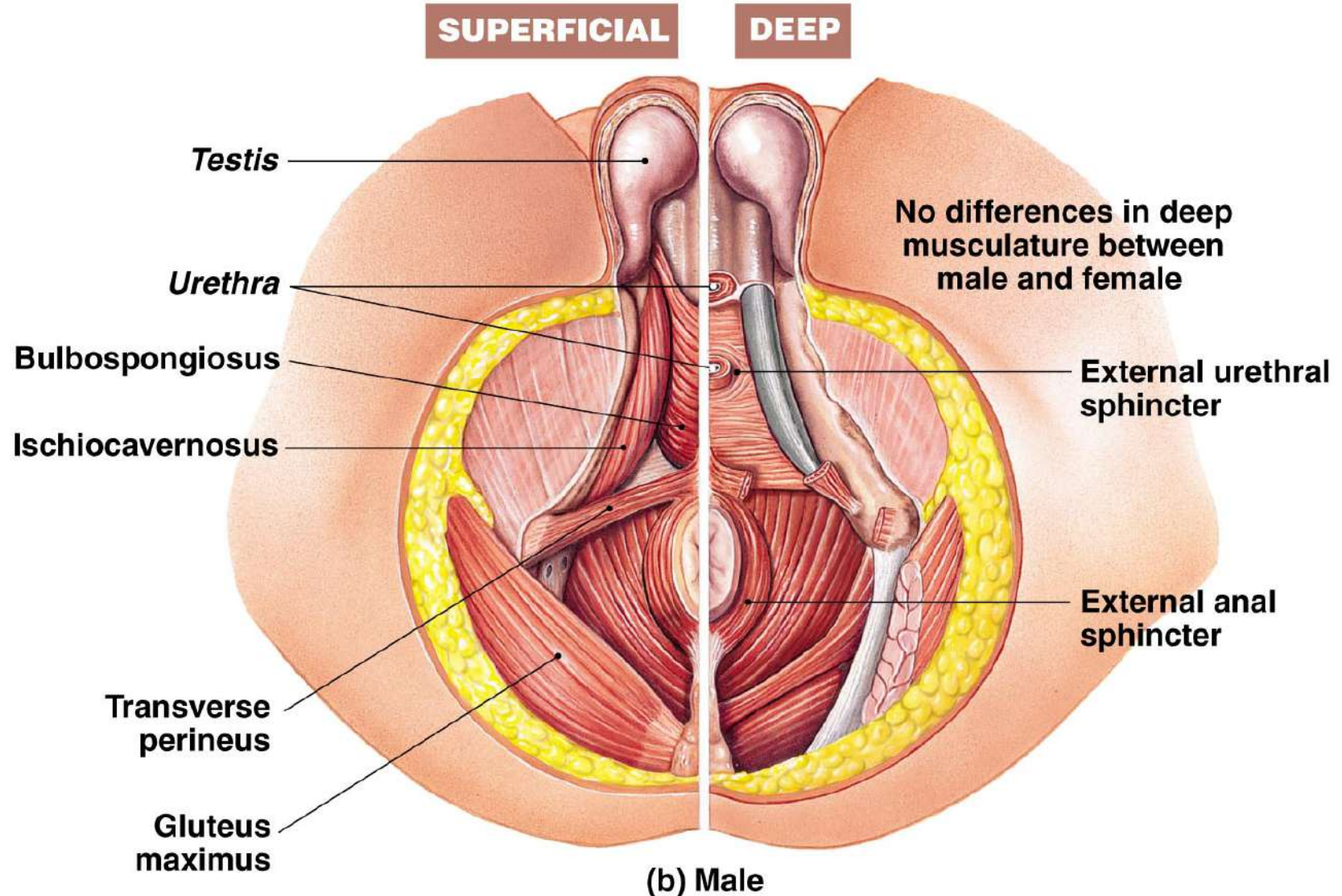
Muscles of the Perineum—Female



(a) Female

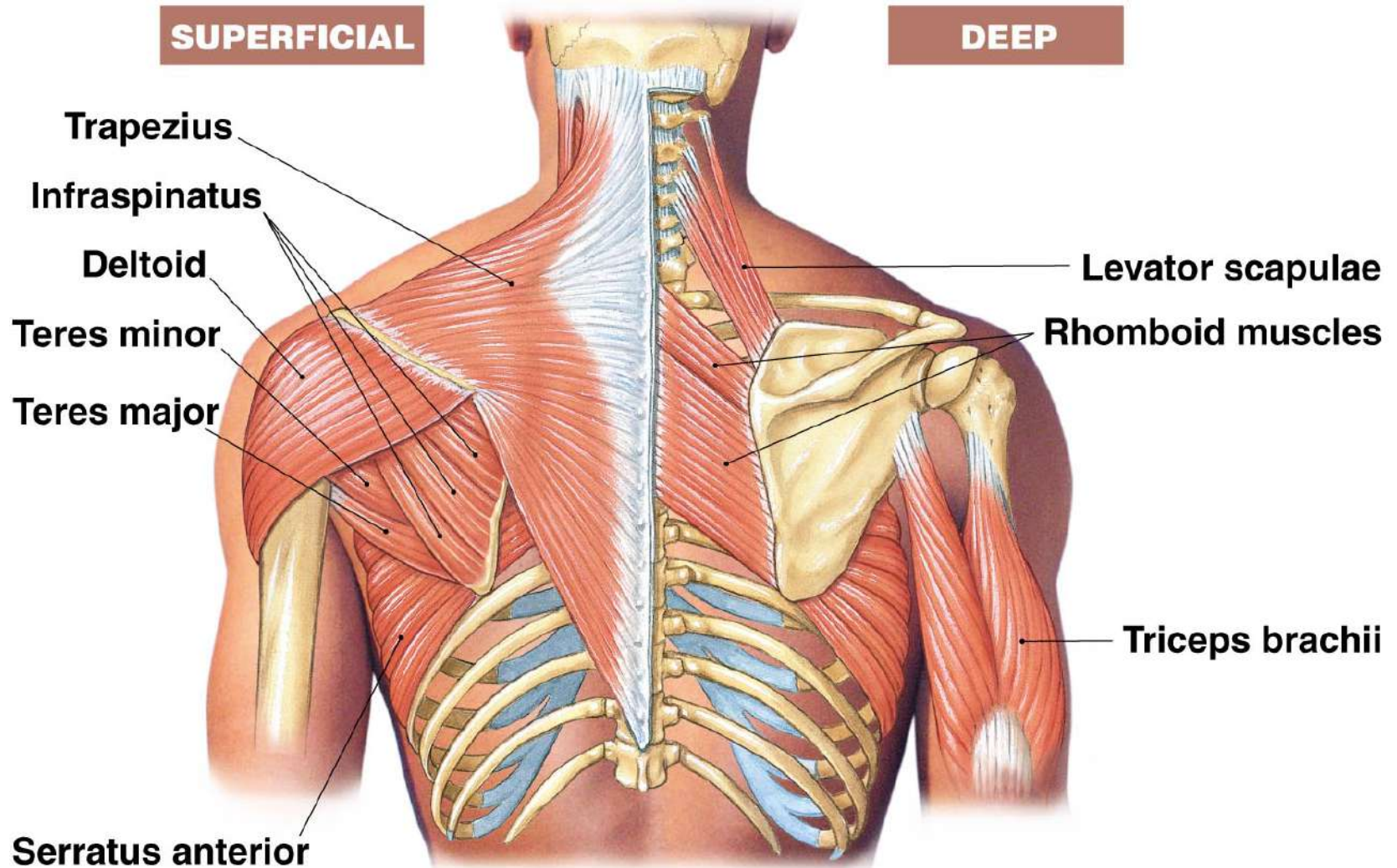
Anatomy of the Muscular System

