

# PHYSIOLOGY



Lec: 25

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**General physiology**  
**Second semester 2023-2024**  
**Lecture 25**  
**Neuromuscular junction and excitation contraction coupling**  
**in skeletal muscle**

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# Innervation of skeletal muscles :The Motor unit

NMJ

• **Neuromuscular junction** : the synapse between motor neuron and muscle fiber is called the neuromuscular junction

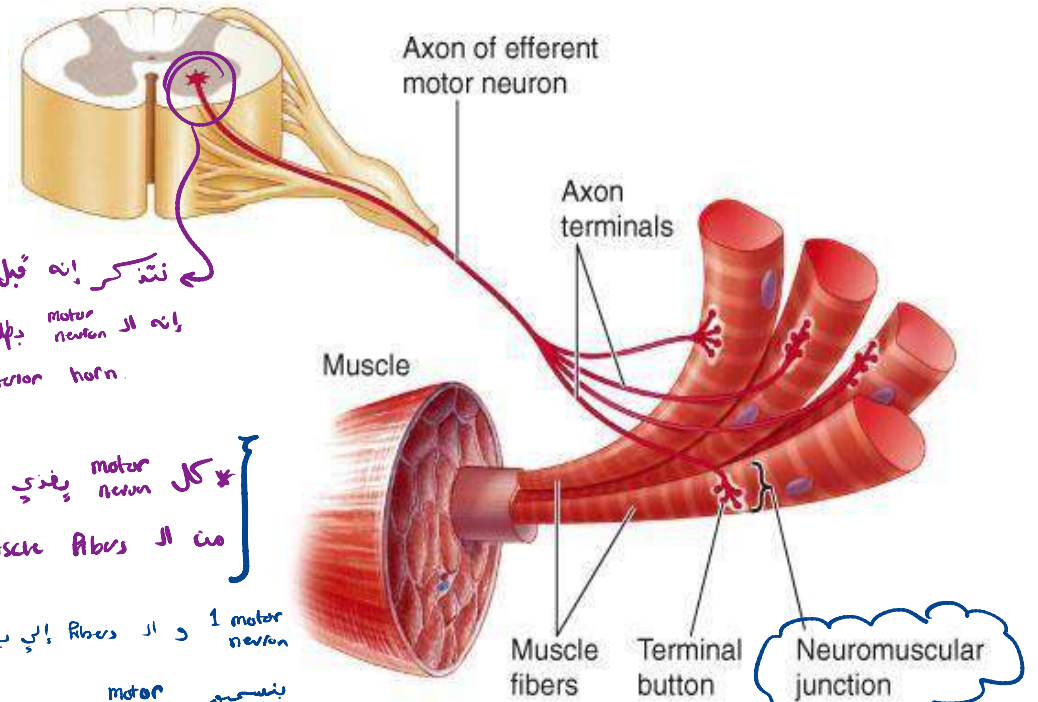
• **Motor neurons** : are the nerves that innervate muscle fibers  
 بتصلح من الـ Anterior horn لـ SC و

• **Motor unit** : single motor neuron and the muscle fibers it innervate

كل Skeletal muscle يغذيها motor neuron

كل ← muscle fiber يغذيها motor neuron  
 كل ← motor neuron يغذيها muscle fiber

Spinal cord (section)



