Fig. 11.1

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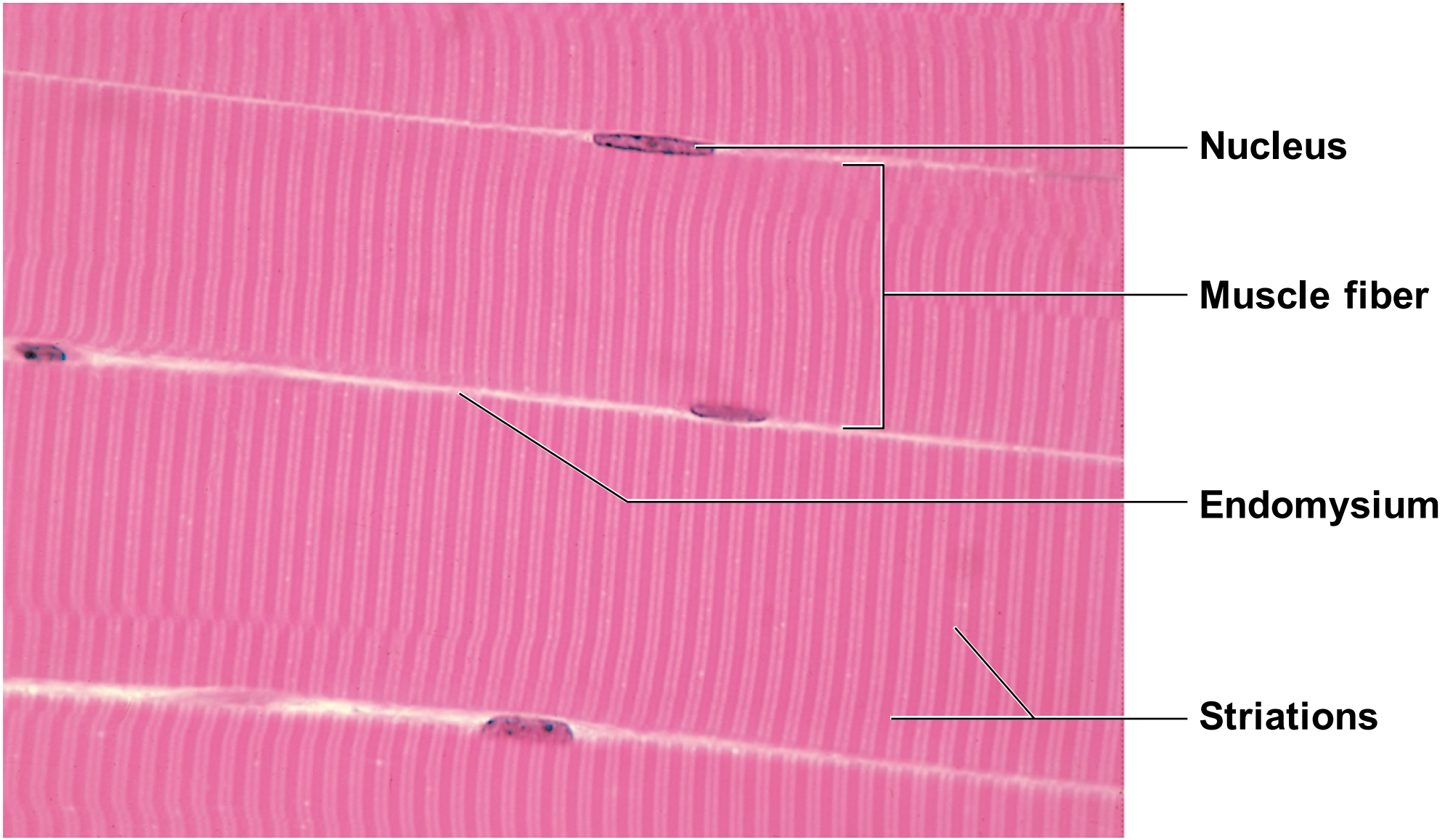


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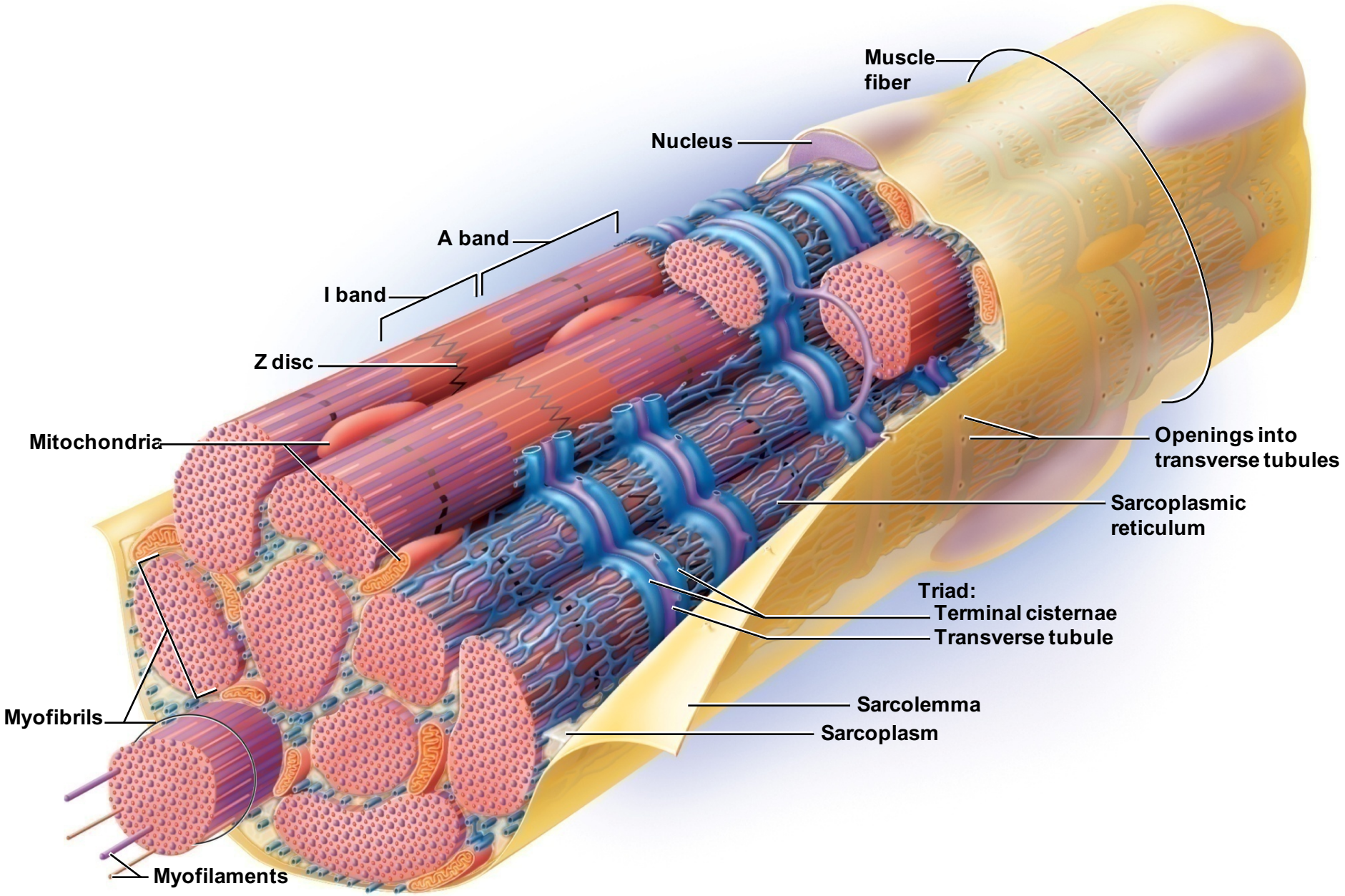

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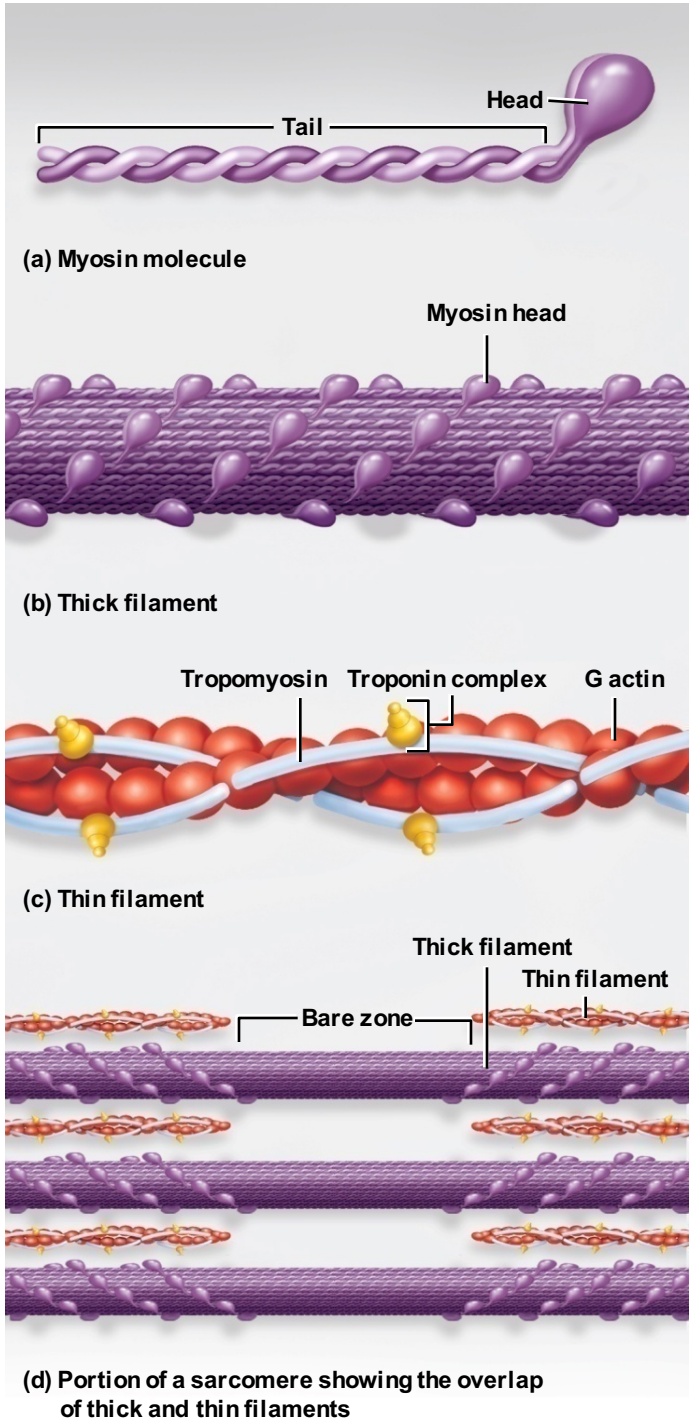