Muscles of the Perineum—Male



Anatomy of the Muscular System

Muscles of the Shoulder

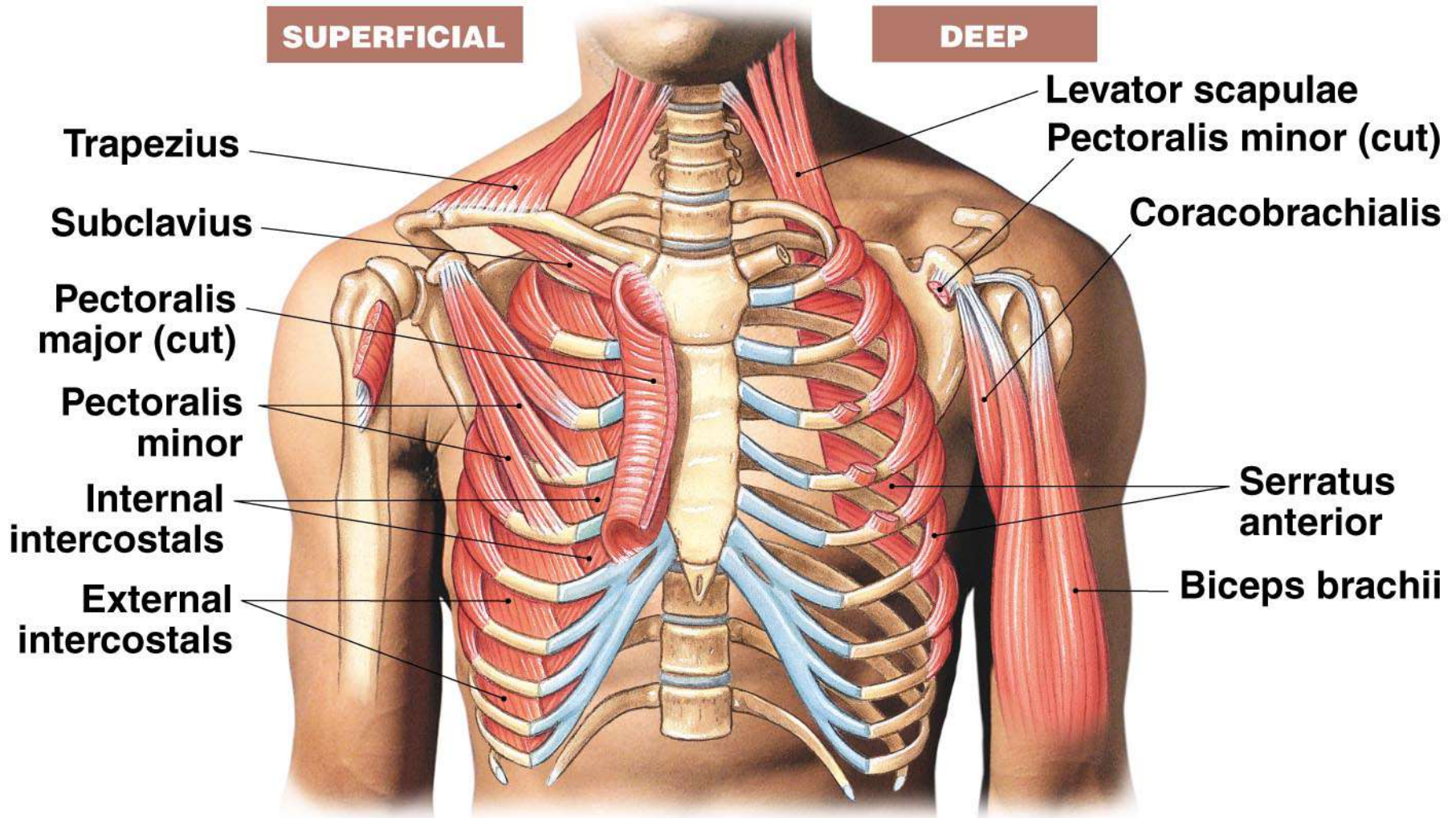


(a) Posterior view

Figure 7-17(a)

