Neuromuscular Junction

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25/03/2026

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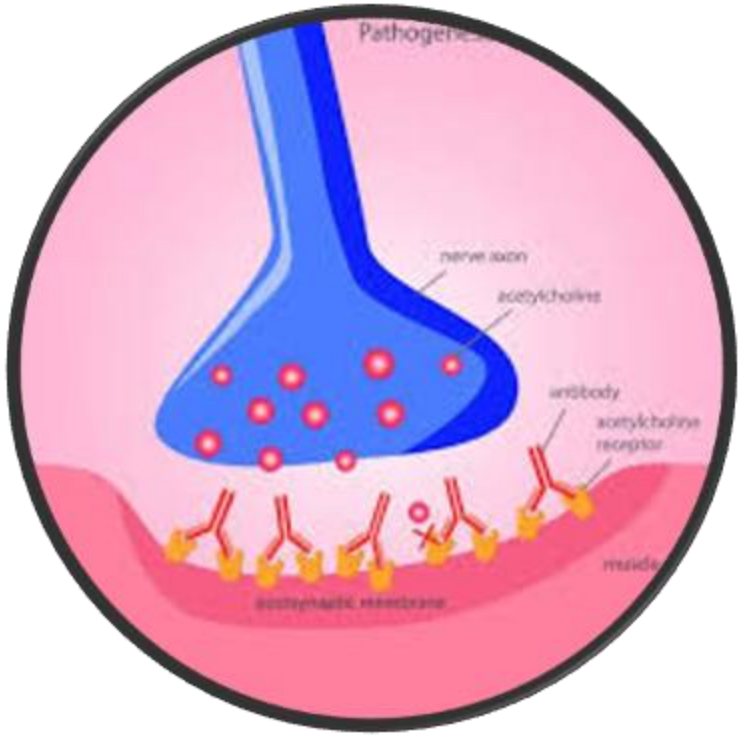
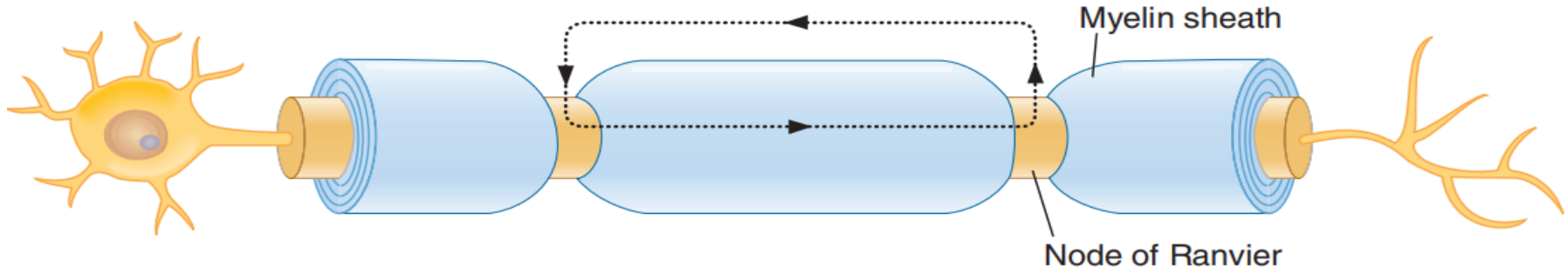
Introduction





IGURE 1-8 Myelinated axon. Action potentials can occur at nodes of Ranvier.

- An action potential in a motor neuron is rapidly propagated from the cell body within the CNS to the skeletal muscle along the large myelinated axon (efferent fiber) of the neuron.
- As the axon approaches a muscle, it divides and loses its myelin sheath.
- Each of these axon terminals forms a special junction, a neuromuscular junction, with one of the many muscle cells that compose the whole muscle.

