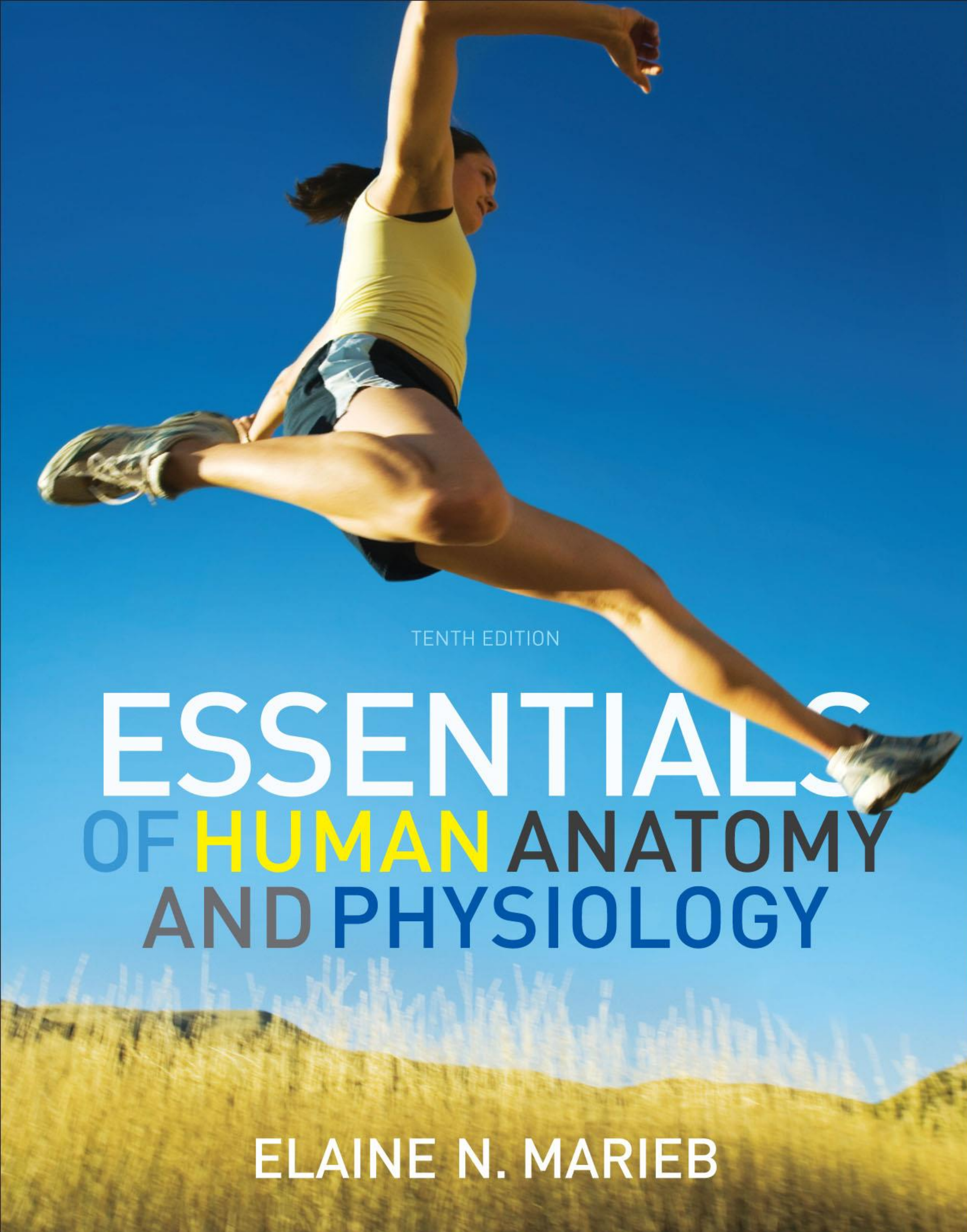

PowerPoint® Lecture Slides

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Florence-Darlington Technical College

CHAPTER 6

The Muscular System

The Muscular System

- Muscles are responsible for all types of body movement
- Three basic muscle types are found in the body
  - Skeletal muscle
  - Cardiac muscle
  - Smooth muscle

Characteristics of Muscles

- Skeletal and smooth muscle cells are elongated (**muscle cell = muscle fiber**)

- Contraction and shortening of muscles is due to the movement of **microfilaments**

- All muscles share some terminology
  - Prefixes ***myo*** and ***mys*** refer to "muscle"
  - Prefix ***sarco*** refers to "flesh"

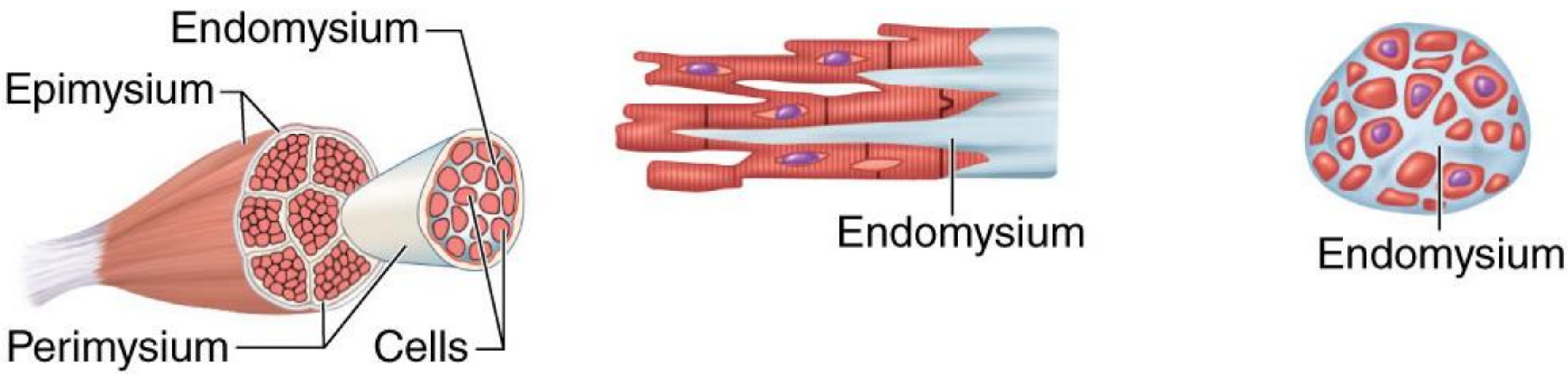

Endomysium
Epimysium
Perimysium
Cells
Endomysium
Endomysium

Table 6.1

Comparison of Skeletal, Cardiac, and Smooth Muscles

Characteristic	Skeletal	Cardiac	Smooth
Body location	Attached to bone or skin (for some facial muscles)	Walls of the heart	Mostly in walls of visceral organs (other than the heart)
Cell shape and appearance	Single, very long, cylindrical, multinucleate cells with very obvious striations	Branching chains of cells, uninucleate, striations, intercalated discs	Single, fusiform, uninucleate, no striations
Connective tissue components	Endomysium, perimysium, and epimysium	Endomysium	Endomysium

Comparison of Skeletal, Cardiac, and Smooth Muscles

Characteristic	Skeletal	Cardiac	Smooth
Regulation of contraction	Voluntary	Involuntary	Involuntary
Speed of contraction	Slow to fast	Slow	Very slow
Rhythmic contractions	No	Yes	Yes, in some

Skeletal Muscle Characteristics

- Most are attached by tendons to bones
- Cells are multinucleate
- Striated—have visible banding
- Voluntary—subject to conscious control

Connective Tissue Wrappings of Skeletal Muscle

- Cells are surrounded and bundled by connective tissue
  - **Endomysium**—encloses a single muscle fiber
  - **Perimysium**—wraps around a **fascicle** (bundle) of muscle fibers
  - **Epimysium**—covers the entire skeletal muscle
  - **Fascia**—on the outside of the epimysium

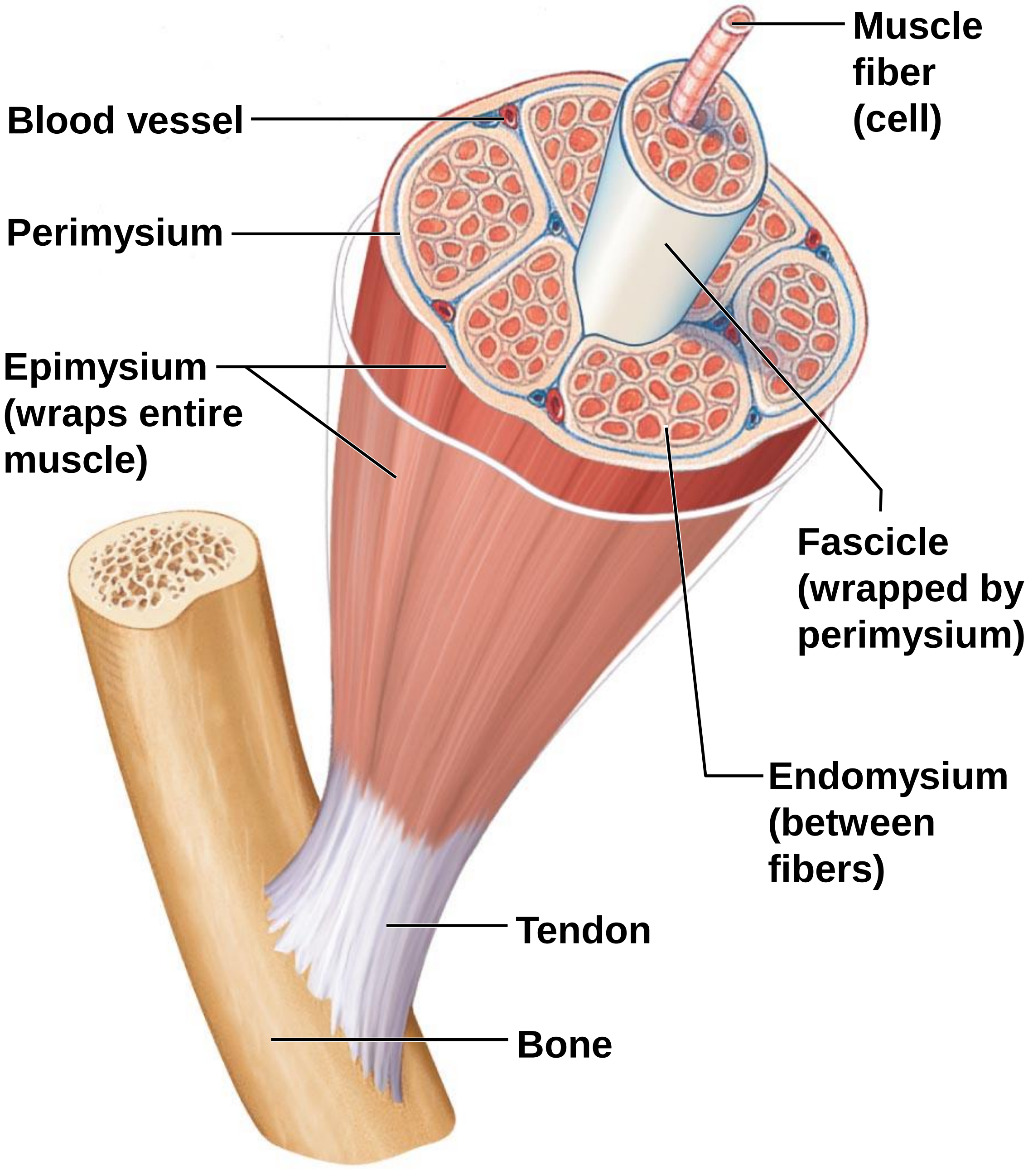

Muscle fiber (cell)
Blood vessel
Perimysium
Epimysium (wraps entire muscle)
Fascicle (wrapped by perimysium)
Endomysium (between fibers)
Tendon
Bone

