SYNAPSE

Dhivakar Murugan
MPT – Neurology
Assistant Professor
SNSCOP

- DEFINITION
- CLASSIFICATION
  - ANATOMICAL CLASSIFICATION
  - FUNCTIONAL CLASSIFICATION
- FUNCTIONS
  - EXCITATORY FUNCTION
  - INHIBITORY FUNCTION
- PROPERTIES
  - ONE WAY CONDUCTION – BELL-MAGENDIE LAW
  - SYNAPTIC DELAY
  - FATIGUE
  - SUMMATION
  - ELECTRICAL PROPERTY
- CONVERGENCE AND DIVERGENCE
  - CONVERGENCE
  - DIVERGENCE

DEFINITION:

Synapse is the **junction between two neurons**. It is not an anatomical continuation. But, it is only a physiological continuity between two nerve cells.

CLASSIFICATION OF SYNAPSE:

Synapse is classified by two methods:

A. Anatomical classification

B. Functional classification.

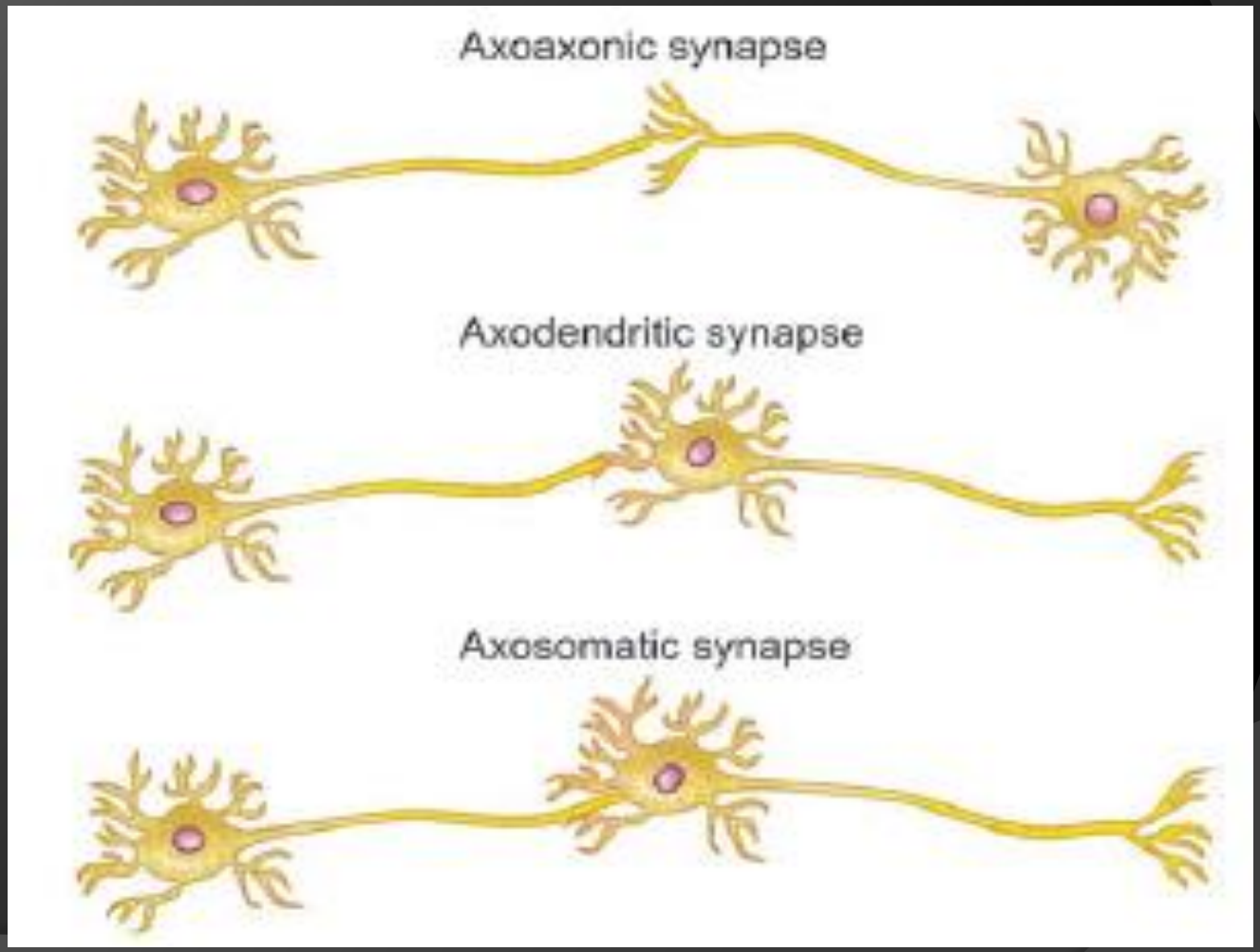
ANATOMICAL CLASSIFICATION

Usually synapse is formed by **axon of one neuron ending on the cell body, dendrite or axon** of the next neuron. Depending upon **ending of axon, synapse is** classified into three types:

1. **Axoaxonic synapse in which axon of one neuron** terminates on axon of another neuron.