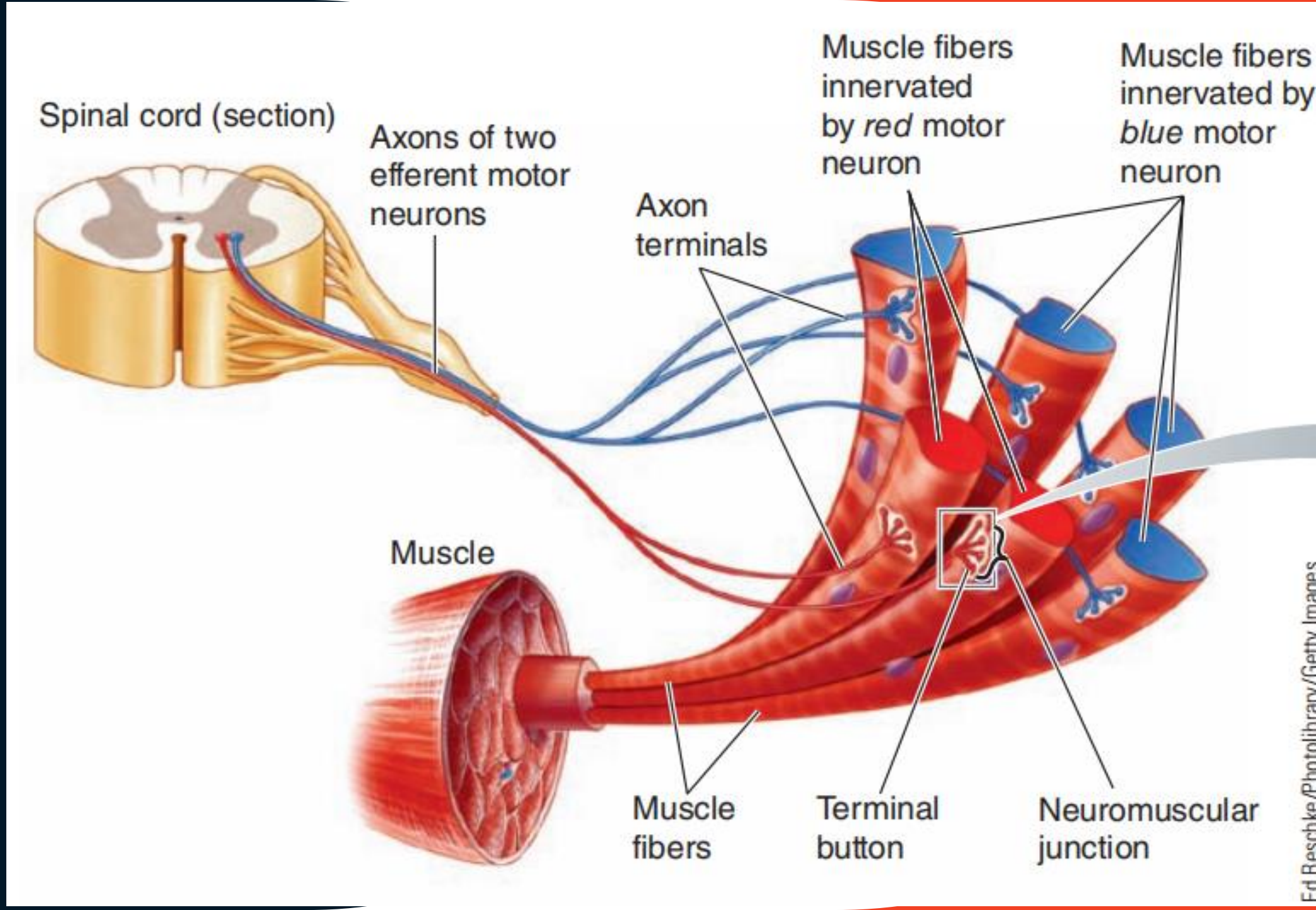
Introduction

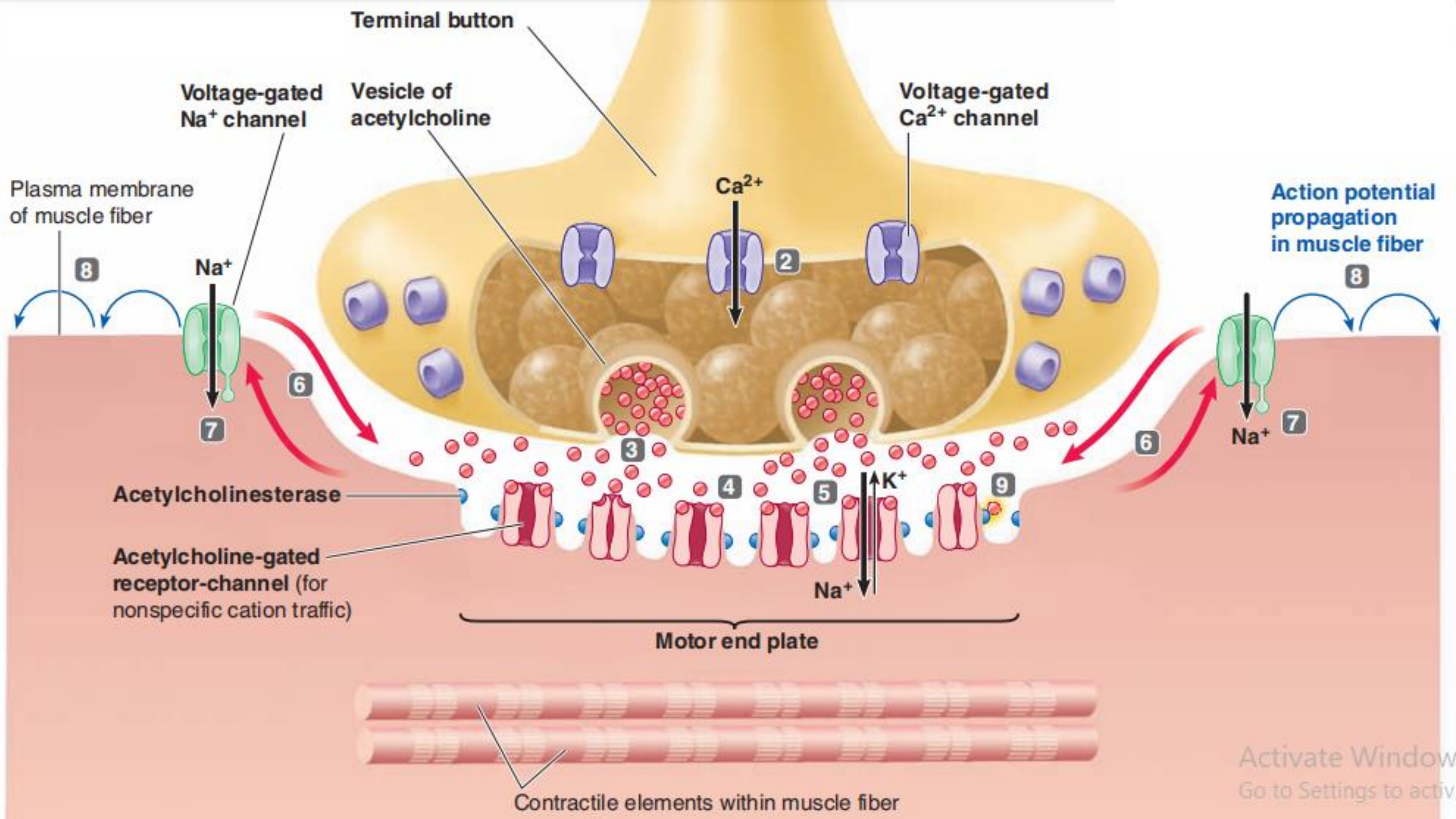
- Each branch innervates only one muscle cell; therefore, each muscle cell has only one neuromuscular junction.
- Both the neural and muscular components make up the neuromuscular junction.
- A single muscle cell, called a muscle fiber, is long and cylindrical.

Introduction

- Within a neuromuscular junction, the **axon terminal splits** into **multiple fine branches**, each of which ends in an **enlarged knoblike** structure called the **terminal button, or bouton**.

- The entire axon terminal ending **fits into a shallow depression**, or **groove**, in the underlying muscle fiber, this depression is called **motor end plate.**


Spinal cord (section)
Axons of two efferent motor neurons
Muscle fibers innervated by *red* motor neuron
Muscle fibers innervated by *blue* motor neuron
Axon terminals
Muscle
Muscle fibers
Terminal button
Neuromuscular junction
Ed Reschke/Photolibrary/Getty Images