Figure 6.1

Skeletal Muscle Attachments

- Epimysium blends into a connective tissue attachment
  - **Tendons**—cord-like structures
    - Mostly collagen fibers
    - Often cross a joint due to toughness and small size
  - **Aponeuroses**—sheet-like structures
    - Attach muscles indirectly to bones, cartilages, or connective tissue coverings

Skeletal Muscle Attachments

- Sites of muscle attachment
  - Bones
  - Cartilages
  - Connective tissue coverings

Smooth Muscle Characteristics

- Lacks striations
- Spindle-shaped cells
- Single nucleus
- Involuntary—no conscious control
- Found mainly in the walls of hollow organs

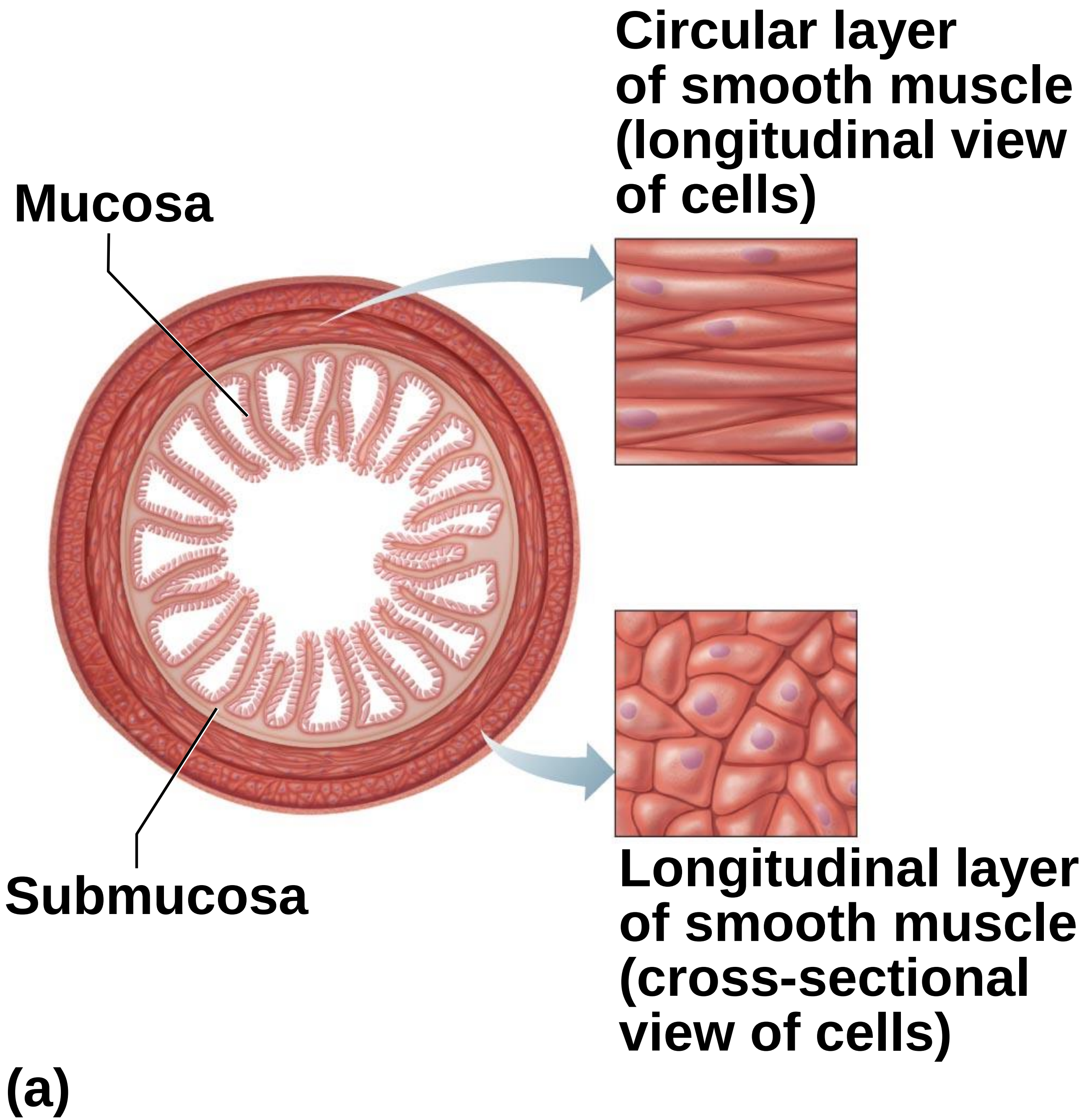
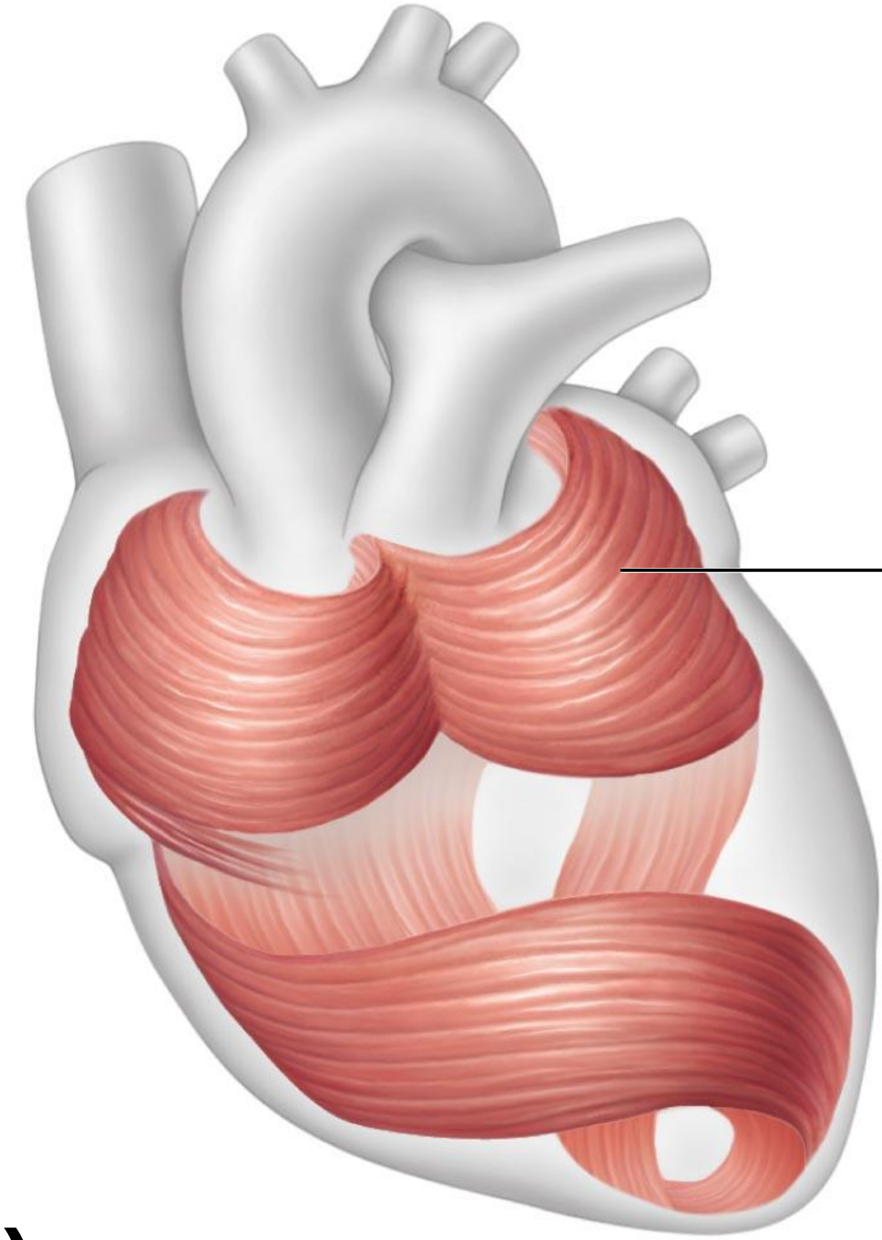

Circular layer of smooth muscle (longitudinal view of cells)
Mucosa
Submucosa
Longitudinal layer of smooth muscle (cross-sectional view of cells)
(a)

Figure 6.2a

Cardiac Muscle Characteristics

- Striations
- Usually has a single nucleus
- Branching cells
- Joined to another muscle cell at an intercalated disc
- Involuntary
- Found only in the walls of the heart



(b)