ننتقل من الـ Anterior horn لـ motor neuron بتصلح من الـ

كل ← motor neuron يغذيها muscle fibers  
 من الـ muscle fibers

1 motor neuron و الـ muscle fibers التي يغذيها  
 بتسمى motor unit

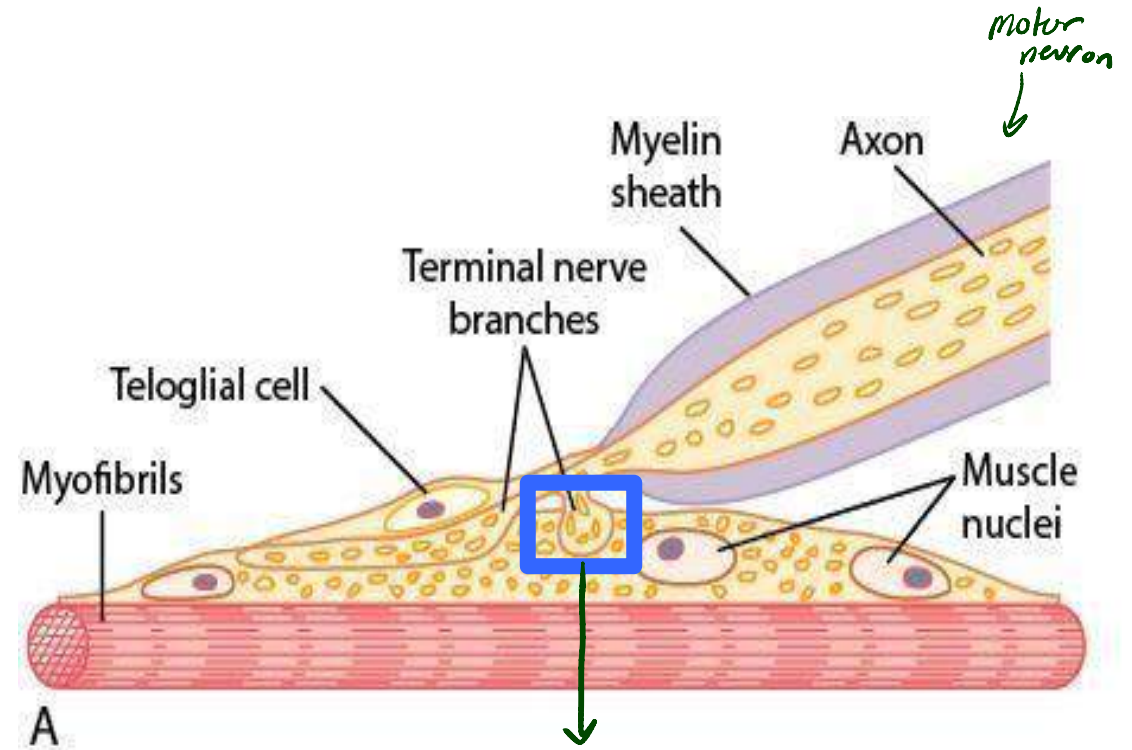
Neuromuscular junction

نقطة اتصال الـ neuron بالـ muscle fiber  
 (مكان الـ Synapse) 3

# Component of neuromuscular Junction

The synapse between mn + m

- Specialized **synapse** between a **motoneuron** and a muscle fiber
- Occurs at a structure on the muscle fiber called the **motor end plate** (*usually only one per fiber*)
- **Teloglia** : Parasynaptic Schwann cells (also known as Terminal Schwann cells) are Neuroglia found at the Neuromuscular junction (NMJ)
- Function : synaptogenesis, and nerve regeneration.



motor end plate  
مكان ال  
Synapse  
يكون على ال  
muscle fiber

وتُعرفُ ال teloglia  
بتشابه في ال teloglia [تتشابه في ال teloglia بين ال mn و m]  
قد تساعد في عملية ال nerve regeneration في حال  
هناك عديني تنهدر بالأعصاب

