Physiology of Synapses

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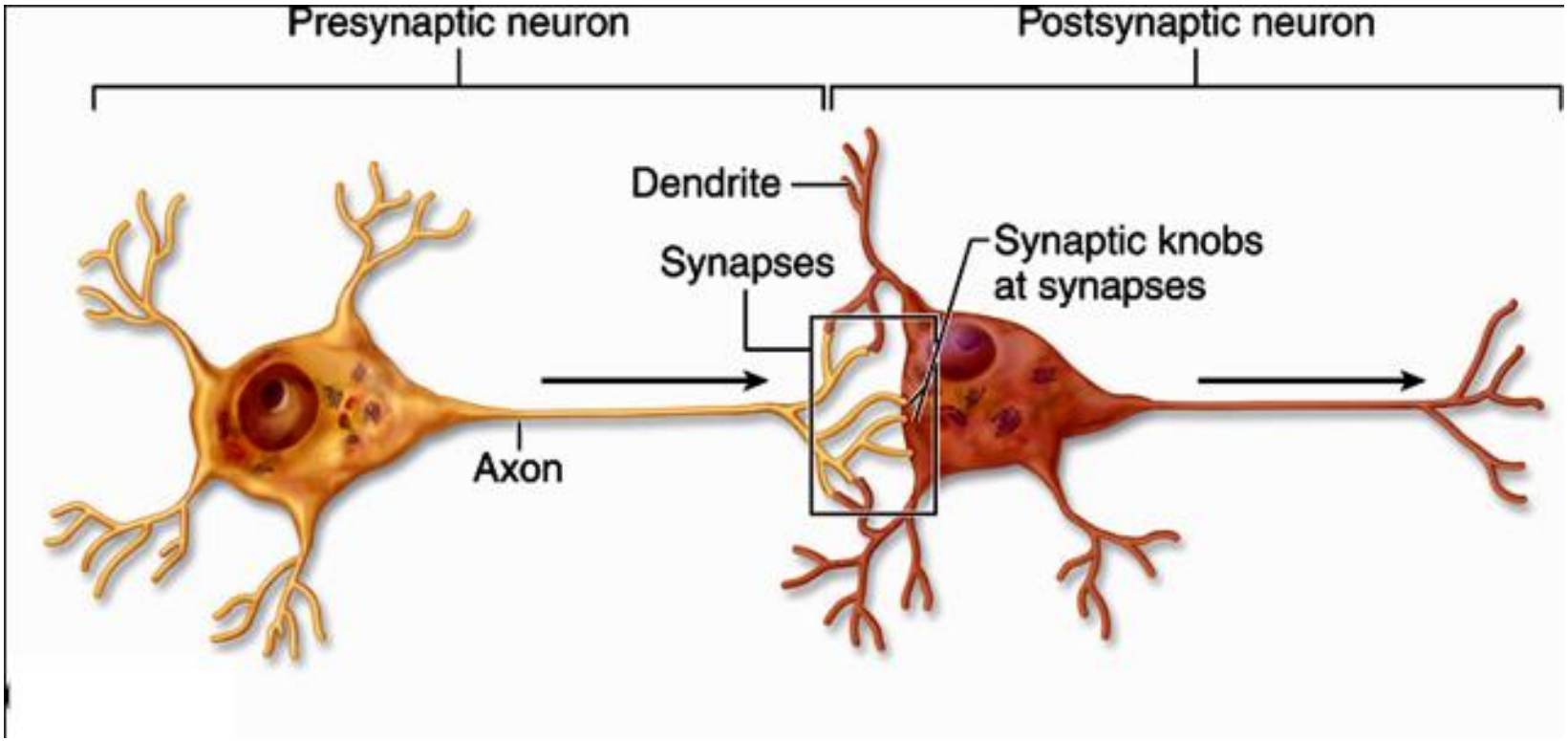
Objectives

- At the end of this lecture the student should :
- (1) define synapses and show where they are located .
- (2) describe the parts of a synapse , & what does each part contain .
- (3) know how to classify synapses .
- (4) define synaptic transmitters , give examples of excitatory & inhibitory ones ; explain how they are released
- (5) explain ionic channels that mediate actions on synaptic receptors .
- (6) explain : EPSP , IPSP , LTP .
- (7) describe properties of synapses such as convergence , divergence , spatial & temporal sunmmation , subliminal fringe , types of inhibition and their physiological significance .
- (8) expalin how acidosis and alkalosis can affect synaptic transmission .

References :Ganong Review of Medical physiology, 23rd edition . Barret et al (eds) . Mc Graw Hill , Boston 2010 .
Page 115 onward

- What is a synapse ? It is a n area of communication between 2 neurons .



- What are its components & their function ? does each part of synapse contain ?

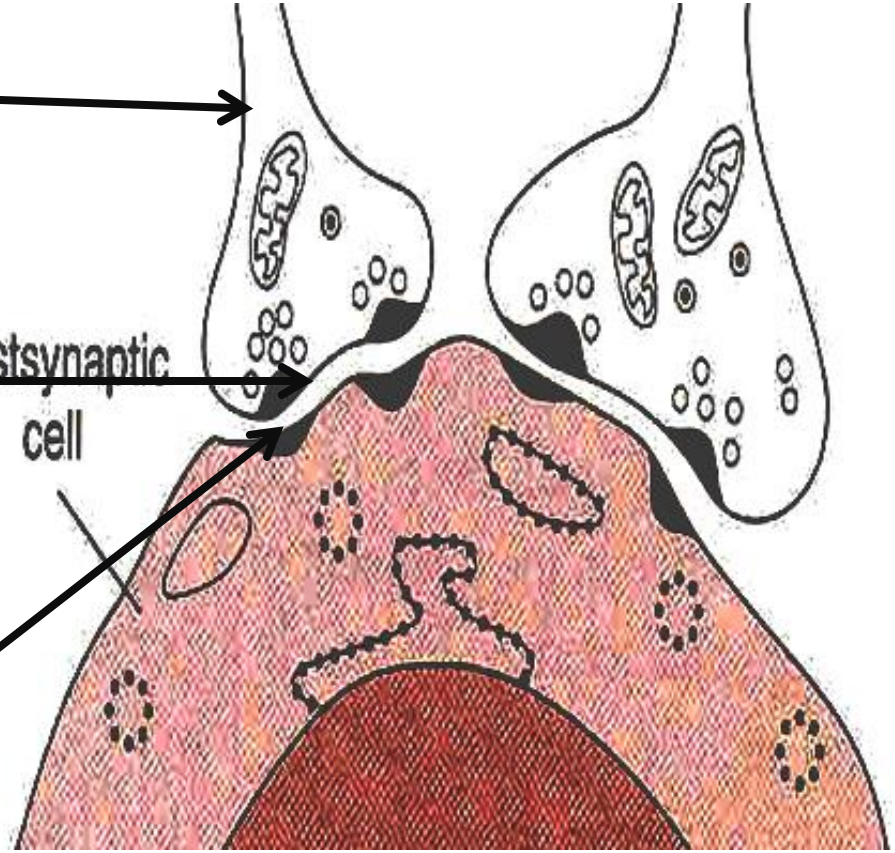
Components of a Synapse

Q: What are the components of a synapse ?