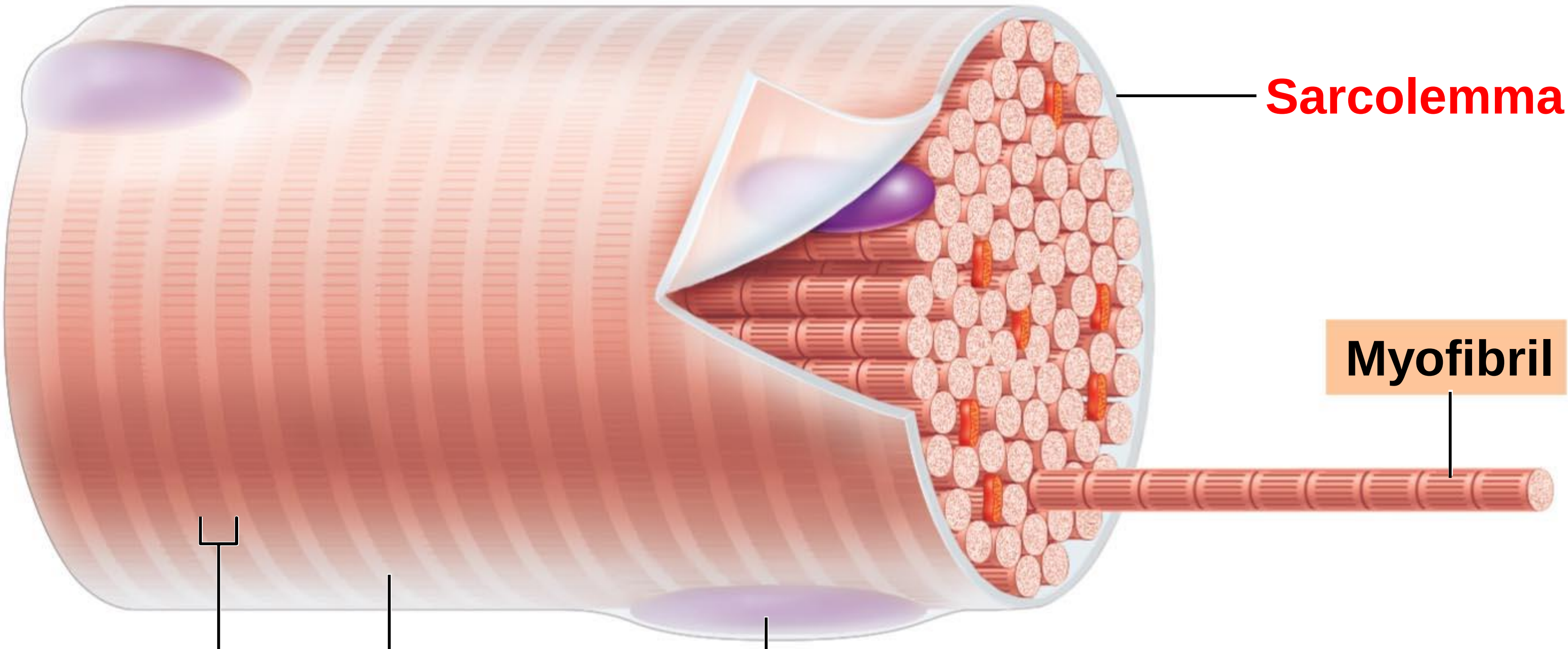
Figure 6.2b

Skeletal Muscle Functions

- Produce movement
- Maintain posture
- Stabilize joints
- Generate heat

Microscopic Anatomy of Skeletal Muscle

- **Sarcolemma**—specialized plasma membrane
- **Myofibrils**—long organelles inside muscle cell
- **Sarcoplasmic reticulum**—specialized smooth endoplasmic reticulum

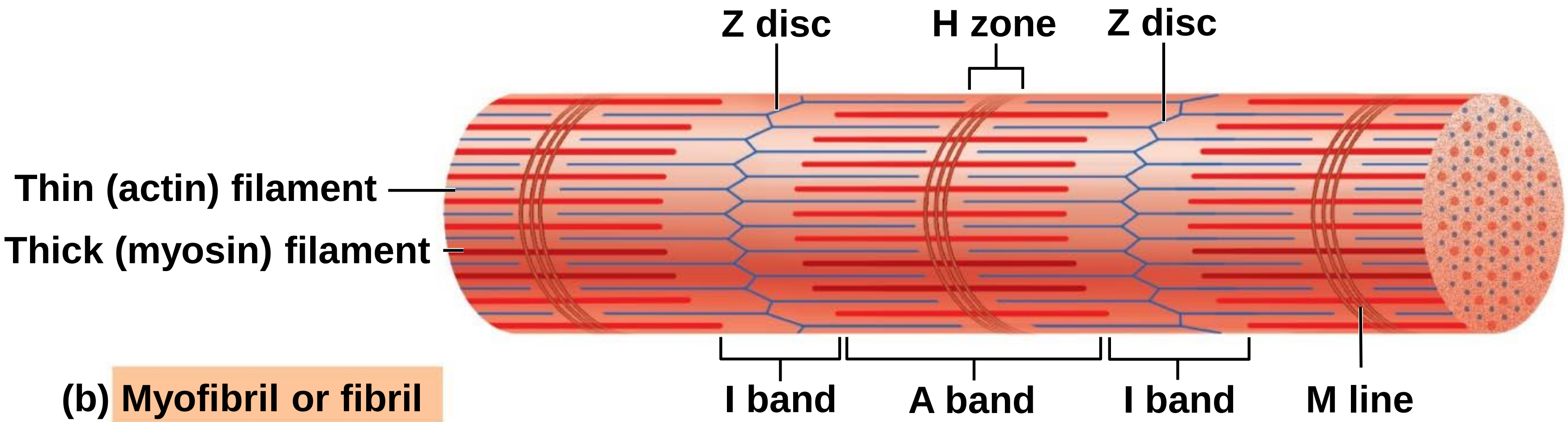


(a) Segment of a muscle fiber (cell)

Figure 6.3a

Microscopic Anatomy of Skeletal Muscle

- Myofibrils are aligned to give distinct bands
  - **I band = light band**
    - Contains only **thin** filaments
  - **A band = dark band**
    - Contains the entire length of the **thick** filaments



(b) Myofibril or fibril
(complex organelle
composed of bundles
of myofilaments)

Figure 6.3b

Microscopic Anatomy of Skeletal Muscle

- **Sarcomere**—contractile unit of a muscle fiber

- Organization of the sarcomere

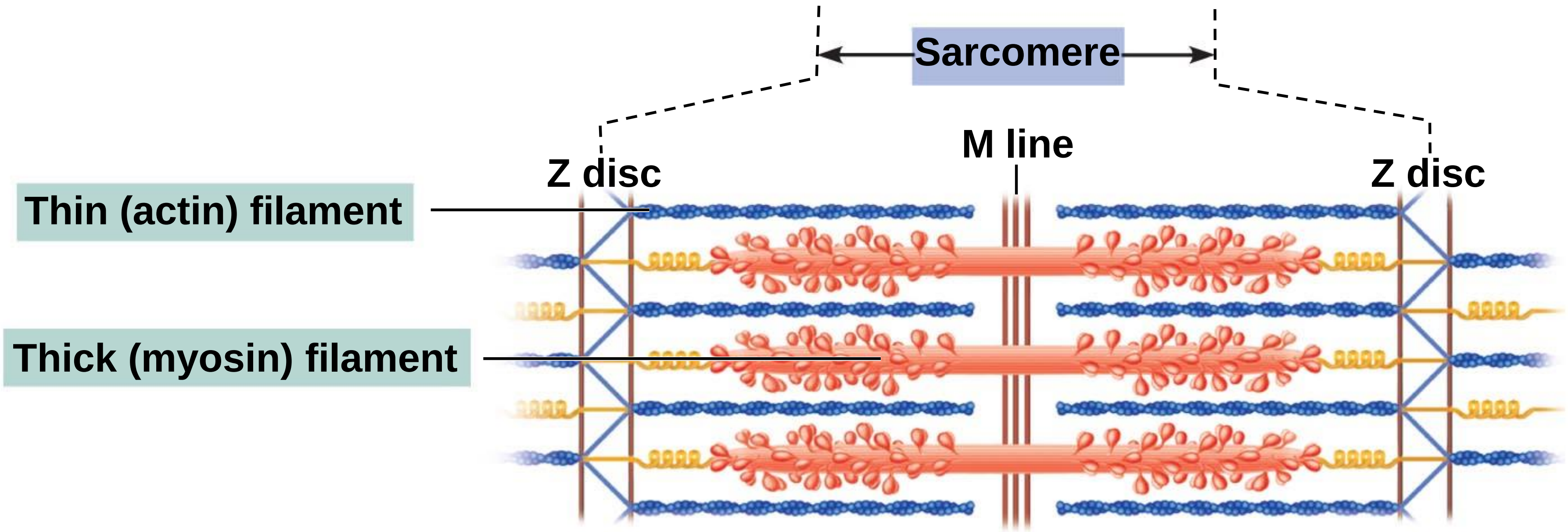
  - Myofilaments
    - **Thick** filaments = **myosin** filaments
    - **Thin** filaments = **actin** filaments

Microscopic Anatomy of Skeletal Muscle

- **Thick** filaments = **myosin** filaments
  - Composed of the protein myosin
  - Has ATPase enzymes
  - Myosin filaments have **heads (extensions, or cross bridges)**
  - Myosin and actin overlap somewhat

Microscopic Anatomy of Skeletal Muscle

- **Thin** filaments = **actin** filaments
  - Composed of the protein actin
  - Anchored to the **Z disc**