Anatomy of the Muscular System

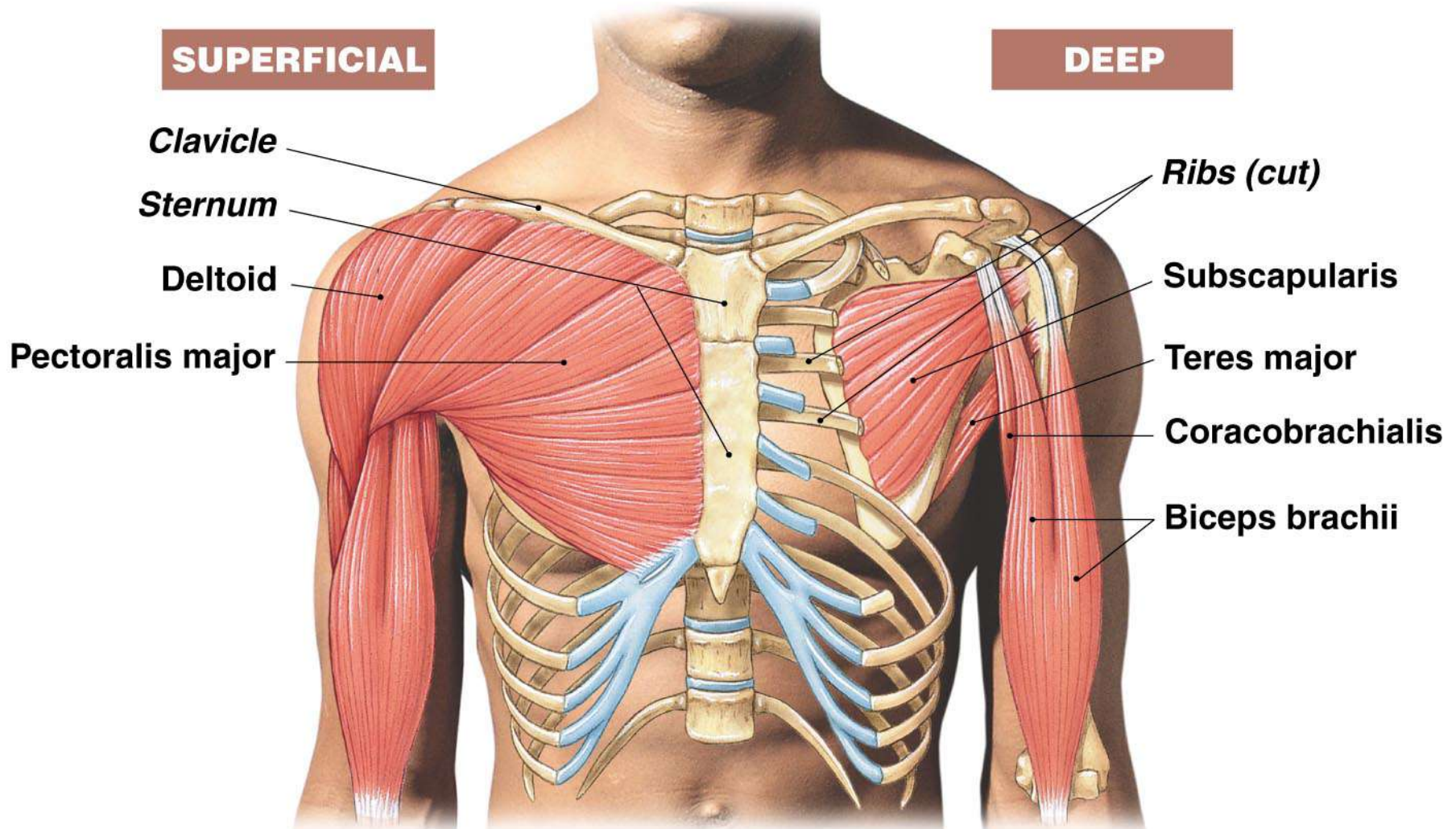
Muscles of the Shoulder



(b) Anterior view

Anatomy of the Muscular System

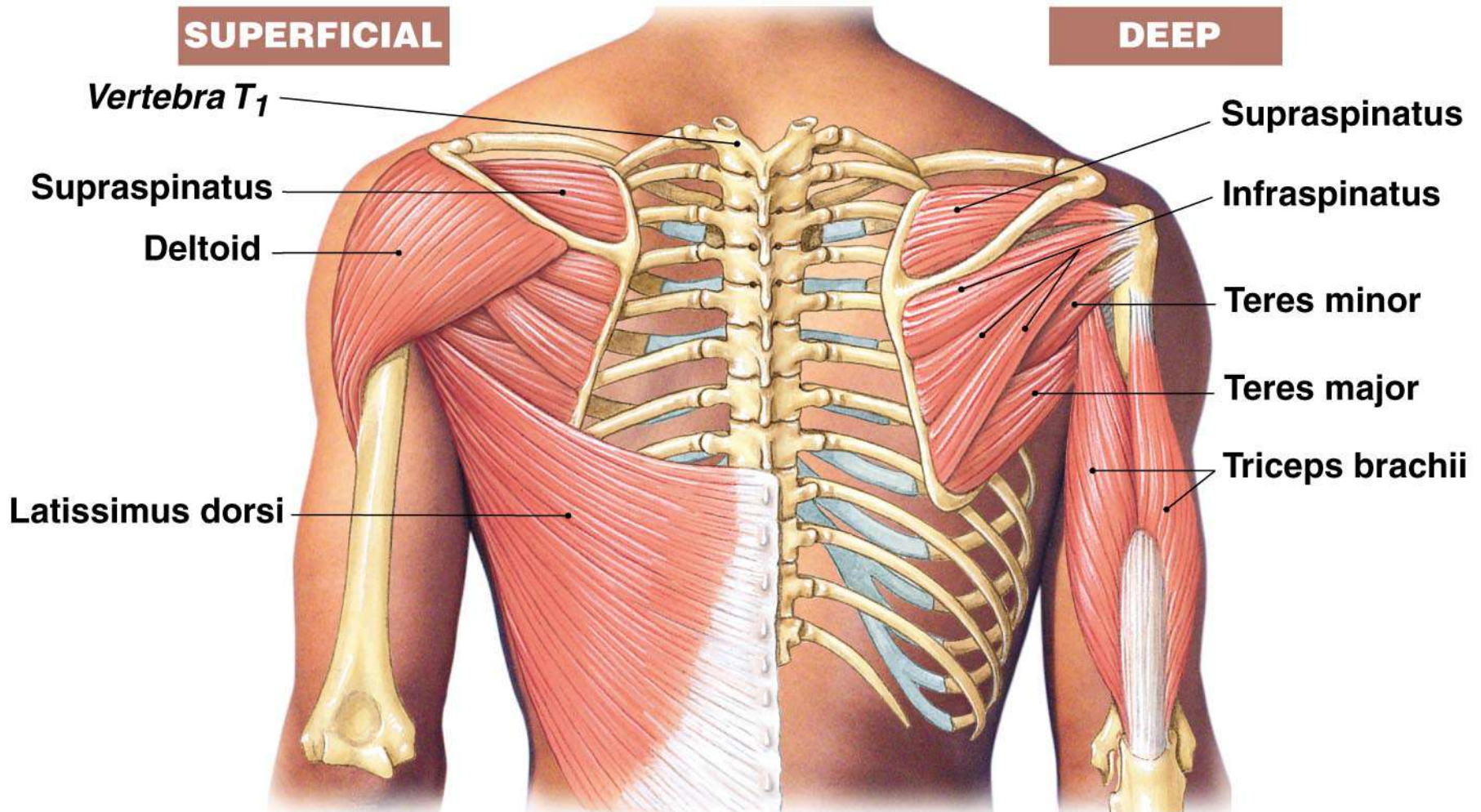
Muscles that Move the Arm



(a) Anterior view