(1) Synaptic knob of the pre-synaptic cell (contains transmitter)

(2) Synaptic cleft (space) contains enzyme that destroys the transmitter

(3) Post-synaptic membrane (contains receptors for the transmitter)



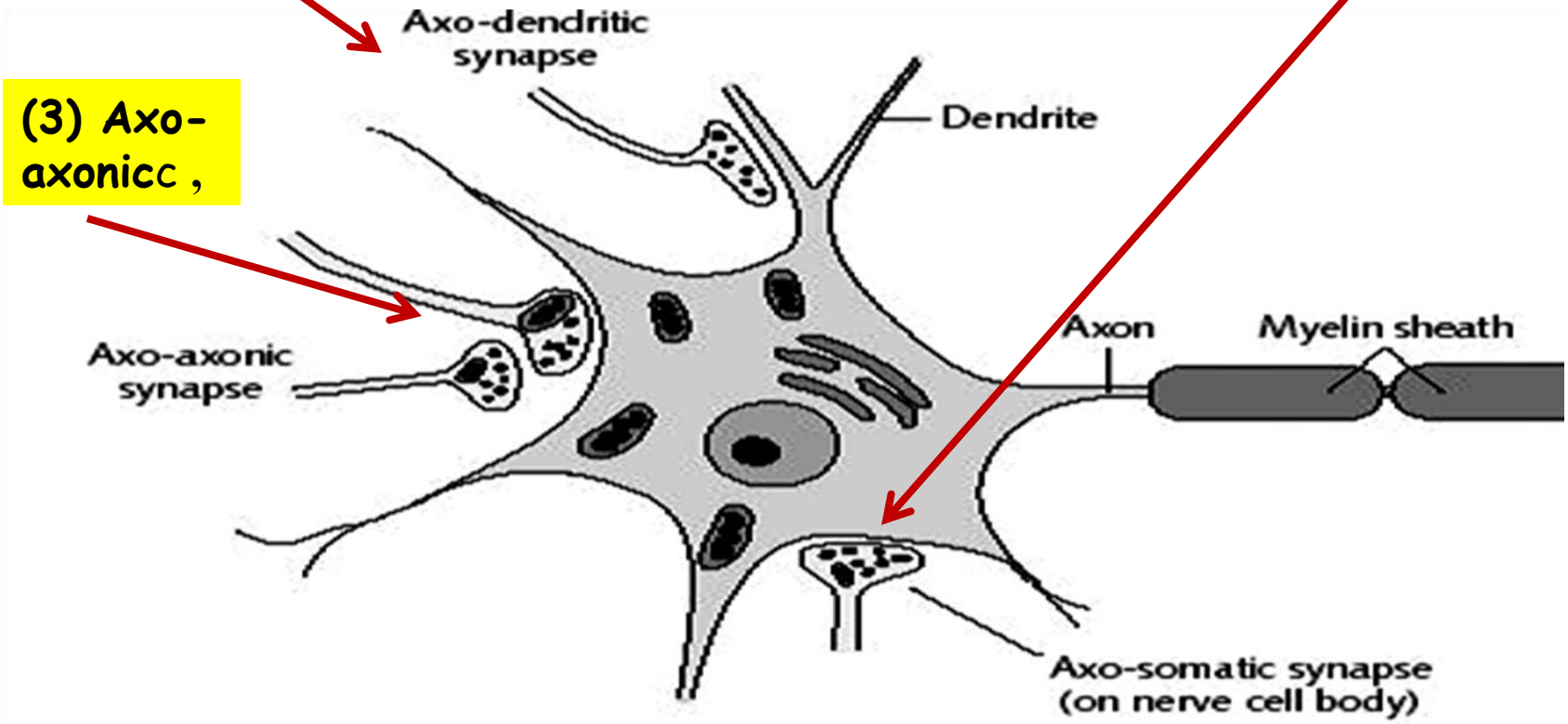
Classification of Synapses According to Location

(1) Axo-dendritic ,

(2) Axo-somatic

,

(3) Axo-axonicc ,



& less commonly →

(4) Dendro-somatic

(5) Somato-somatic

Q : What is a synaptic transmitter (neurotransmitter) ?

- A neurotransmitter is a chemical substances that is released by a neuron (called presynaptic cell) , crosses the synaptic cleft , and binds to a receptor located on the membrane (postsynaptic membrane) of another cell .

Q : What are the types of transmitters ?

- Excitatory neurotransmitter :

  a transmitter that produces excitatory postsynaptic potential (EPSP) on the postsynaptic neuron .
- Inhibitory neurotransmitter :

  a transmitter that produces inhibitory postsynaptic potential (IPSP) on the postsynaptic neuron .

- Q : What are EPSP and IPSP ?
- A : They are local responses

- Q : What is their bioelectric nature ?
- A : They are Graded Potentials (i.e., proportional to the strength of the stimulus).

- Q: In what way do they affect the excitability of the postsynaptic membrane ?
- A: EPSP makes the postsynaptic membrane more excitable

(thus more liable to fire AP ; & IPSP makes it less excitable)

Q: In what ways do they differ from action potentials ?

- (1) They are proportional to the strength of the stimulus (i.e., do not obey All-or-None Law)
- (2) They can summate (add up)

✓ Q : Give examples of excitatory transmitters ?

- (1) Acetylcholine : Opens sodium channels in the Postsynaptic Cell Membrane → depolarization → EPSP .

- (2) Glutamate : Produces EPSP by opening of calcium channels .

✓ Q : What is long-term-potentiation (LTP) ?, what transmitter is involved in it ? What is the physiological function of LTP ?

Give examples of Inhibitory Tran smitters

- When the inhibitory transmitter combines to its receptors , it produce Inhibitory Postsynaptic potential (IPSP) that hyperpolarizes the post-synaptic cell , thereby making it less excitable (more difficult to produce APs) .
- Examples of inhibitory transmitter is

- GABA → which in some places opens chloride channels , and in others opens potassium channels
- Enkephalin → Inhibitory transmitter . Found in the GIT and spinal cord . It exerts analgesic activity, reducing the feeling of pain .
- Glycine (mainly in spinal cord) .