2. **Axodendritic synapse in which the axon of one** neuron terminates on dendrite of another neuron

3. **Axosomatic synapse in which axon of one neuron** ends on soma (cell body) of another neuron



FUNCTIONAL CLASSIFICATION

Functional classification of synapse is on the basis of **mode of impulse transmission.** According to this, synapse is classified into two categories:

1. **Electrical synapse**
2. **Chemical synapse.**

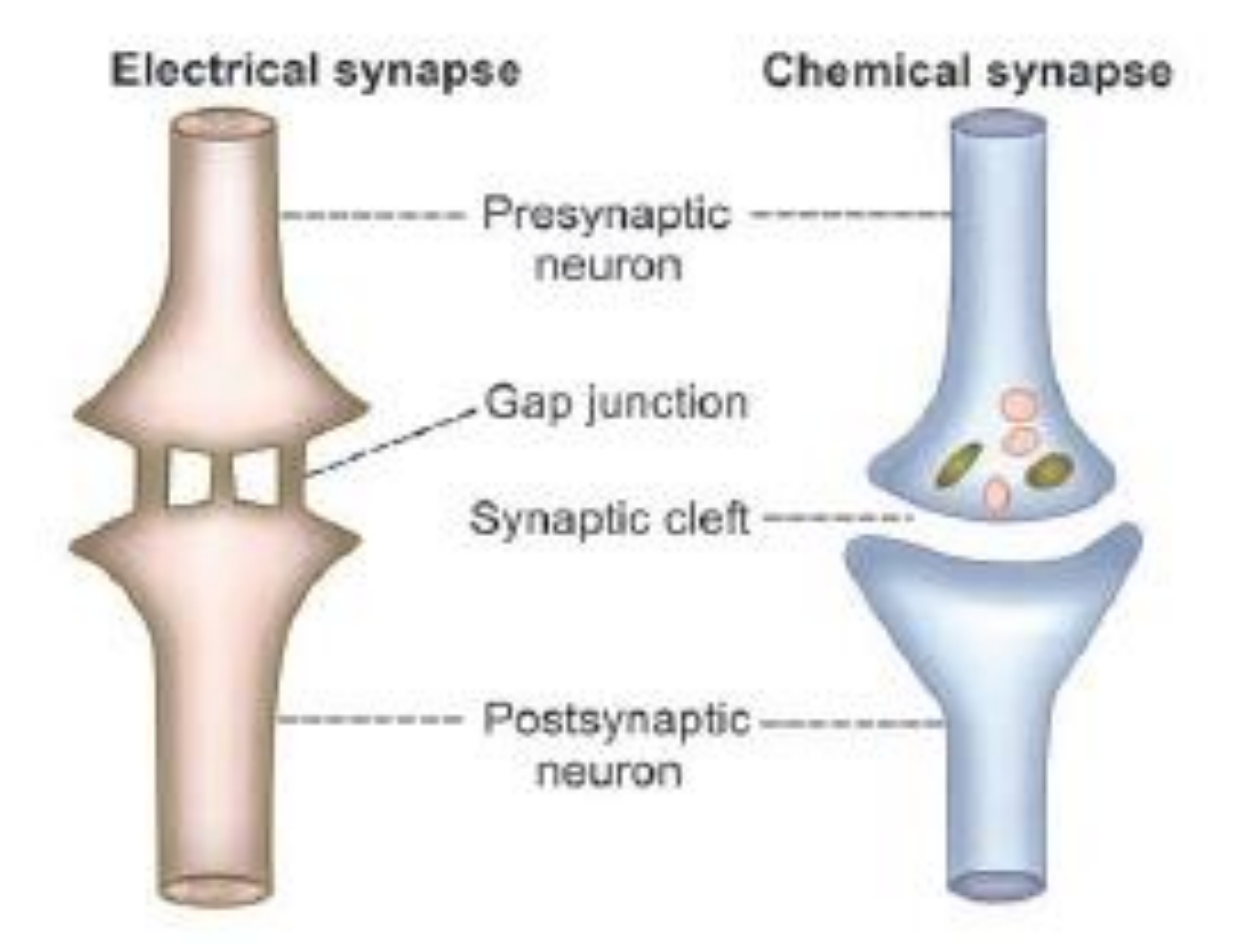
1. *Electrical Synapse*

Electrical synapse is the synapse in which the physiological continuity between the pre-synaptic and the post synaptic neurons is provided by **gap junction** between the two neurons.