Anatomy of the Muscular System

Muscles that Move the Arm



(b) Posterior view

Anatomy of the Muscular System

Muscles That Move the Forearm and Wrist

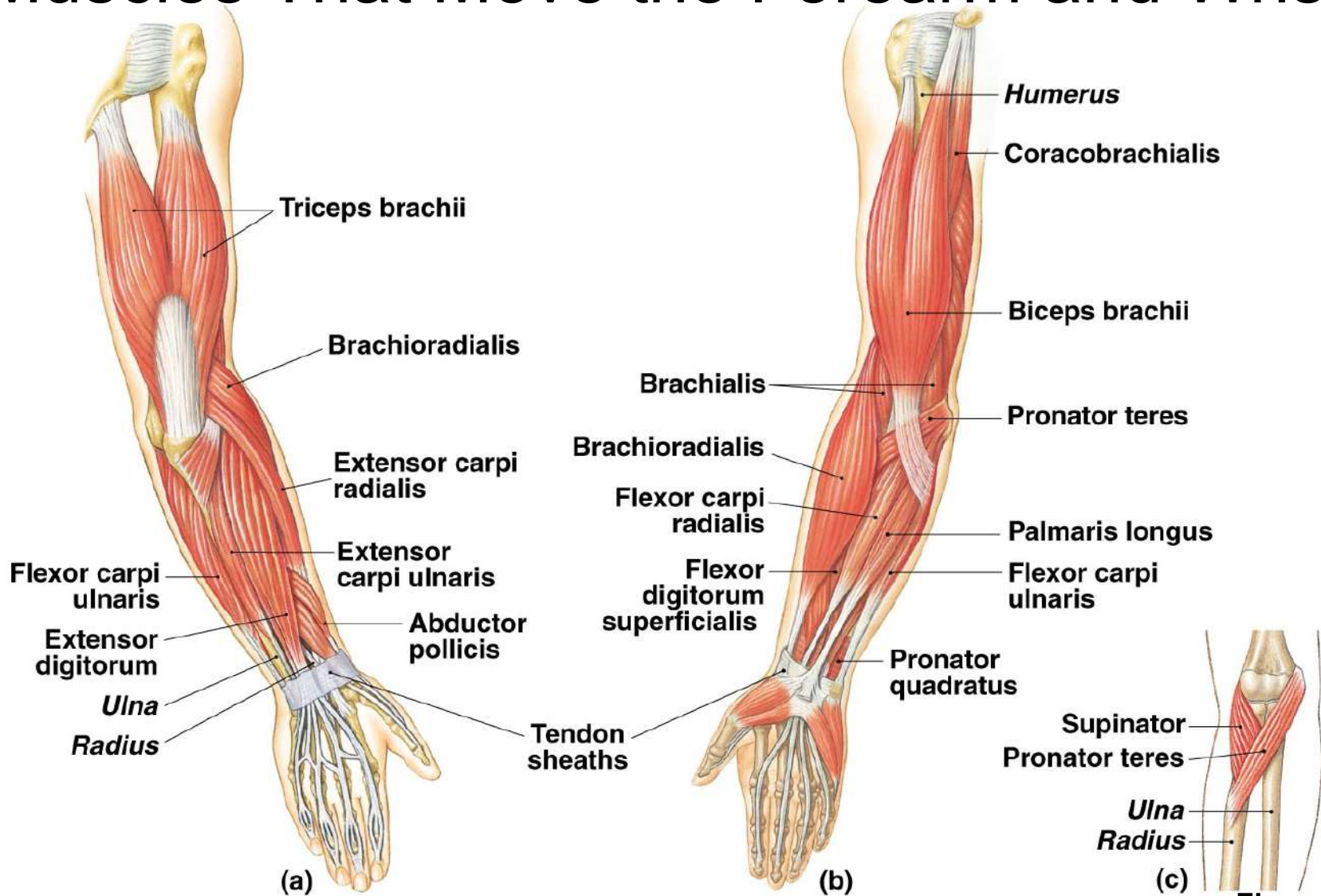
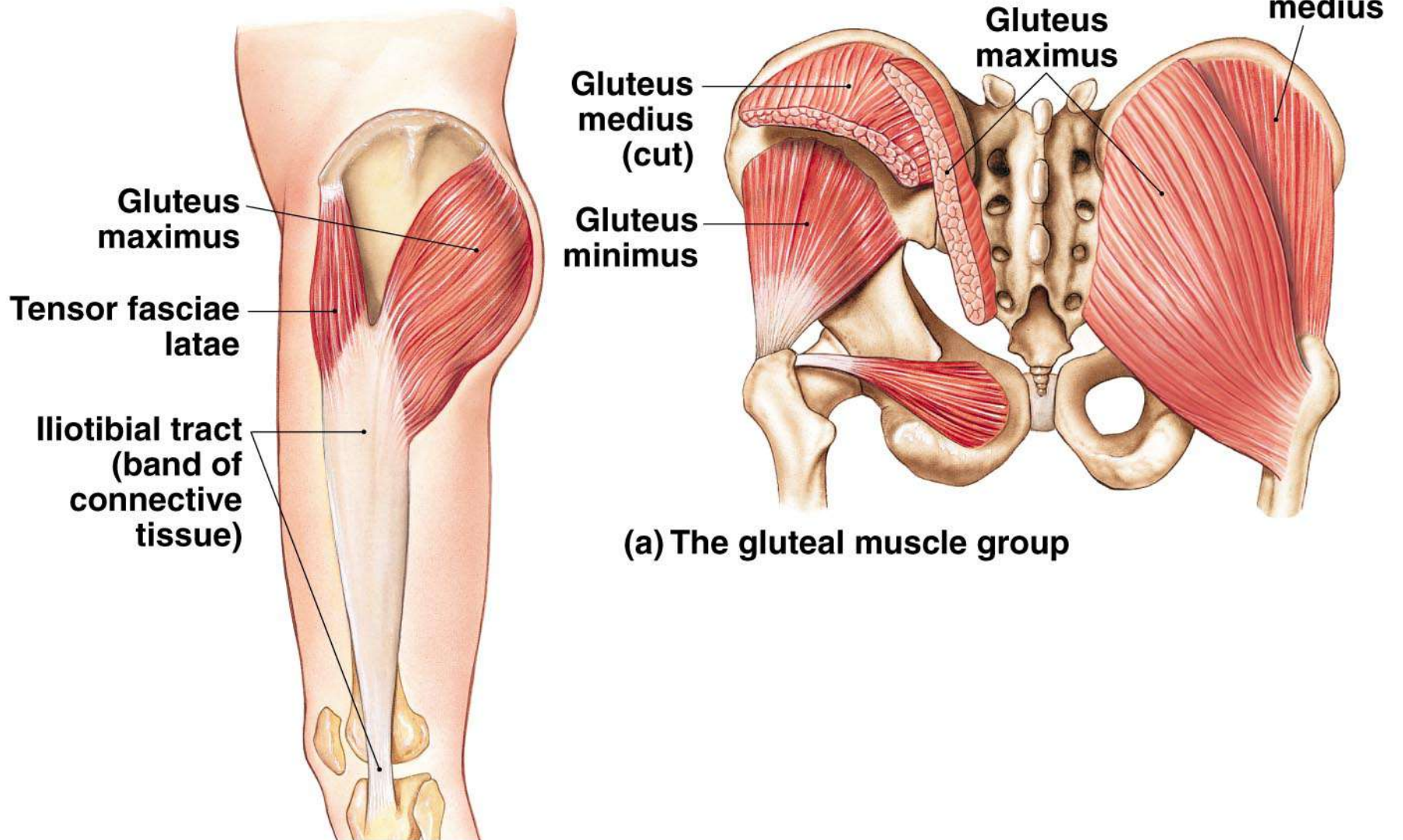