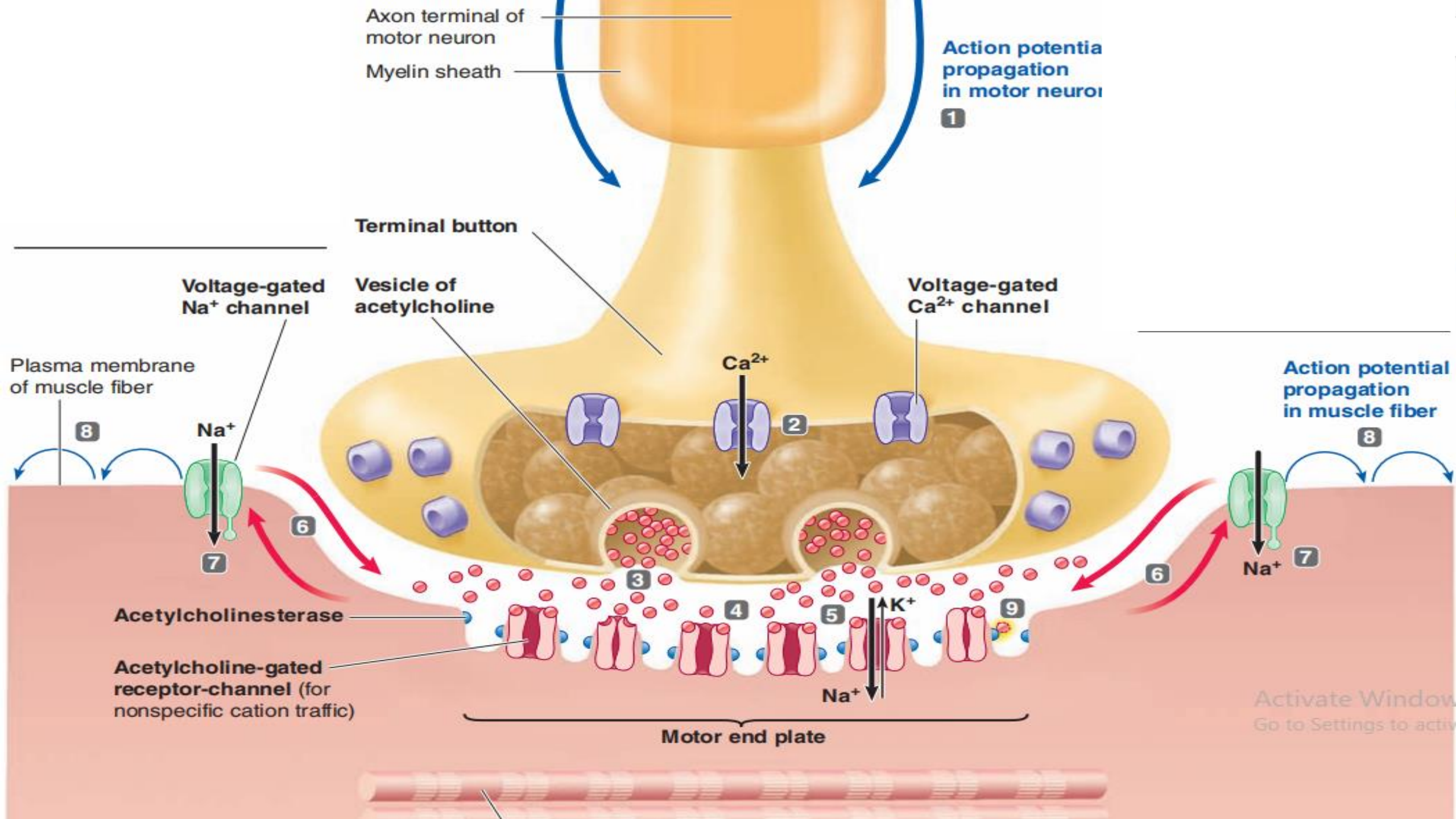

Terminal button
Voltage-gated
Na+ channel
Vesicle of
acetylcholine
Voltage-gated
Ca2+ channel
Plasma membrane
of muscle fiber
Ca2+
Action potential
propagation
in muscle fiber
8
Na+
2
8
6
7
Na+
7
6
3
4
5
K+
9
Acetylcholinesterase
Acetylcholine-gated
receptor-channel (for
nonspecific cation traffic)
Na+
Motor end plate
Contractile elements within muscle fiber

Introduction

- Nerve and muscle cells do **not come into direct contact** at a neuromuscular junction.
- The space, or **(synaptic cleft)**, between these two structures is **too large for electrical transmission** of an impulse between them.
- A chemical messenger carries the signal between a terminal button and the muscle fiber. **This neurotransmitter is Ach**.

