بسم الله الرحمن الرحيم

Physiology | Lecture 2

Synapses

Written by : Ruqaiya Moqbel
Bushra Masalha

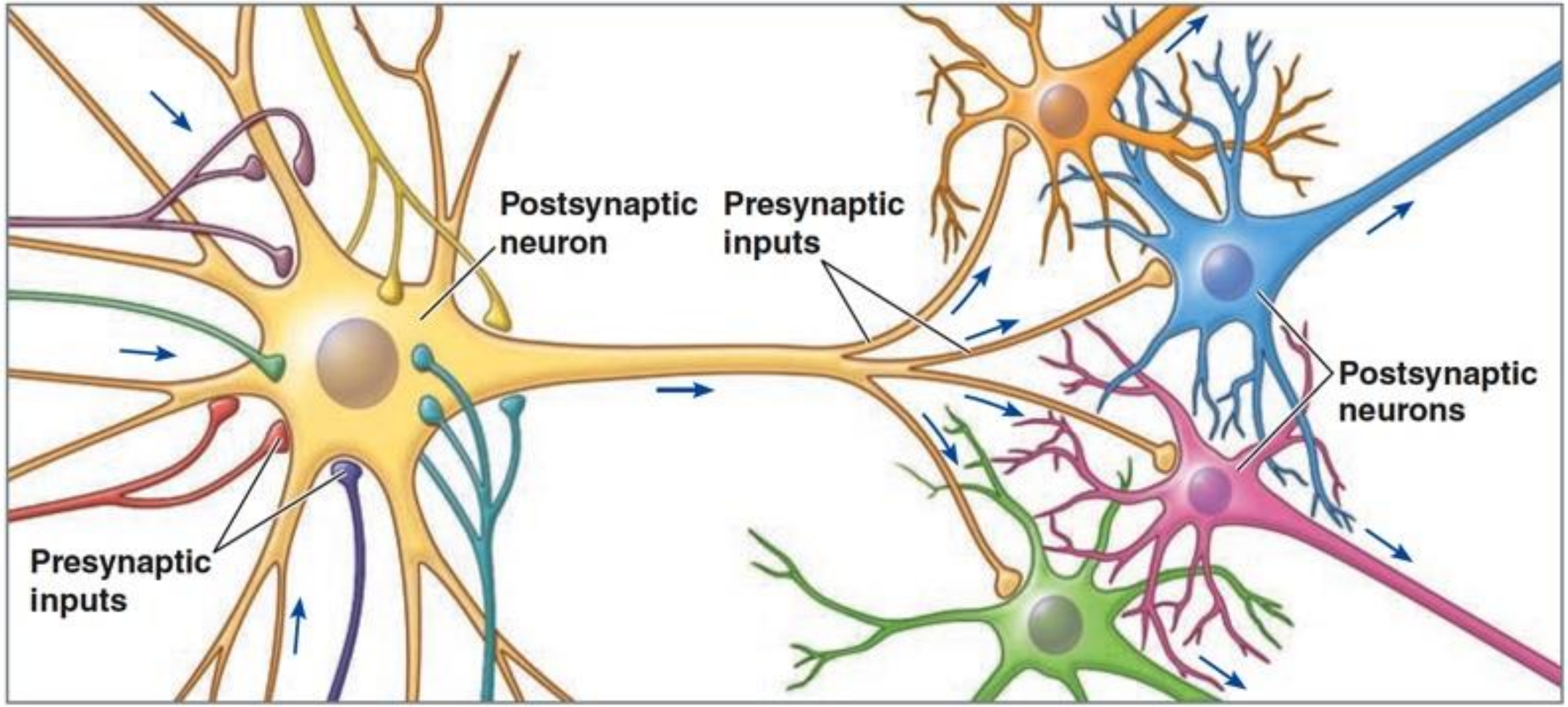
Reviewed by : Ruqaiya Moqbel
Bushra Masalha

Introduction to Neurophysiology 2

Synapses

Fatima Ryalat, MD, PhD

Assistant Professor, Physiology and Biochemistry Department,
School of Medicine, The University of Jordan


Postsynaptic neuron
Presynaptic inputs
Postsynaptic neurons
Presynaptic inputs

Synapses

"The area of communication"

- The synapse is a region where communication occurs between two neurons or between a neuron and an effector cell (muscle cell or glandular cell).

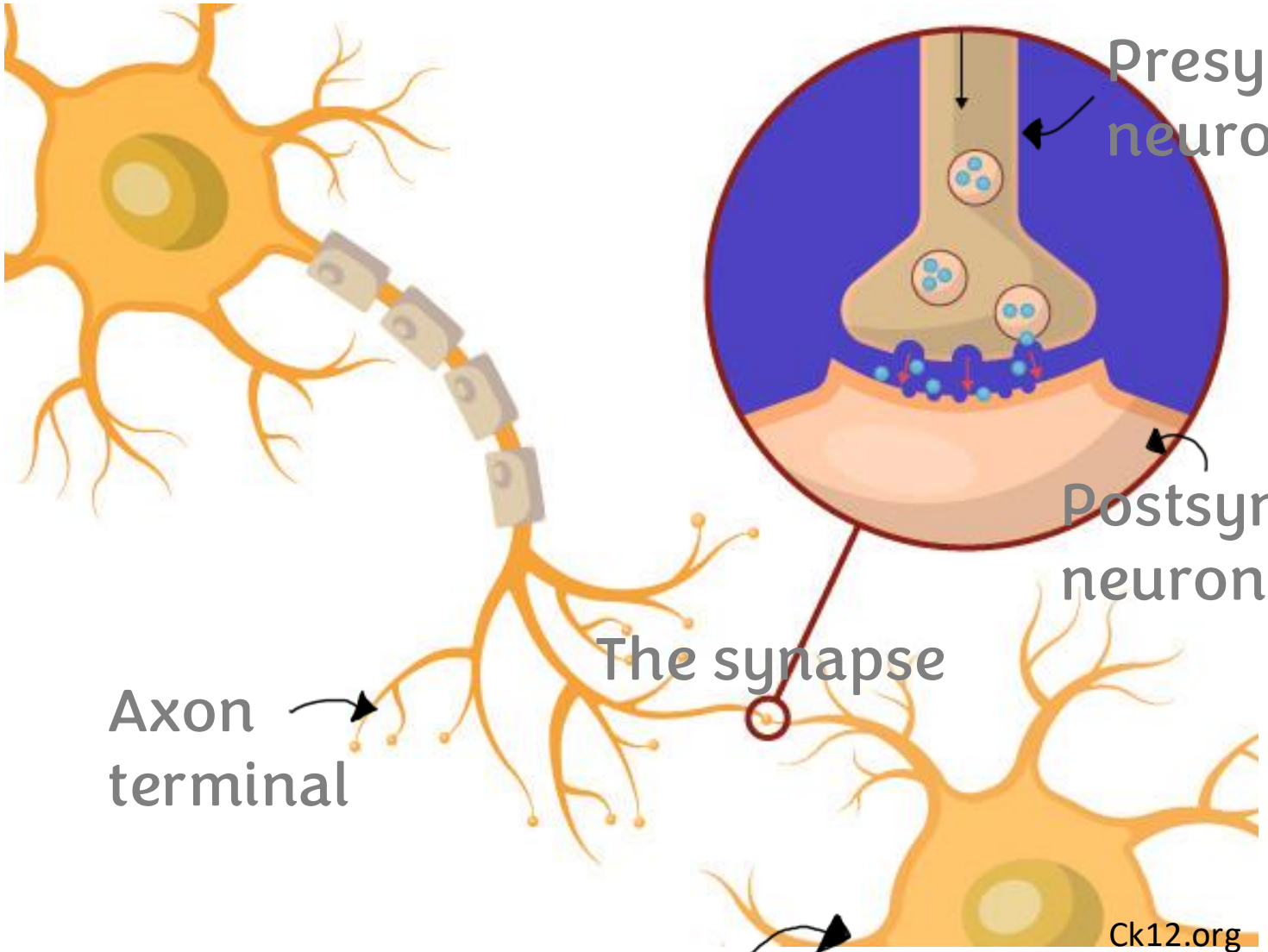
Synaptic functions of neurons

Information is transmitted in the central nervous system mainly in the form of nerve action potentials, called nerve impulses, through a succession of neurons, one after another.

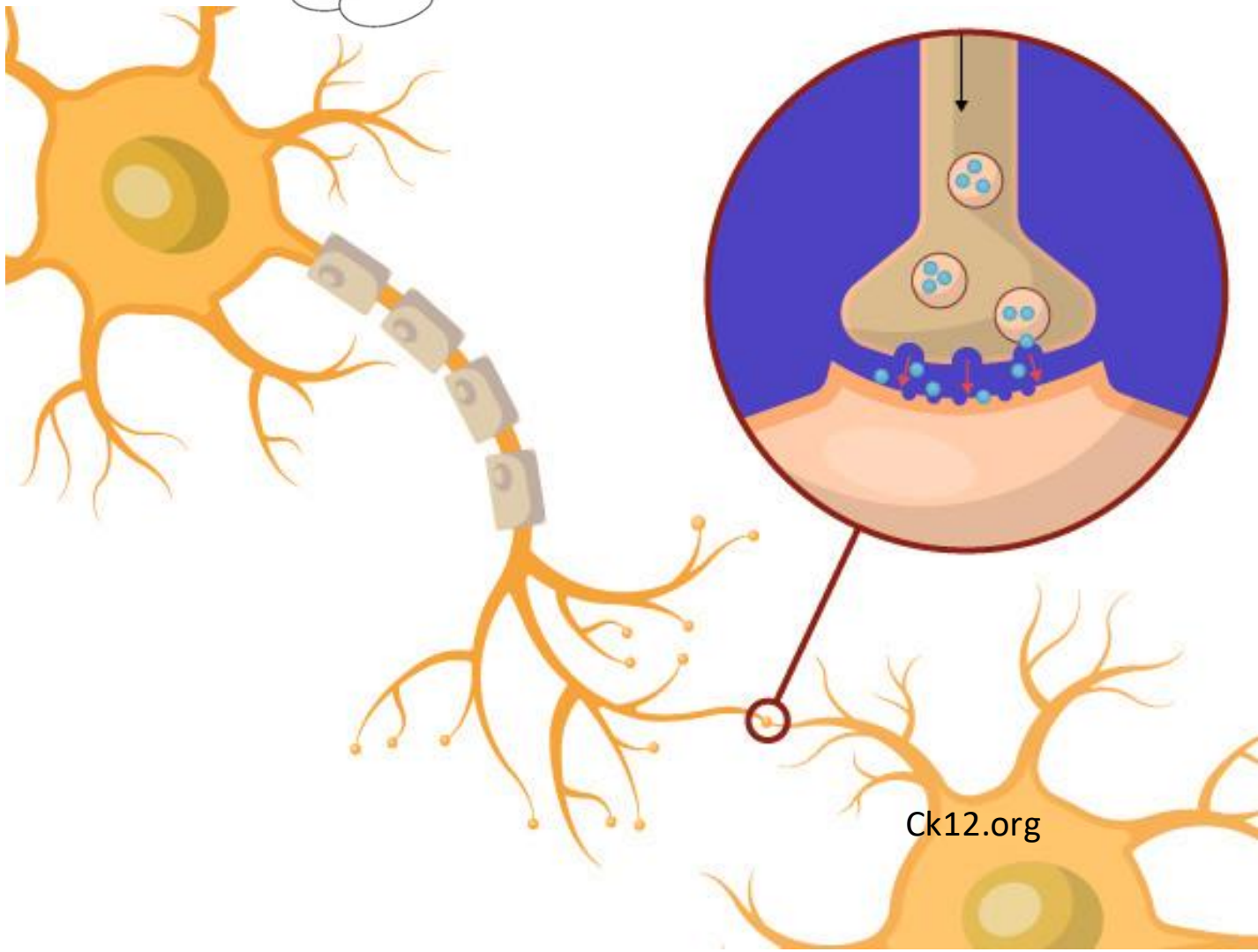
However, this impulse may be blocked, changed into repetitive impulses, or integrated with other impulses.