Figure 7-19

Anatomy of the Muscular System

Muscles That Move the Thigh



Anatomy of the Muscular System

Muscles That Move the Thigh

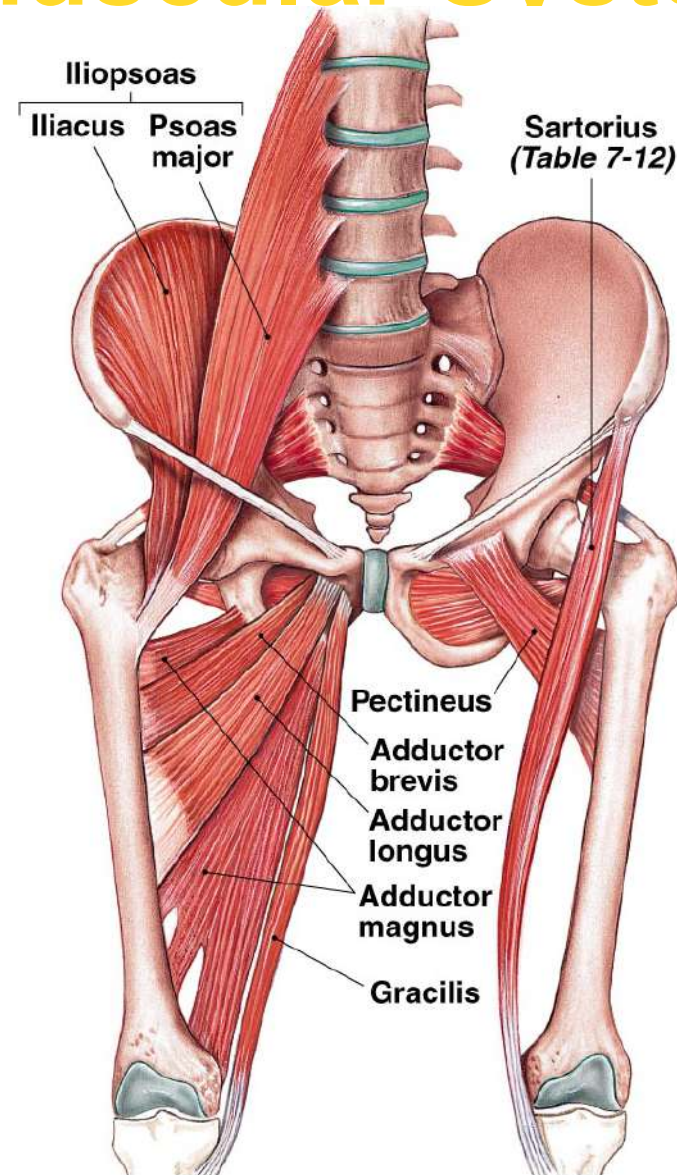


Figure 7-20(b)