There is **direct exchange of ions** between the two neurons through the gap junction. Because of this reason, the action potential reaching the terminal portion of presynaptic neuron directly enters the postsynaptic neuron.

Important feature of electrical synapse is that the synaptic delay is very less because of the direct flow of current.

Moreover, the impulse is transmitted in either direction through the electrical synapse. This type of impulse transmission occurs in some tissues like the cardiac muscle fibers, smooth muscle fibers of intestine and the epithelial cells of lens in the eye.


Electrical synapse
Chemical synapse
Presynaptic neuron
Gap junction
Synaptic cleft
Postsynaptic neuron

2. Chemical Synapse:

Chemical synapse is the junction between a nerve fiber and a muscle fiber or between two nerve fibers, through which the signals are transmitted by the release of chemical transmitter.

In the chemical synapse, there is no continuity between the two neurons because of the presence of a space called **synaptic cleft** between the two neurons.

Action potential reaching the presynaptic terminal causes release of neurotransmitter substance from the vesicles of this terminal.

Neurotransmitter reaches the postsynaptic neuron through synaptic cleft and causes the production of potential change.

FUNCTIONS OF SYNAPSE

Main function of the synapse is to transmit the impulses, i.e. action potential from one neuron to another. However, some of the synapses inhibit these impulses. So the impulses are not transmitted to the postsynaptic neuron. On the basis of functions, synapses are divided into two types:

1. Excitatory synapses, which transmit the impulses

2. Inhibitory synapses, which inhibit the transmission of impulses .

EXCITATORY FUNCTION:

- **Excitatory Postsynaptic Potential:**

  Excitatory postsynaptic potential (EPSP) is the nonpropagated electrical potential that develops during the process of synaptic transmission.

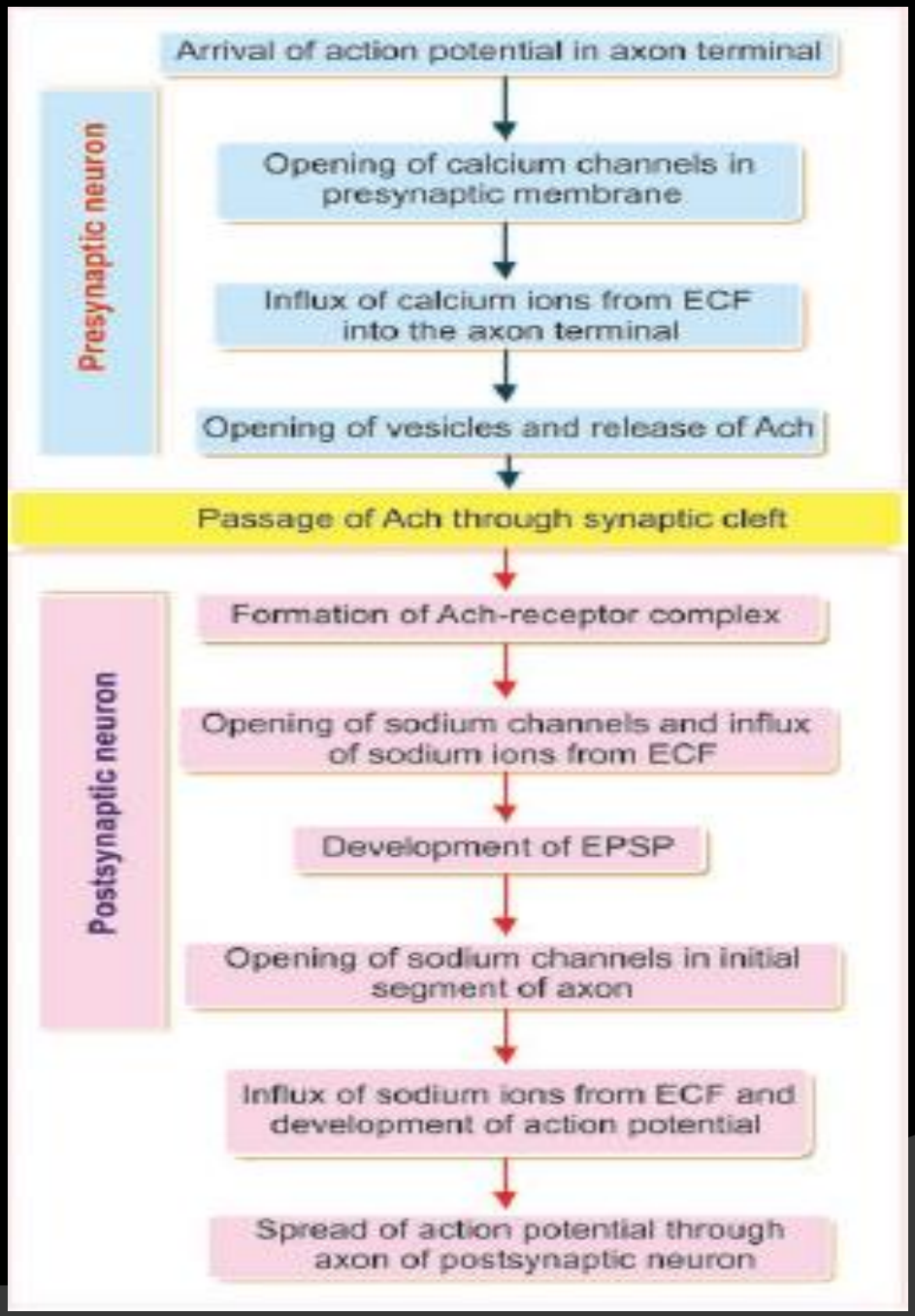
  When the action potential reaches the presynaptic axon terminal, the voltage gated **calcium channels at the presynaptic** membrane are opened. Now, the **calcium ions enter** the axon terminal from ECF.