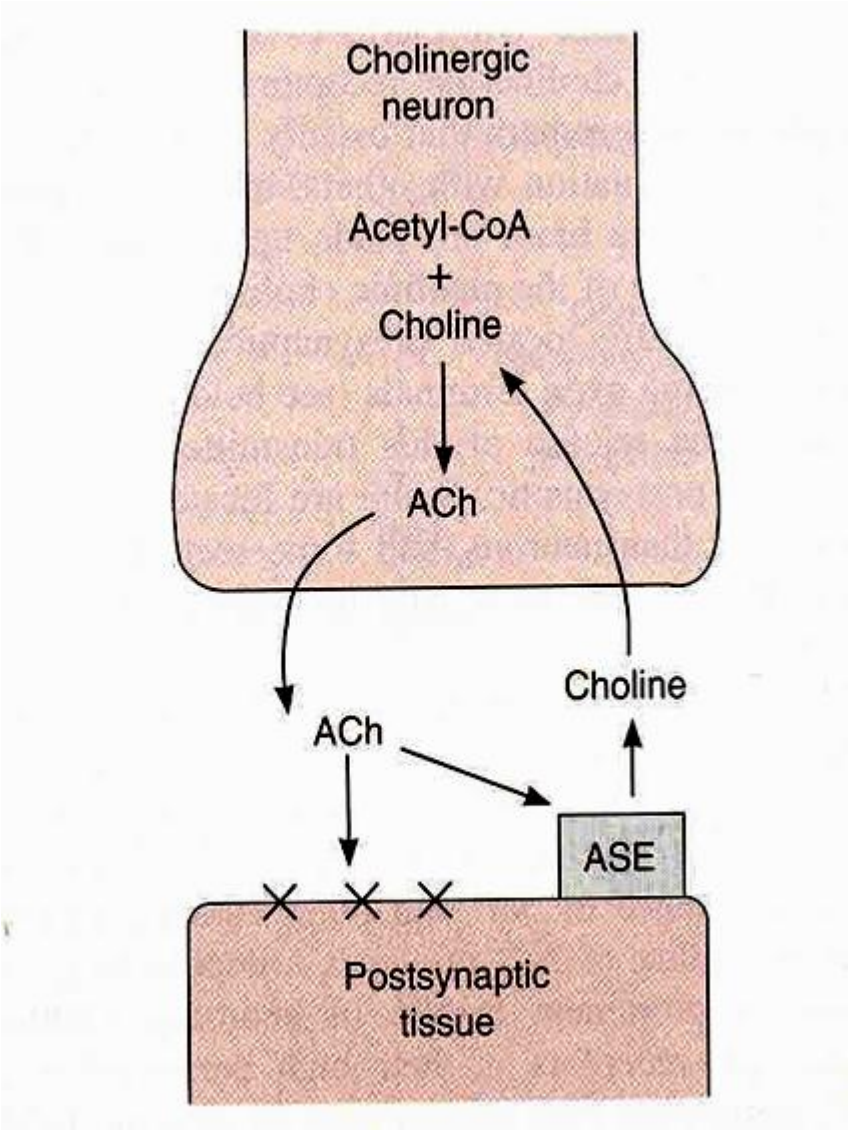
Formation of a Transmitter

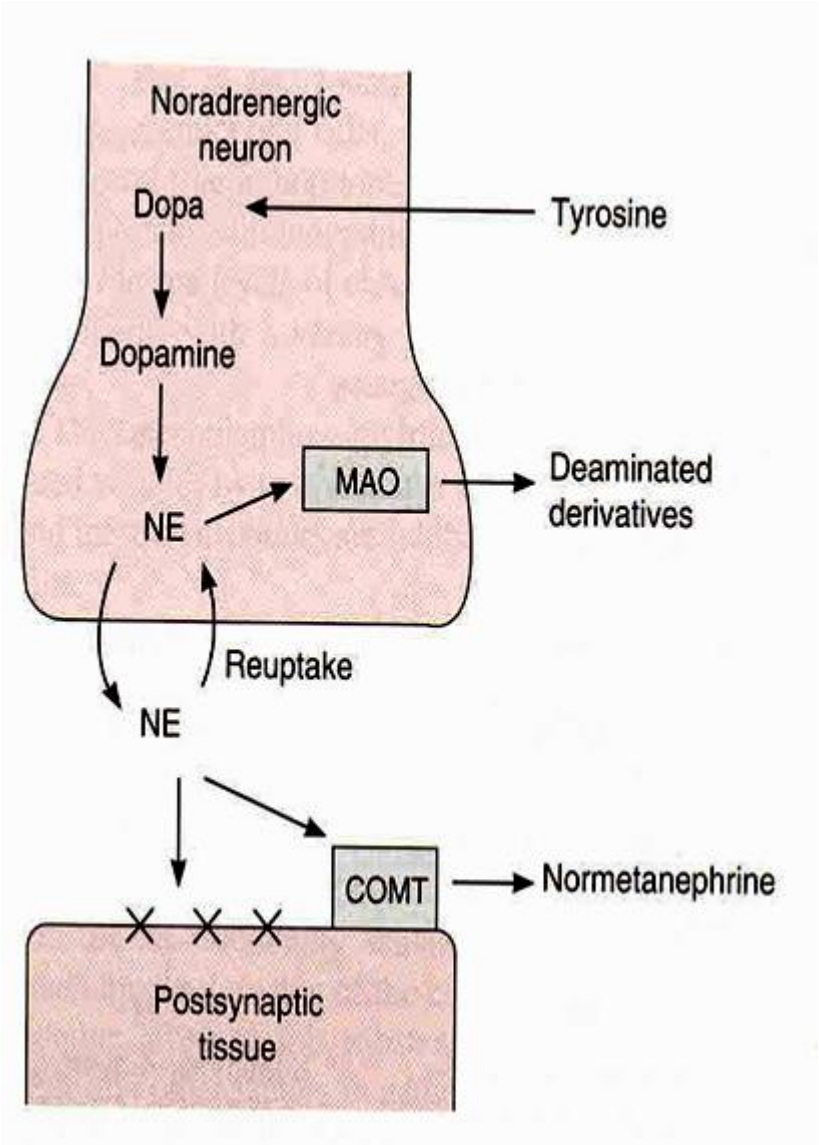
- Q : In what location of the neuron is the neurotransmitter synthesized ?
- Q : In what location of the neuron is the transmitter vesicle synthesized ?
- How are these processes functionally coupled to produce successful synaptic transmission ?