These functions are called **synaptic functions of neurons**.

-When the signal reaches the first neuron if it's strong enough to produce an action potential, the signal will be transmitted all the way until it reaches the axon terminal and then to the next neuron (the Postsynaptic neuron).



-The transmission is not straight forward and many
processes can occur at the level of synapse.



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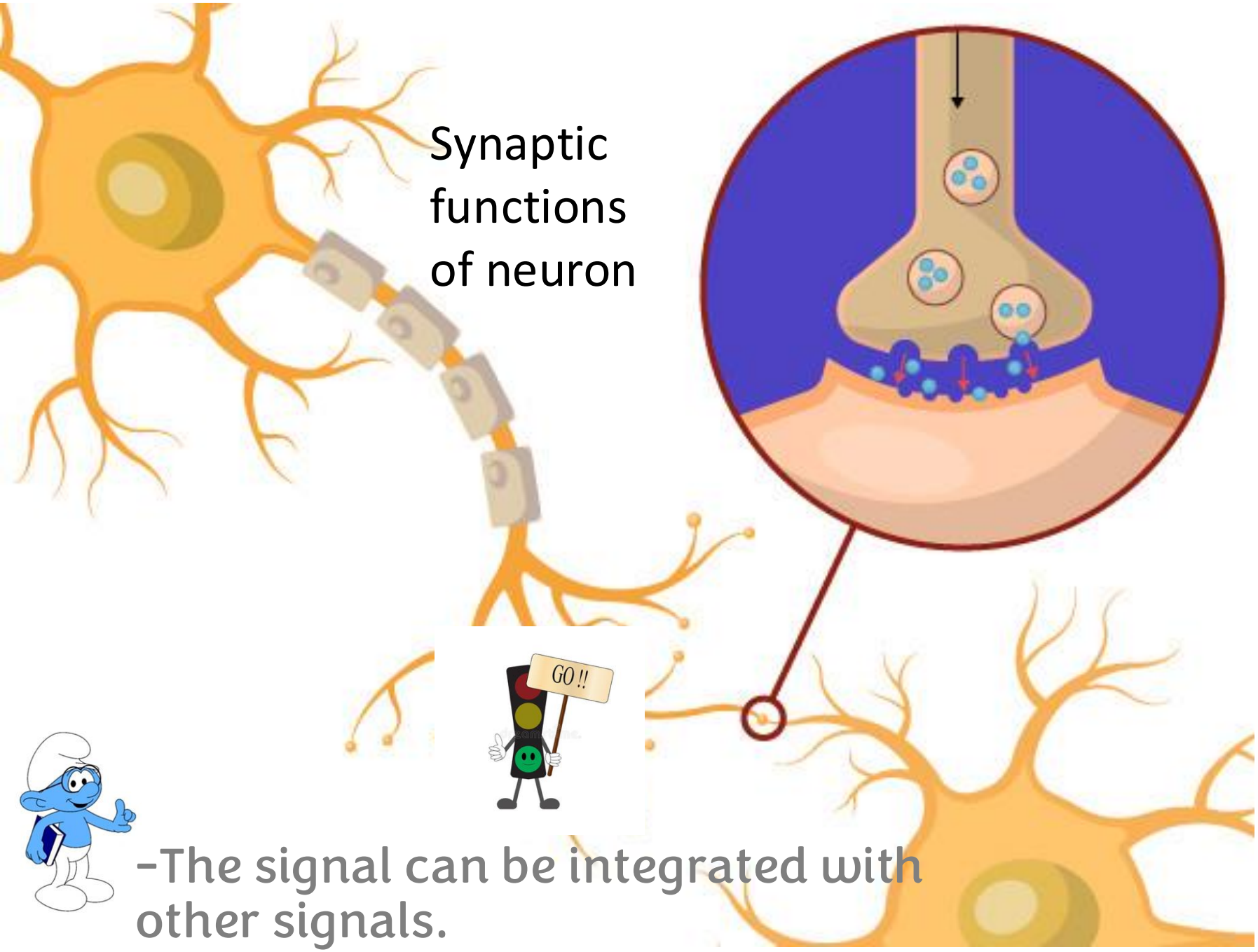
Synaptic functions of neuron



-The signal can be integrated with other signals.

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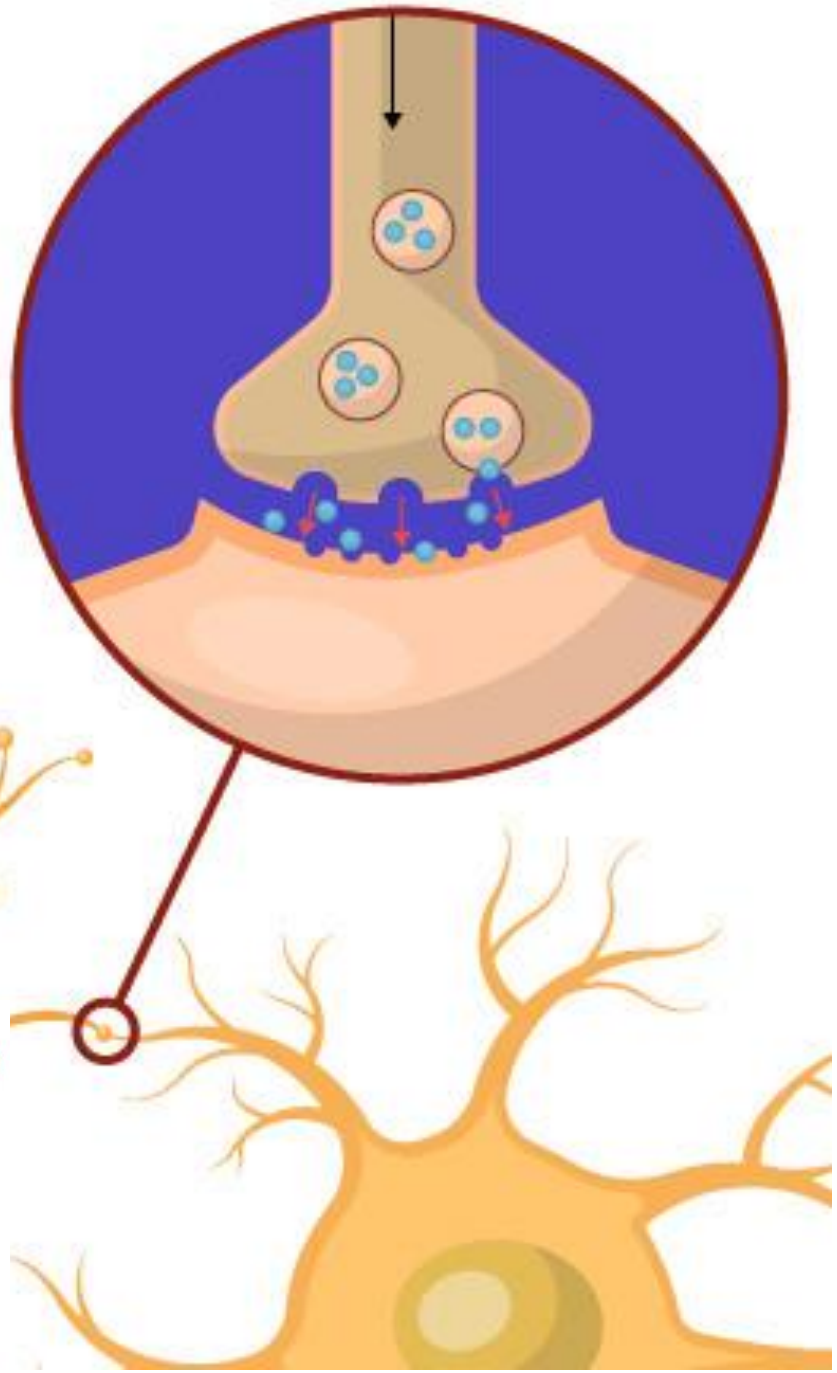
Synaptic functions of neuron

-In other situations, the transmission of signals between the synaptic neuron and the post synaptic neuron may be blocked/ inhibited.



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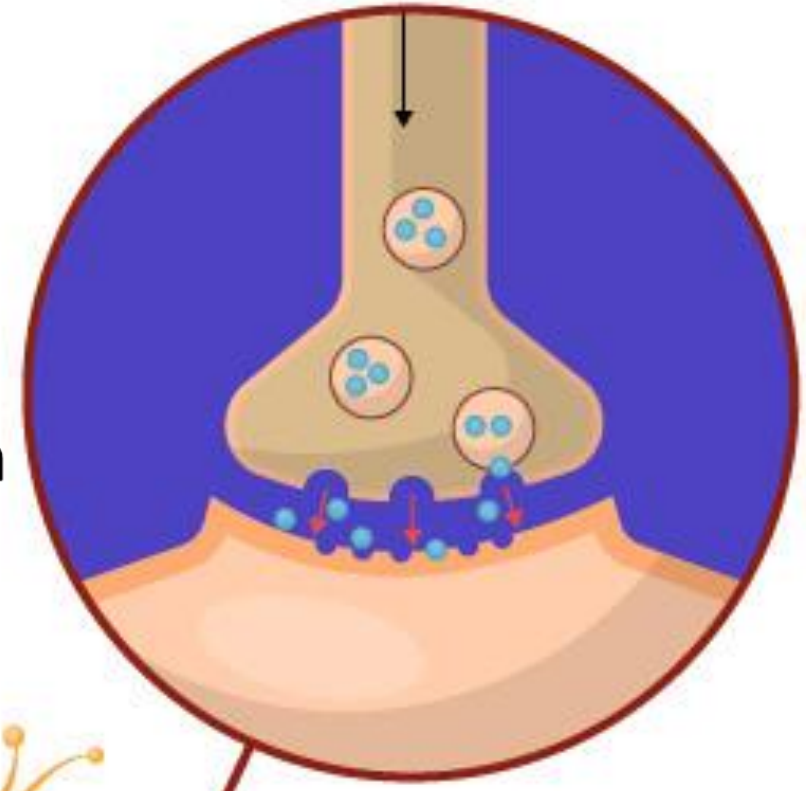
Synaptic functions of neuron



-In other cases
At the level of synapse there will be repetition of the signal over and over again for this signal to be transmitted for a longer time across this pathway.