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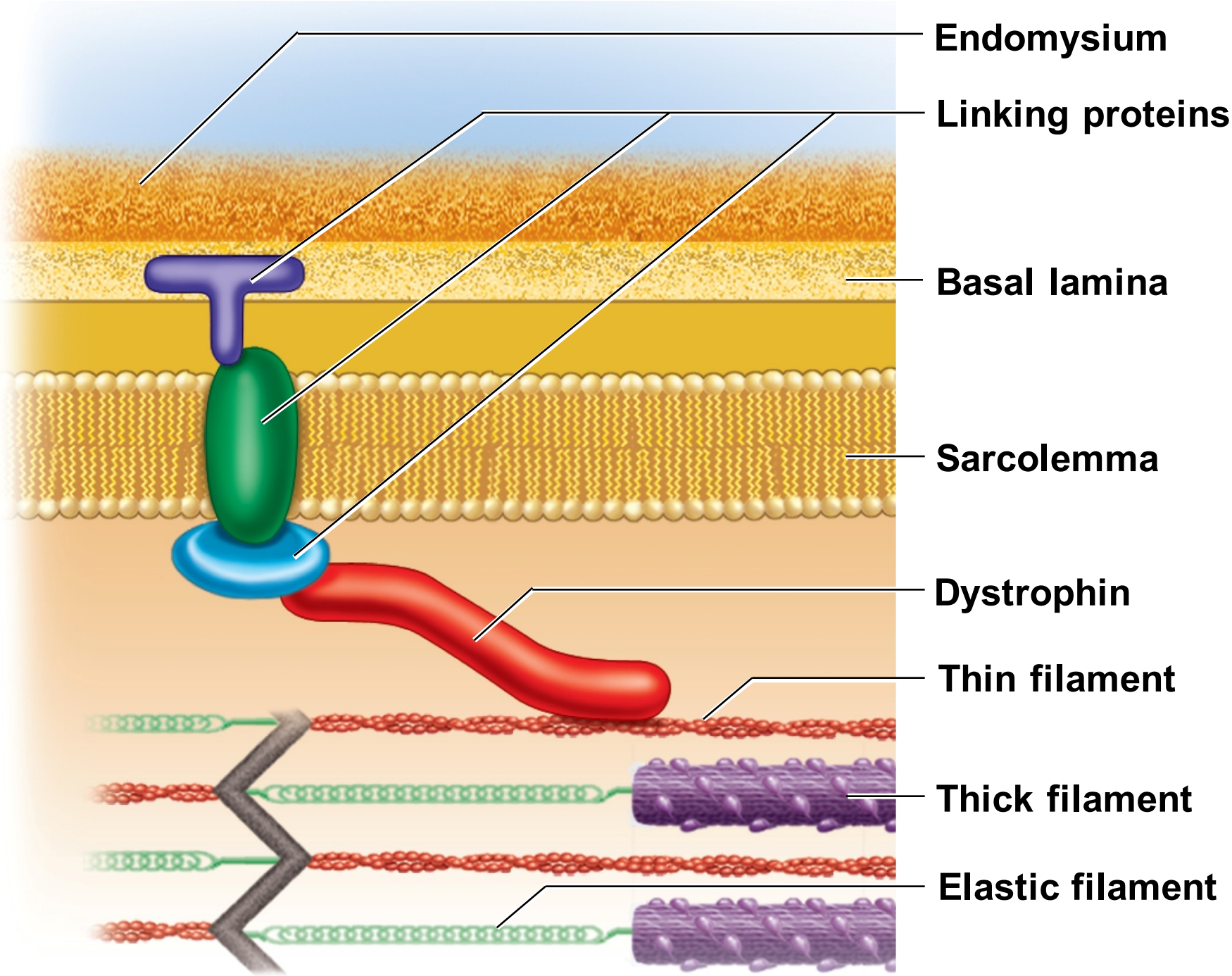

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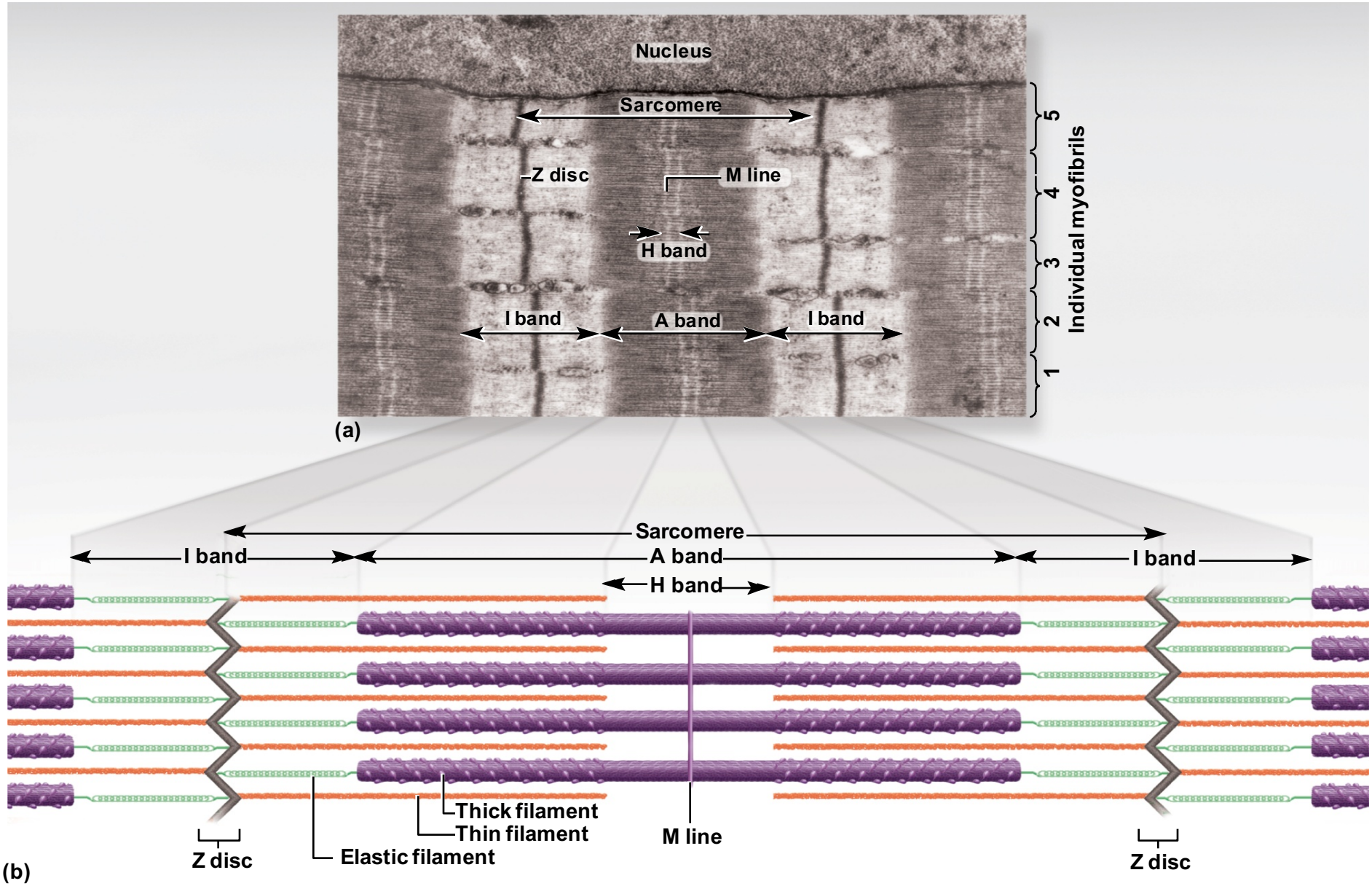


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Table 11.1

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**TABLE 11.1 The Structural Hierarchy of a Skeletal Muscle**

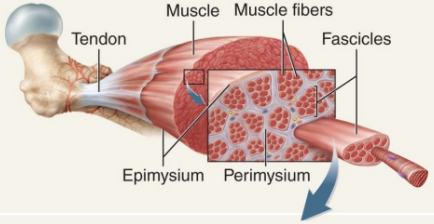
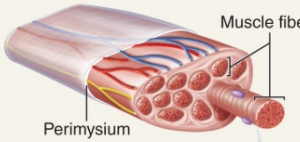
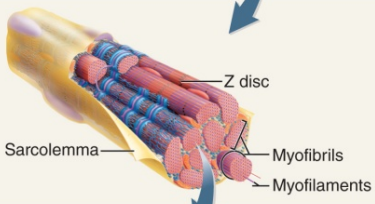
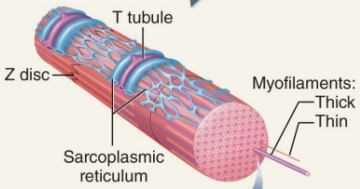
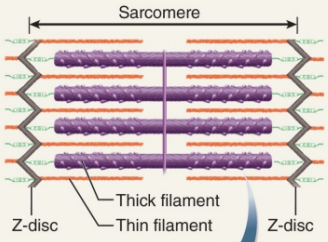
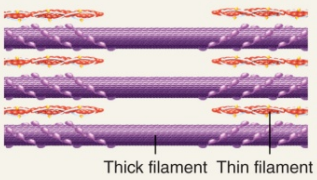
| Structural Level | Description |
|---|---|
| Muscle   | A contractile organ, usually attached to bones by way of tendons. Composed of bundles (fascicles) of tightly packed, long, parallel cells (muscle fibers). Supplied with nerves and blood vessels and enclosed in a fibrous epimysium separating it from neighboring muscles. |
| Fascicle   | A bundle of muscle fibers within a muscle. Supplied by nerves and blood vessels and enclosed in a fibrous perimysium separating it from neighboring fascicles. |
| Muscle Fiber   | A single muscle cell. Slender, elongated, threadlike, enclosed in a specialized plasma membrane (sarcolemma). Contains densely packed bundles (myofibrils) of contractile protein filaments, multiple nuclei immediately beneath the sarcolemma, and an extensive network of specialized smooth endoplasmic reticulum (sarcoplasmic reticulum). Enclosed in a thin fibrous sleeve called endomysium. |
| Myofibril   | A bundle of protein myofilaments within a muscle fiber, filling most of the cytoplasm. Surrounded by sarcoplasmic reticulum and mitochondria. Has a banded (striated) appearance due to orderly overlap of protein myofilaments. |
| Sarcomere   | A segment of myofibril from one Z disc to the next in the fiber's striation pattern. Hundreds of sarcomeres end to end compose a myofibril. The functional, contractile unit of the muscle fiber. |
| Myofilaments   | Fibrous protein strands that carry out the contraction process. Two types: thick filaments composed mainly of myosin, and thin filaments composed mainly of actin. Thick and thin filaments slide over each other to shorten each sarcomere. Shortening of end-to-end sarcomeres shortens the entire muscle. |

Fig. 11.6

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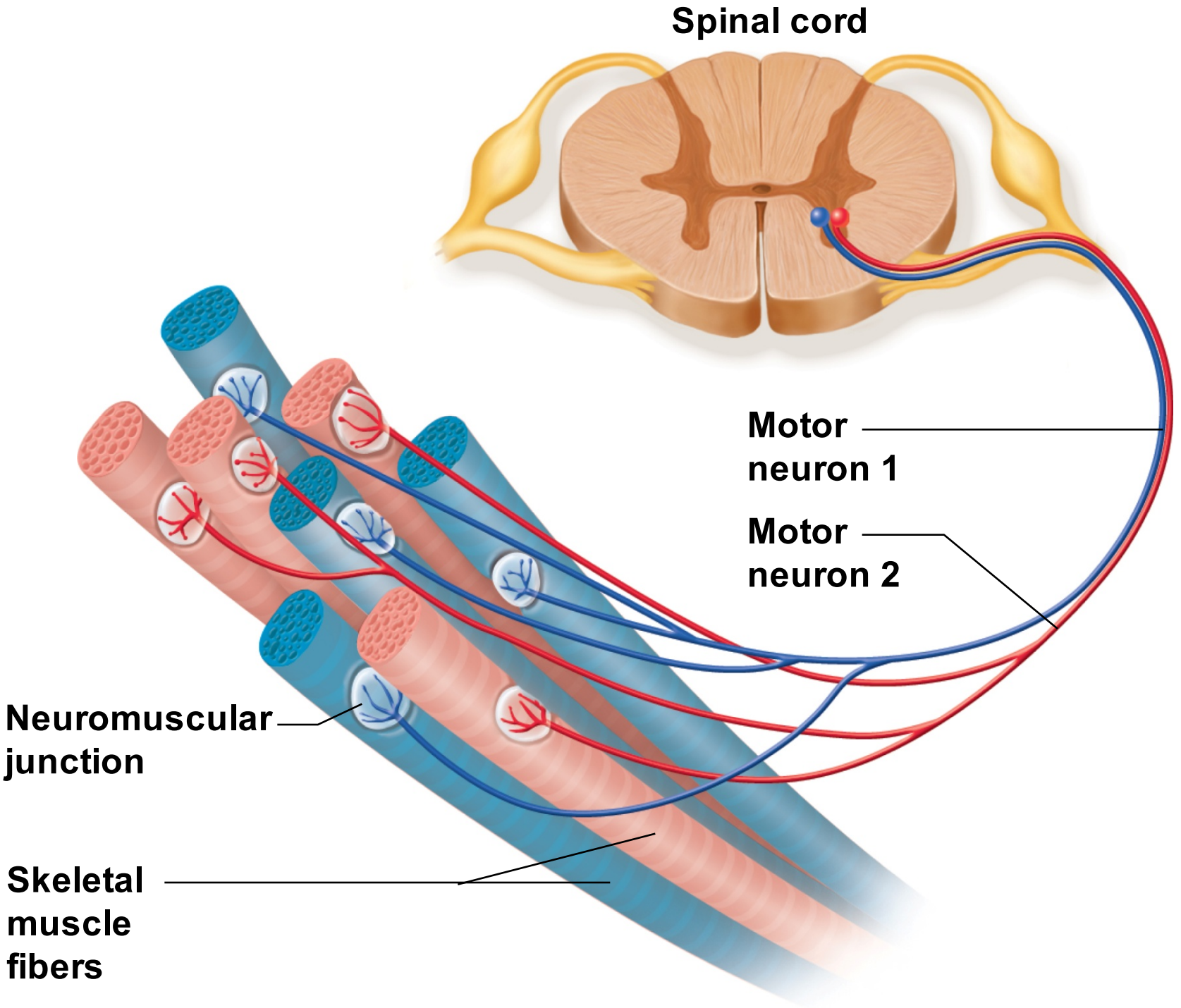