(b) The iliopsoas muscle and the adductor group

Anatomy of the Muscular System

Muscles That Move the Leg

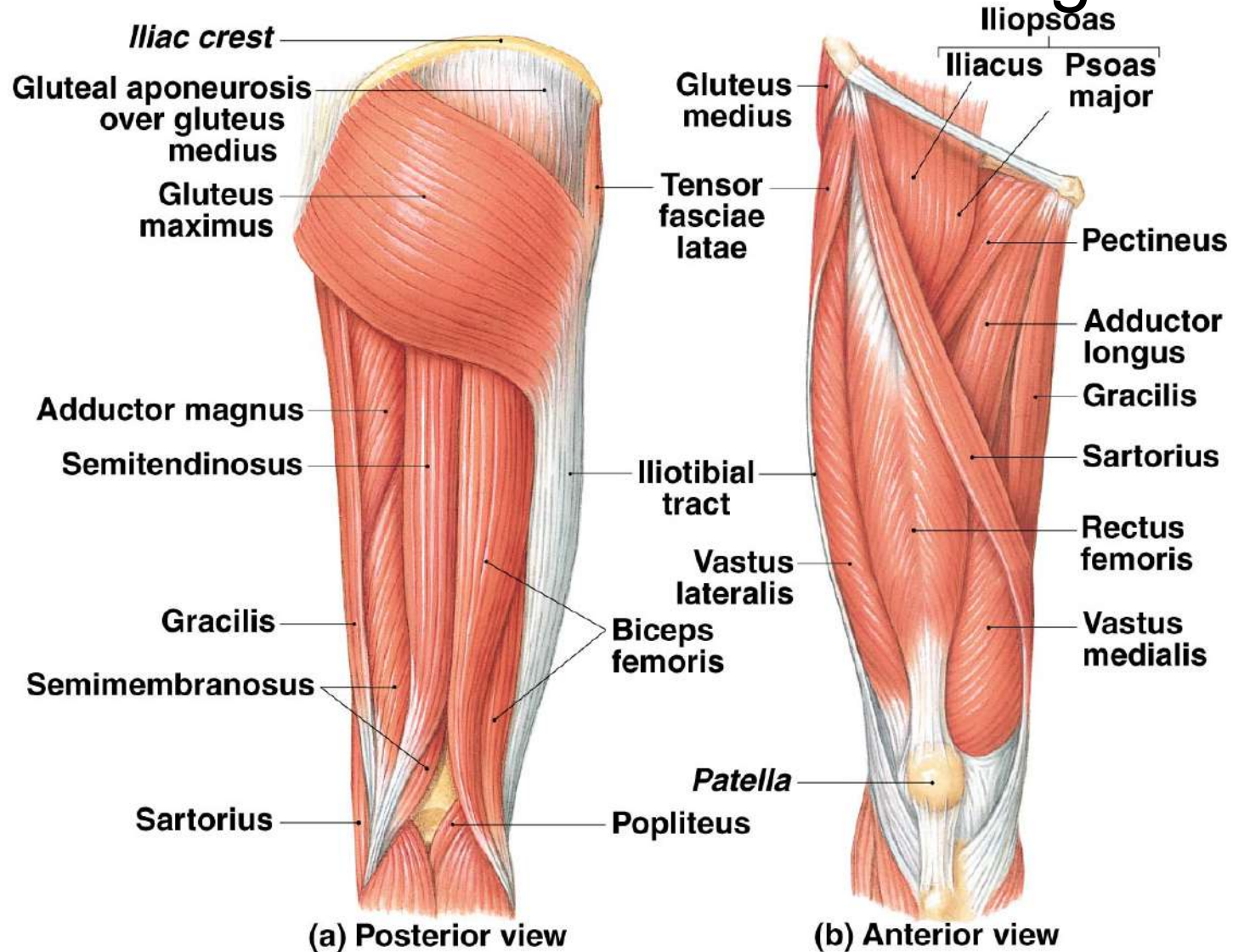
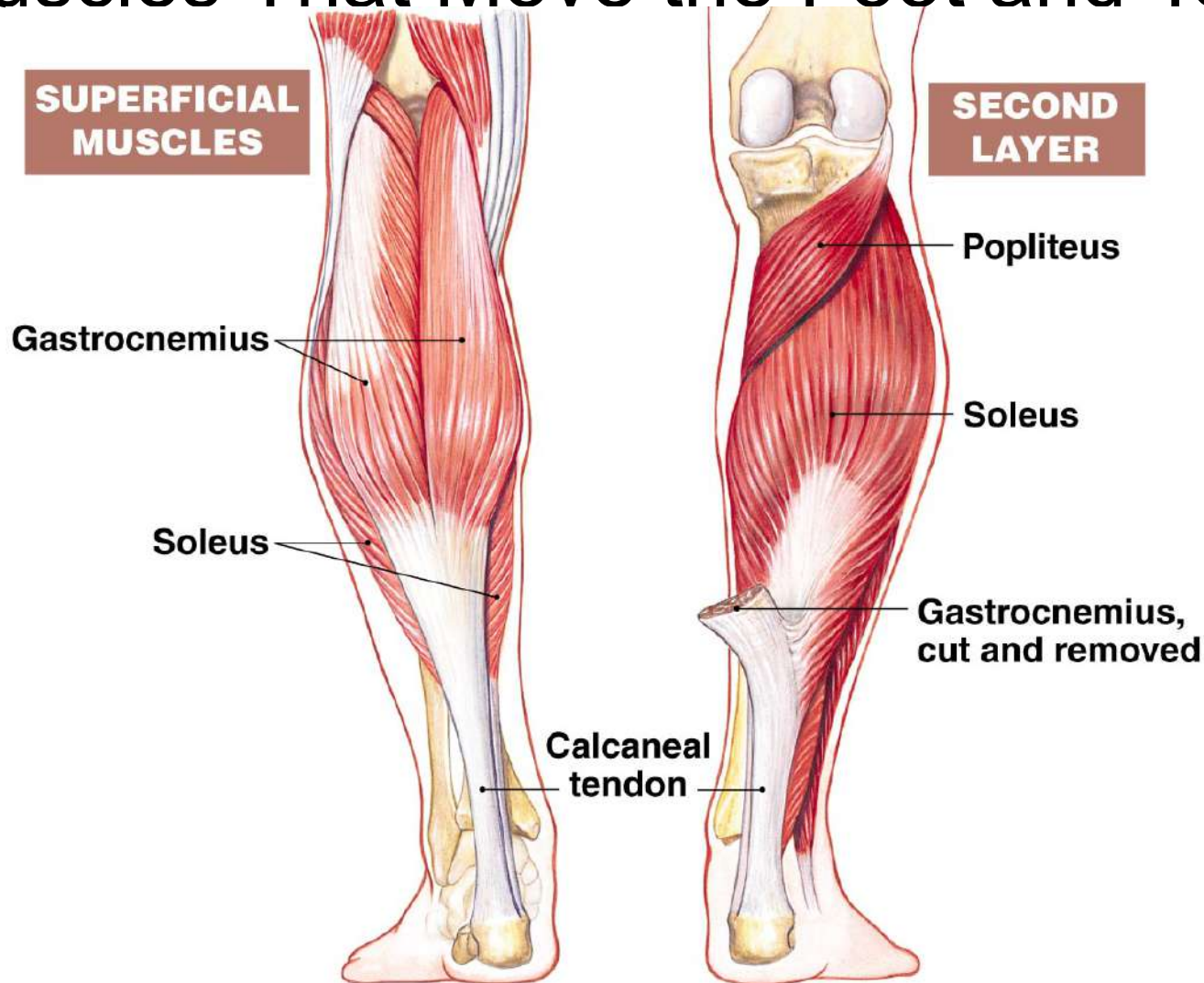