Release of ACh at the Neuromuscular Junction

- Each **terminal button** contains thousands of **vesicles** that **store ACh.**
- 1- Propagation of an **action potential** to the axon terminal **triggers** the **opening of voltage-gated calcium (Ca^{2+}) channels** in its terminal buttons.
- 2- When **Ca^{2+}** channels open, **Ca^{2+}** diffuses into the terminal button from its higher extracellular concentration, 3- which in turn **causes release of ACh** by **exocytosis** from several hundred vesicles into the **synaptic cleft**.


Axon terminal of motor neuron
Myelin sheath
Action potentia propagation in motor neuro
1
Terminal button
Voltage-gated Na+ channel
Vesicle of acetylcholine
Voltage-gated Ca2+ channel
Plasma membrane of muscle fiber
Ca2+
2
Action potential propagation in muscle fiber
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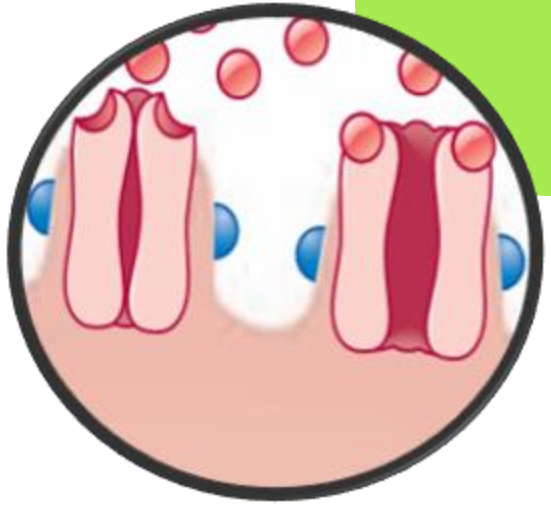
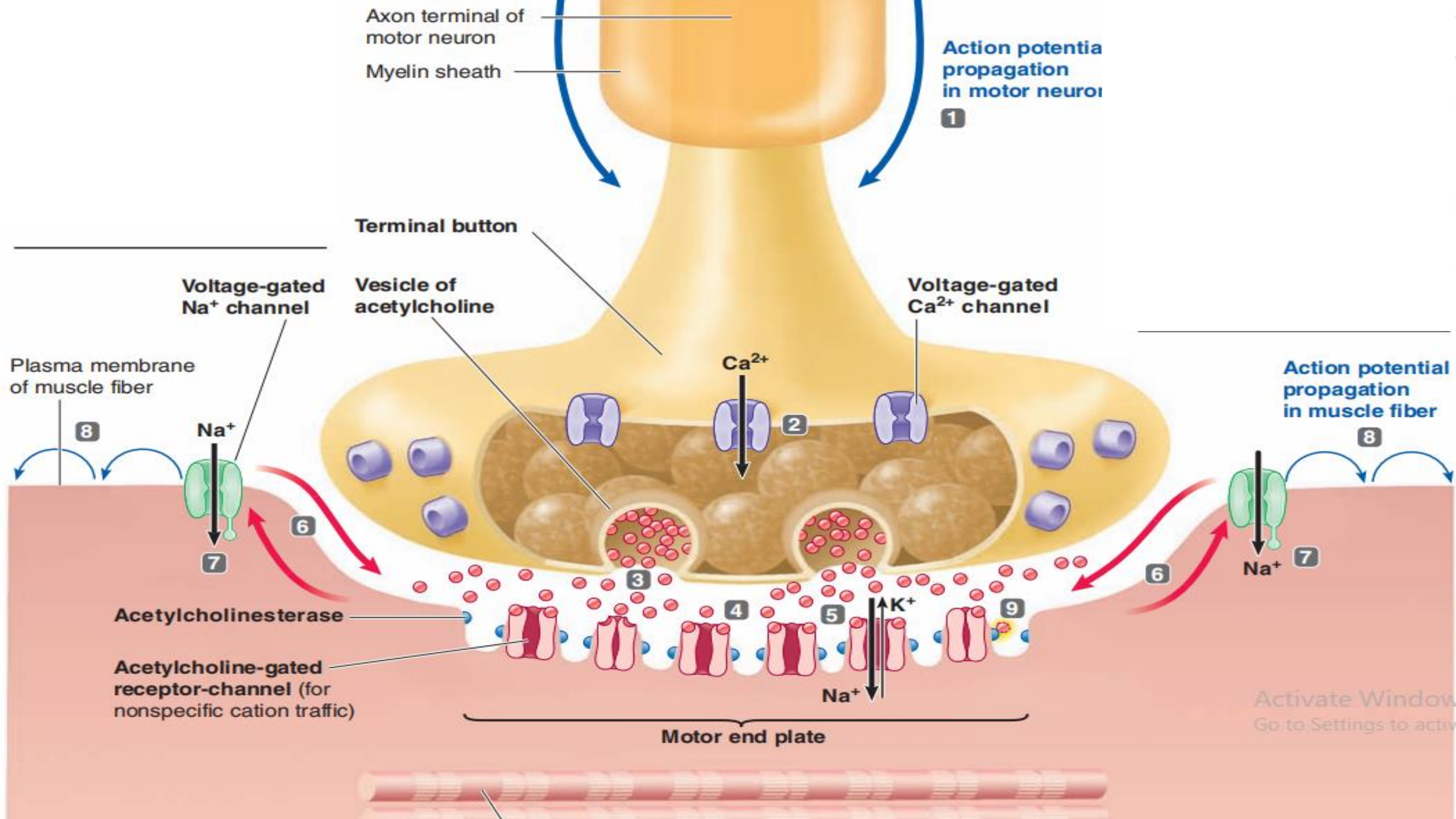
Na+
8
6
7
3
Na+
7
6
Acetylcholinesterase
4
5
K+
9
Acetylcholine-gated receptor-channel (for nonspecific cation traffic)
Na+
Motor end plate