Final Fate of Transmitter

- Q : What happens to the transmitter after it has combined with its postsynaptic receptors and produced it physiological effect ?
- It will be destroyed
- Examples :
- In case of **Acetylcholine (Ach)** →

  Acetylcholinesterase (Ach-esterase) ;
- In case of **Norepineohrine (Noradrenaline)** → Monoamine Oxidase (MAO) intracellularly (more important) ; or Catechol-O-Methyl Transferase (COMT) extracellularly .


Cholinergic neuron
Acetyl-CoA + Choline
ACh
ACh
Choline
ASE
Postsynaptic tissue


Noradrenergic neuron
Dopa
Tyrosine
Dopamine
MAO
Deaminated derivatives
NE
Reuptake
NE
COMT
Normetanephrine
Postsynaptic tissue

Examples of Factors that Affect Neurotransmission

- What is the effect of :
- Alkalosis ?
- Hypoxia ?
- Acidosis ?

Some Properties of Synapses & Synaptic Transmission

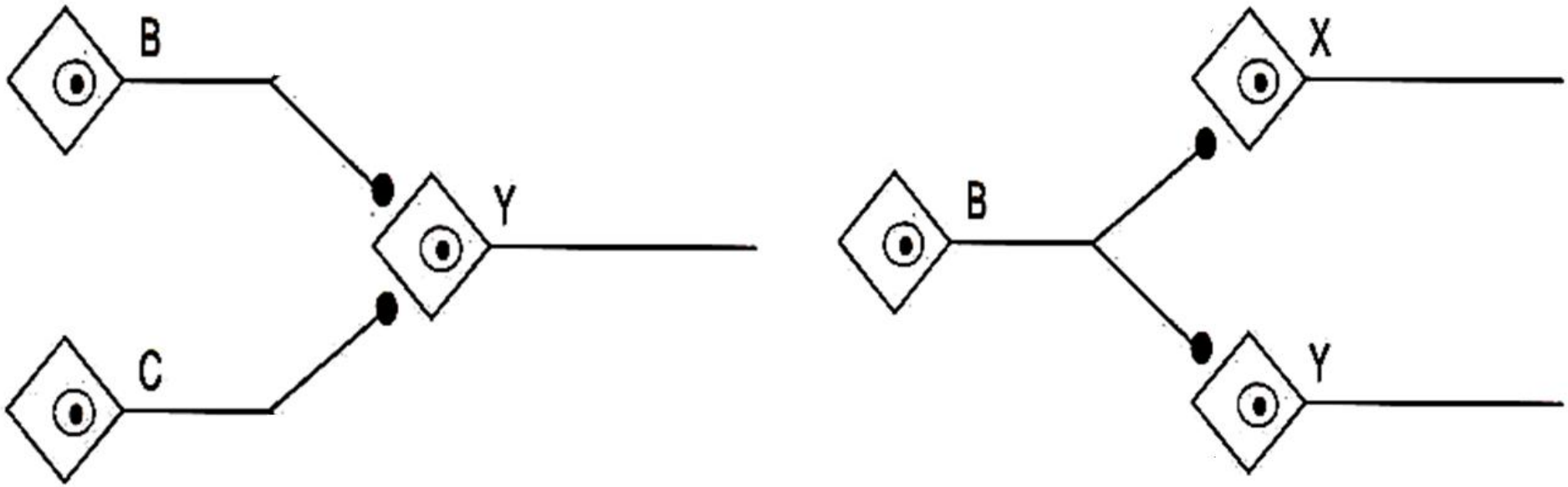
1/ ONE WAY CONDUCTION

Why ?

2/ SYNAPTIC DELAY

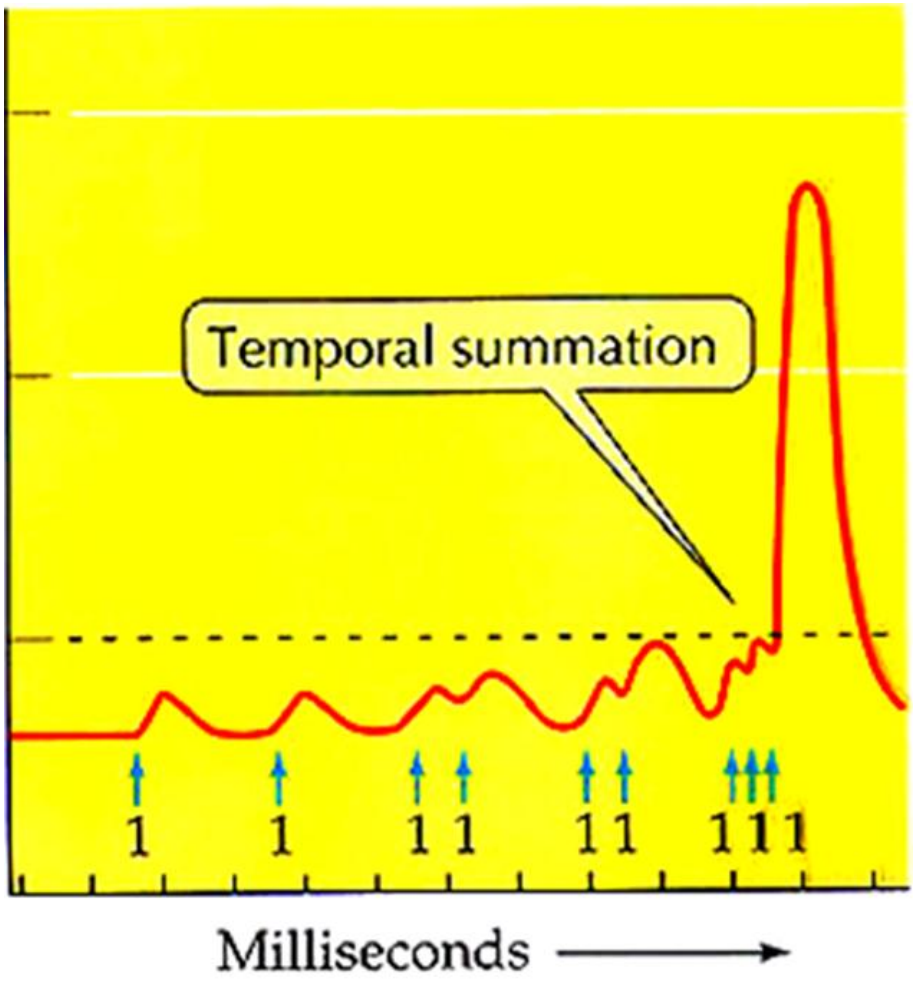
Why ?
Duration in a one synapse ?
What do we mean by total (overall)
synaptic delay ?
How can we determine the number of synapses between two neurons ?