Figure 7-21

Anatomy of the Muscular System

Muscles That Move the Foot and Toes



(a) Posterior view

Anatomy of the Muscular System

Muscles That Move the Foot and Toes

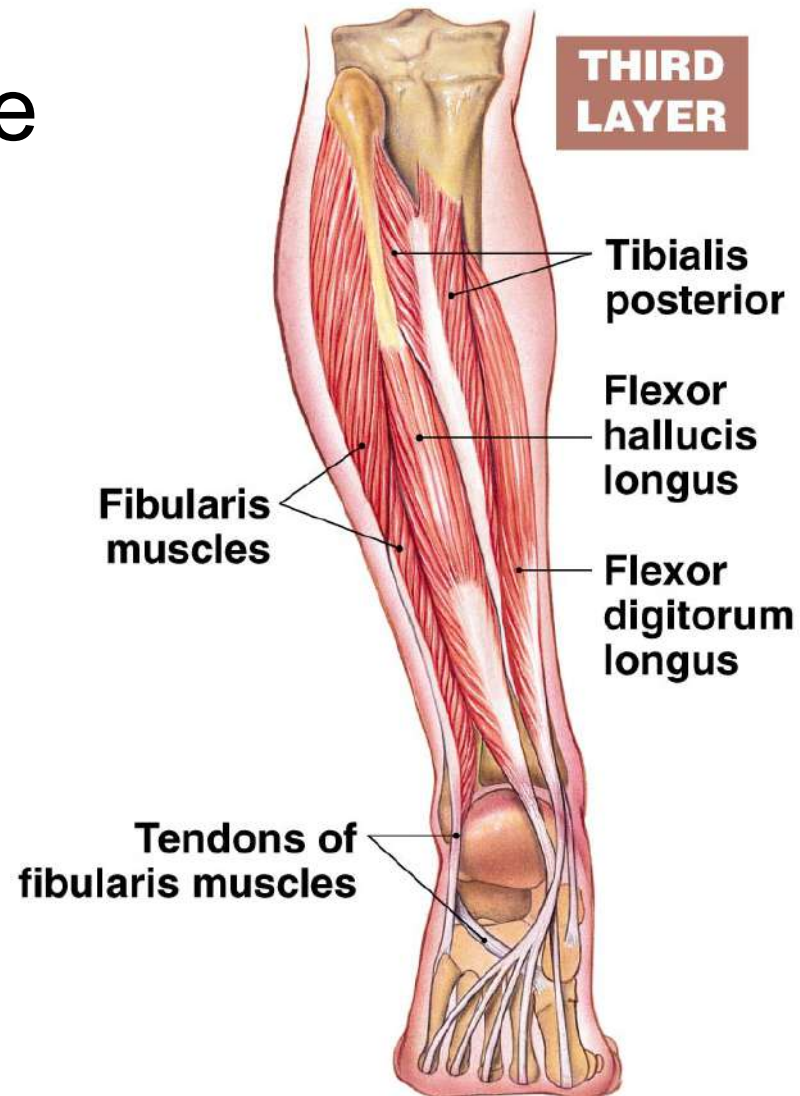


Figure 7-22(b)