# Neuromuscular Junction (cont.)

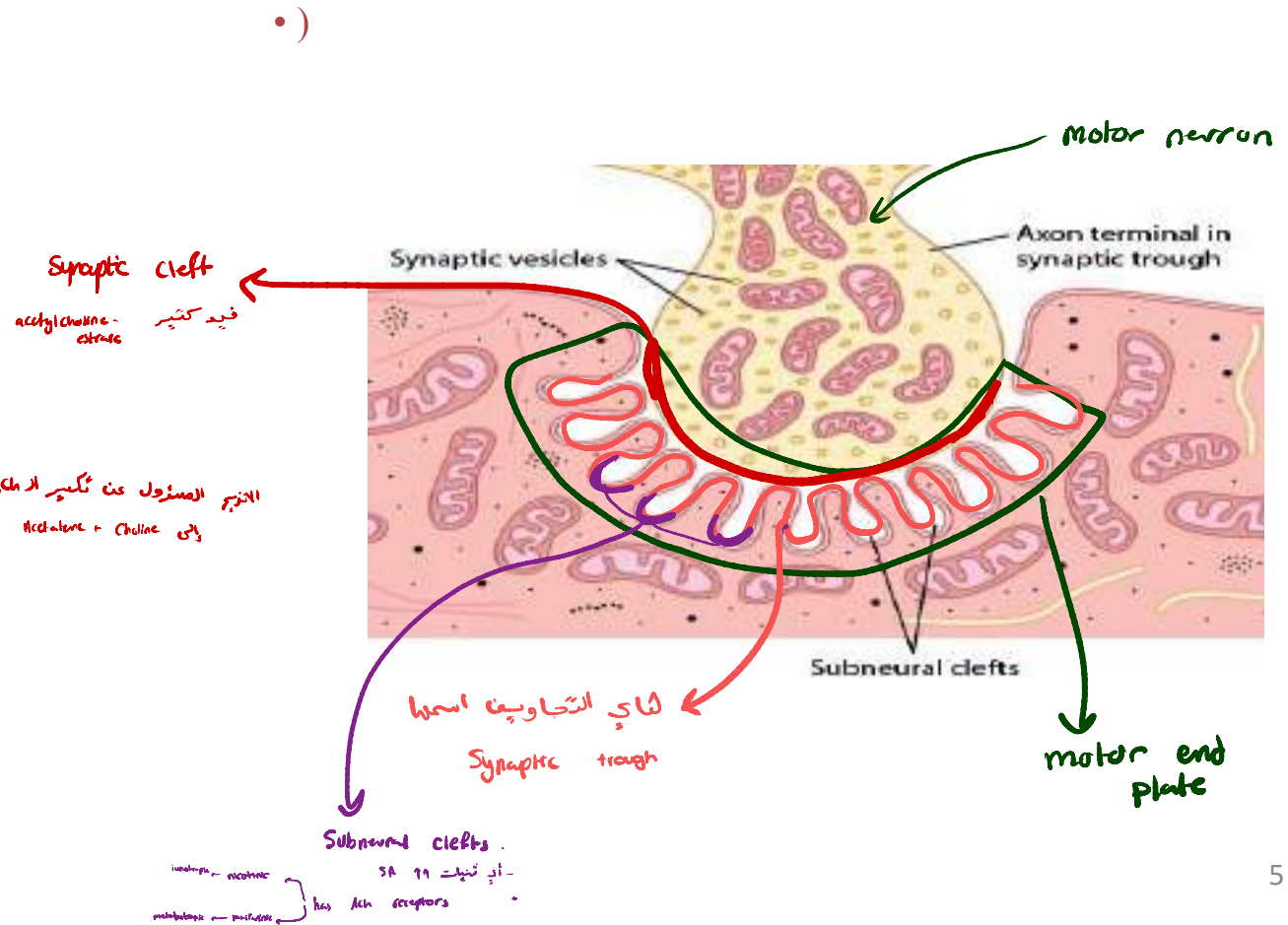
**Synaptic trough:** invagination in the motor endplate membrane

**Synaptic cleft:**

- 20-30 nm wide
- contains large quantities of acetylcholinesterase (AChE)