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Types of Synapses

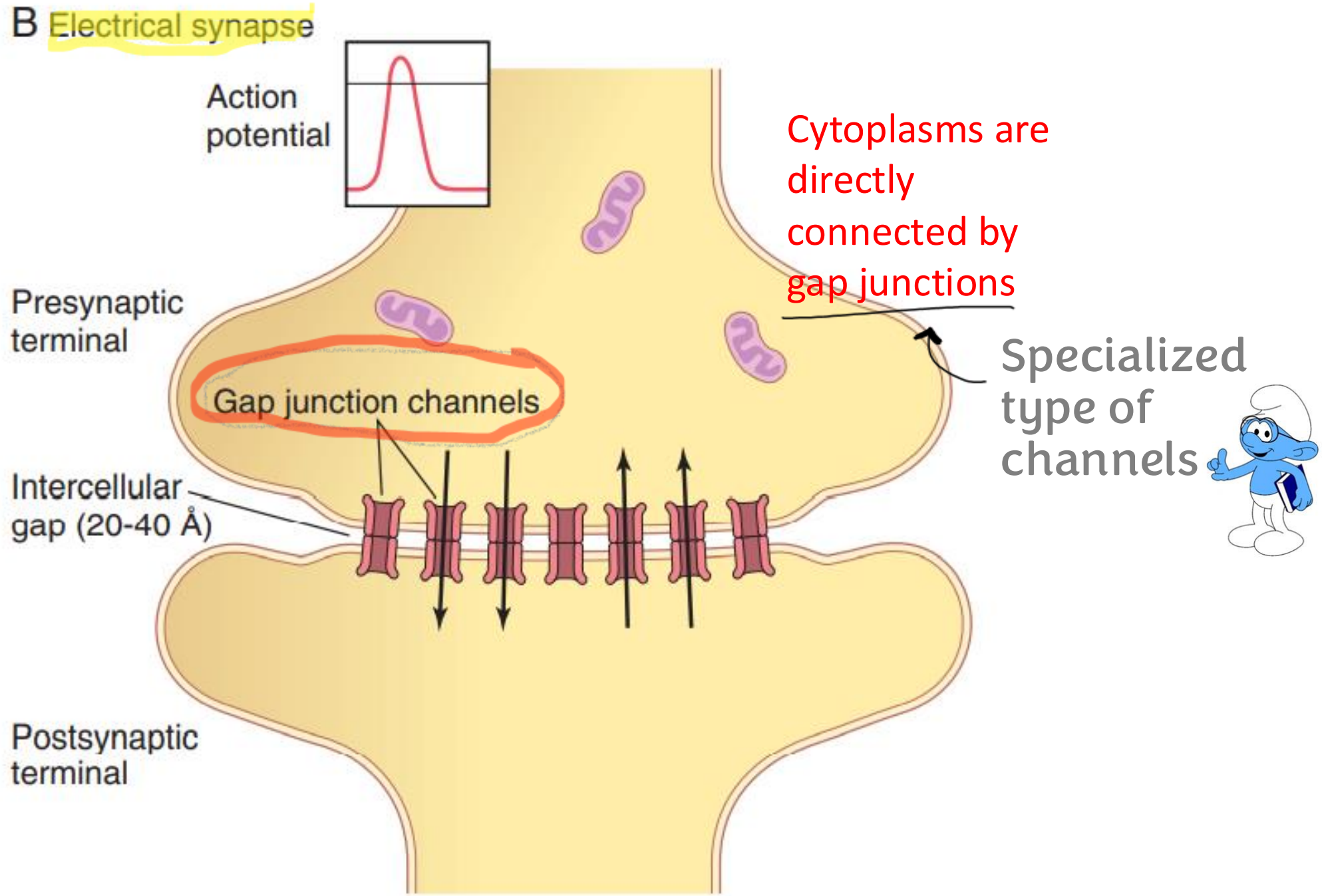
- Chemical synapses. (more common)
- Electrical synapses.

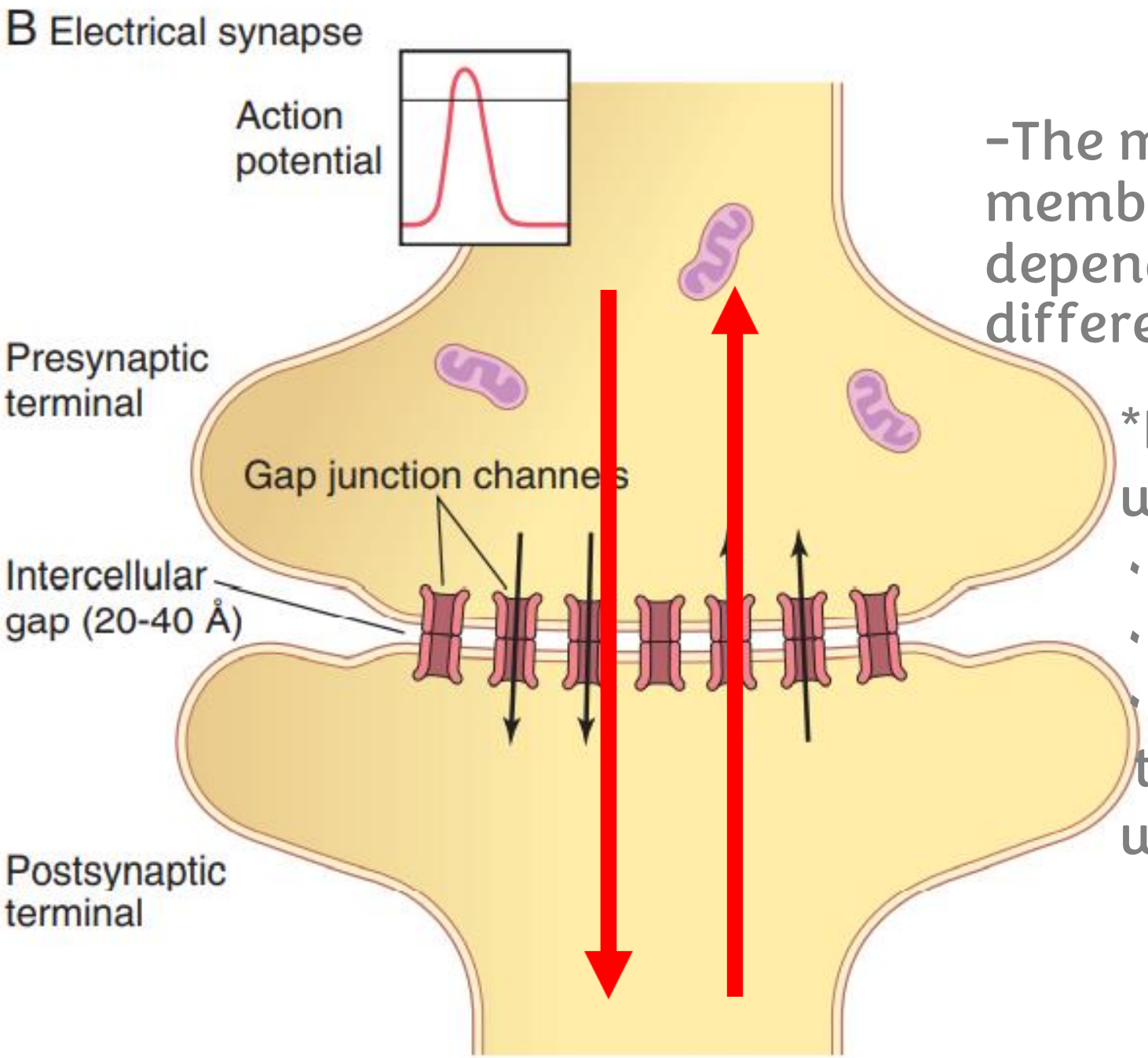
Electrical Synapses

-In neurophysiology when we say electrical synapses then we mean that there's a flow of ions across the membrane, this movement of charged ions will create electrical changes.

- The **cytoplasms of adjacent cells are directly connected by gap junctions** that allow free movement of ions between cells.

- Similar to the ones in smooth muscles and cardiac muscles.


B Electrical synapse
Action potential
Presynaptic terminal
Gap junction channels
Intercellular gap (20-40 Å)
Postsynaptic terminal
Cytoplasms are directly connected by gap junctions
Specialized type of channels



-The movement of ions across the membrane can be bidirectional depending on the concentration difference.

*It can start either way from this neuron

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to this or the other way around.