3/ Convergence and Divergence

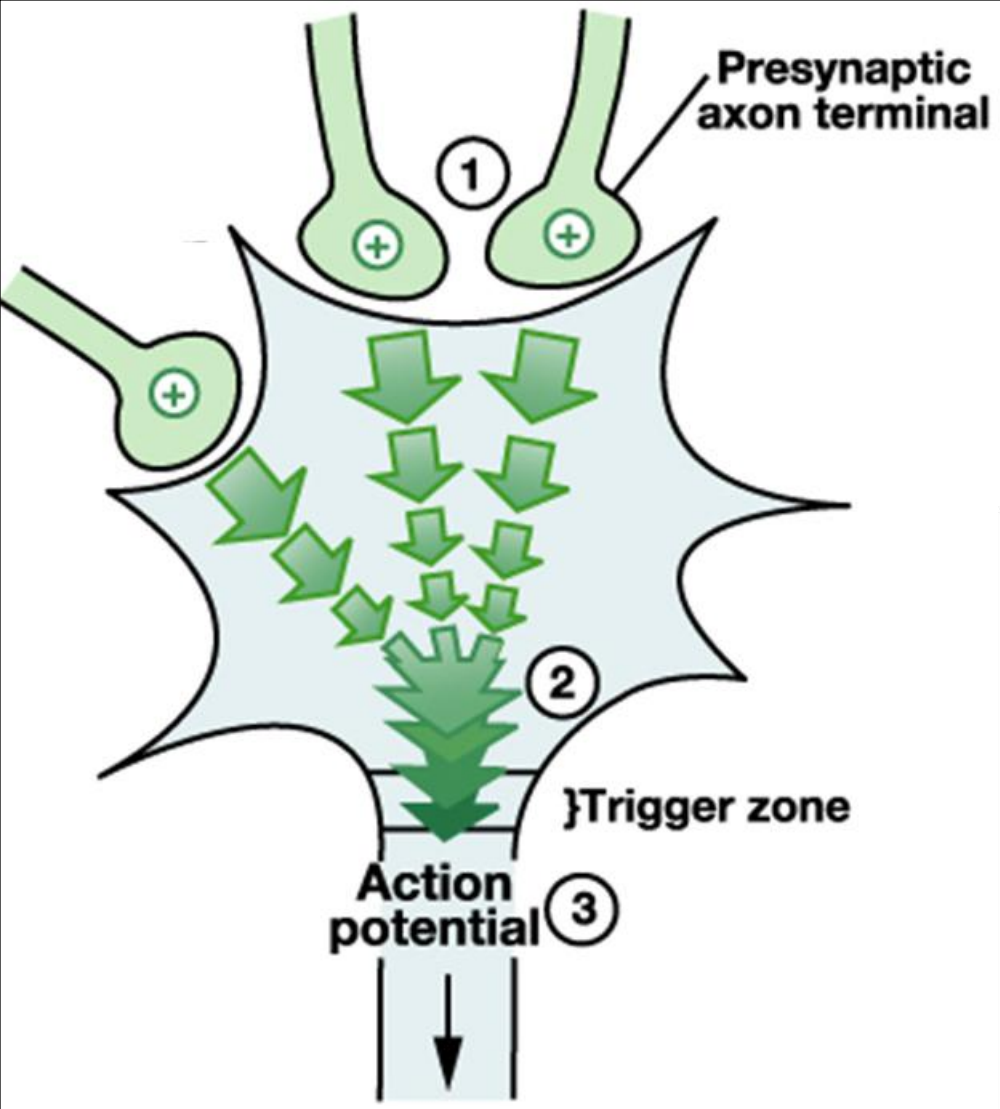


- What is the importance of convergence ?
- What is the importance of divergence ?

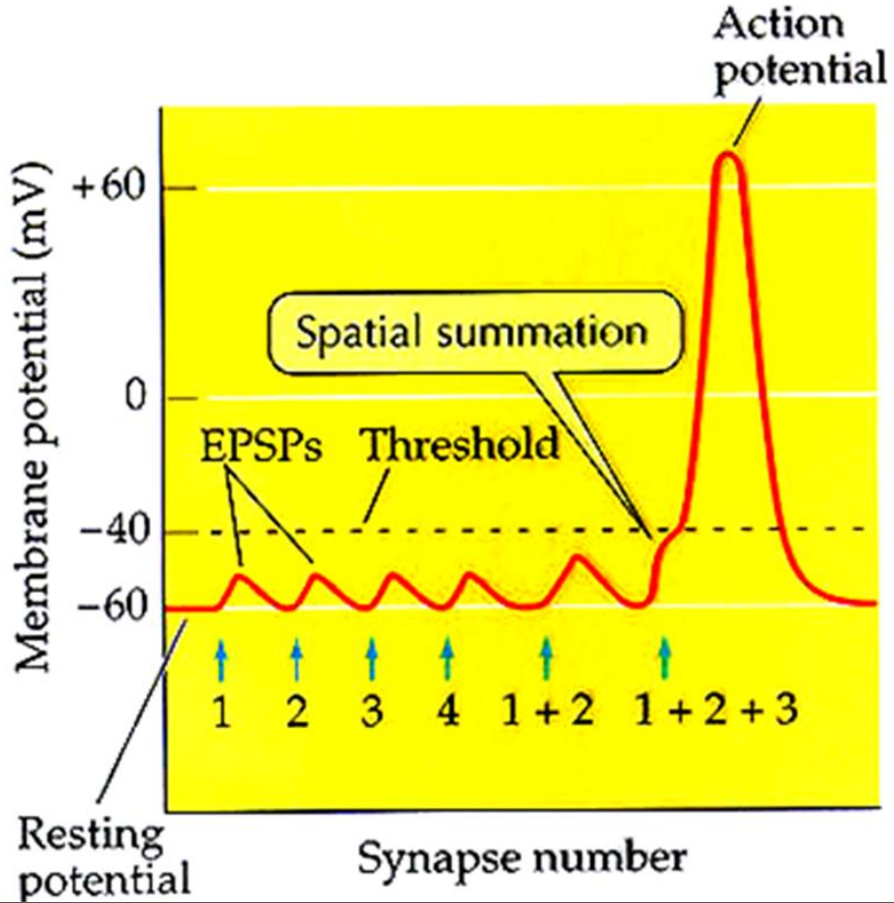
4/ Summation (how the postsynaptic membrane sums information) → Spatially & Temporally



- <u>Temporal summation</u>
  : Repeated afferent stimuli (even if from a single synaptic knob) cause new EPSPs before previous EPSPs have decayed.