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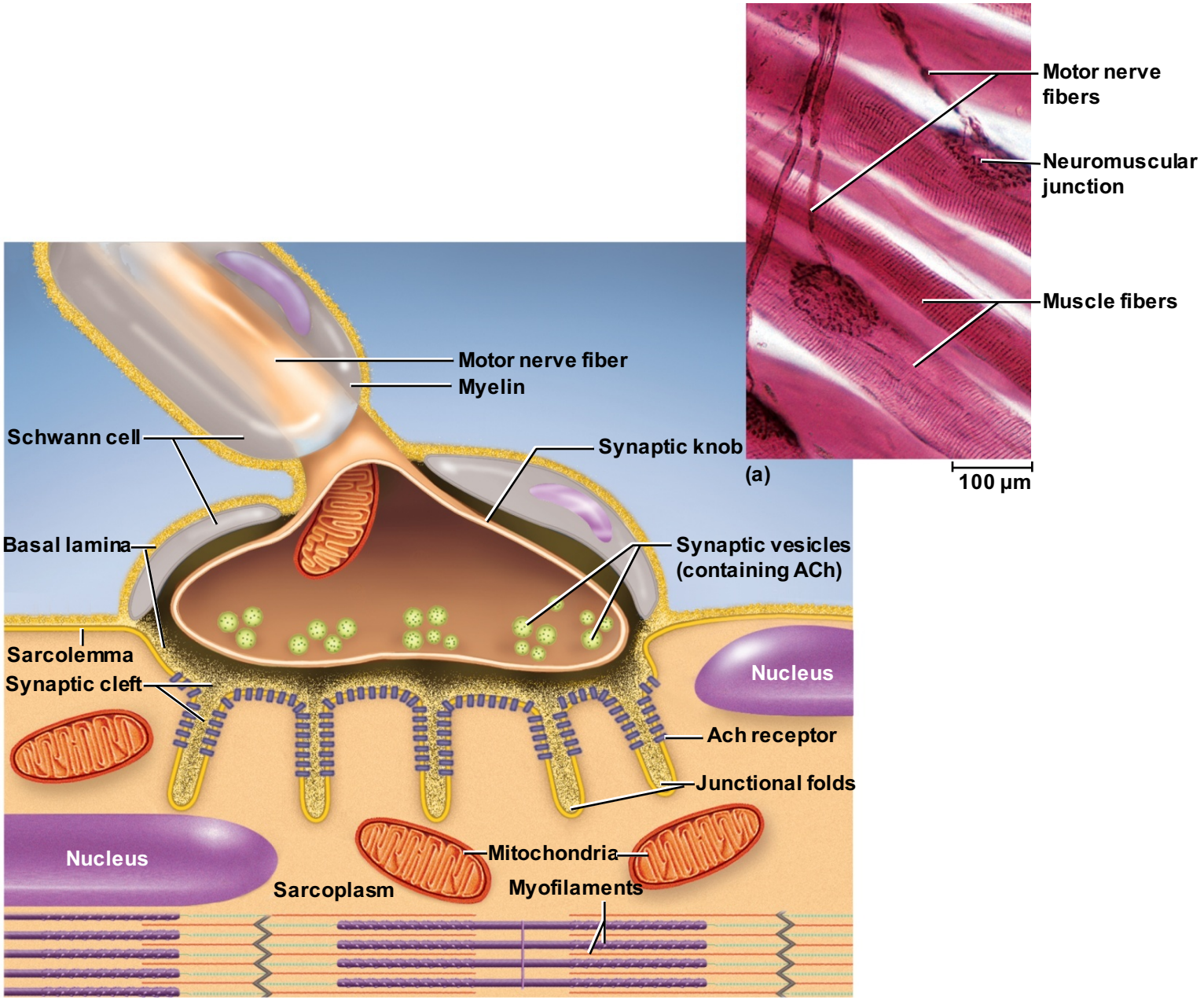


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Table 11.2

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| TABLE 11.2 | Components of the Neuromuscular Junction |
|---|---|
| **Term** | **Definition** |
| Neuromuscular junction | A functional connection between the distal end of a nerve fiber and the middle of a muscle fiber |
| Synaptic knob | The dilated tip of a nerve fiber; contains synaptic vesicles |
| Synaptic cleft | A gap of about 60 to 100 nm between the synaptic knob and sarcolemma |
| Synaptic vesicle | A secretory vesicle in the synaptic knob; contains acetylcholine |
| Junctional folds | Invaginations of the sarcolemma where ACh receptors are especially concentrated |
| Acetylcholine (ACh) | The neurotransmitter released by a somatic motor fiber that stimulates a skeletal muscle fiber (also used elsewhere in the nervous system) |
| ACh receptor | A transmembrane protein in the sarcolemma of the neuromuscular junction that binds to ACh |
| Acetylcholinesterase (AChE) | An enzyme in the sarcolemma and basal lamina of the muscle fiber in the synaptic region; responsible for degrading ACh and stopping the stimulation of the muscle fiber |

Fig. 11.8

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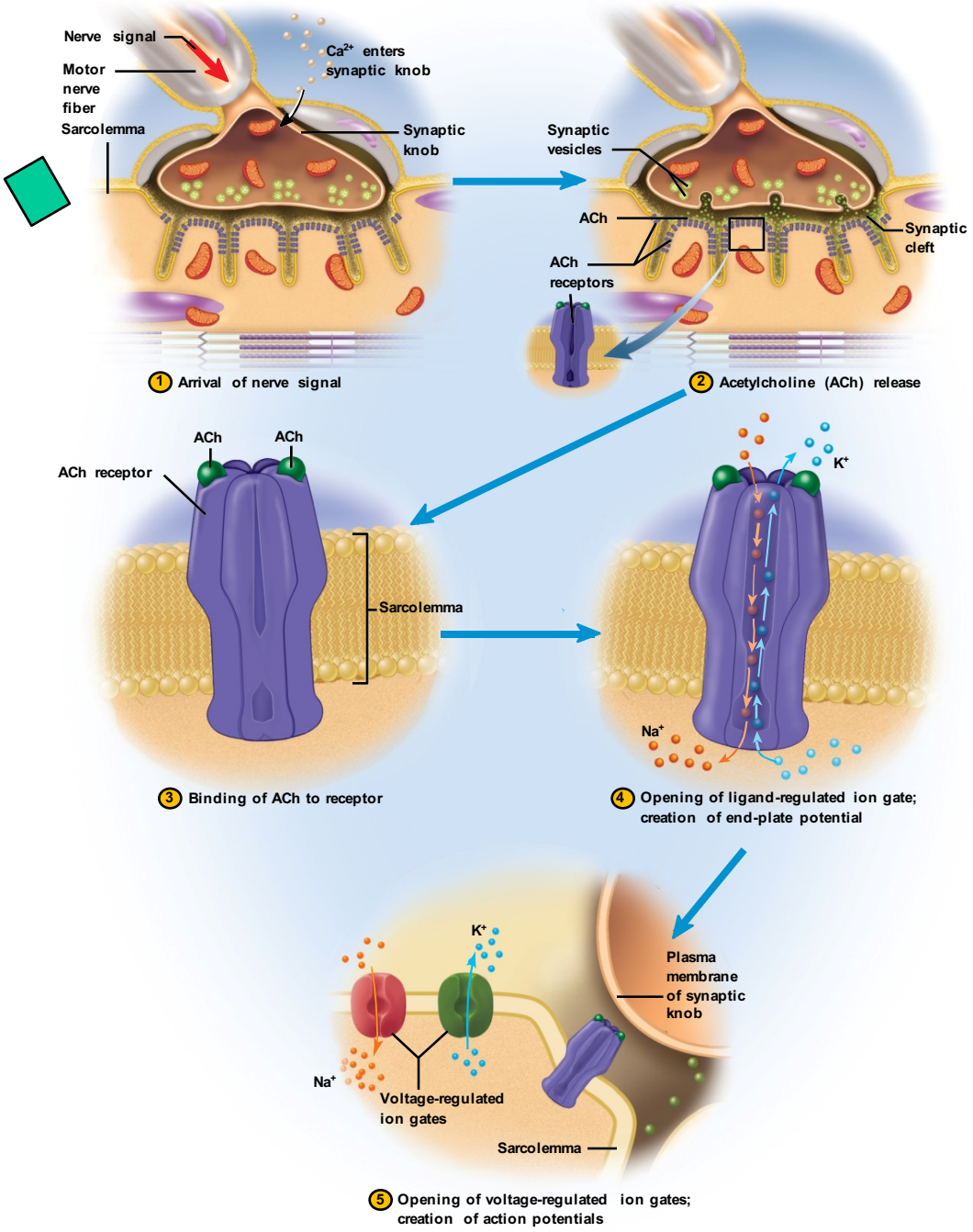

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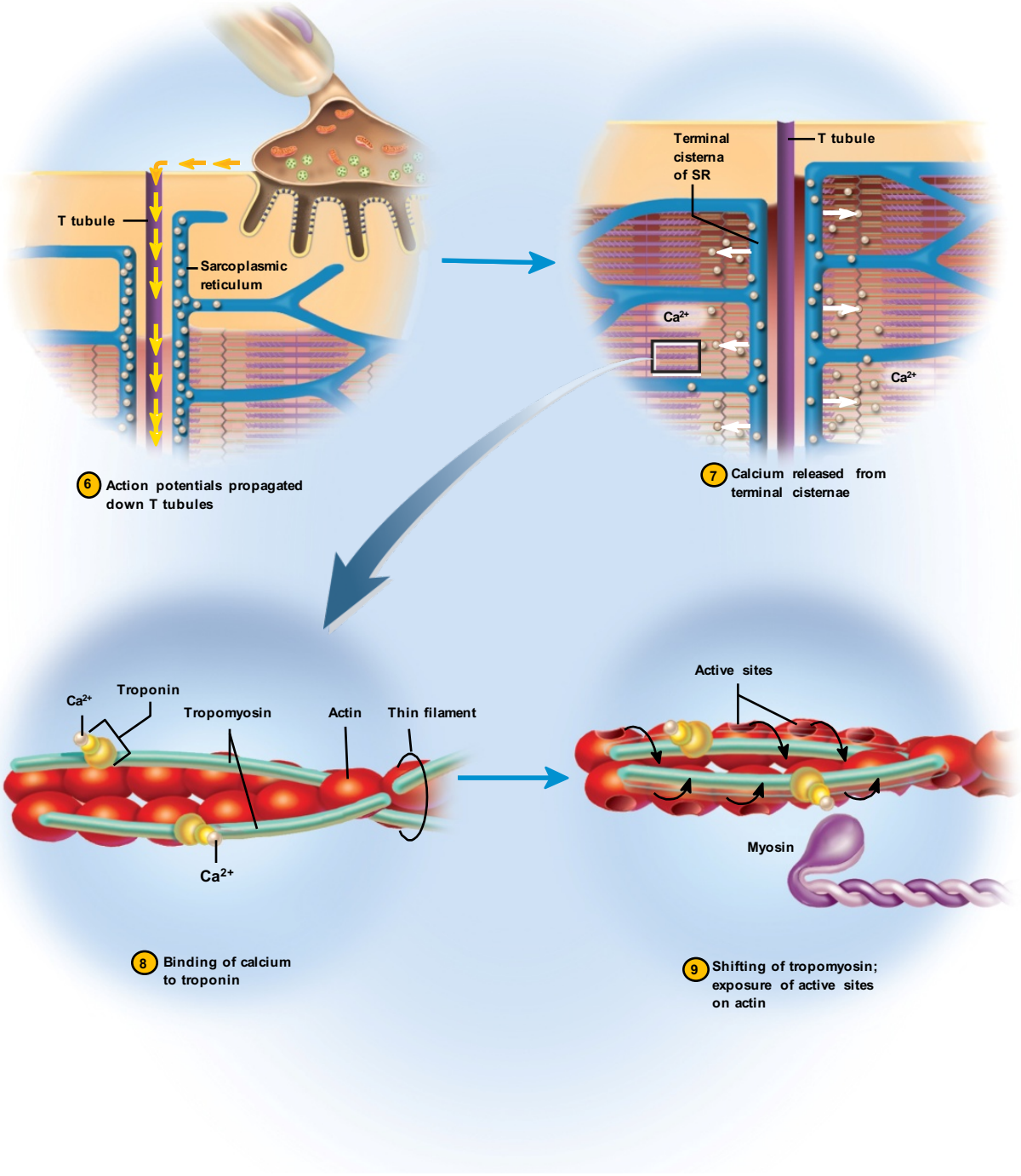