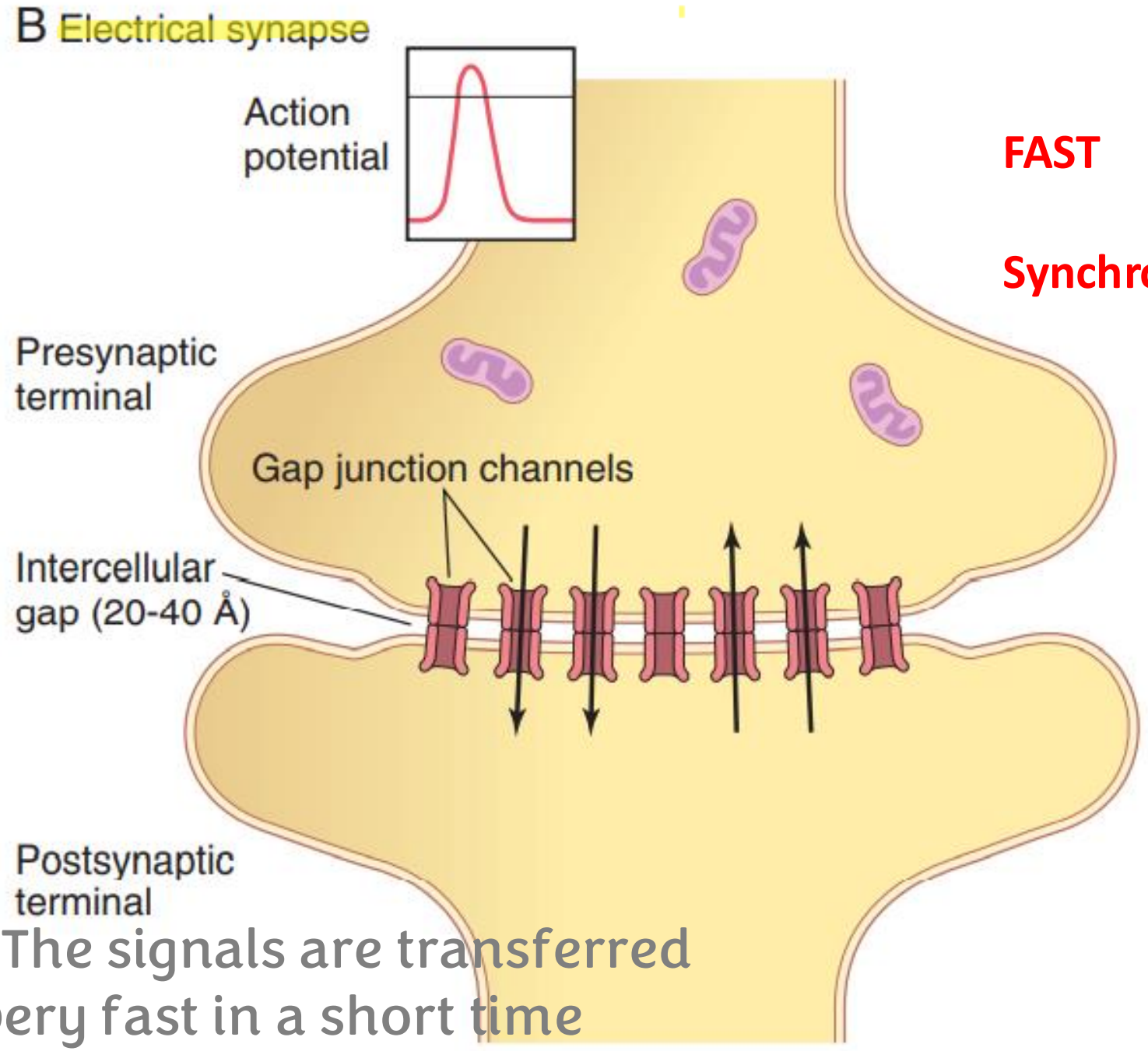
Bidirectional transmission of electrical synapses

Two main advantages:

- 1. **Faster communication**. Because action potentials conduct directly through gap junctions, electrical synapses are faster than chemical synapses.

- 2. **Synchronization**. Electrical synapses can synchronize (coordinate) the activity of a group of neurons or muscle fibers. As well as increasing neuronal sensitivity of connected neurons.

*Example: cardiac and smooth muscles



FAST

Synchronization

- They act as a one unit ((specialized communication))
The Cells work together almost at the same time to have an action potential at the same time.

-The signals are transferred very fast in a short time

Chemical synapses

-action potential CAN NOT be transmitted directly from cell to the next (ions cannot flow directly).

*It's called chemical synaptic because the electrical energy will be converted into a chemical type of energy to transmit these signals, then it will be converted again in the postsynaptic neuron as electrical energy again.

- **Most of the synapses** in the CNS are chemical synapses.

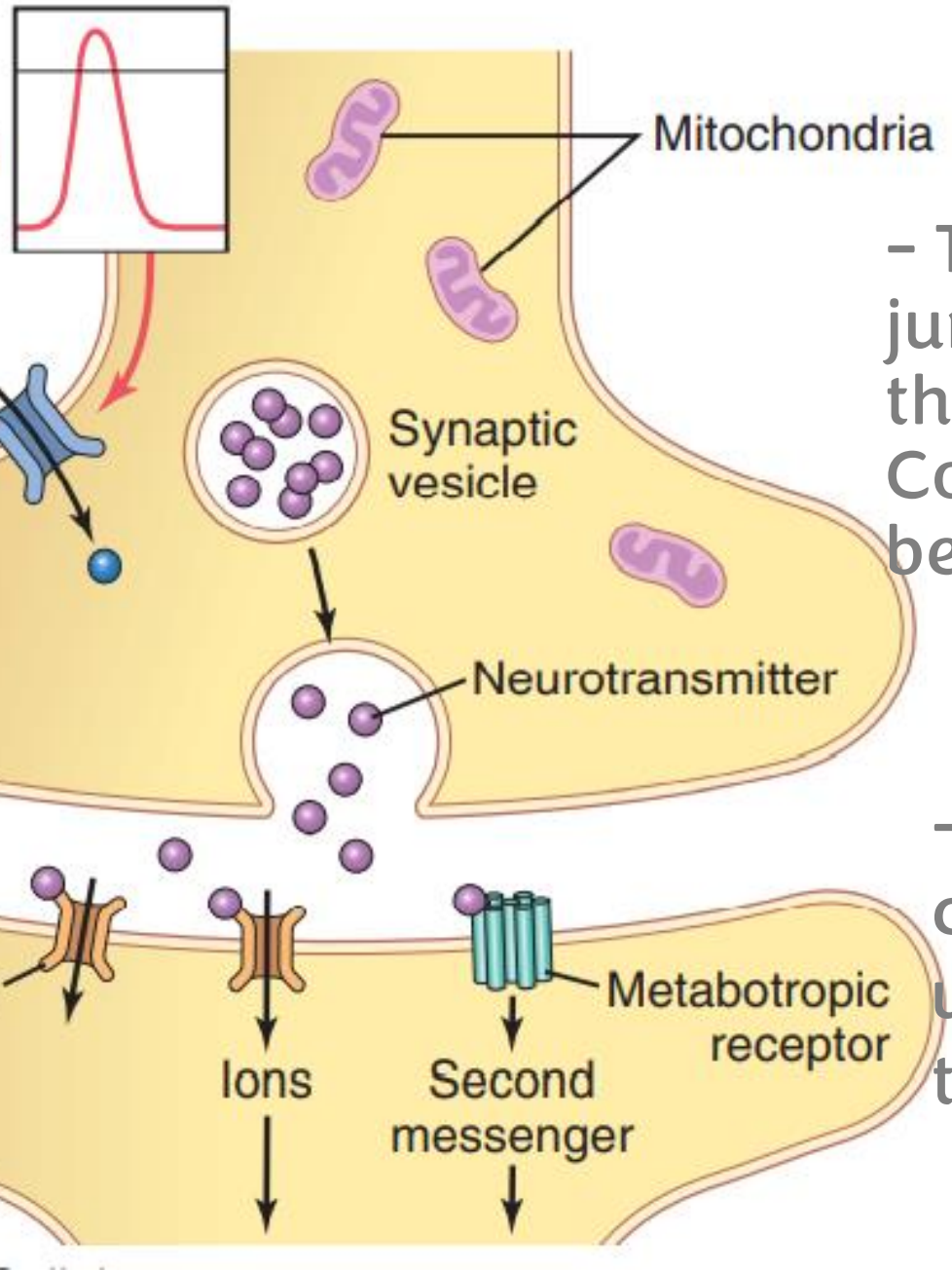
- The first neuron secretes at its nerve ending synapse a chemical substance called a **neurotransmitter.**

- Neurotransmitters are chemicals that are synthesized within the neurons and be transmitted FROM the presynaptic neurons

- Neurotransmitter acts on receptor proteins in the membrane of the next neuron **to excite the neuron, inhibit it, or modify its sensitivity in some other way**.