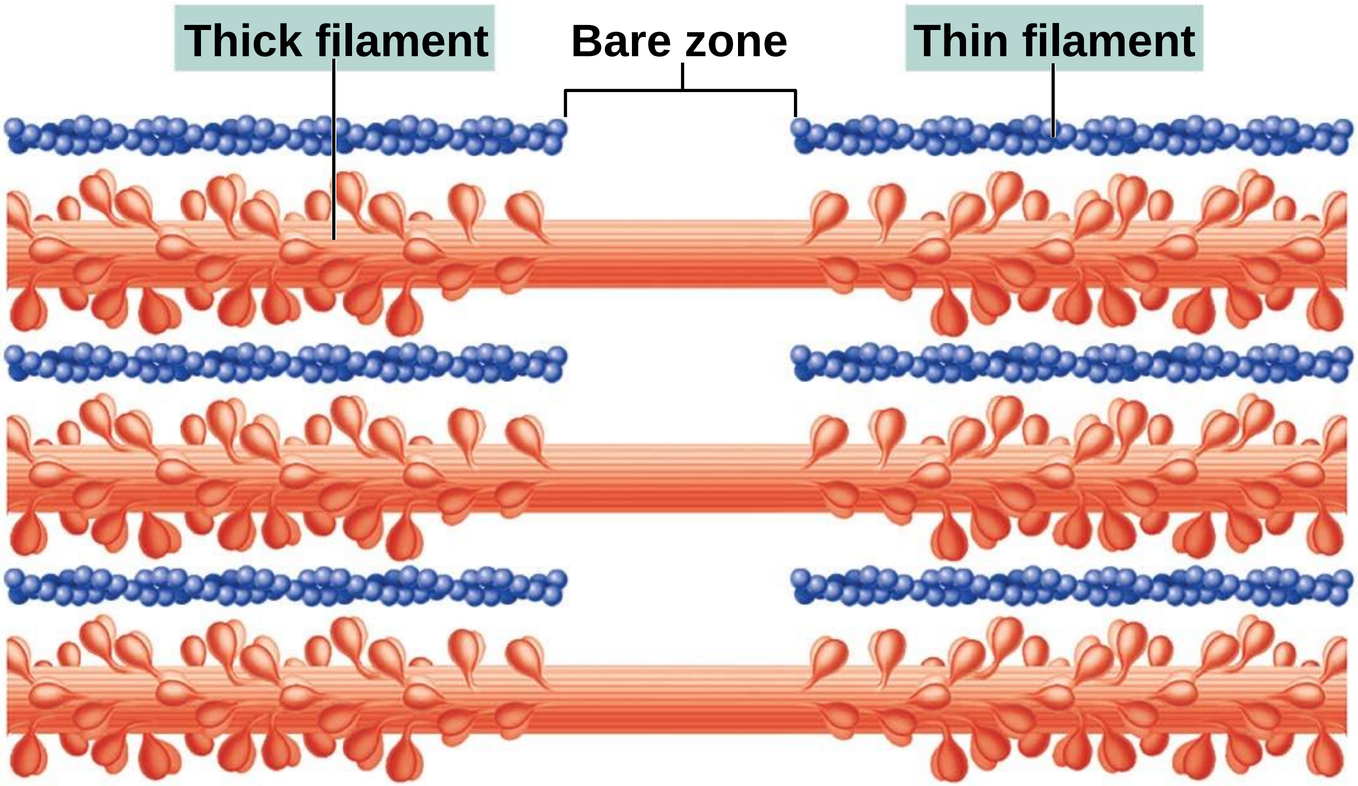
(c) Sarcomere (segment of a myofibril)

Figure 6.3c

Microscopic Anatomy of Skeletal Muscle

- At rest, within the A band there is a zone that lacks actin filaments
  - Called either the **H zone or bare zone**

- **Sarcoplasmic reticulum (SR)**
  - Stores and releases calcium
  - Surrounds the myofibril



(d) Myofilament structure (within one sarcomere)

Figure 6.3d

Stimulation and Contraction of Single Skeletal Muscle Cells

- **Excitability** (also called responsiveness or irritability)—ability to receive and respond to a stimulus
- **Contractility**—ability to shorten when an adequate stimulus is received
- **Extensibility**—ability of muscle cells to be stretched
- **Elasticity**—ability to recoil and resume resting length after stretching

The Nerve Stimulus and Action Potential

- Skeletal muscles must be stimulated by a motor neuron (nerve cell) to contract
- **Motor unit**—one motor neuron and all the skeletal muscle cells stimulated by that neuron

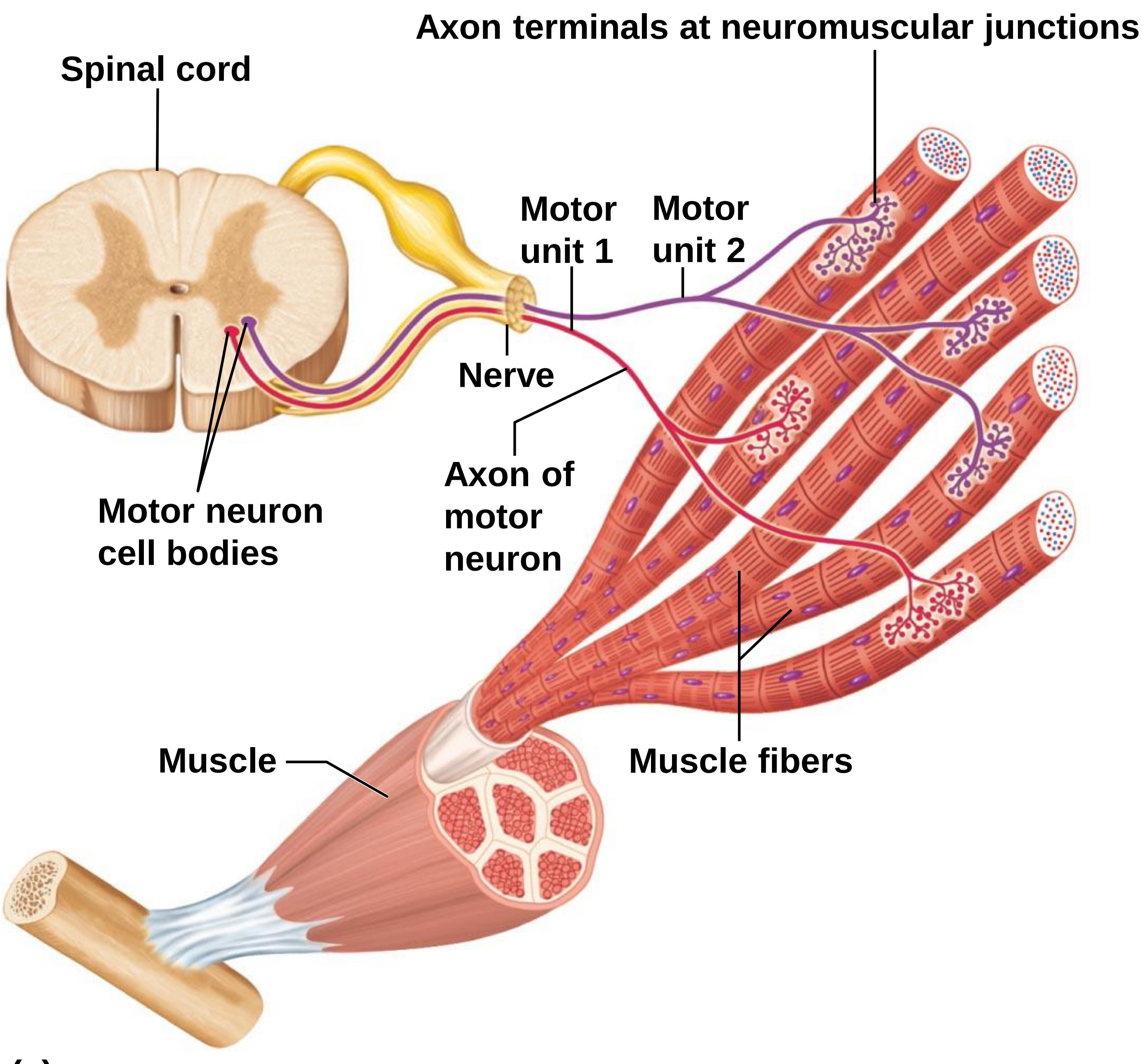
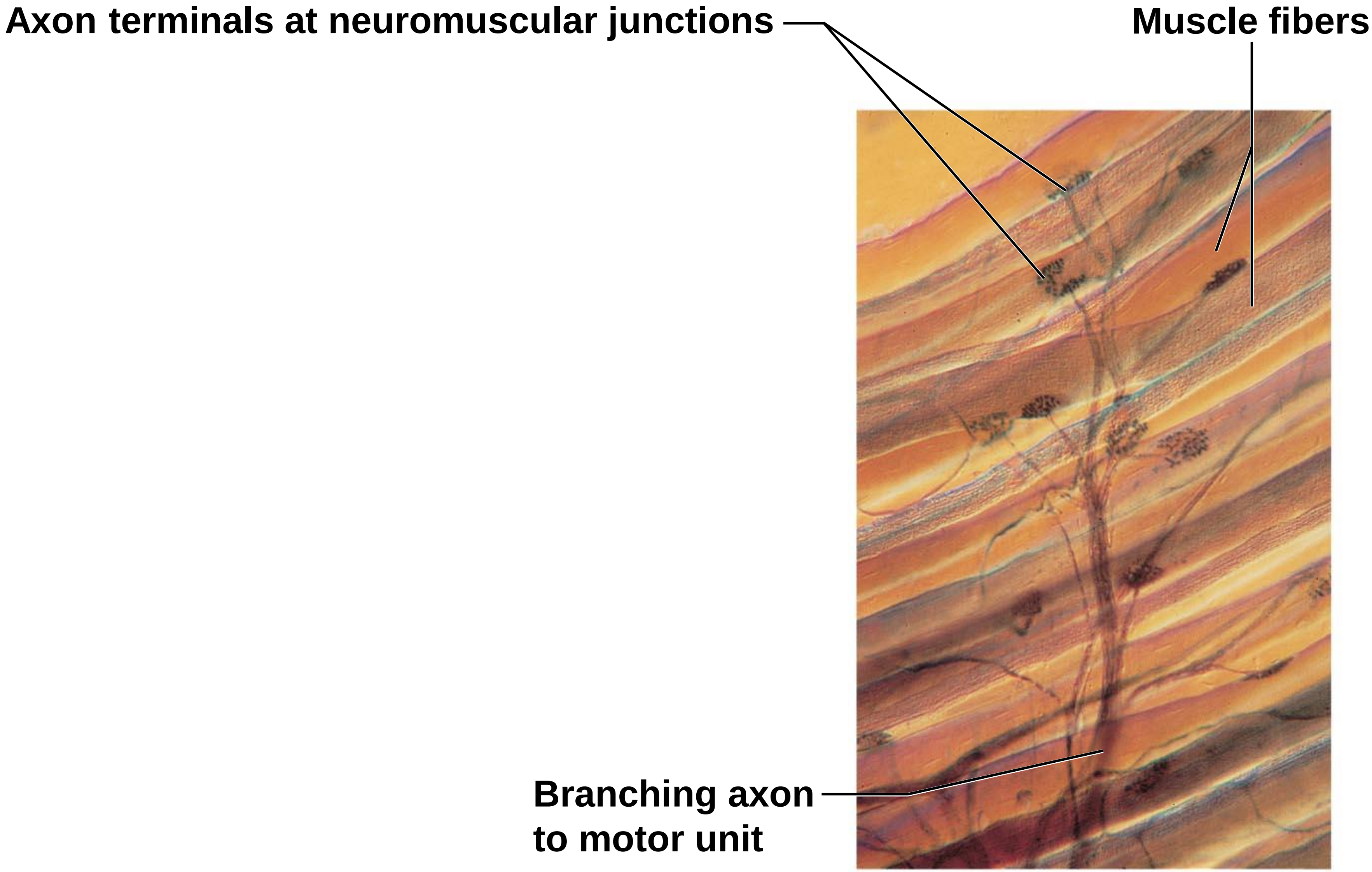