Fig. 11.10

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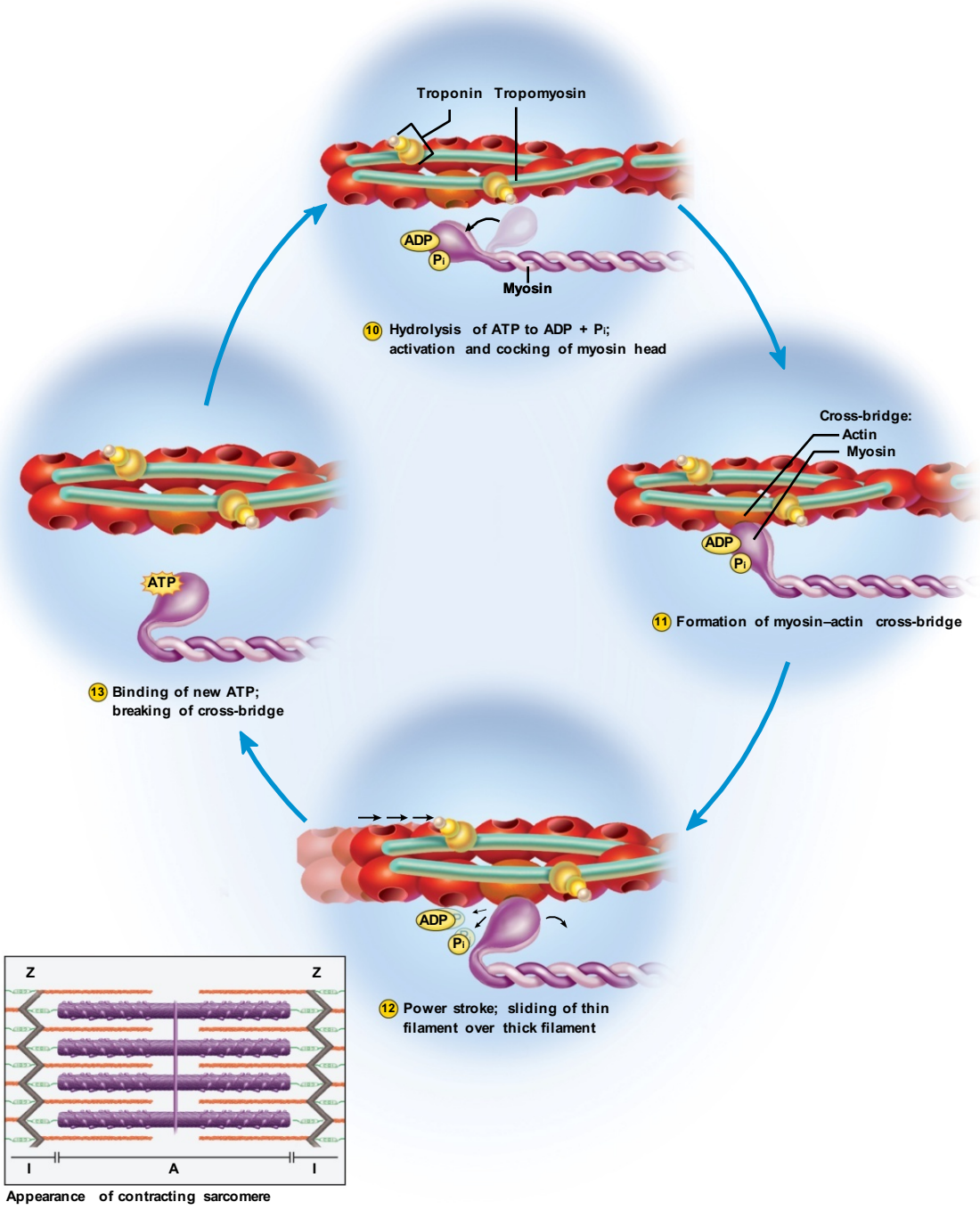

Fig. 11.11

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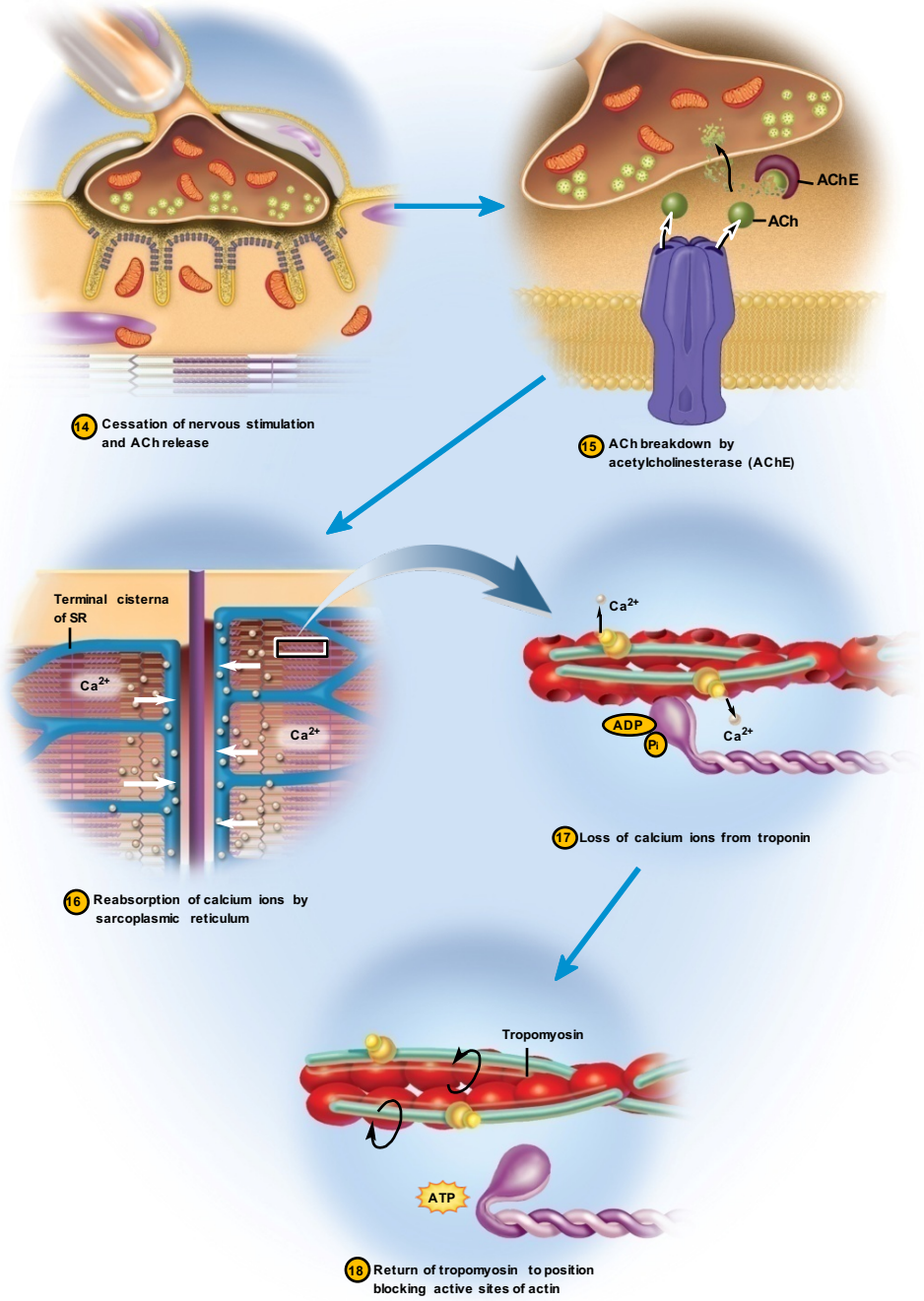

Fig. 11.12

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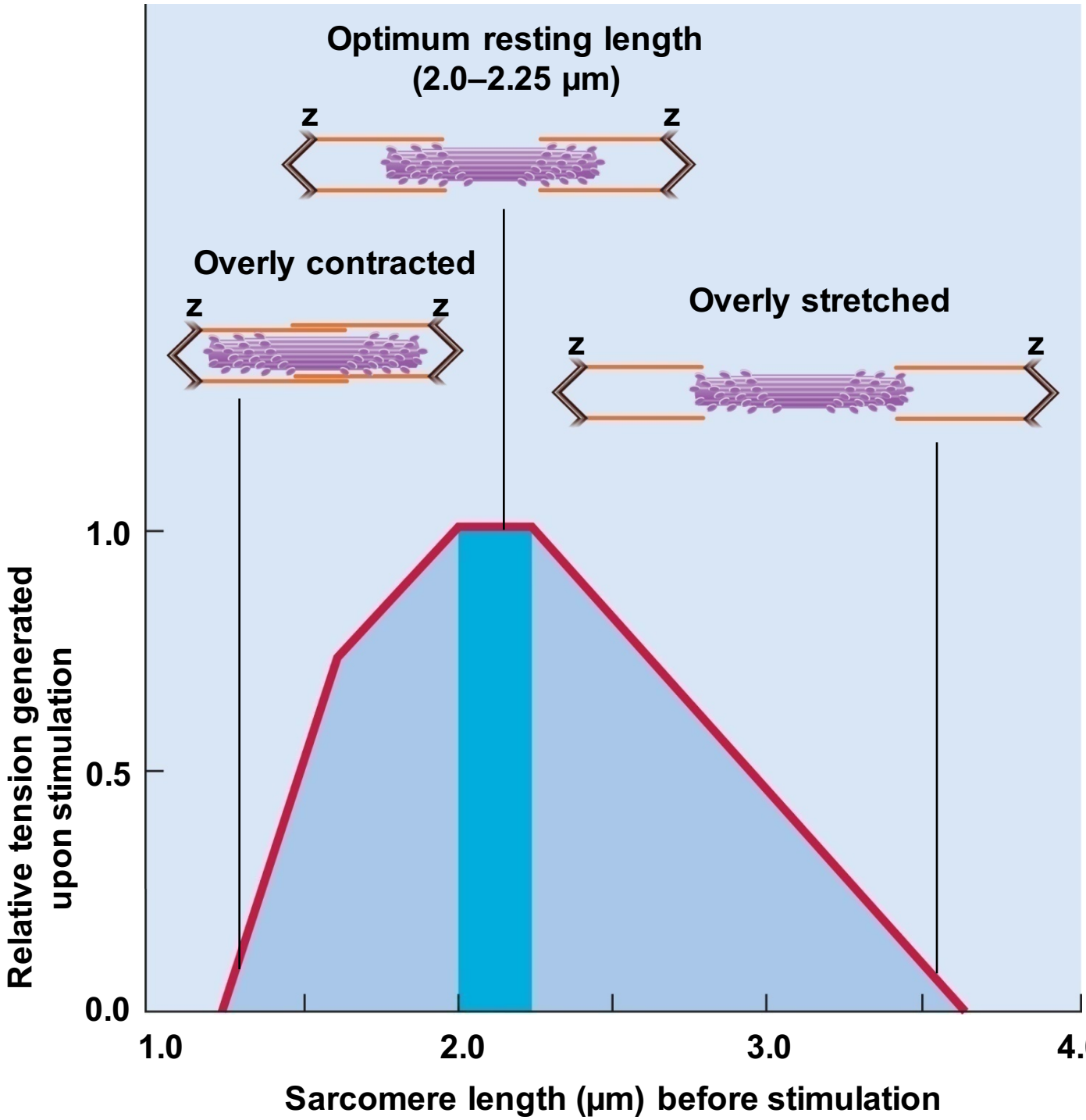