Formation of an End-Plate Potential



- **4-** The **released ACh** diffuses across the **synaptic cleft** and **binds with chemically gated receptor channels(Ligand-gated channels)** of the **cholinergic nicotinic type** on the **motor end-plate portion** of the muscle fiber membrane.
- **5-** Binding with **ACh causes these receptor-channels to open**.
- They are nonspecific cation channels that permit both Na+ and K+ traffic through them.

(**more Na+ moves inward than K+ moves outward**, leading to **depolarizing the motor end plate**)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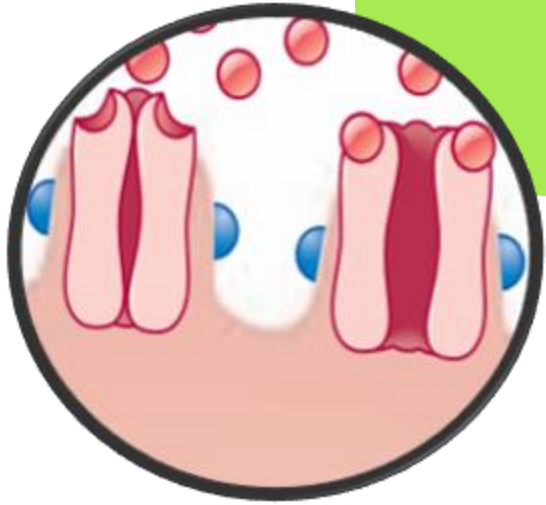
Na+
Motor end plate

Formation of an End-Plate Potential

- The **collective potential change** resulting from these ion movements across **all of the terminal buttons within a neuromuscular junctions** is called the **end-plate potential (EPP).**