**Subneural clefts:**

- increases surface area of post-synaptic membrane

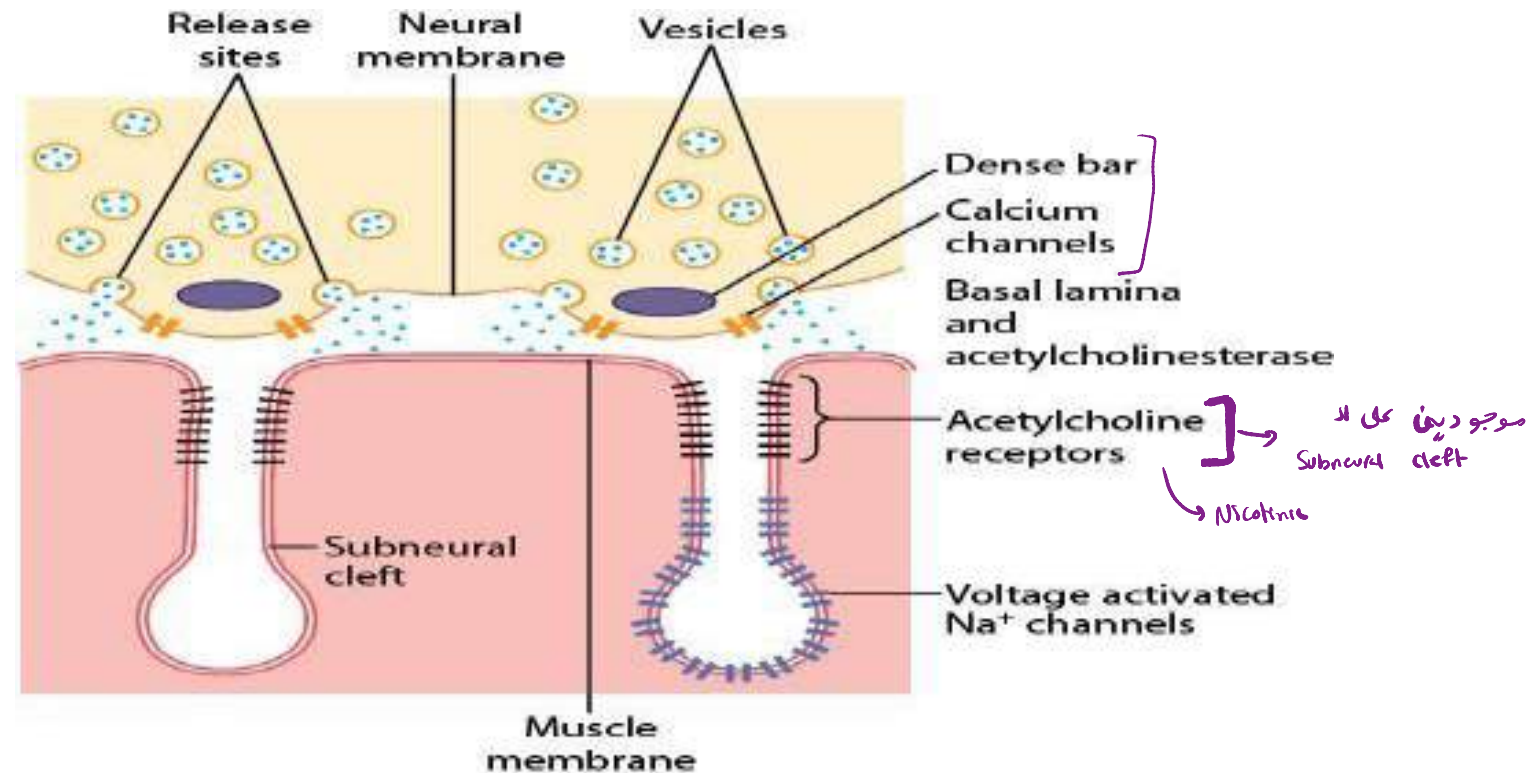


## ACh Release - *details*

- **Ca<sup>2+</sup> channels** are localized around linear structures on the pre-synaptic membrane called