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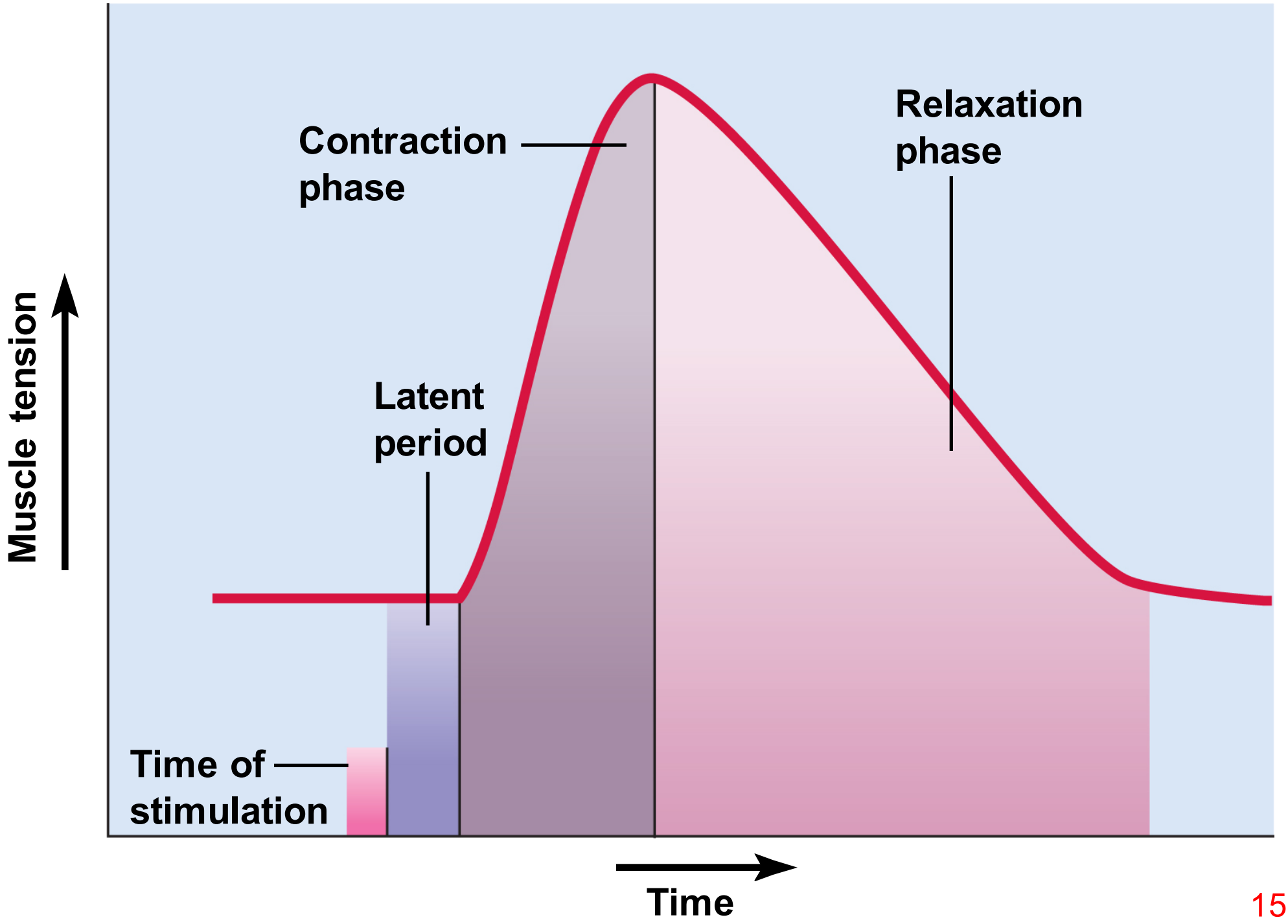

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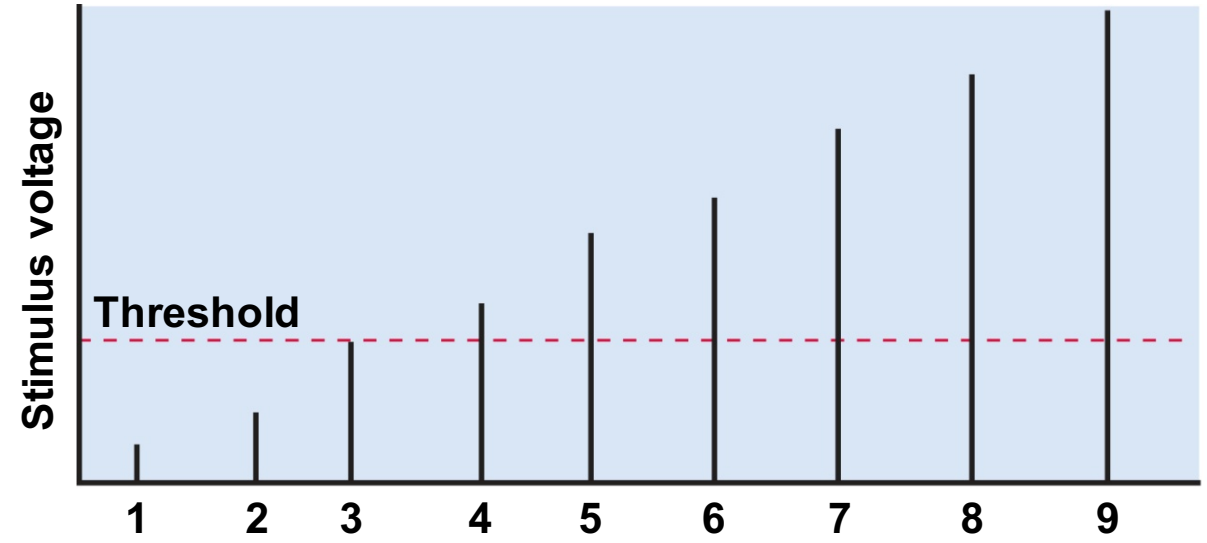

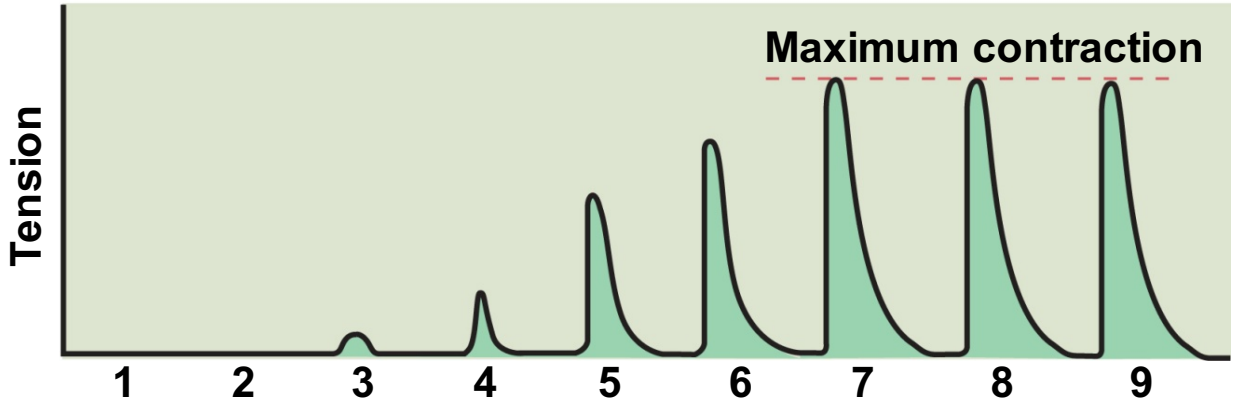

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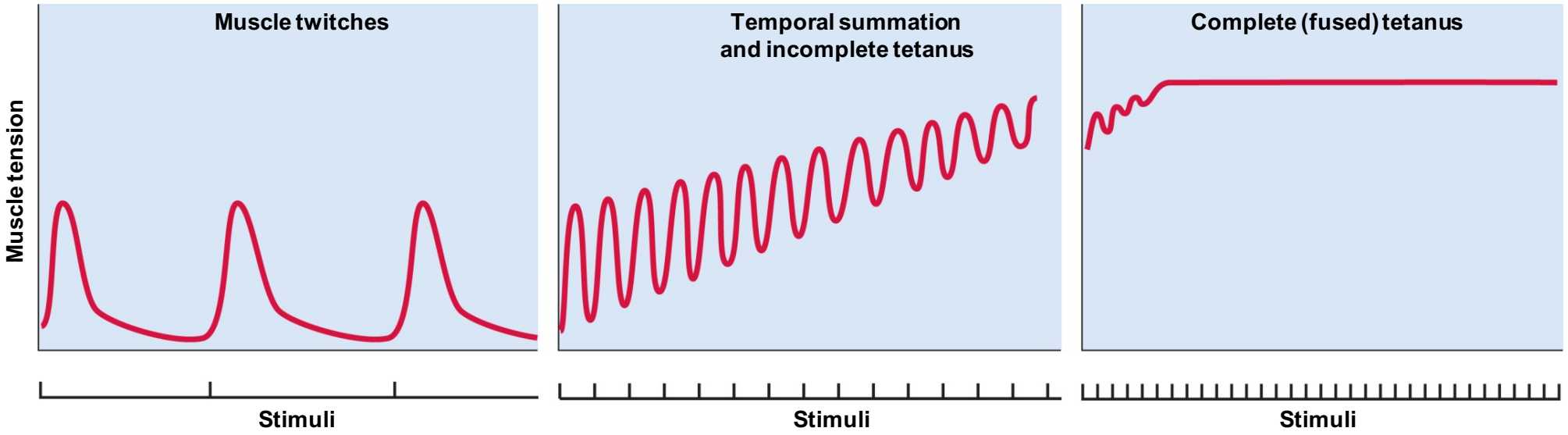