Axon terminals at neuromuscular junctions
Spinal cord
Motor unit 1
Motor unit 2
Nerve
Axon of motor neuron
Motor neuron cell bodies
Muscle
Muscle fibers
(a)

Figure 6.4a


Axon terminals at neuromuscular junctions
Muscle fibers
Branching axon
to motor unit

(b)

Figure 6.4b

The Nerve Stimulus and Action Potential

- **Neuromuscular junction**
  - Association site of axon terminal of the motor neuron and muscle

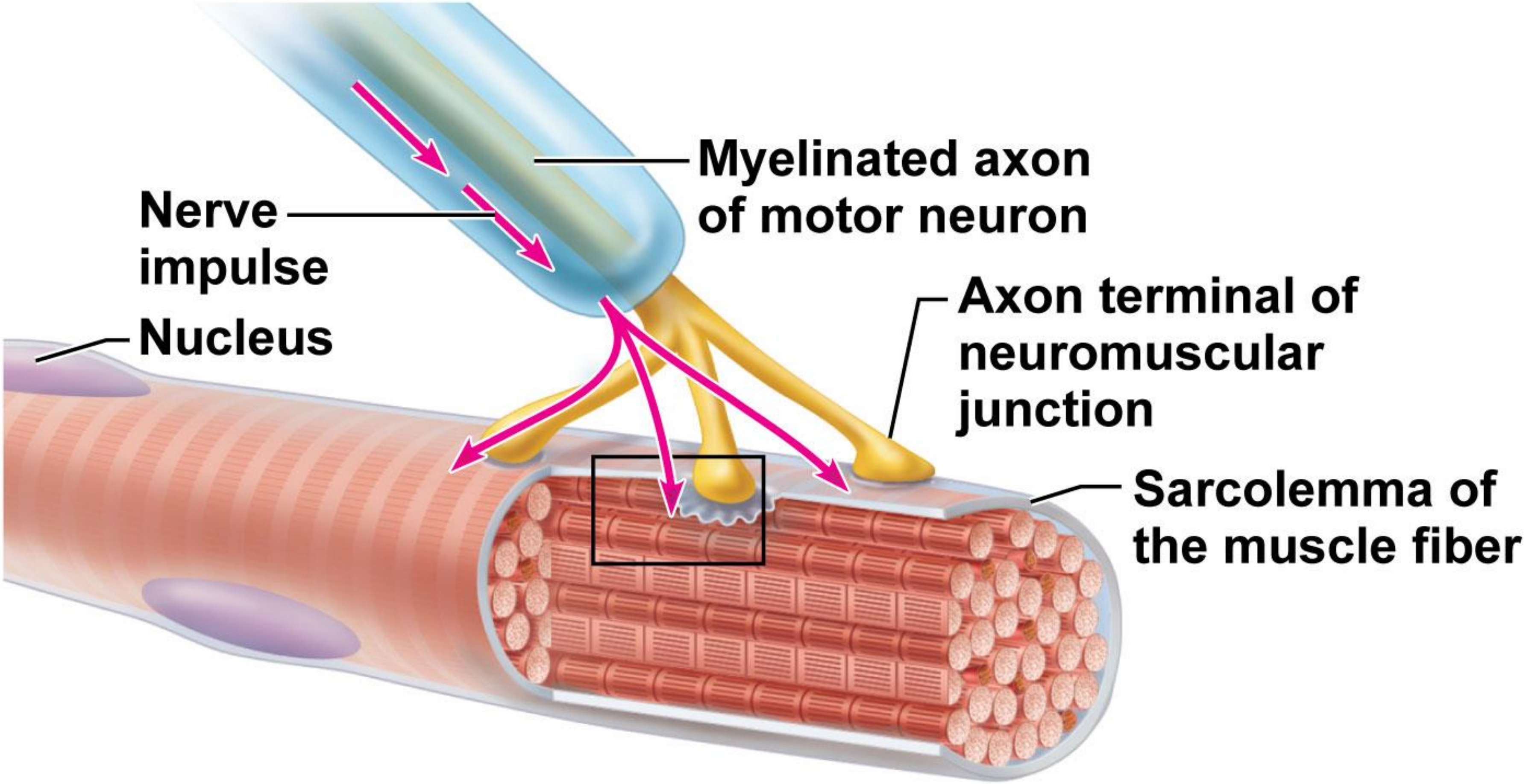

Myelinated axon
of motor neuron
Nerve
impulse
Nucleus
Axon terminal of
neuromuscular
junction
Sarcolemma of
the muscle fiber

Figure 6.5

The Nerve Stimulus and Action Potential

- **Synaptic cleft**
  - Gap between nerve and muscle
  - Nerve and muscle do not make contact
  - Area between nerve and muscle is filled with interstitial fluid
- **Action potential reaches the axon terminal** of the motor neuron
- **Calcium channels open and calcium ions enter** the axon terminal

Transmission of Nerve Impulse to Muscle

- Calcium ion entry causes some synaptic vesicles to release their contents (**acetylcholine**, a neurotransmitter) by exocytosis
- **Neurotransmitter**—chemical released by nerve upon arrival of nerve impulse in the axon terminal
  - The neurotransmitter for skeletal muscle is acetylcholine (ACh)

Transmission of Nerve Impulse to Muscle

- **Acetylcholine attaches to receptors on the sarcolemma** of the muscle cell
- In response to the binding of ACh to a receptor, the **sarcolemma becomes permeable to sodium (Na^+)**
- **Sodium rushes into the cell generating an action potential and potassium leaves the cell**
- Once started, muscle contraction cannot be stopped

1 Action potential reaches axon terminal of motor neuron.

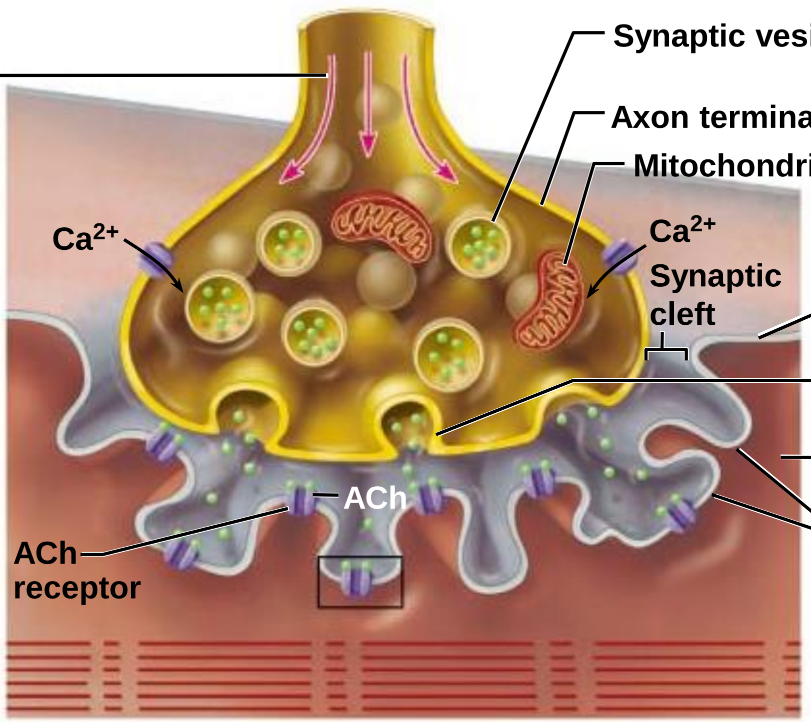


Figure 6.5, step 1

1 Action potential reaches axon terminal of motor neuron.

2 Calcium (Ca^{2+}) channels open and Ca^{2+} enters the axon terminal.

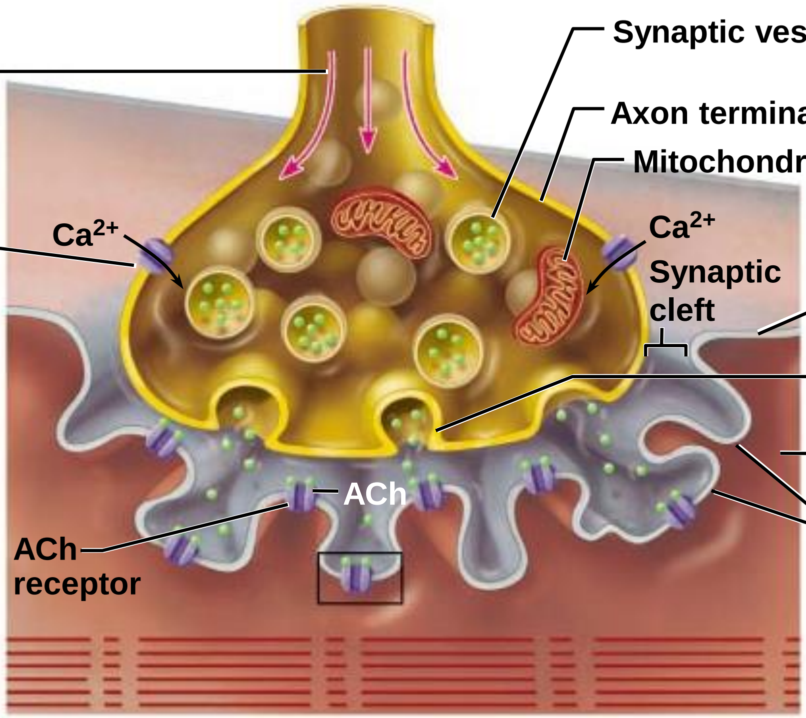


Figure 6.5, step 2

1 Action potential reaches axon terminal of motor neuron.

2 Calcium (Ca^{2+}) channels open and Ca^{2+} enters the axon terminal.

3 Ca^{2+} entry causes some synaptic vesicles to release their contents (acetylcholine, a neurotransmitter) by exocytosis.