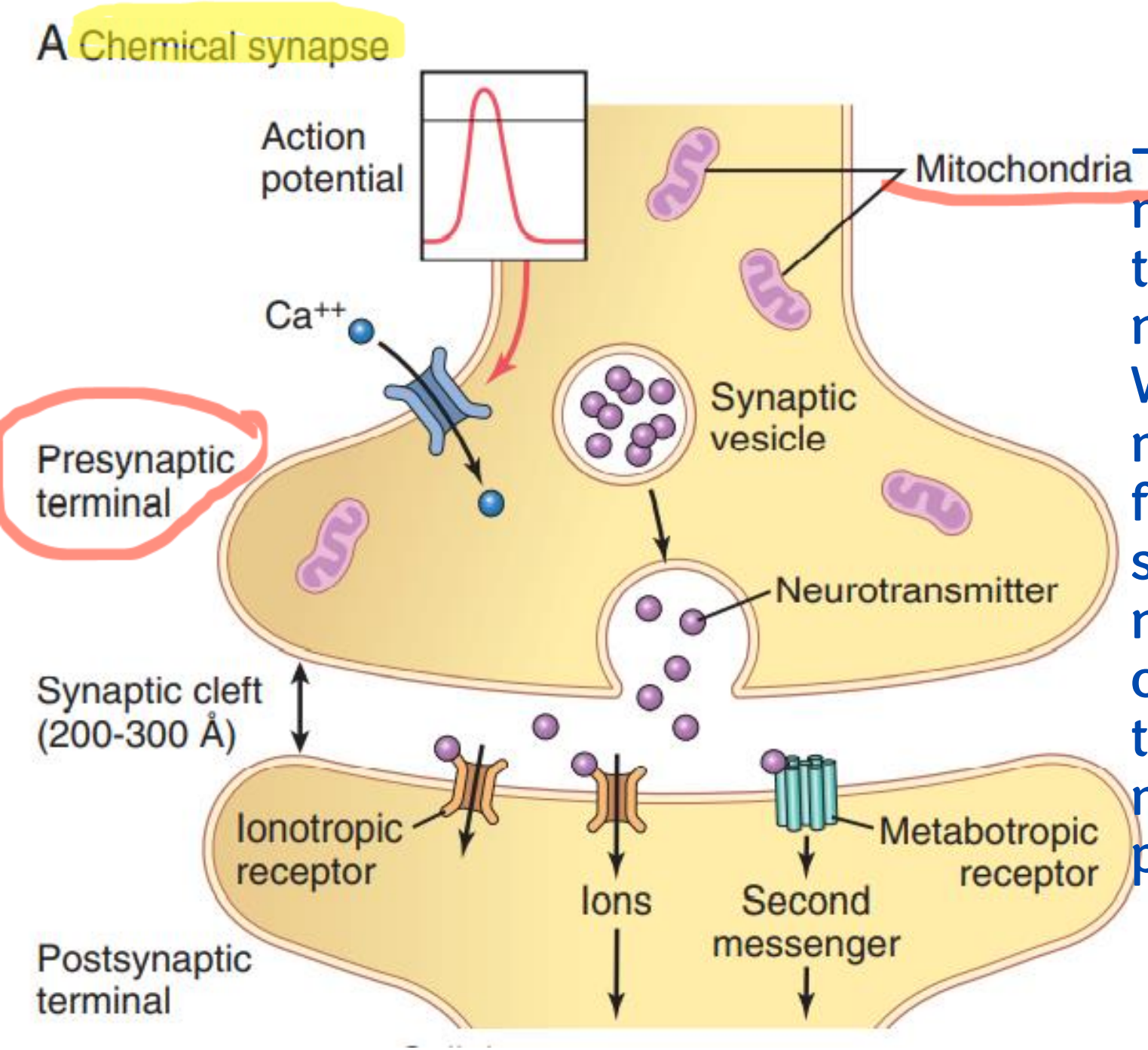
A Chemical synapse

More common

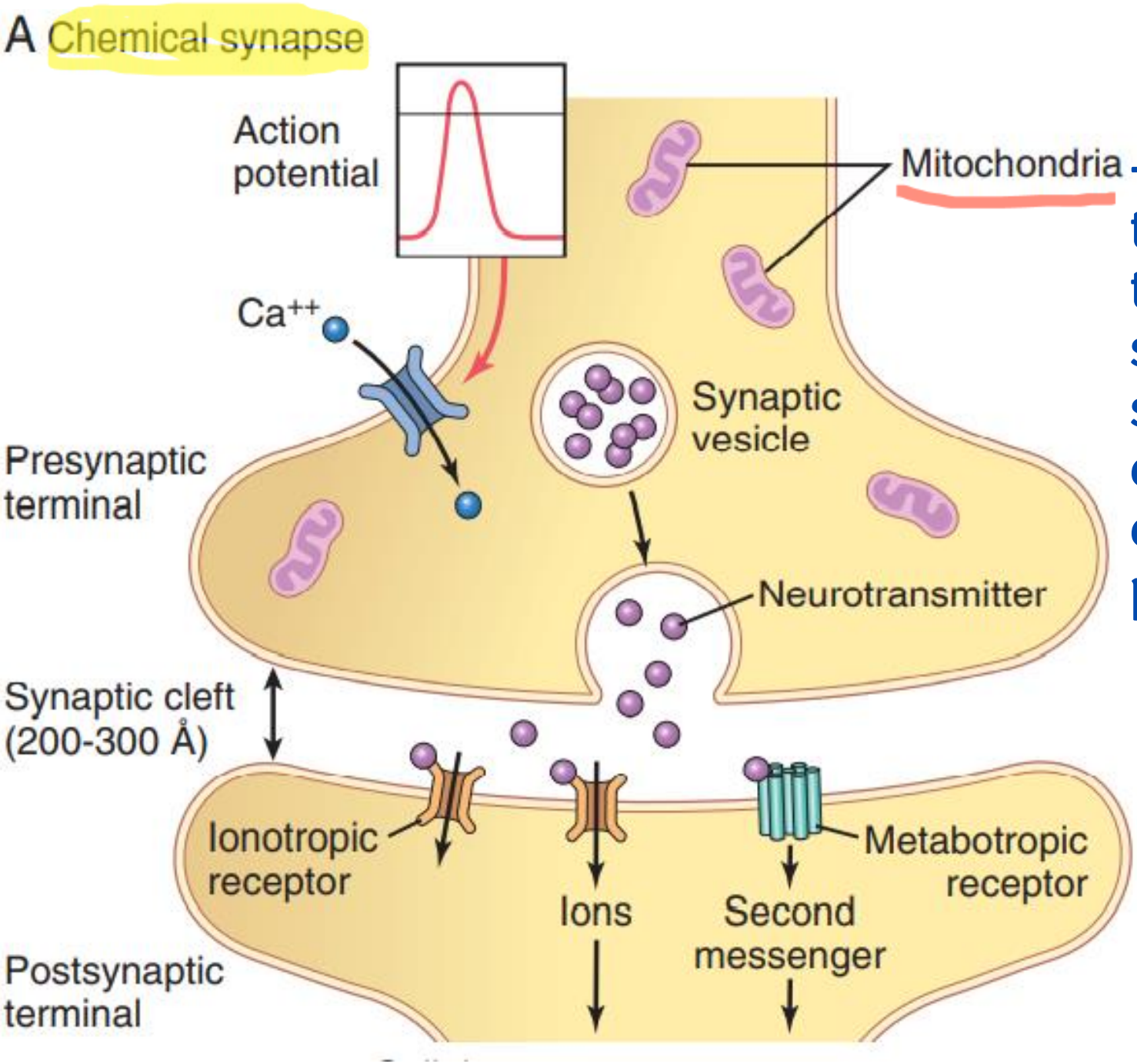


- There's no gap junctions here therefore no direct Communication between cells.

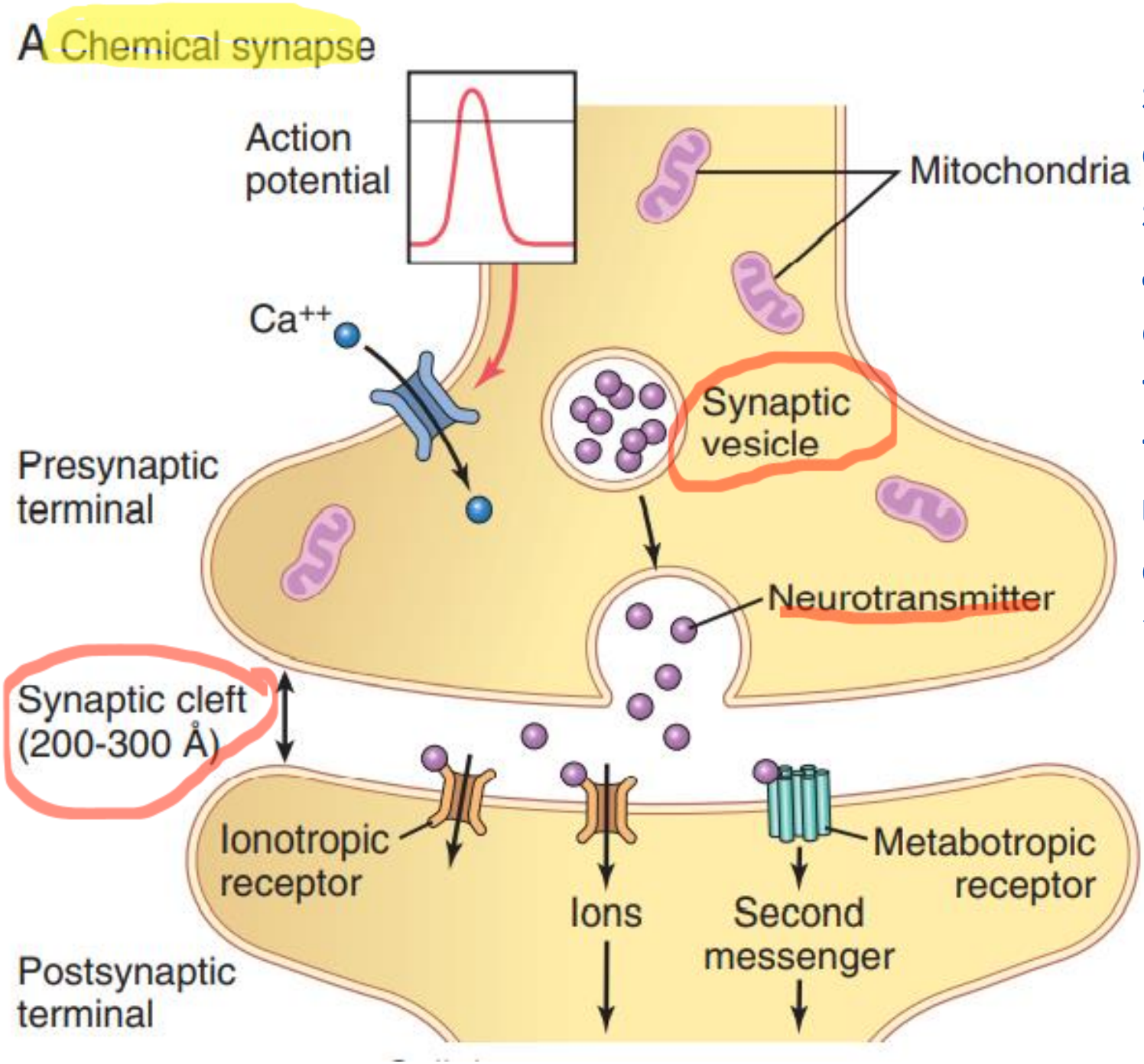
-The space between the cells is filled with fluid which the signal pass through.



-There's abundant of mitochondria in the axon terminals of presynaptic neurons.
We need energy from mitochondria for several functions specially for the synthesis of neurotransmitters~many of them will be synthesized that's why there are so many mitochondria present here