(a) Low stimulus frequency

(b) Physiologicially normal stimulus frequency

(c) Unnaturally high stimulus frequency

Fig. 11.16

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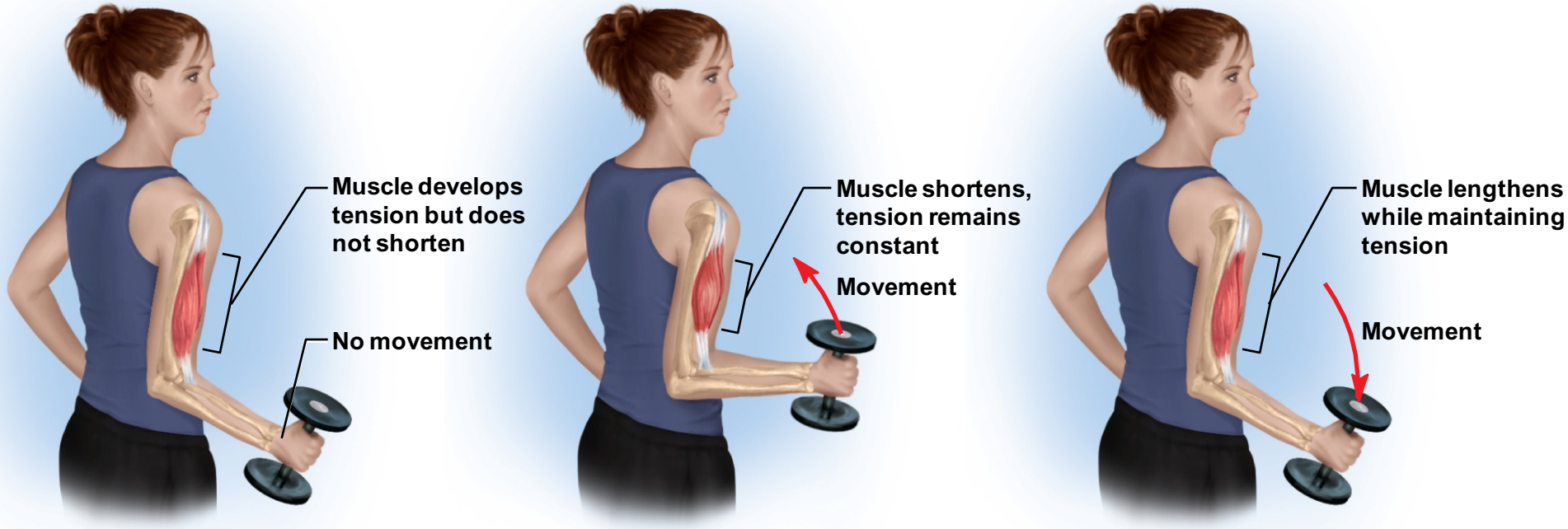


(a) Isometric contraction

(b) Isotonic concentric contraction

(c) Isotonic eccentric contraction

Fig. 11.17

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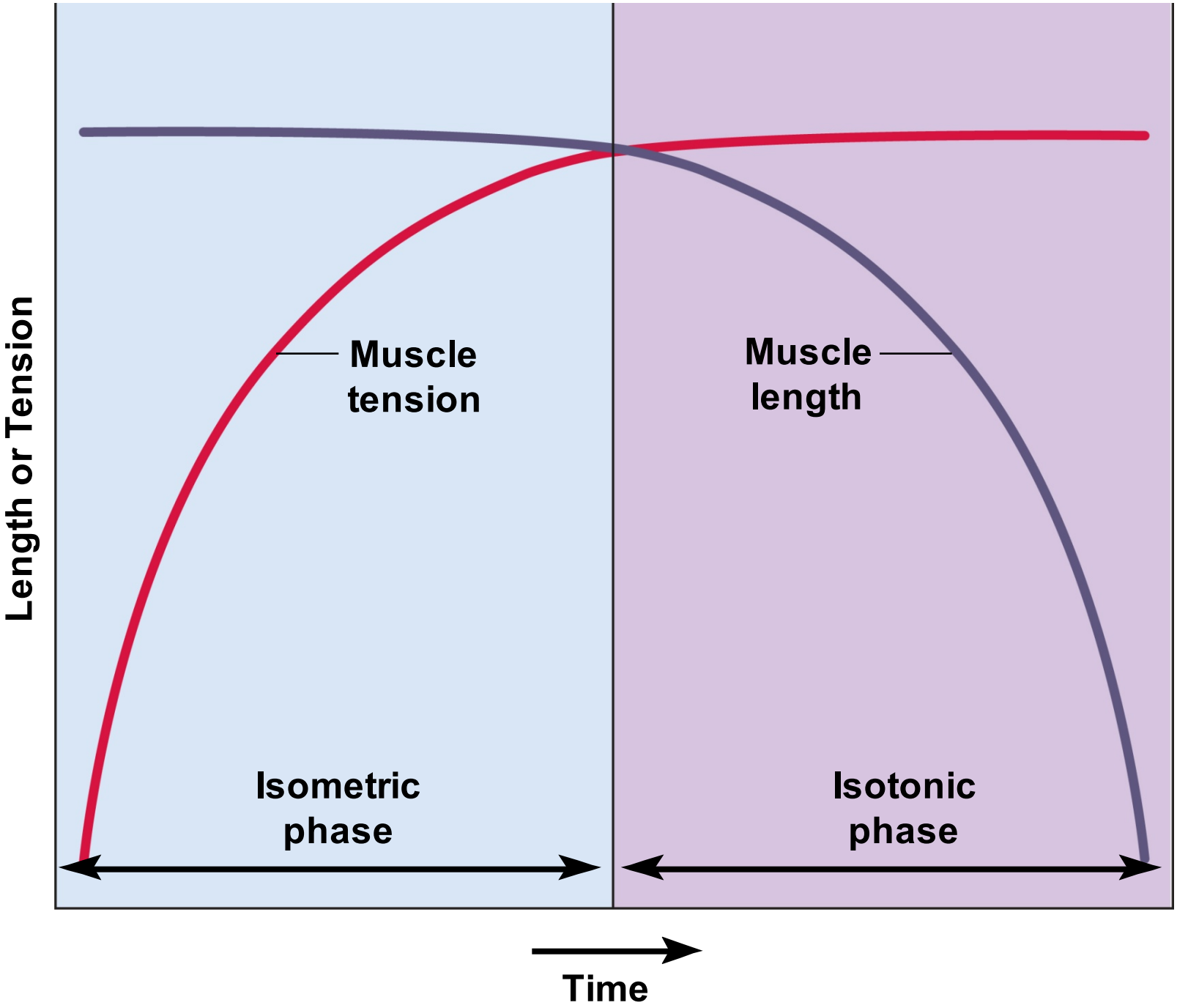

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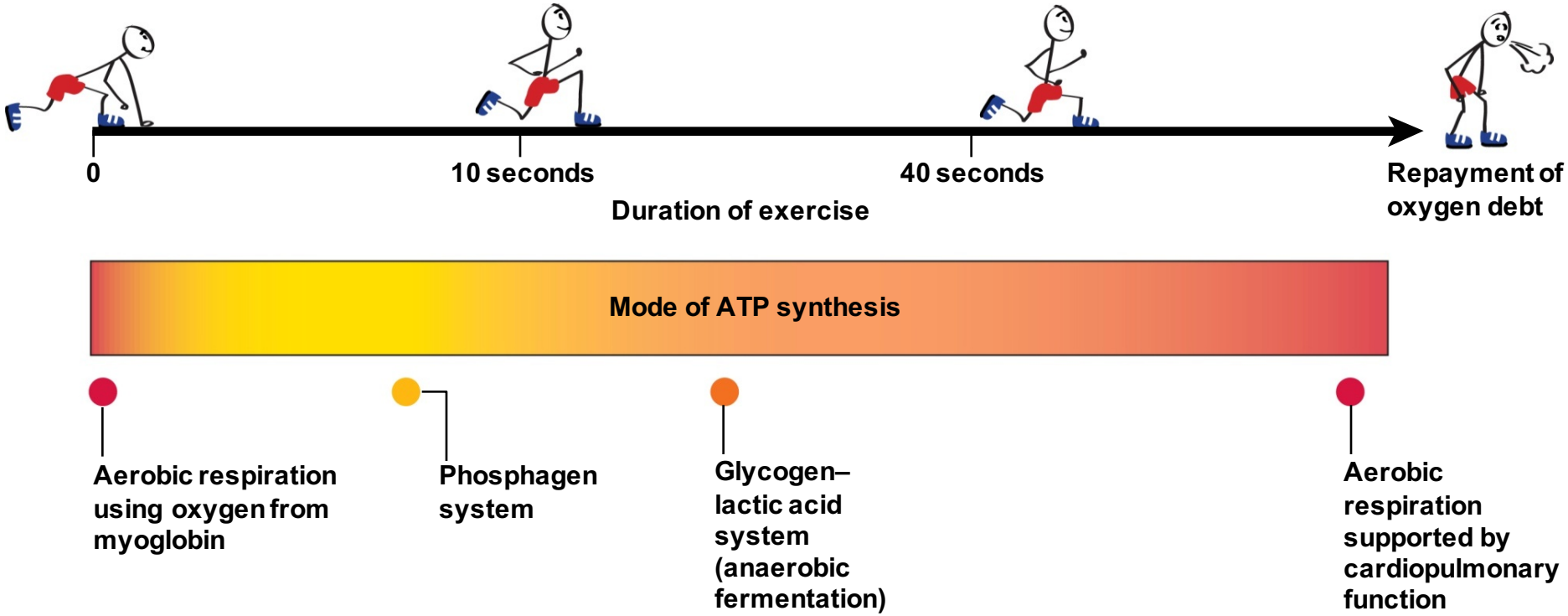

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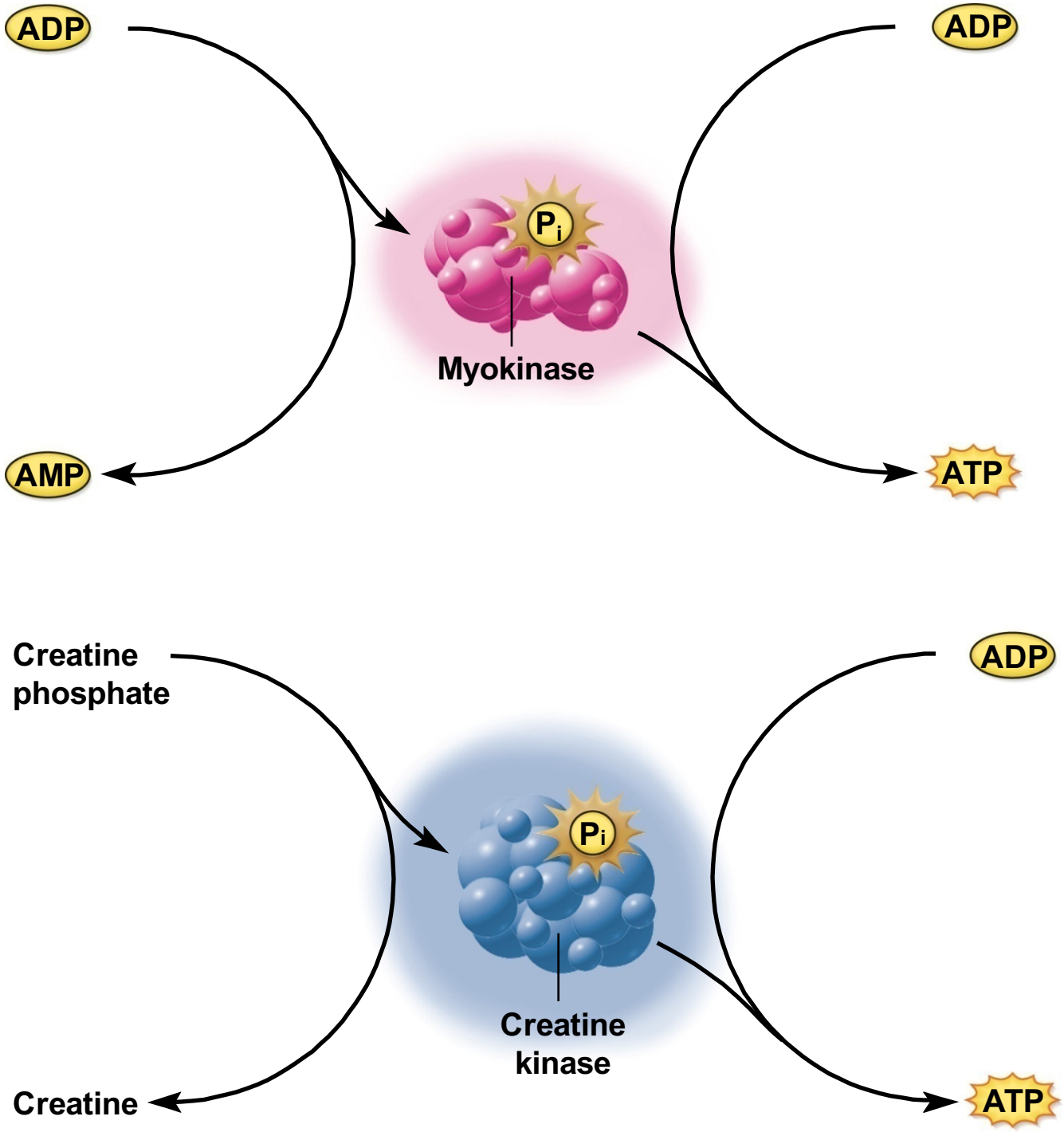