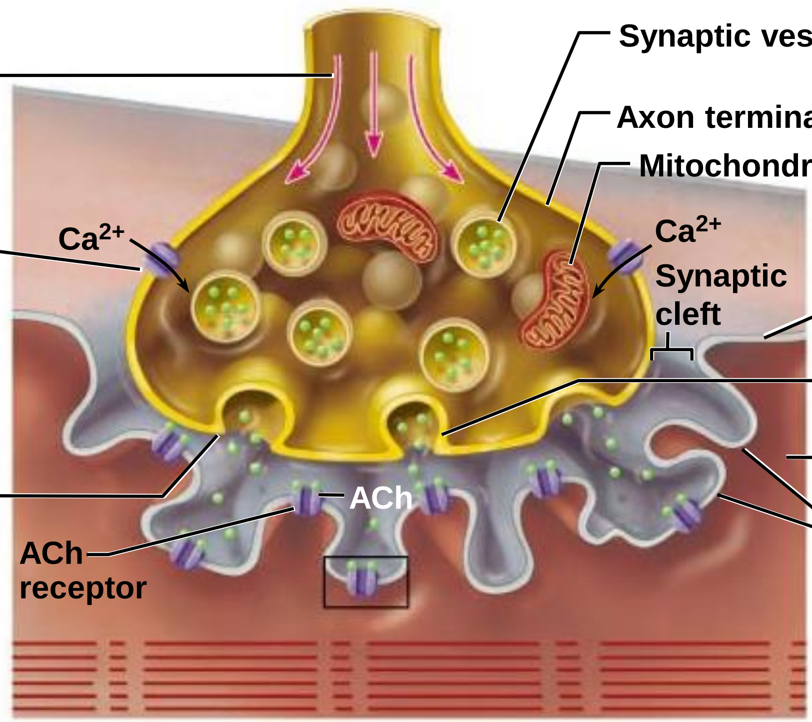


Figure 6.5, step 3

1 Action potential reaches axon terminal of motor neuron.

2 Calcium (Ca^{2+}) channels open and Ca^{2+} enters the axon terminal.

3 Ca^{2+} entry causes some synaptic vesicles to release their contents (acetylcholine, a neurotransmitter) by exocytosis.

4 Acetylcholine diffuses across the synaptic cleft and binds to receptors in the sarcolemma.

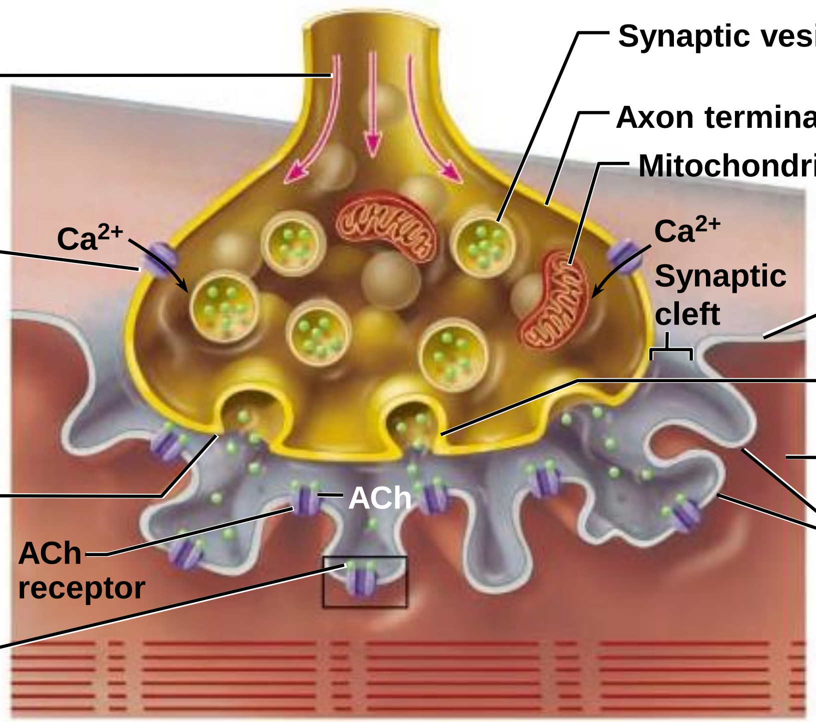


Figure 6.5, step 4

5 ACh binds and channels open that allow simultaneous passage of Na^+ into the muscle fiber and K^+ out of the muscle fiber. More Na^+ ions enter than K^+ ions leave and this produces a local change in the electrical conditions of the membrane (depolarization), which eventually leads to an action potential.

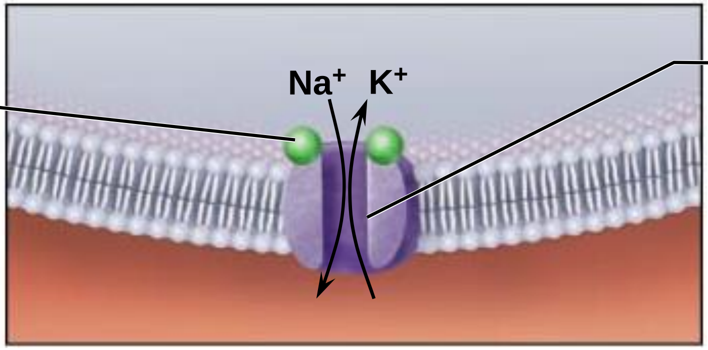
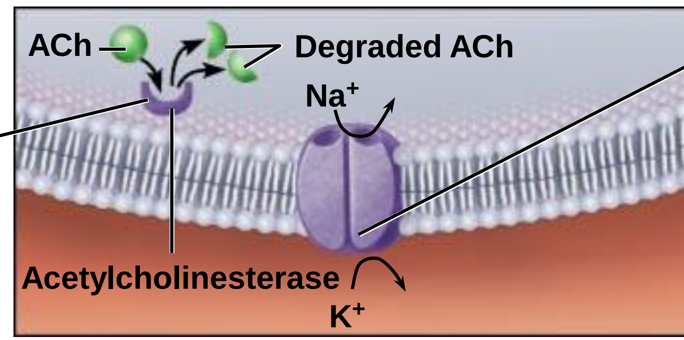


Figure 6.5, step 5

6 ACh effects are ended by its breakdown in the synaptic cleft by the enzyme acetylcholinesterase.



Ion channel closed; ions cannot pass.

Figure 6.5, step 6

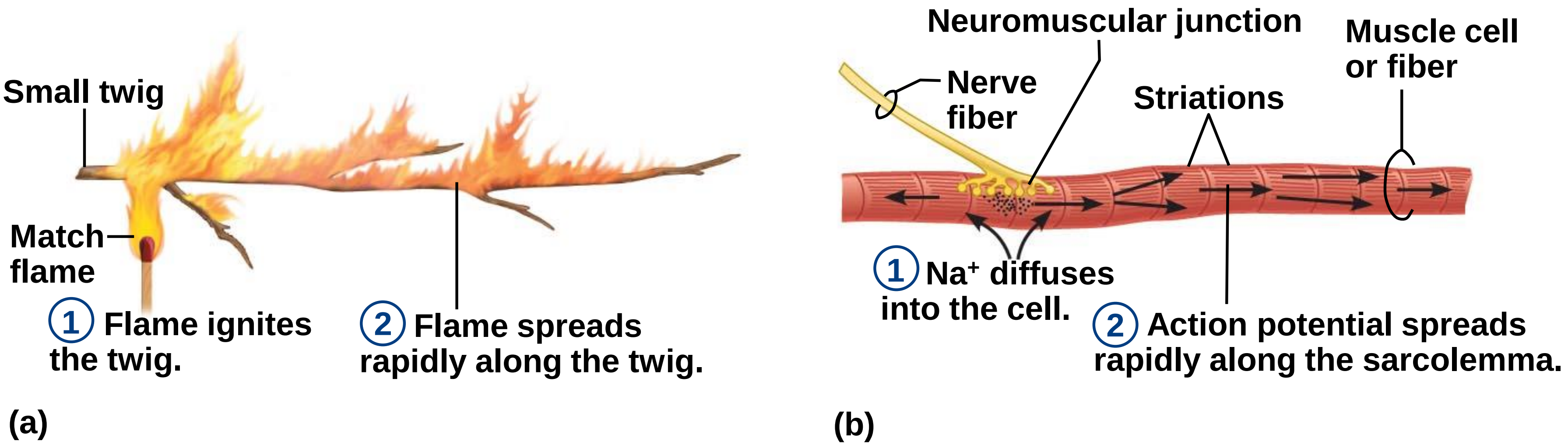

Small twig
Match flame
1 Flame ignites the twig.
2 Flame spreads rapidly along the twig.
(a)
Neuromuscular junction
Muscle cell or fiber
Nerve fiber
Striations
1 Na+ diffuses into the cell.
2 Action potential spreads rapidly along the sarcolemma.
(b)

Figure 6.6a-b

The Sliding Filament Theory of Muscle Contraction

- Activation by nerve causes **myosin heads (cross bridges) to attach to binding sites on the <u>thin</u> filament**
- Myosin heads then bind to the next site of the thin filament and **pull them toward the center** of the sarcomere
- This continued action causes a **sliding of the myosin along the actin**
- The result is that the **muscle is shortened (contracted)**