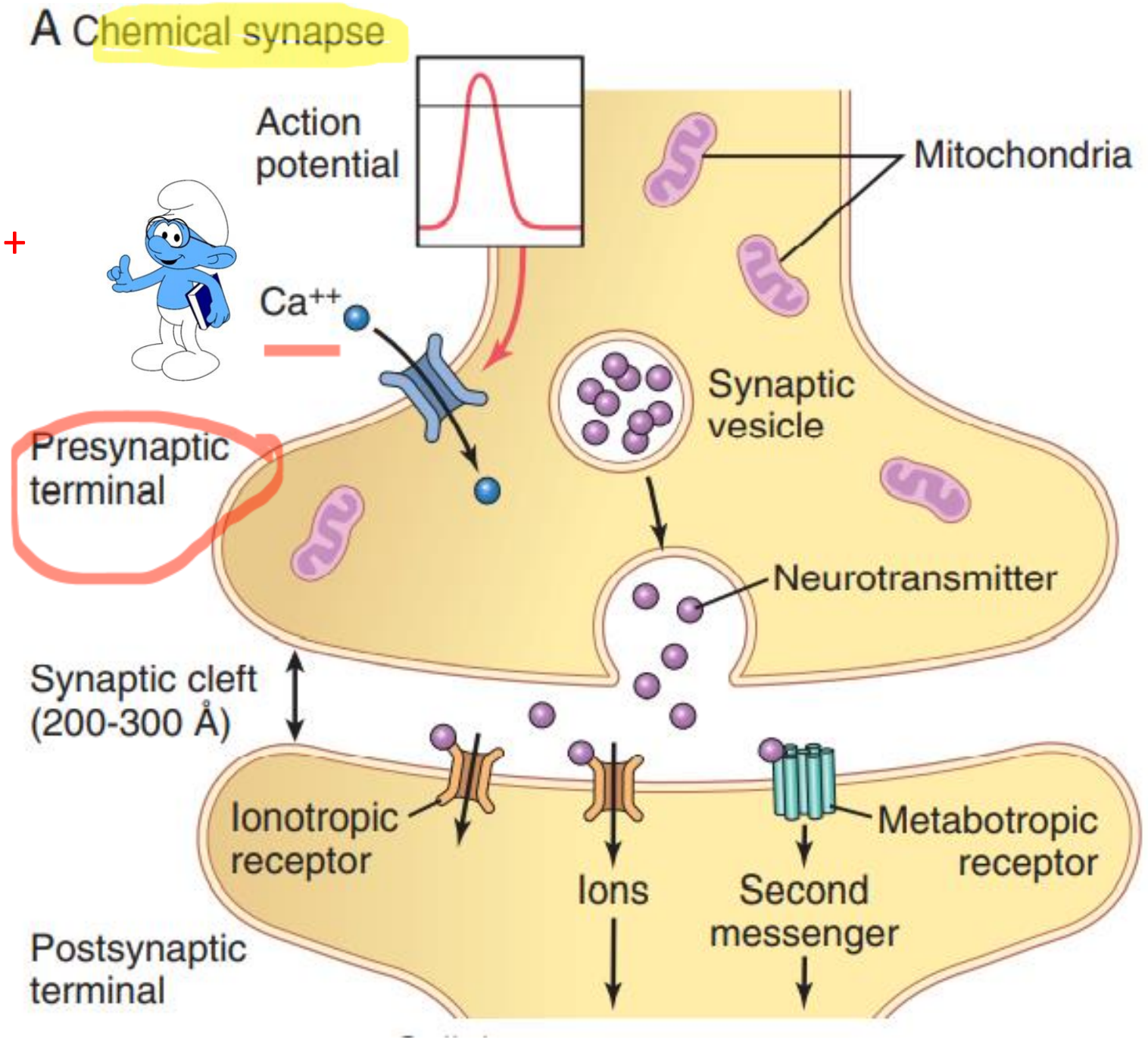


-Also we need mitochondria for the process of exocytosis, the transmitters will be stored in a synaptic vesicles until a stimulus comes and allows exocytosis– which requires energy (it's not a passive process).



Neurotransmitters can be stored anywhere else but most of them are stored within synaptic vesicles, so when action potential comes these chemicals will be released by the process of exocytosis into the synaptic cleft and then they will bind to specific receptors on the membrane of the postsynaptic neurons

More Ca++
More NT



Presynaptic terminals

- The terminal has two important internal structures:

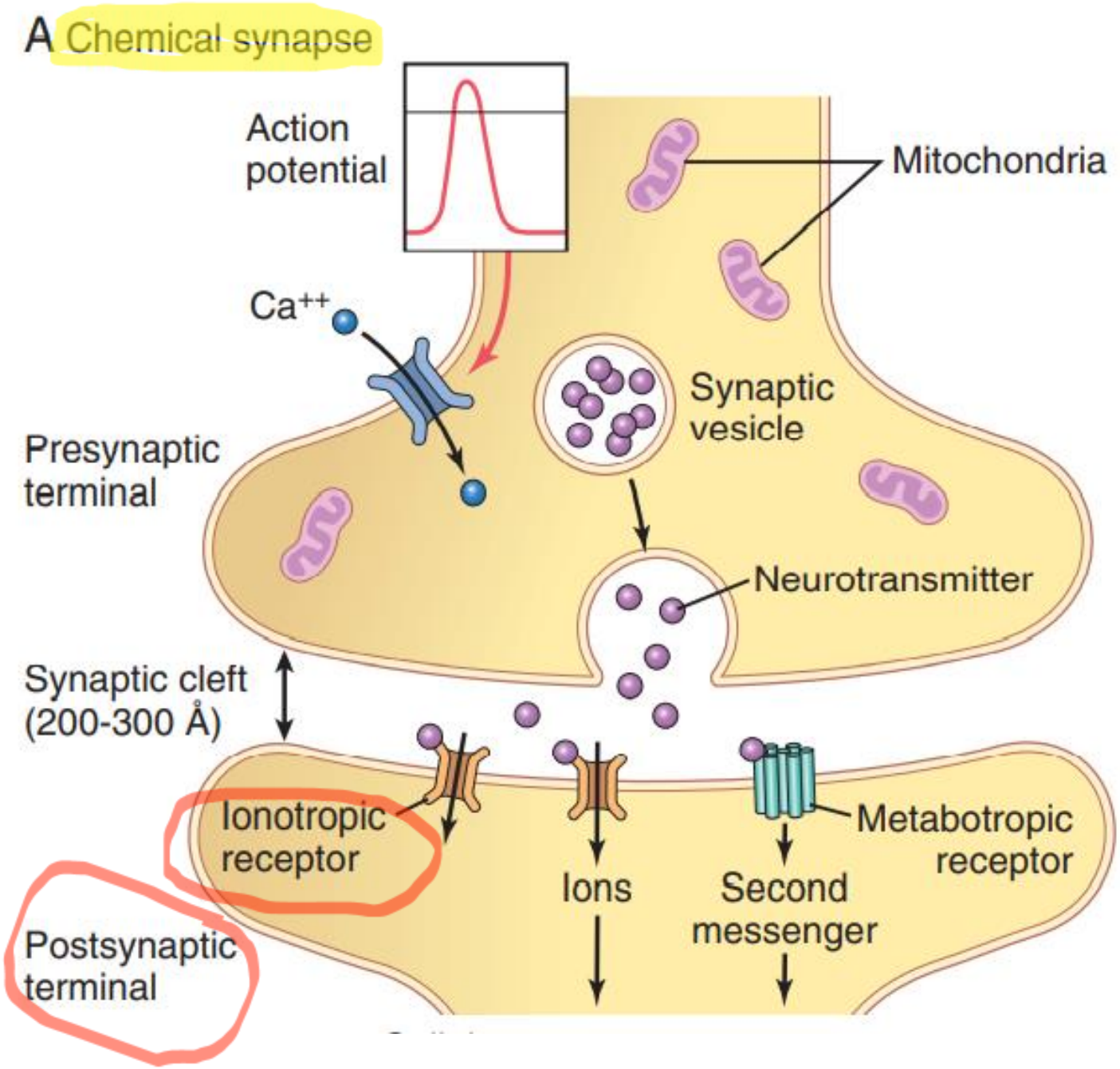
- The transmitter vesicles contain the neurotransmitter that, when released into the synaptic cleft, either excites or inhibits the postsynaptic neuron.

- The mitochondria provide adenosine triphosphate (ATP), which in turn supplies the energy for synthesizing new transmitter substance.

Presynaptic terminals

- The presynaptic membrane contains large numbers of **voltage-gated calcium channels**.

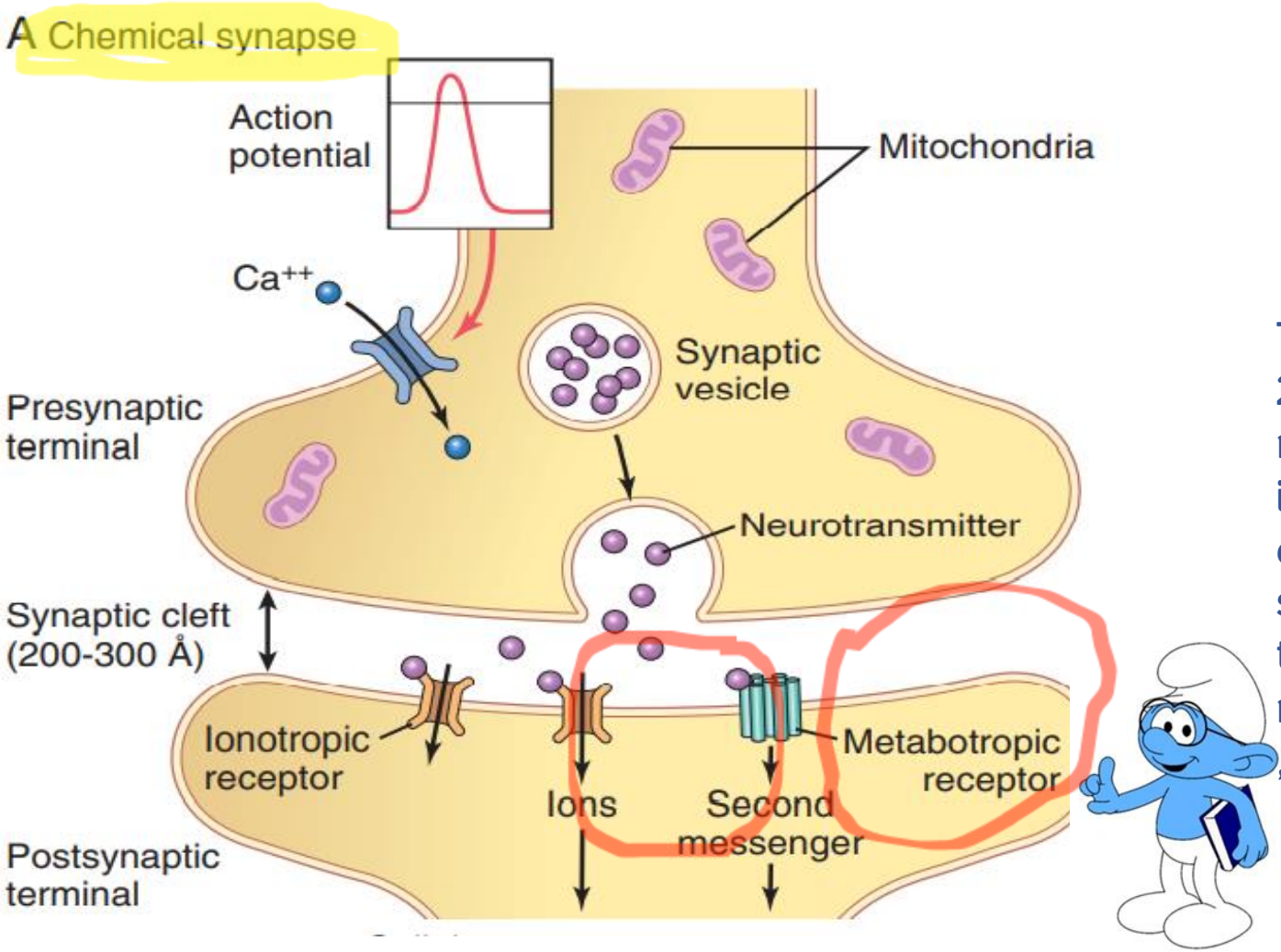
- When an action potential depolarizes the presynaptic membrane, these calcium channels open.
- The more influx of calcium – the more calcium concentrations inside these axon terminals – the more process of exocytosis– the more neurotransmitter to be released.
- The quantity of neurotransmitter that is released is directly related to the number of calcium ions that enter.
-