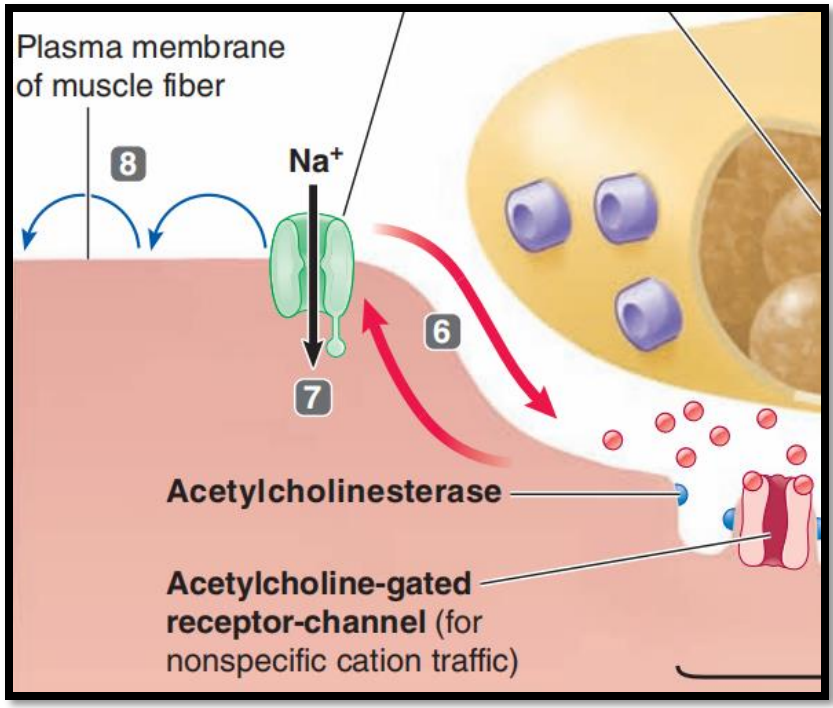
Initiation of an Action Potential



- The **motor end-plate region** itself does **not have a threshold potential**, so an action potential cannot be initiated at this site.
- The neuromuscular junction is usually in **the middle of the long, cylindrical muscle fiber.**
- **When an EPP takes place, local current flow occurs between the depolarized end plate and the adjacent, resting cell membrane in both directions, opening voltage-gated Na+ channels and thus reducing the potential to threshold in the adjacent areas**

Initiation of an Action Potential

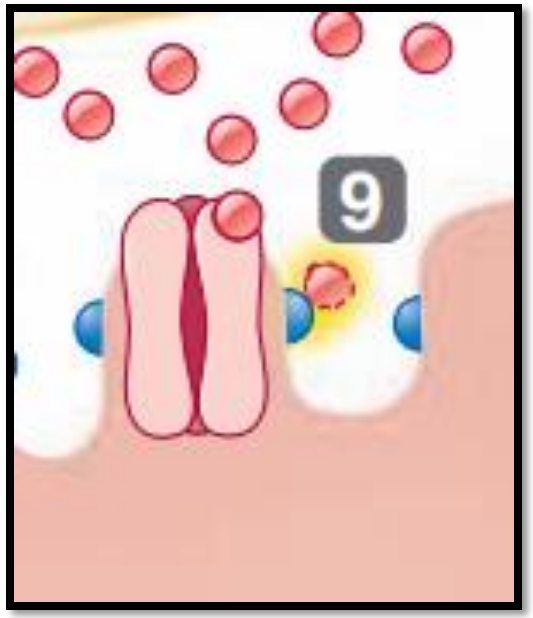
- **6-** When an **EPP takes place**, **local current flow occurs between the depolarized end plate and the adjacent resting cell membrane** in **both directions**, **7-** **opening voltage-gated Na+ channels** and thus reducing the potential to threshold in the adjacent areas.