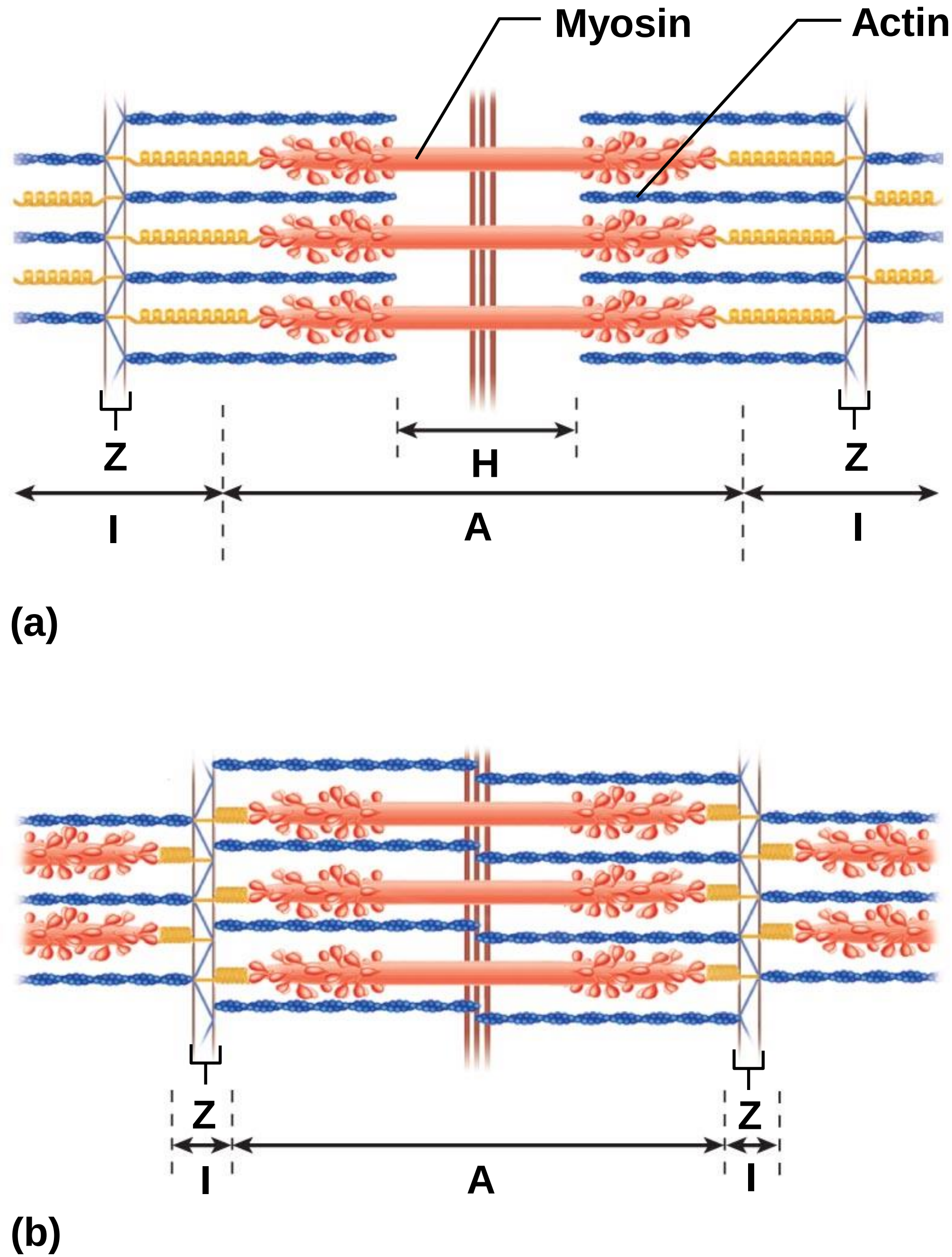
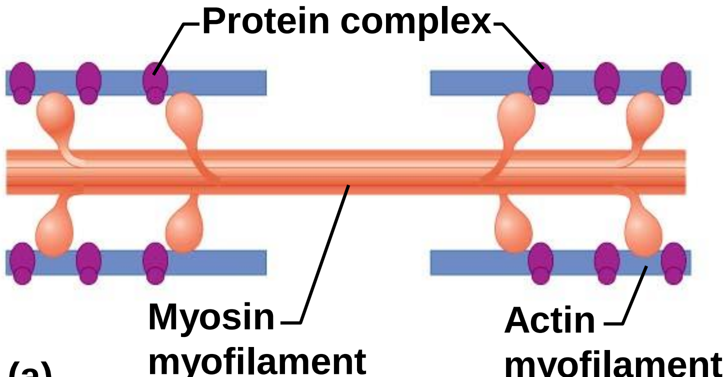


Figure 6.7a–b

Sliding Filament

Sliding Filament 1

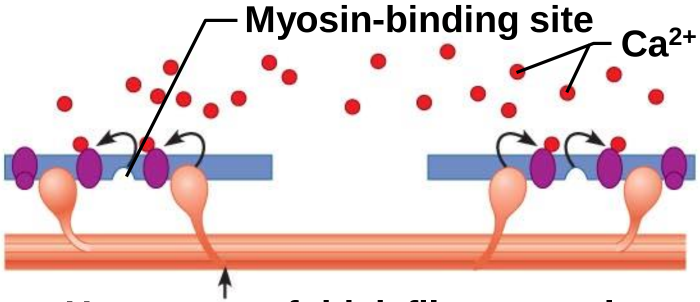
Sliding Filament 2



(a)

In a relaxed muscle cell, the regulatory proteins forming part of the actin myofilaments prevent myosin binding (see a). When an action potential (AP) sweeps along its sarcolemma and a muscle cell is excited, calcium ions (Ca^{2+}) are released from intracellular storage areas (the sacs of the sarcoplasmic reticulum).

Figure 6.8a



(b)

The flood of calcium acts as the final trigger for contraction, because as calcium binds to the regulatory proteins on the actin filaments, the proteins undergo a change in both their shape and their position on the thin filaments. This action exposes myosin-binding sites on the actin, to which the myosin heads can attach (see b), and the myosin heads immediately begin seeking out binding sites.

Figure 6.8b

Contraction of Skeletal Muscle

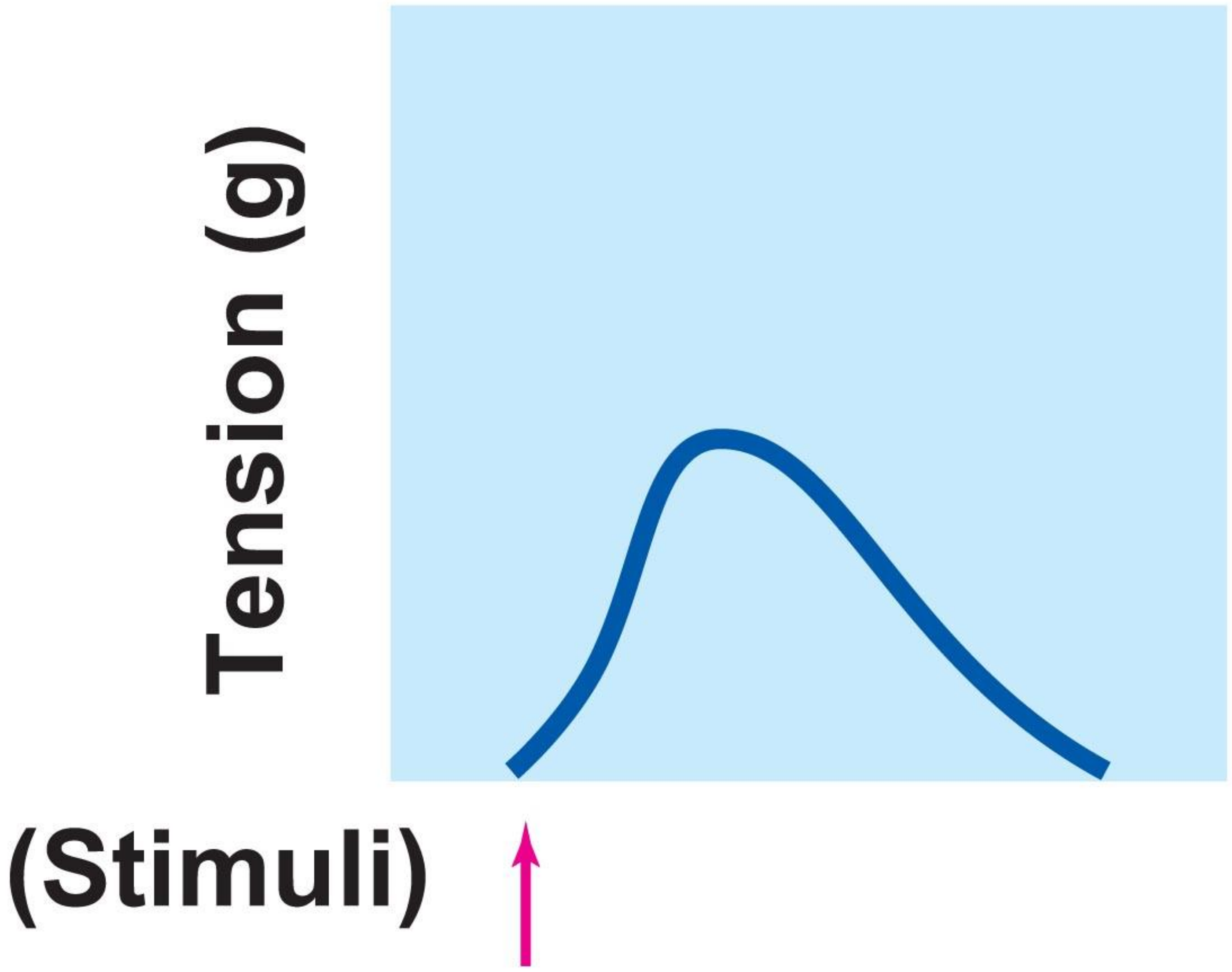
- Muscle fiber contraction is “all or none”
- Within a skeletal muscle, not all fibers may be stimulated during the same interval
- Different combinations of muscle fiber contractions may give differing responses
- **Graded responses**—different degrees of skeletal muscle shortening

Contraction of Skeletal Muscle

- Graded responses can be produced by changing:
  - The ***frequency*** of muscle stimulation
  - The ***number*** of muscle cells being stimulated at one time