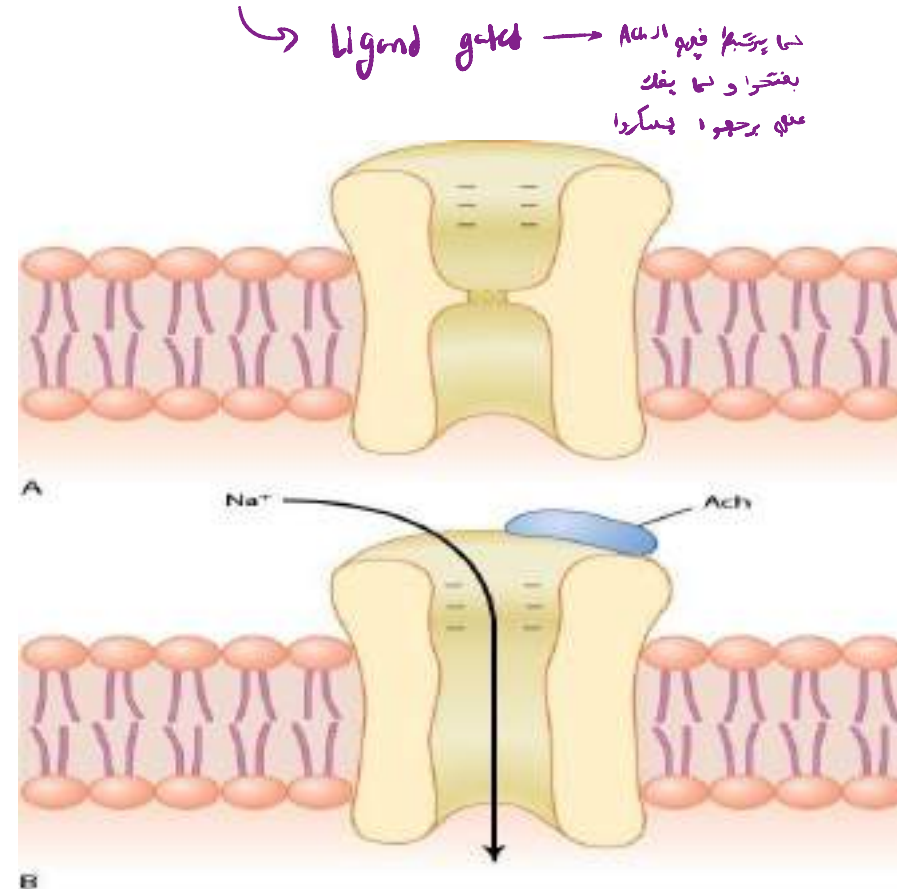
**dense bars** → Voltage-gated Calcium channels  
 أماكن وجود الـ

- Vesicles fuse with the membrane in the region of the dense bars.
- ACh receptors located at top of subneural cleft.
- Voltage gated Na<sup>+</sup> channels in bottom half of subneural cleft



## Acetylcholine gated channel

Acetylcholine-gated channel. **A**, Closed state.  
**B**, After acetylcholine (*Ach*) has become attached and a conformational change has opened the channel, allowing sodium ions to enter the muscle fiber and excite muscle cells and causing contraction. Note the negative charges at the channel mouth that prevent passage of negative ions such as chloride ions.







# Summary of events at the neuromuscular junction

مکمل  
Steps

تجزیه

- 1 An action potential in a motor neuron is propagated to the terminal button.
- 2 The presence of an action potential in the terminal button triggers the opening of voltage-gated  $Ca^{2+}$  channels and the subsequent entry of  $Ca^{2+}$  into the terminal button.
- 3  $Ca^{2+}$  triggers the release of acetylcholine by exocytosis from a portion of the vesicles.
- 4 Acetylcholine diffuses across the space separating the nerve and muscle cells and binds with receptor sites specific for it on the motor end plate of the muscle cell membrane.
- 5 This binding brings about the opening of cation channels, leading to a relatively large movement of  $Na^{+}$  into the muscle cell compared to a smaller movement of  $K^{+}$  outward.
- 6 The result is an **end-plate potential**. Local current flow occurs between the depolarized end plate and adjacent membrane.
- 7 This local current flow opens voltage-gated  $Na^{2+}$  channels in the adjacent membrane.
- 8 The resultant  $Na^{2+}$  entry reduces the potential to threshold, initiating an action potential, which is propagated throughout the muscle fiber.
- 9 Acetylcholine is subsequently destroyed by acetylcholinesterase, an enzyme located on the motor end-plate membrane, terminating the muscle cell's response.