Table 11.3

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| TABLE 11.3 | Classification of Skeletal Muscle Fibers | |
|---|---|---|
| | Fiber Type | |
| **Properties** | **Slow-Twitch (Slow Oxidative)** | **Fast-Twitch (Fast Glycolytic)** |
| Twitch duration | As long as 100 ms | As short as 7.5 ms |
| Motor unit size | Smaller | Larger |
| Motor neurons | Smaller, more excitable | Larger, less excitable |
| Motor unit strength | Weaker | Stronger |
| Relative diameter | Smaller | Larger |
| ATP synthesis | Aerobic | Anaerobic |
| Fatigue resistance | Good | Poor |
| ATP hydrolysis | Slow | Fast |
| Glycolysis | Moderate | Fast |
| Myoglobin content | Abundant | Low |
| Glycogen content | Low | Abundant |
| Mitochondria | Abundant and large | Fewer and smaller |
| Capillaries | Abundant | Fewer |
| Color | Red | White, pale |
| *Representative muscles in which fiber type is predominant* | Soleus<br>Erector spinae<br>Quadratus lumborum | Gastrocnemius<br>Biceps brachii<br>Muscles of eye movement |

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## TABLE 11.4 Proportion of Slow Oxidative (SO) and Fast Glycolytic (FG) Fibers in the Quadriceps Femoris Muscle of Male Athletes

| Sample Population | SO | FG |
|---|---|---|
| Marathon runners | 82% | 18% |
| Swimmers | 74 | 26 |
| Average males | 45 | 55 |
| Sprinters and jumpers | 37 | 63 |

Table 11.5

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**TABLE 11.5 Comparison of Skeletal, Cardiac, and Smooth Muscle**

| Feature | Skeletal Muscle | Cardiac Muscle | Smooth Muscle |
|---|---|---|---|
| Location | Associated with skeletal system | Heart | Walls of viscera and blood vessels, iris of eye, piloerector of hair follicles |
| Cell shape | Long threadlike fibers | Short, slightly branched cells | Short fusiform cells |
| Cell length | 100 μm–30 cm | 50–100 μm | 30–200 μm |
| Cell width | 10–500 μm | 10–20 μm | 5–10 μm |
| Striations | Present | Present | Absent |
| Nuclei | Multiple nuclei, adjacent to sarcolemma | Usually one nucleus, near middle of cell | One nucleus, near middle of cell |
| Connective tissues | Endomysium, perimysium, epimysium | Endomysium only | Endomysium only |
| Sarcoplasmic reticulum | Abundant | Present | Scanty |
| T tubules | Present, narrow | Present, wide | Absent |
| Gap junctions | Absent | Present in intercalated discs | Present in single-unit smooth muscle |
| Autorhythmicity | Absent | Present | Present in single-unit smooth muscle |
| Thin filament attachment | Z discs | Z discs | Dense bodies |
| Regulatory proteins | Tropomyosin, troponin | Tropomyosin, troponin | Calmodulin, myosin light-chain kinase |
| $Ca^{2+}$ source | Sarcoplasmic reticulum | Sarcoplasmic reticulum and extracellular fluid | Mainly extracellular fluid |
| $Ca^{2+}$ receptor | Troponin of thin filament | Troponin of thin filament | Calmodulin of thick filament |
| Innervation and control | Somatic motor fibers (voluntary) | Autonomic fibers (involuntary) | Autonomic fibers (involuntary) |
| Nervous stimulation required? | Yes | No | No |
| Effect of nervous stimulation | Excitatory only | Excitatory or inhibitory | Excitatory or inhibitory |
| Mode of tissue repair | Limited regeneration, mostly fibrosis | Limited regeneration, mostly fibrosis | Relatively good capacity for regeneration |

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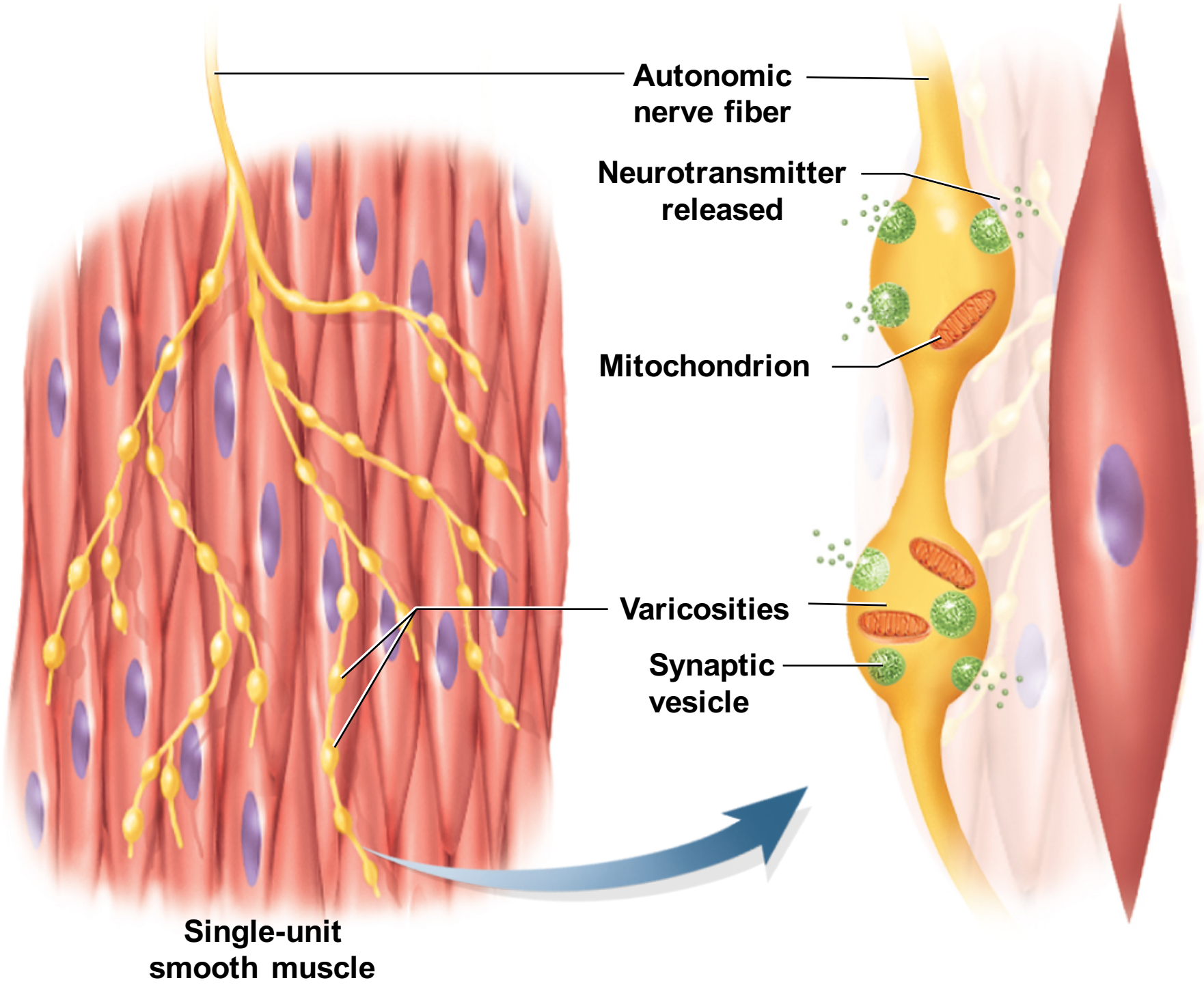

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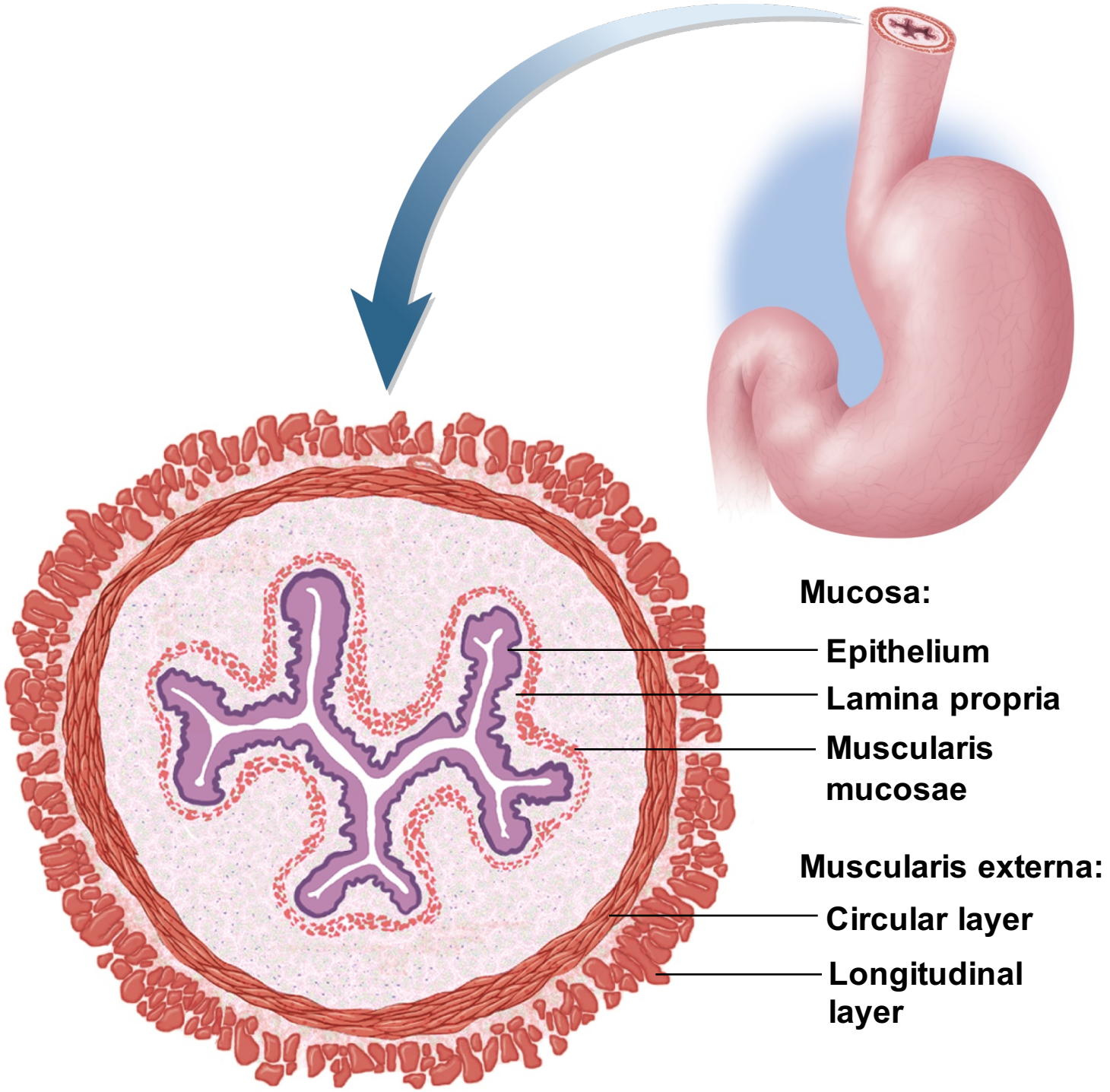