Types of Graded Responses

- **Twitch**
  - Single, brief contraction
  - Not a normal muscle function

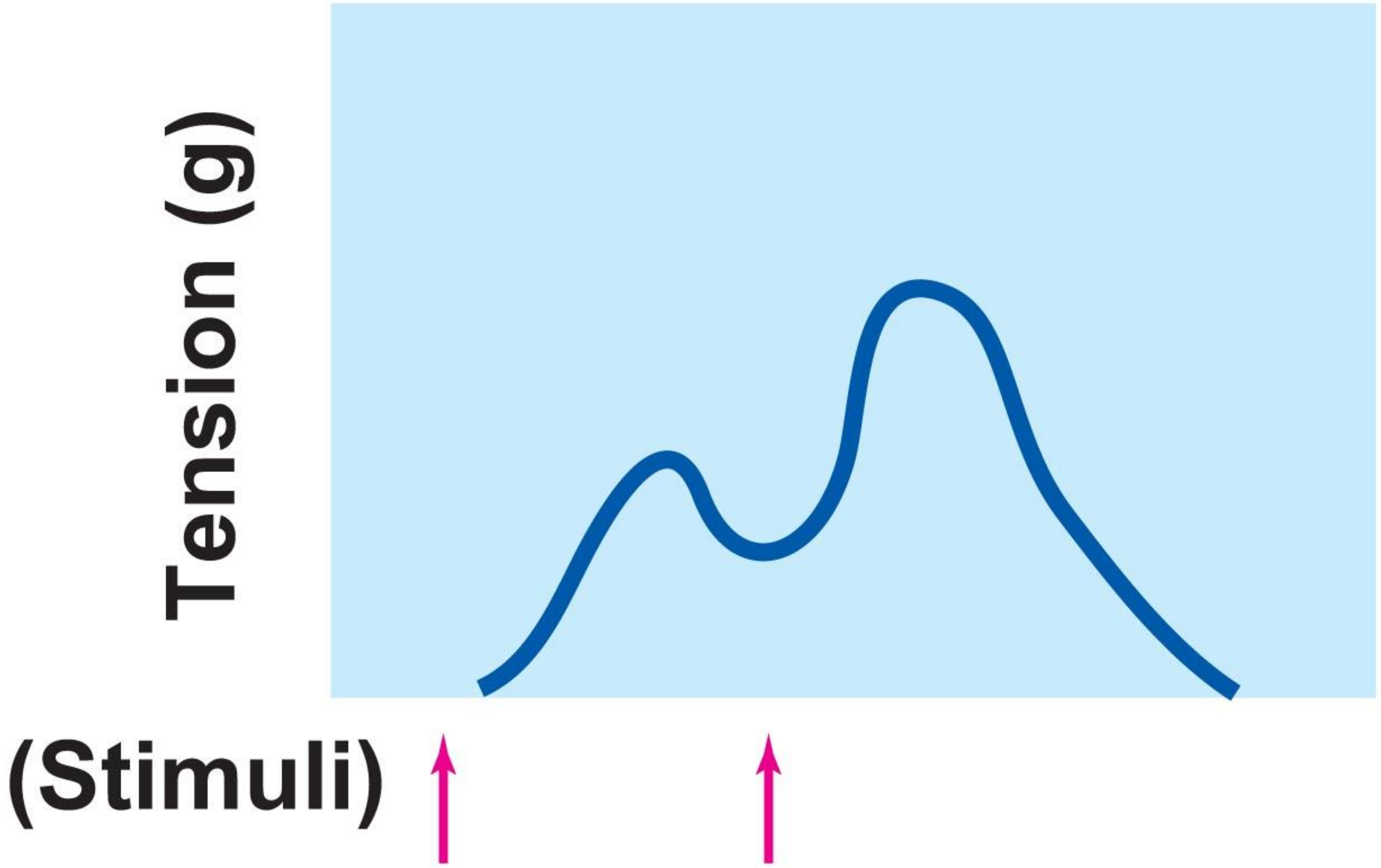


(a) Twitch

Figure 6.9a

Types of Graded Responses

- **Summing of contractions**
  - One contraction is immediately followed by another
  - The muscle does not completely return to a resting state due to more frequent stimulations
  - The effects are added

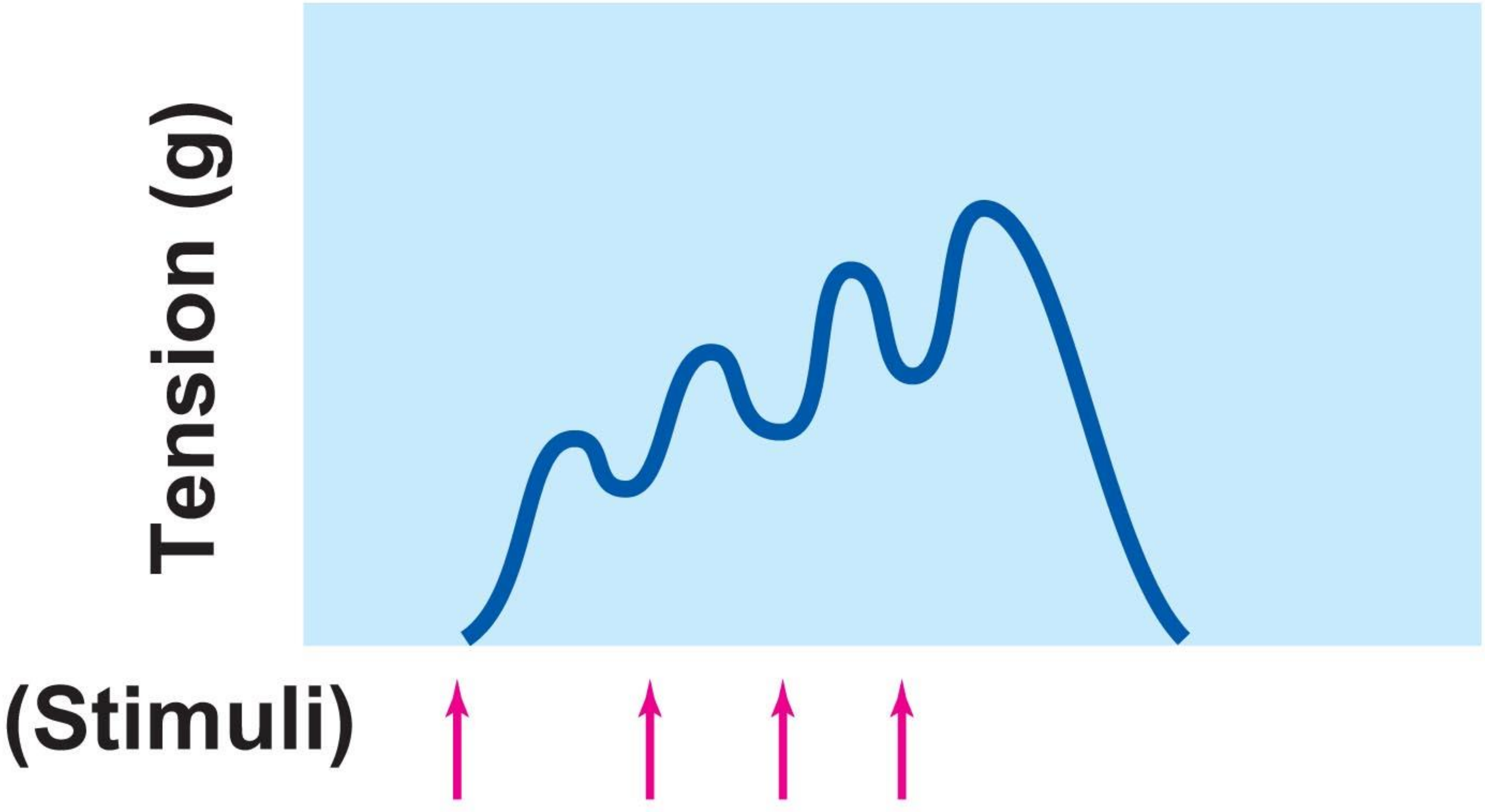


(b) Summing of contractions

Figure 6.9b

Types of Graded Responses

- **Unfused (incomplete) tetanus**
  - Some relaxation occurs between contractions but nerve stimuli arrive at an even faster rate than during summing of contractions
  - Unless the muscle contraction is smooth and sustained, it is said to be in unfused tetanus

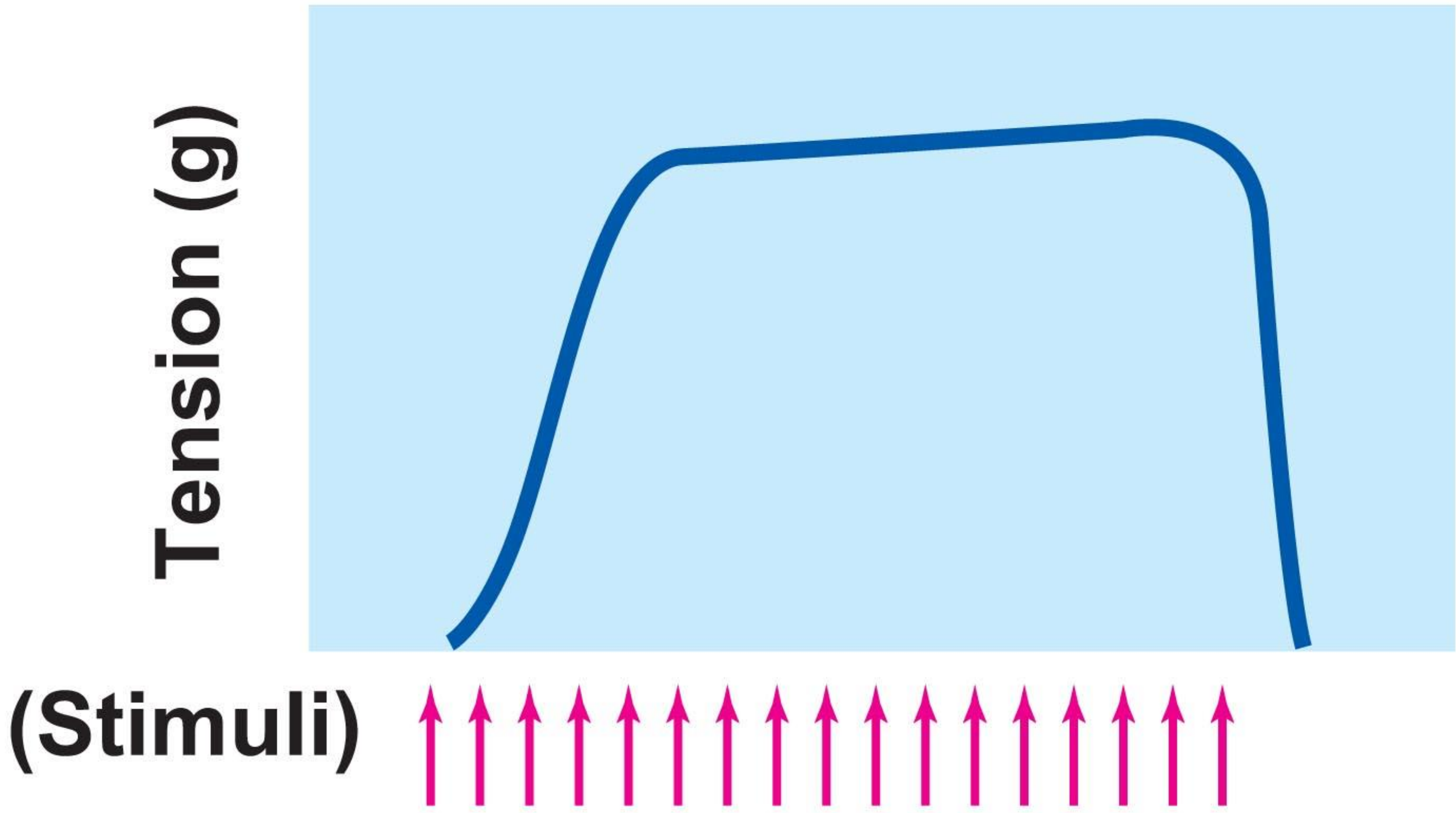


(c) Unfused (incomplete) tetanus

Figure 6.9c

Types of Graded Responses

- **Fused (complete) tetanus**
  - No evidence of relaxation before the following contractions
  - Frequency of stimulations does not allow for relaxation between contractions
  - The result is a smooth and sustained muscle contraction



(d) Fused (complete) tetanus

Figure 6.9d

Muscle Response to Strong Stimuli

- Muscle force depends upon the number of fibers stimulated
- More fibers contracting results in greater muscle tension
- Muscles can continue to contract unless they run out of energy