(b) Posterior view, left leg

Anatomy of the Muscular System

Muscles That Move the Foot and Toes

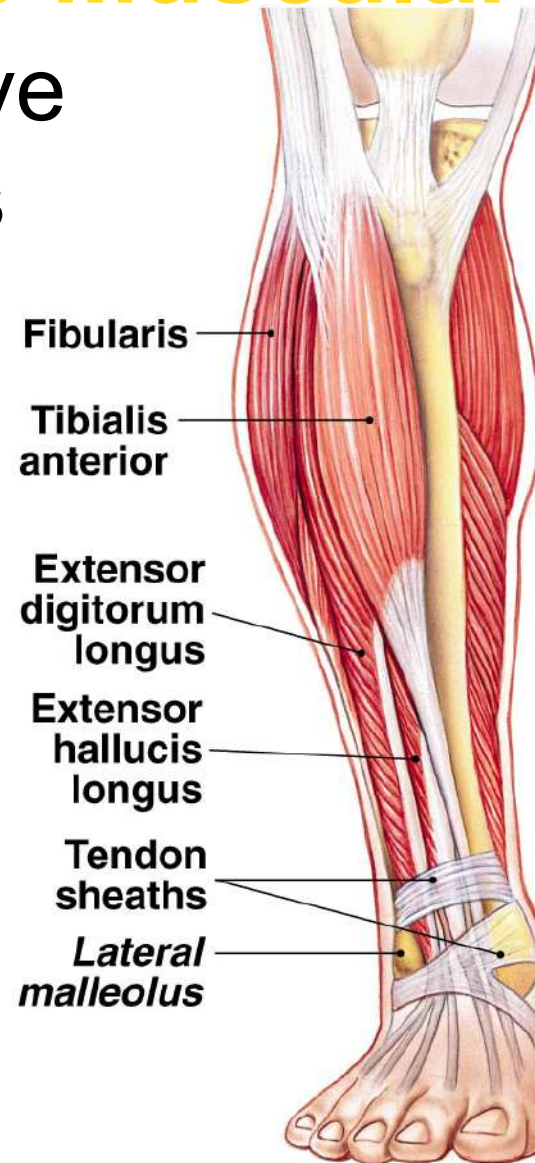


Figure 7-22(c)

(c) Anterior view, right leg

Anatomy of the Muscular System

Muscles That Move the Foot and Toes

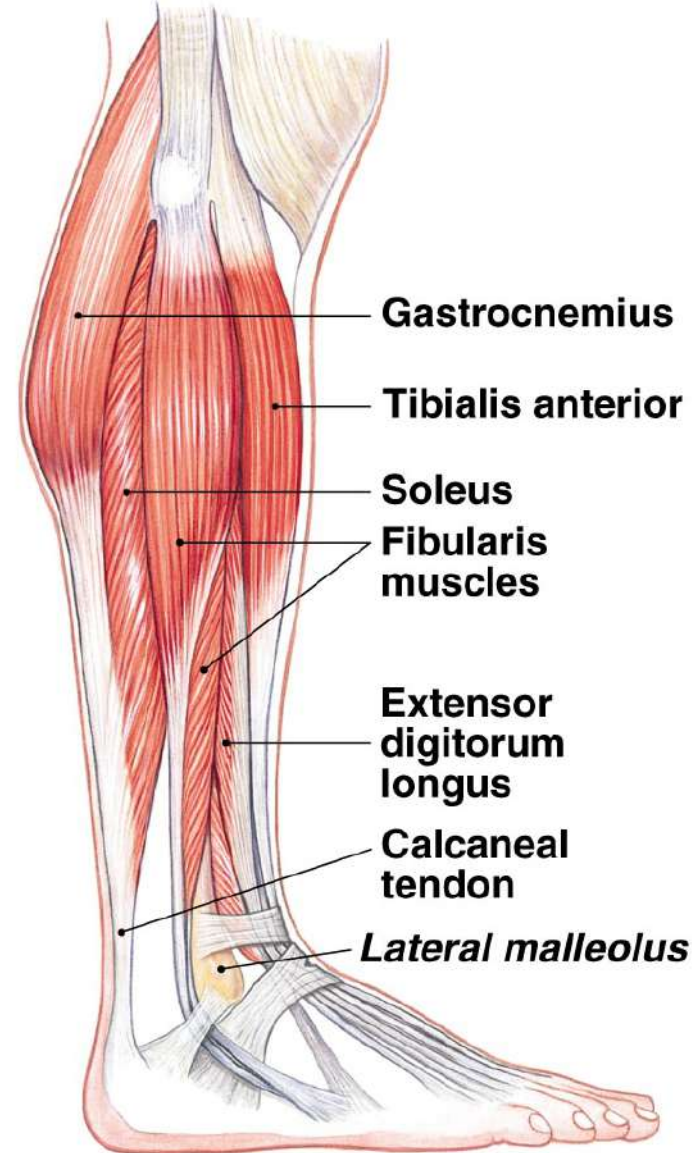


Figure 7-22(d)

(d) Lateral view

Aging and the Muscular System

What are Age-Related
Reductions?

Muscle size

Muscle elasticity

Muscle strength

Exercise tolerance

Injury recovery ability