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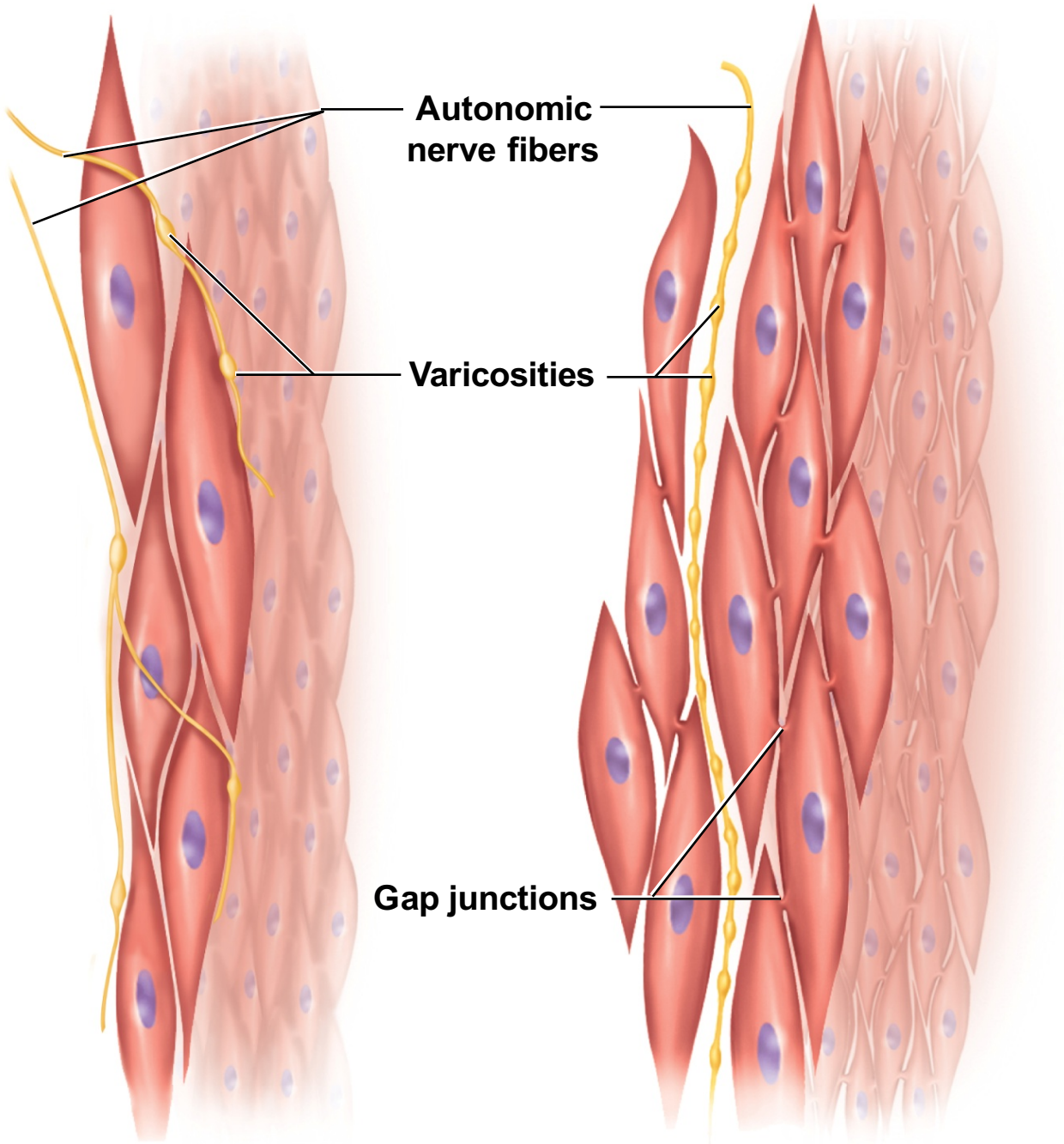

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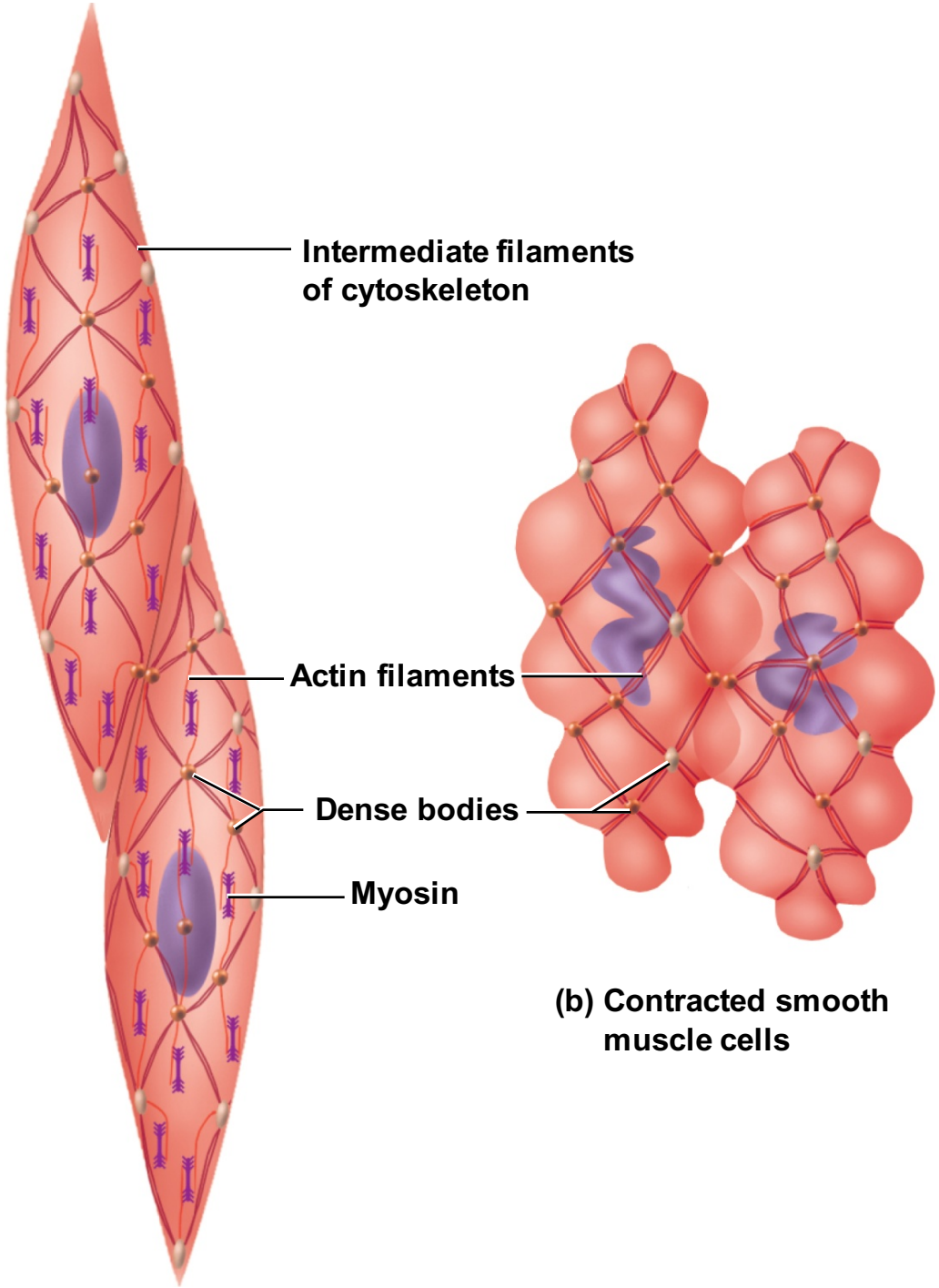

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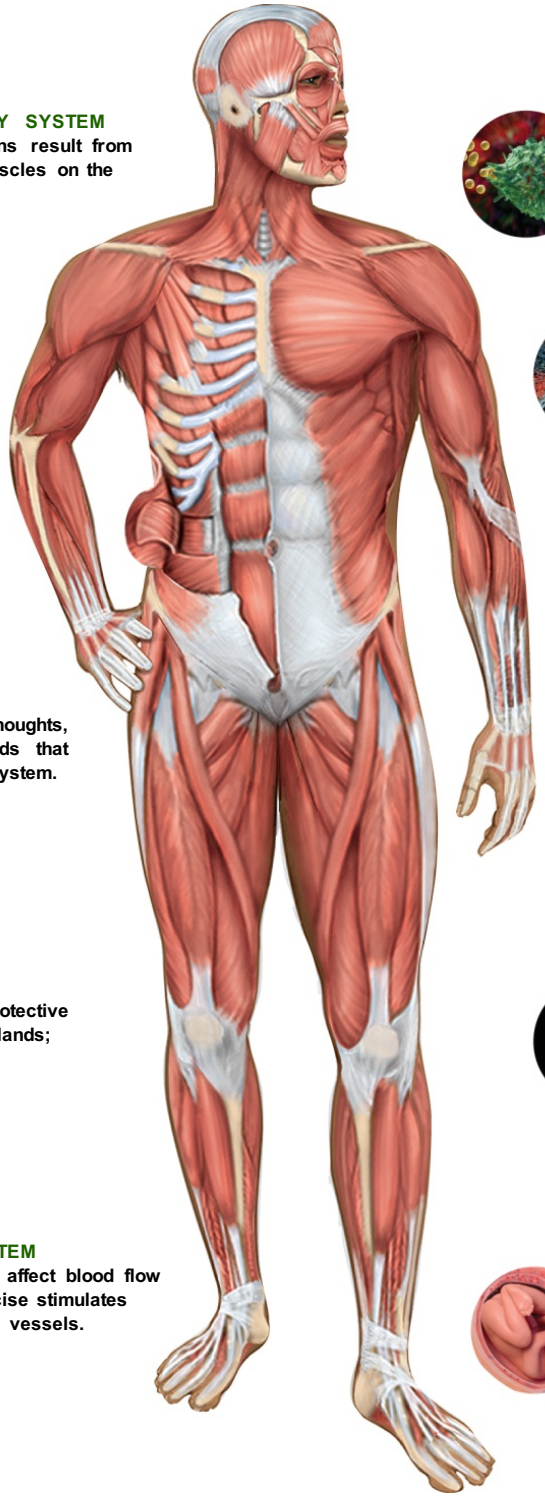
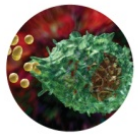


**INTEGUMENTARY SYSTEM**
Facial expressions result from the action of muscles on the skin.



**LYMPHATIC/IMMUNE SYSTEM**
Muscle contractions aid flow of lymph; exercise elevates levels of immune cells and antibodies in circulation; excessive exercise can inhibit immunity.

**SKELETAL SYSTEM**
Muscles move and stabilize joints and produce stresses that affect ossification, bone remodeling, and the shapes of bones.

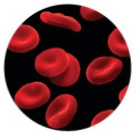
**RESPIRATORY SYSTEM**
Muscle contractions ventilate the lungs; muscles of the larynx and pharynx regulate airflow; $CO_2$ generated by muscular activity stimulates respiration; abdominal muscles produce pressure bursts of coughing and sneezing and aid in deep breathing.

**NERVOUS SYSTEM**
Muscles give expression to thoughts, emotions, and motor commands that arise in the central nervous system.

**URINARY SYSTEM**
A skeletal muscle sphincter retains urine in bladder until convenient for release; abdominal and pelvic muscles aid in compressing and emptying bladder; muscles of pelvic floor support bladder; bulbospongiosus muscle helps clear urine from male urethra.

**ENDOCRINE SYSTEM**
Skeletal muscles provide protective cover for some endocrine glands; muscle mass affects insulin sensitivity.

**DIGESTIVE SYSTEM**
Muscles enable chewing and swallowing; muscles control voluntary aspect of defecation; abdominal muscles produce vomiting; abdominal and lumbar muscles protect digestive organs.



**CIRCULATORY SYSTEM**
Muscle contractions affect blood flow in many veins; exercise stimulates growth of new blood vessels.

**REPRODUCTIVE SYSTEM**
Muscles are involved in sexual responses including erection and ejaculation; abdominal and pelvic muscles aid in childbirth.