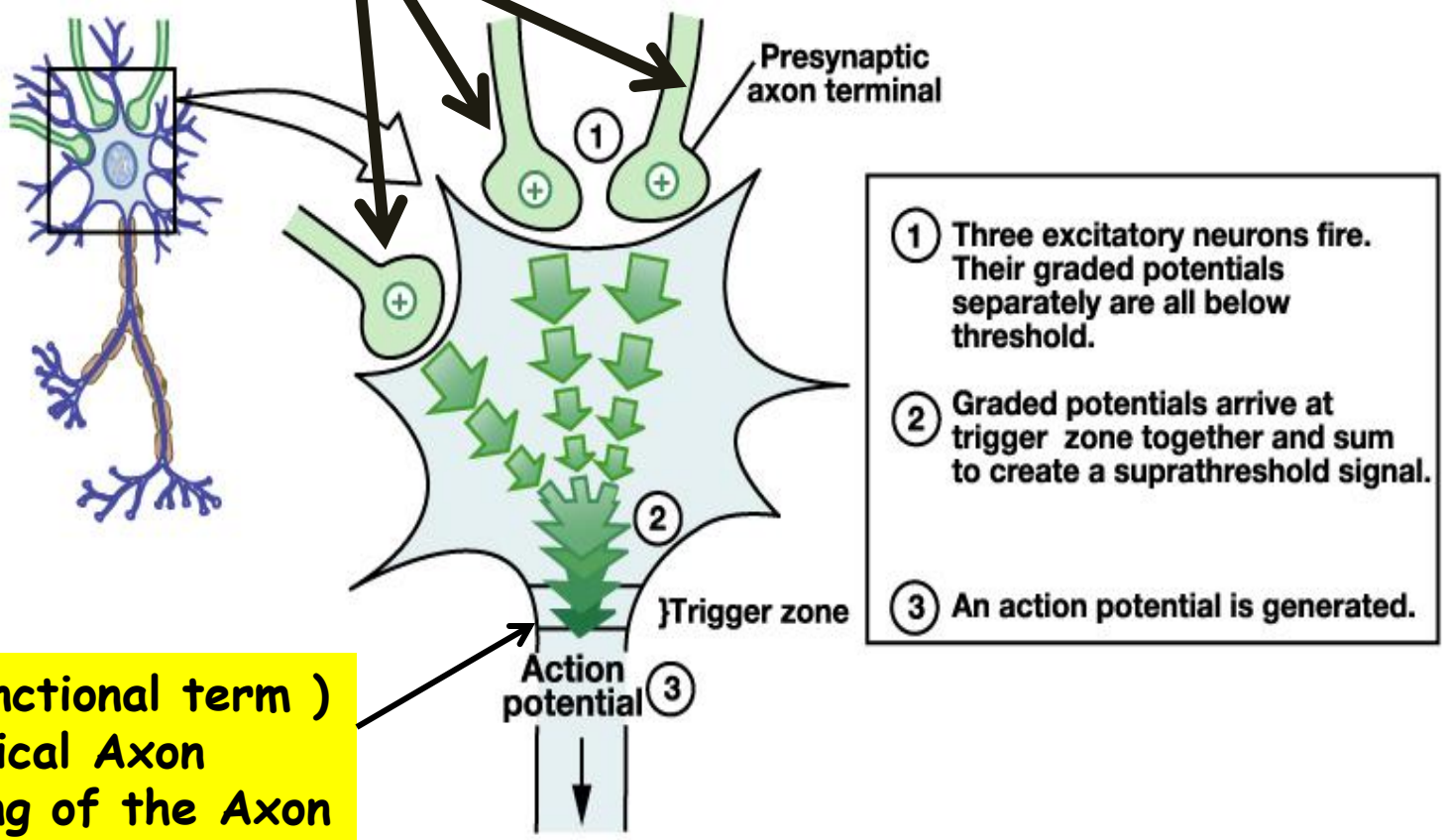


- **Spatial summation** due to adding up of EPSPs produced by more than one synaptic knob . Thus activity in one synaptic knob facilitates activity in another.



What is the Trigger zone ?

Convergence



Trigger zone (functional term) is at the anatomical Axon Hillockn (Beginning of the Axon as it comes out of the Soma)

5/ Inhibition

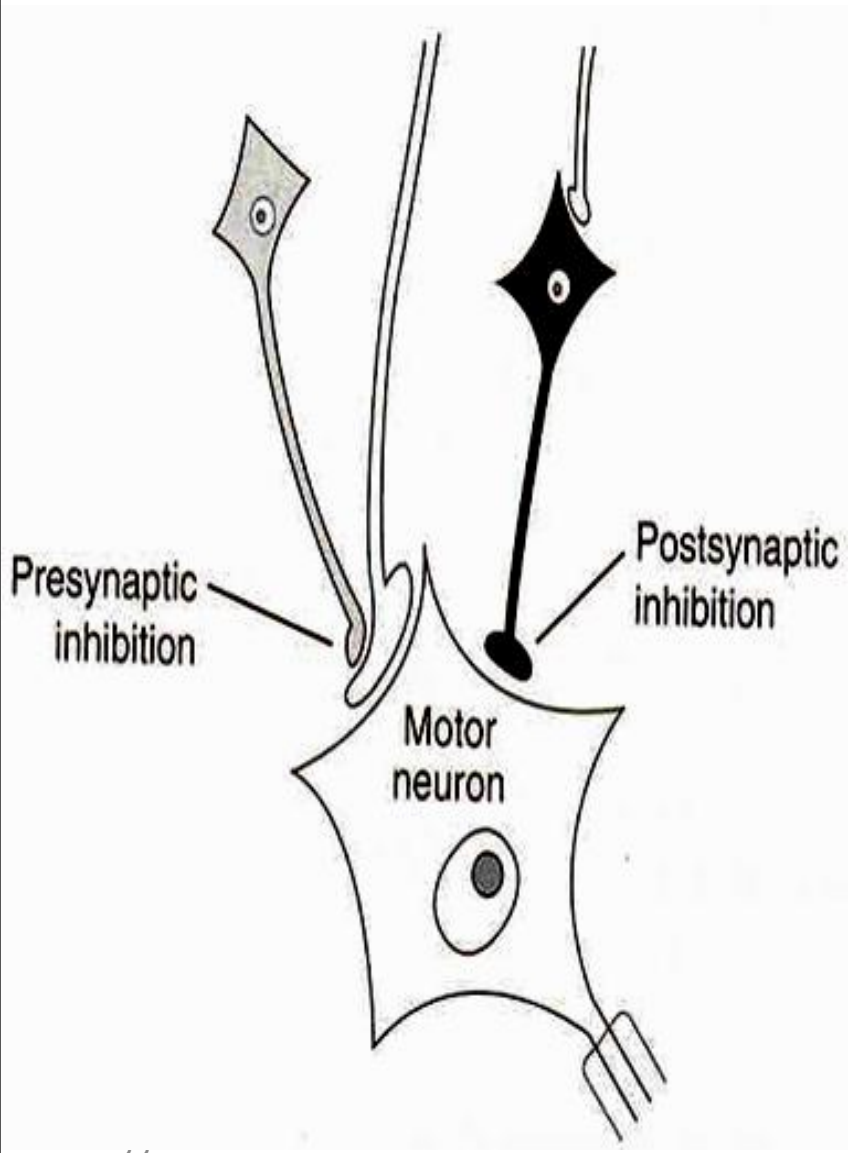
- Explain Presynaptic inhibition ?