We have two types of specific receptors:
1) **Ionotropic receptor** it is an ion channel (ligand gated channel because it like this chemical neurotransmitter will activate channel by binding on specific area of channel , that allow flow of ion influx or eflux depend on a specific type of ions which effect of changing the membrane potential on post synaptic
It fast acting and short duration

Cation and anion channels

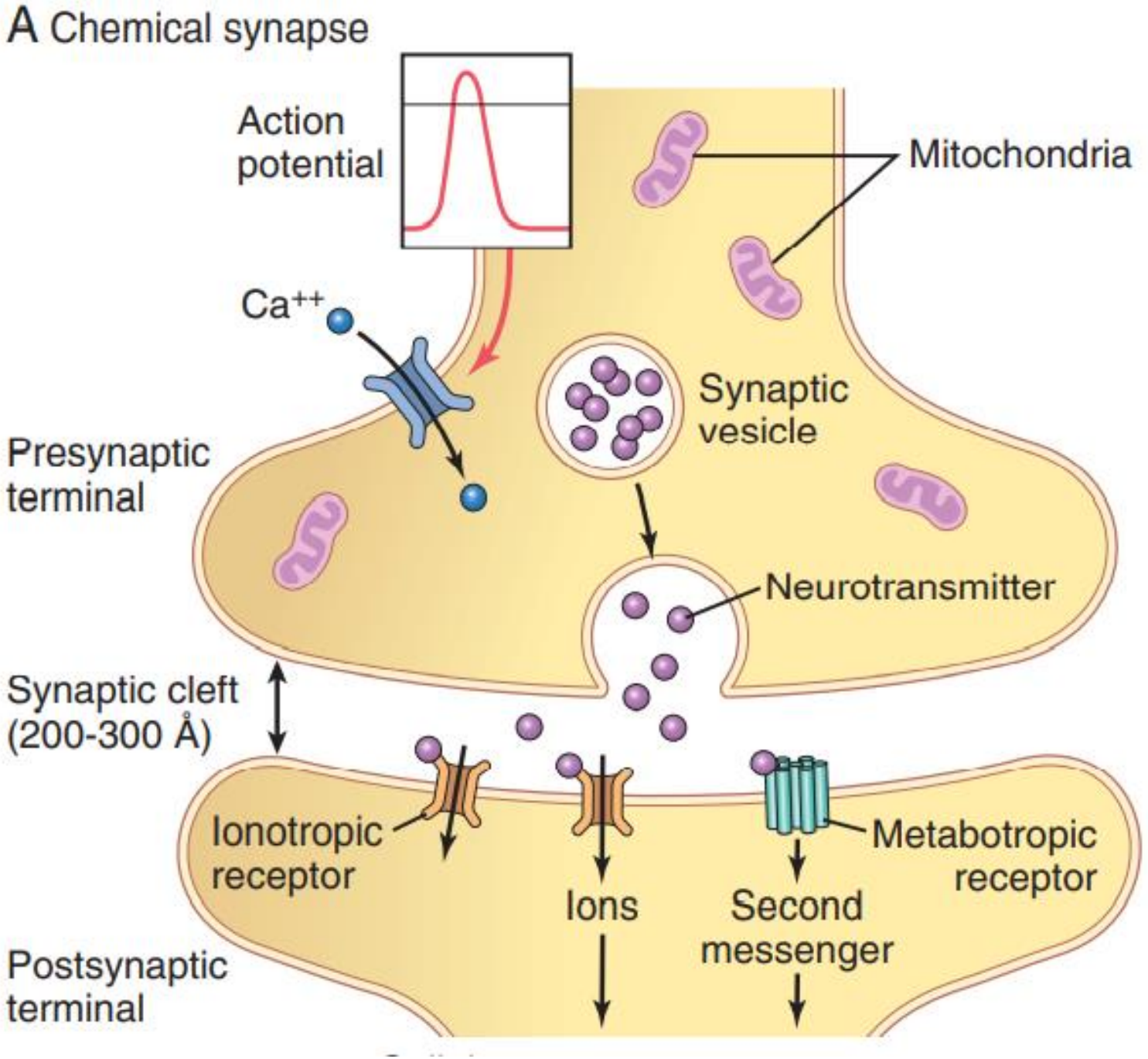
This change may be Excitation (Na+) or inhibition (Cl-)



The other type receptor in post synaptic :
2) **Metabotropic receptor**: it is a second messenger like a G- protein coupled receptor it take longer time to allow flowing ions and changing the membrane potential or to make structural changes it a common example for that we need for long time like longer term memory so we can store it for days ,week,and maybe years.

Prolonged action
e.g. memory

The neurotransmitter shouldn't be forever so it removed from receptors by different mechanisms may be by certain enzyme to distract and bark it down no longer to attach with receptors, some of them they will flow out of the synaptic cleft so will diffuse away , and some small molecules neurotransmitters they will re-uptake and resynthesized within synaptic terminals

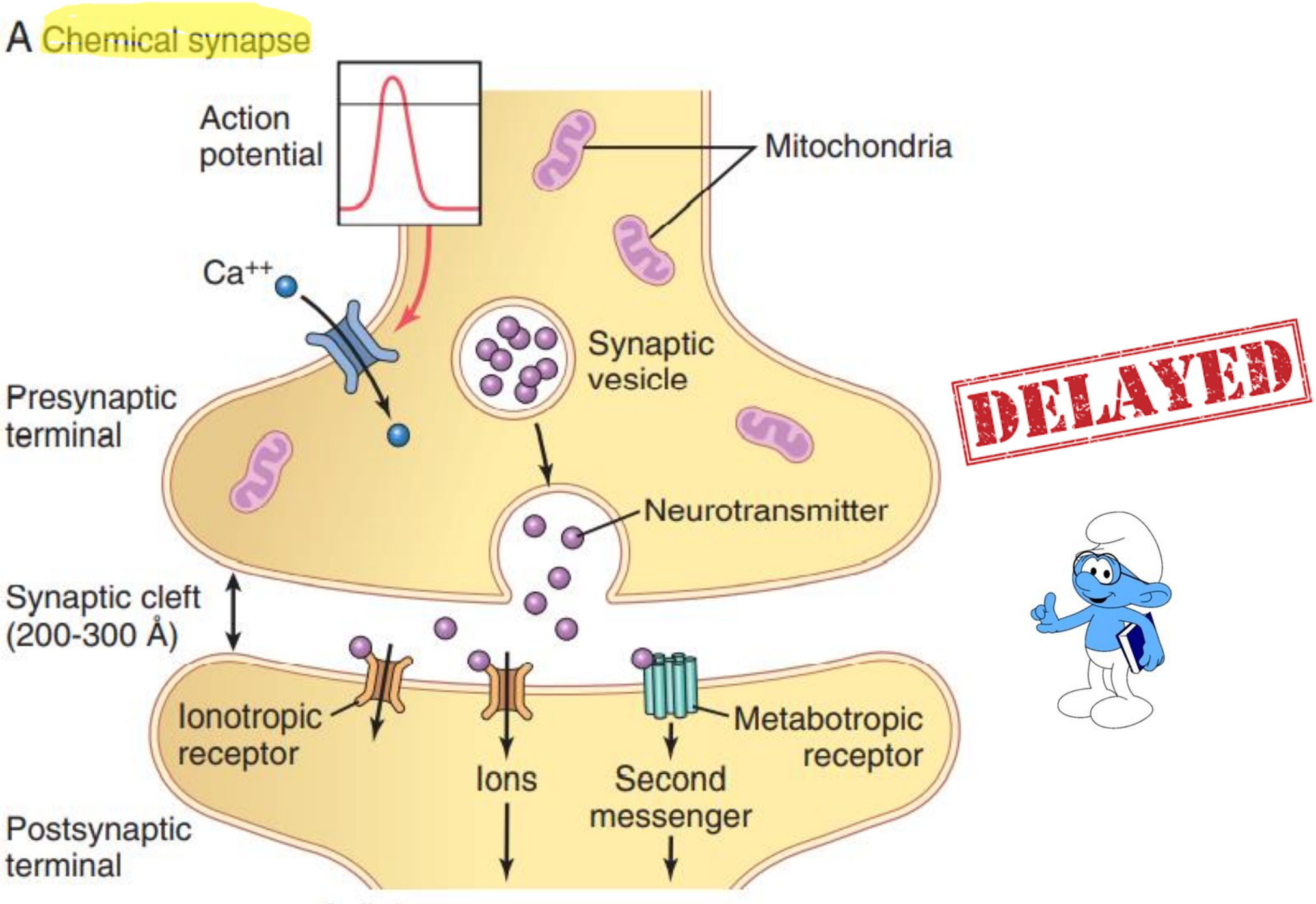


Principle of one-way conduction at chemical synapse

Principle of one-way conduction at chemical synapses

- **Always transmit the signals in one direction:** from the presynaptic neuron to the postsynaptic neuron.

- Allows signals to be directed toward specific goals and perform specific nervous functions.