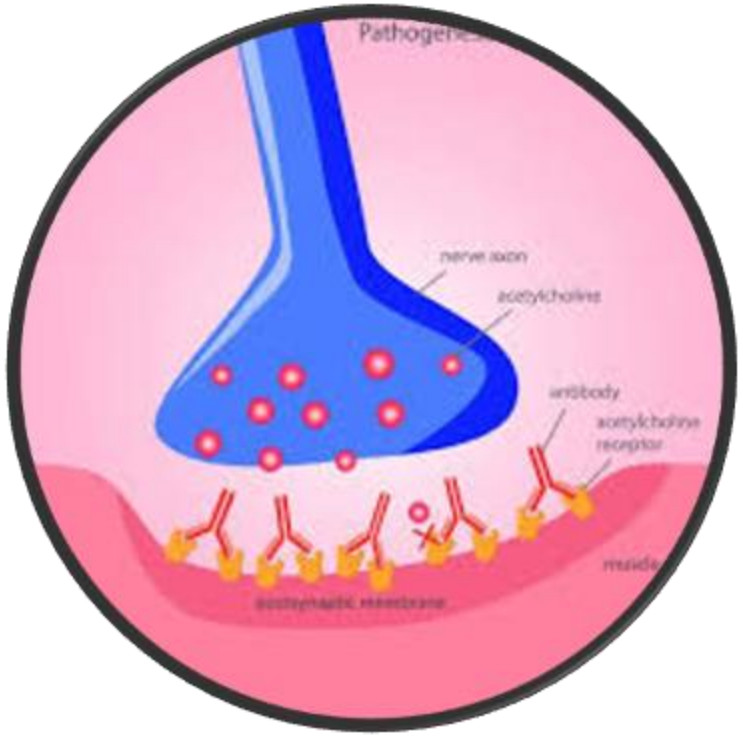
Termination of Ach Activity

- The **muscle cell's electrical response** is **turned off** by an **enzyme in the motor end-plate membrane, acetylcholinesterase (AChE), which inactivates ACh**.

- **ACh removal ends the EPP.**



Clinical correlation



Black Widow Spider

- Black Widow Spider Venom Causes Explosive Release of Ach from the storage vesicles, not only at neuromuscular junctions but at all cholinergic sites.

- The most harmful result of which is **respiratory failure.**

Organophosphates

- Organophosphates (like **malathion and sarin**) **irreversibly inhibiting AChE**, causing accumulation of acetylcholine, leading to prolonged neuromuscular stimulation followed by paralysis.

Botulinum Toxin

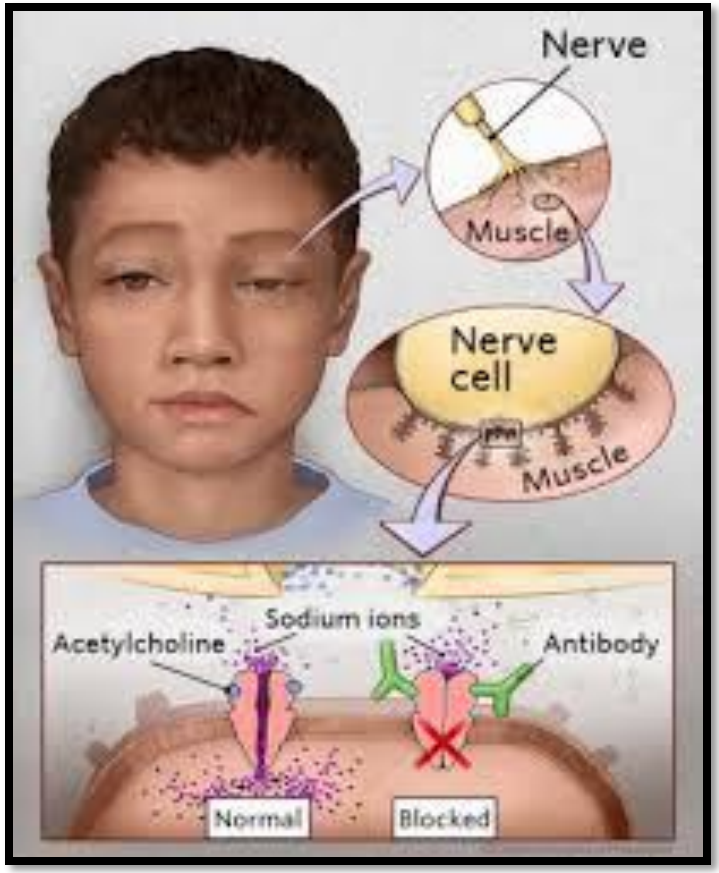
- Botulinum toxin exerts its lethal blow by **blocking the release of ACh** from the terminal button in response to a motorneuron action potential.

Curare

- Curare, which **reversibly binds to the ACh receptor-channels** on the motor end plate.

Myasthenia Gravis

- Myasthenia gravis, an **autoimmune disease** involving the neuromuscular junction, is characterized by extreme muscular weakness.
- The body erroneously produces **antibodies** against its motor end-plate **ACh receptor-channels**.
- Treatment: **neostigmine that inhibits AChE temporarily.**



Thank you