  Where ?

  Neurotransmitter involved ?
- Explain Postsynaptic (Direct) inhibition ?
- Describe Inhibitory interneuron ?

  Example ?
- Describe Reciprocal Inneirvation , & explain how it is nstrumental for (mediates) Reciprocal Inhibition?

(8) Inhhibition



A/ Presynaptic Inhibition

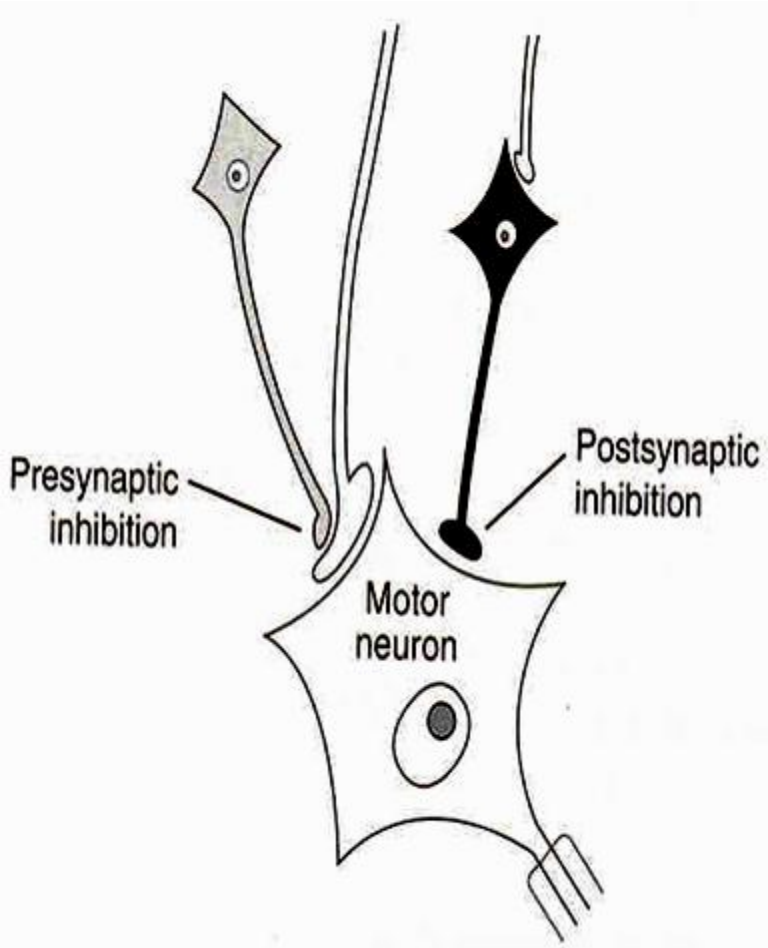
An inhibitory neuron , not acting directly on the target cell , but makes axo-axonal synapse on an excitatory ending that ends on the target cell .

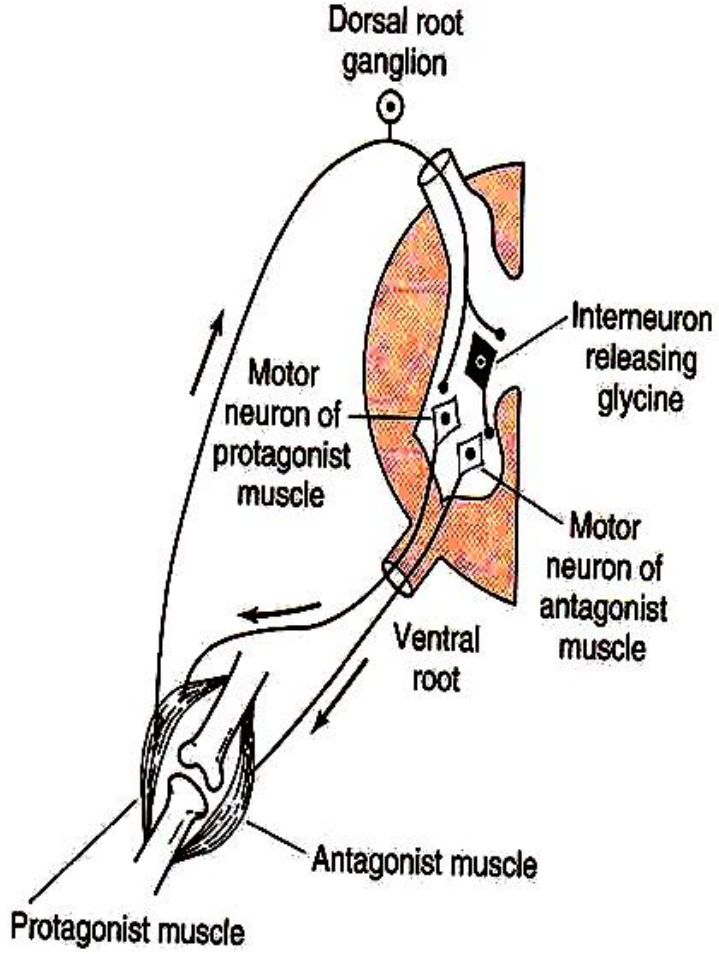
This inhibitory interneuron releases GABA which acts via either :

(1) GABA**a** receptors that increase chloride conductance →decreasing calcium entry into the excitatory synaptic knob →reduced or absent transwmitter release ; OR