بعد دخول  $Na^{+}$  و خروج  $K^{+}$  → يحدث الـ end plate potential

EPSP

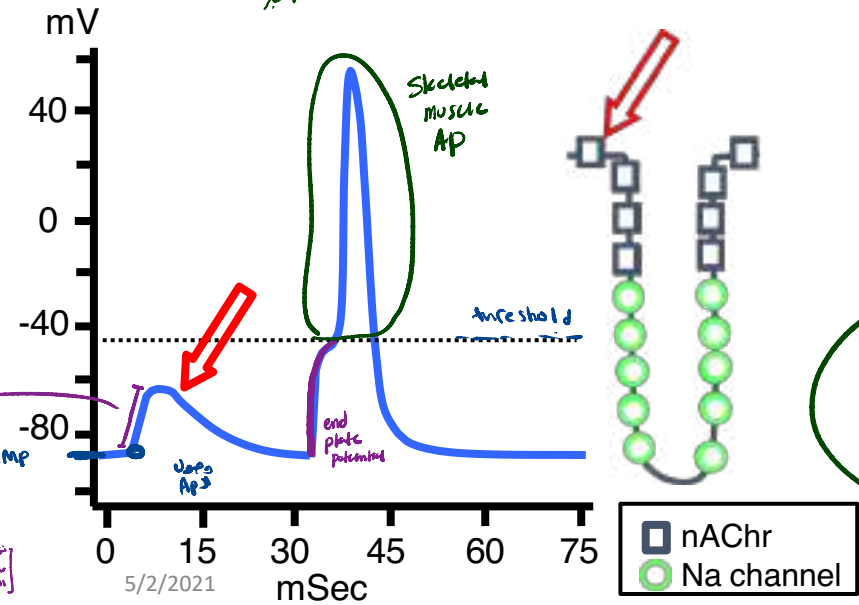
↑↑ membrane potential depolarization الـ EPSP (excitatory postsynaptic potential)

# End plate potential and action potential at the motor endplate.

graded potential = EPSP in motor end plate

•ACh released into the neuromuscular junction binds to, and opens, nicotinic ACh receptor channels on the muscle fiber membranes (Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup>).

دخول Na<sup>+</sup> بكيفية أكبر



في دخول Na<sup>+</sup> وقت  
منه AP و AP من AP  
end plate potential

in order to initiate AP in skeletal muscle, end plate potential must be summated

5/2/2021

•Opening of nACh receptor channels produces an **end plate potential**, which will normally initiate an AP if the local spread of current is sufficient to open voltage sodium channels.

متى يفتح منتهي AP؟؟ عند الوصول إلى ال threshold

•What terminates the process?  
acetylcholinesterase  
terminates signal

# End plate potential

- When the ion channel on post synaptic membrane opens both  $\text{Na}^+$  &  $\text{K}^+$  flow down their concentration gradient. يدخل  $\text{Na}^+$  يخرج  $\text{K}^+$
- At resting potential net driving force for  $\text{Na}^+$  is much greater than  $\text{K}^+$ , when Ach triggers opening of these channels more  $\text{Na}^+$  moves inwards than  $\text{K}^+$  out wards, depolarizing the end plate. This potential change is called end plate potential (EPP).
- EPP is not an action potential but it is simply depolarization of specialized motor end plate
- Small quanta (packets) of Ach are released randomly from nerve cell at rest, each producing smallest possible change in membrane potential of motor end plate, the MINIATURE EPP.
- When nerve impulse reaches the ending, the number of quanta release increases by several folds and result in large EPP. بسبب زيادة ال Ach release  $\uparrow\uparrow \text{Na}^+$  flow
- EPP than spread by local current to adjacent muscle fibers which depolarized to threshold & fire action potential

EPP مش نفس AP  
AP اخا زي  
eps