A Chemical synapse
Action potential
Mitochondria
Ca++
Synaptic vesicle
Presynaptic terminal
Neurotransmitter
Synaptic cleft (200-300 Å)
Ionotropic receptor
Ions
Second messenger
Metabotropic receptor
Postsynaptic terminal
DELAYED

- Delayed of conduction of signal in(chemical synapse) or transmission of signal compared to electrical synapse ,
- Remember that electrical synapses there's almost instantaneous changes in the membrane potential between these cells because of presence of gap junctions and the very fast transmission of ions .
- However,in the chemical synapse when the action potential comes all the way from the axon to the axon termina. , there a steps need before development of an action potential in the post synaptic
- 1) Activate the voltage gated calcium channel
- 2) calcium influx will induce exocytosis so the vesicles will transmit to membrane to fuse with it and release these neurotransmitter
- 3) neurotransmitter will go away through synaptic cleft until they bind to specific site on specific receptor

Synaptic delay

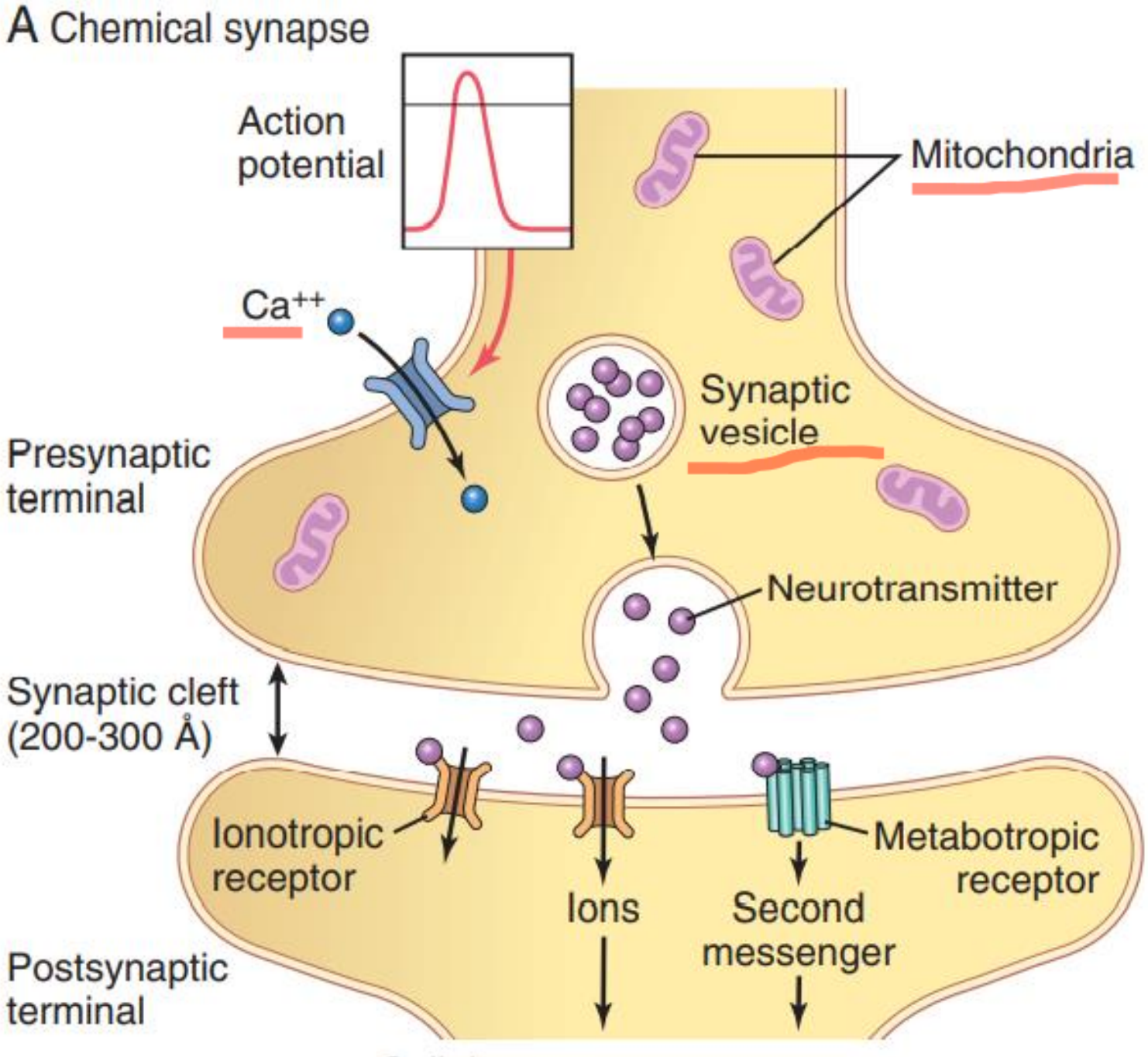
- During transmission of a neuronal signal from a presynaptic neuron to a postsynaptic neuron, a certain amount of time (0.5 msec) is consumed in the process of

- (1) discharge of the transmitter substance by the presynaptic terminal,

- (2) diffusion of the transmitter to the postsynaptic neuronal membrane,

Synaptic delay

- (3) action of the transmitter on the membrane receptor,
- (4) action of the receptor to increase the membrane permeability,
- (5) inward diffusion of sodium to raise the EPSP to a high enough level to elicit an action potential.


A Chemical synapse
Action potential
Mitochondria
Ca++
Synaptic vesicle
Presynaptic terminal
Neurotransmitter
Synaptic cleft (200-300 Å)
Ionotropic receptor
Ions
Metabotropic receptor
Second messenger
Postsynaptic terminal

Postsynaptic neurons

- Receptor activation controls the opening of ion channels in the postsynaptic cell in one of two ways:

(1) by gating ion channels directly (Ionotropic receptors).

(2) by activating a second messenger (metabotropic receptors).

Excitation of postsynaptic neuron

- Opening of sodium channels.

- Changes in the internal metabolism of the postsynaptic neuron to excite cell activity or to increase the number of excitatory membrane receptors or decrease the number of inhibitory membrane receptors.

Inhibition of postsynaptic neuron

- Opening of chloride ion channels through the postsynaptic neuronal membrane.
- Increase in conductance of potassium ions out of the neuron.
- Activation of receptor enzymes that inhibit cellular metabolic functions or that increase the number of inhibitory synaptic receptors or decrease the number of excitatory receptors.

Second-messenger system

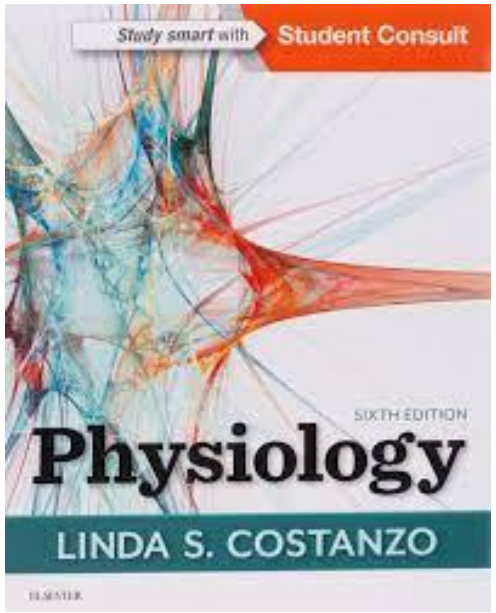
- Many functions of the nervous system—for instance, the process of memory—require prolonged changes in neurons for seconds to months after the initial transmitter substance is gone.

- The ion channels are not suitable for causing prolonged postsynaptic neuronal changes because these channels close within milliseconds after the transmitter substance is no longer present.

Second-messenger system

- However, in many instances, **prolonged** postsynaptic neuronal excitation or inhibition is achieved by activating a “second messenger” chemical system inside the postsynaptic neuronal cell itself, and then it is the second messenger that causes the prolonged effect.

References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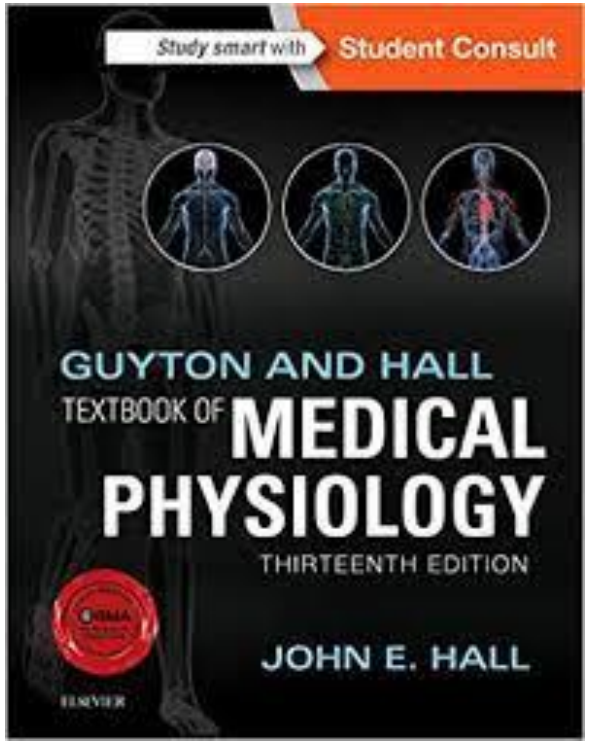
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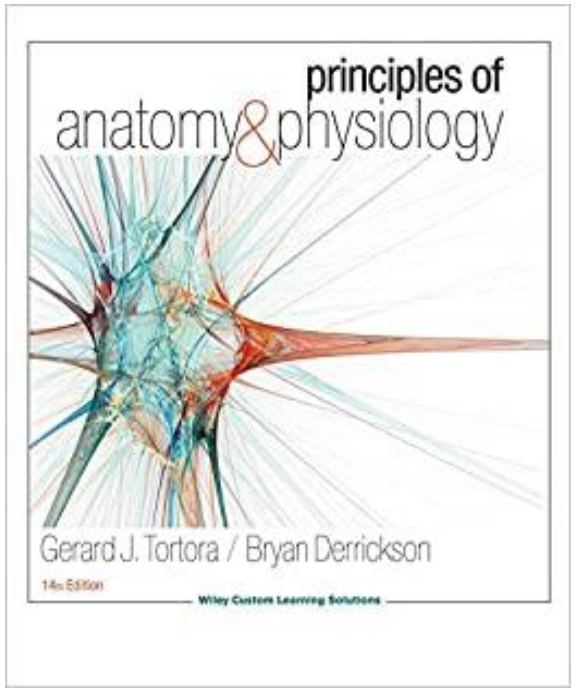
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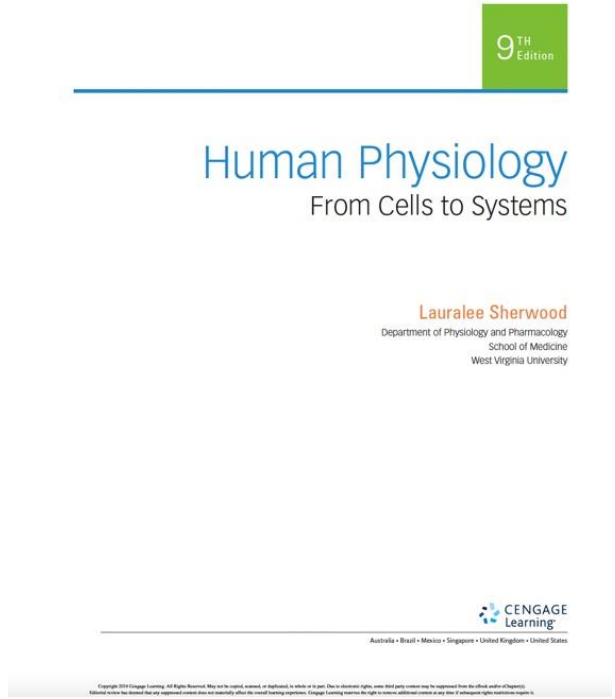
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V1 → V2			

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