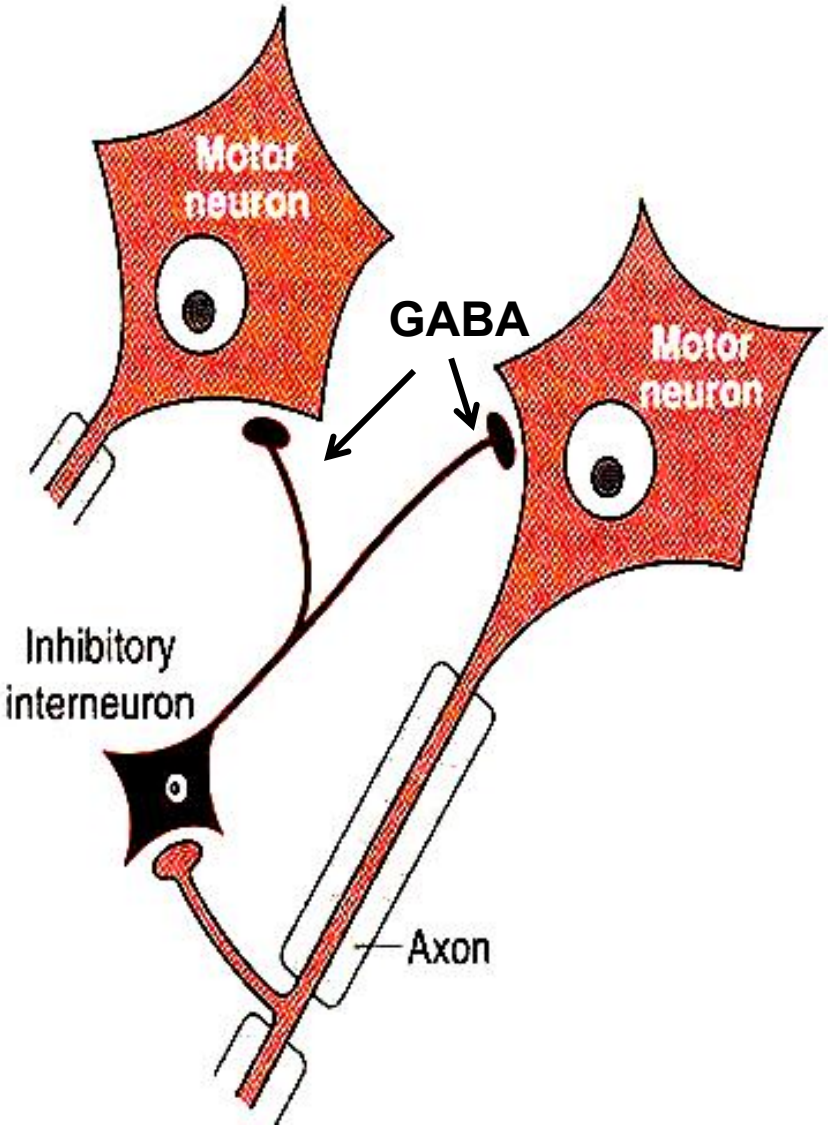
(2) GABA**b** receptors which , through G-protein → increase potassium conductance , thereby decreasing calcium entry into the synaptic knob of the excitatory neuron.

Presynaptic , Postsynaptic (Direct) & Reciprocal Inhibition





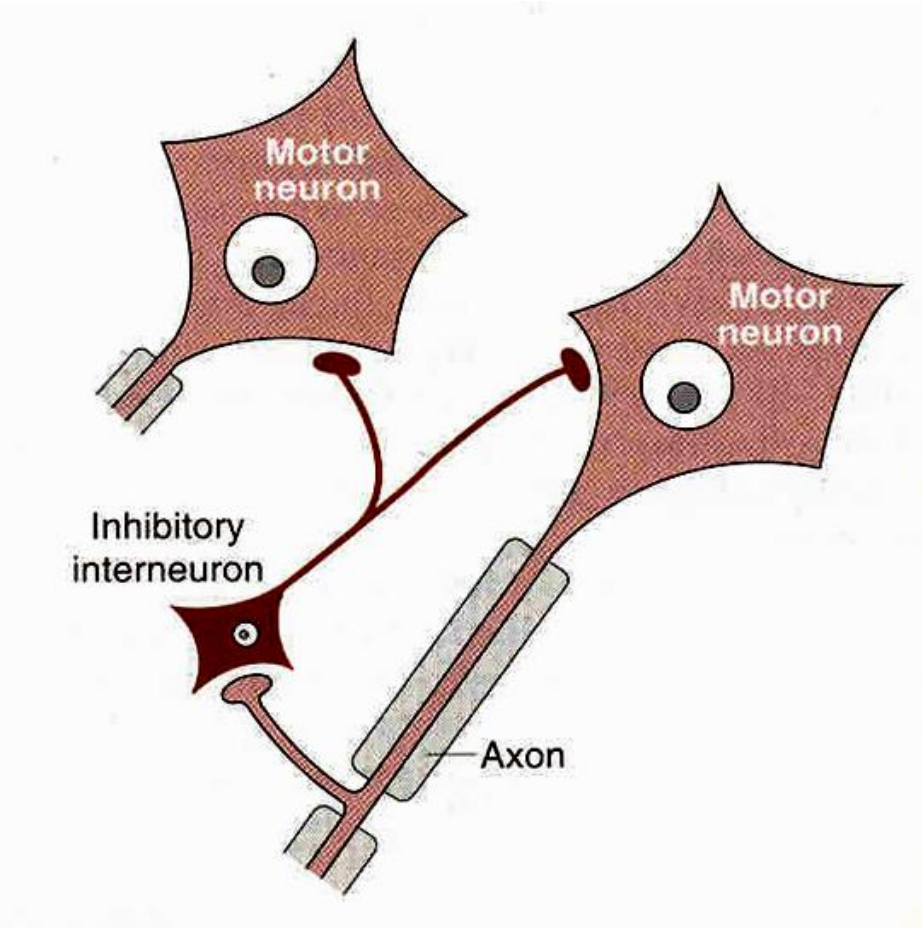
Feedback Inhibition (Renshaw Cell Inhibition)



- Neurons may also inhibit themselves in a negative feedback fashion (Negative Feedback inhibition).
- A spinal motoneuron gives a collateral that synapses Renshaw cell which is inhibitory interneuron , located in the anterior horn of spinal cord .
- Then Renshaw cell , in turn , sends back axons that inhibit the spinal motoneuron .
- These axons secrete an inhibitory transmitter that produces IPSPs on cell-bodies of motoneurons and inhibit them .

The Renshaw cell

- Is located in anterior horn in close association with motor neurons.
- it is an inhibitory cell excited by collaterals from an alpha motor neuron to project back and inhibit the same motor neuron (negative feedback fashion).



After understanding neurophysiology principles, our scientists have developed this thinking robot

Thanks !