Calcium ions cause the release of neurotransmitter substance from the vesicles by means of **exocytosis.**

Neurotransmitter, which is excitatory in function (excitatory neurotransmitter) passes through presynaptic membrane and synaptic cleft and reaches the postsynaptic membrane.

Now, the neurotransmitter binds with receptor protein present in postsynaptic membrane to form neurotransmitter receptor complex.

Neurotransmitter receptor complex causes production of a nonpropagated **EPSP.** Common excitatory neurotransmitter in a synapse is **acetylcholine.**


Arrival of action potential in axon terminal
Presynaptic neuron
Opening of calcium channels in presynaptic membrane
Influx of calcium ions from ECF into the axon terminal
Opening of vesicles and release of Ach
Passage of Ach through synaptic cleft
Postsynaptic neuron
Formation of Ach-receptor complex
Opening of sodium channels and influx of sodium ions from ECF
Development of EPSP
Opening of sodium channels in initial segment of axon
Influx of sodium ions from ECF and development of action potential
Spread of action potential through axon of postsynaptic neuron

INHIBITORY FUNCTION

Inhibition of synaptic transmission is classified into five types:

1. Postsynaptic or direct inhibition
2. Presynaptic or indirect inhibition
3. Negative feedback or Renshaw cell inhibition
4. Feedforward inhibition
5. Reciprocal inhibition.

1. Postsynaptic or Direct Inhibition:

Postsynaptic inhibition is the type of synaptic inhibition that occurs due to the release of an inhibitory neurotransmitter from presynaptic terminal instead of an excitatory neurotransmitter substance.

It is also called **direct inhibition. Inhibitory neurotransmitters are gammaaminobutyric acid (GABA), dopamine and glycine.**

2. Presynaptic or Indirect Inhibition:

Presynaptic inhibition occurs due to the failure of presynaptic axon terminal to release sufficient quantity of excitatory neurotransmitter substance. It is also called indirect inhibition.

Presynaptic inhibition is mediated by axoaxonal synapses. It is prominent in **spinal cord** and regulates the propagation of information to higher centers in brain.

Normally, during synaptic transmission, action potential reaching the presynaptic neuron produces development of EPSP in the postsynaptic neuron. But, in spinal cord, a **modulatory neuron called presynaptic inhibitory neuron forms an axoaxonic synapse with the presynaptic** neuron.

This inhibitory neuron inhibits the presynaptic neuronand decreases the magnitude of action potential in presynaptic neuron.

The **smaller action potential** reduces **calcium influx. This in turn decreases the** quantity of neurotransmitter released by presynaptic neuron. So the magnitude of EPSP in postsynaptic neuron is decreased resulting in synaptic inhibition.

3. Renshaw Cell or Negative Feedback Inhibition:

Negative feedback inhibition is the type of synaptic inhibition, which is caused by Renshaw cells in **spinal cord. Renshaw cells are small motor neurons present in anterior gray horn** of spinal cord.

Anterior nerve root consists of nerve fibers, which leave the spinal cord.

These nerve fibers arise from α - motor neurons in anterior gray horn of the spinal cord and reach the effector organ, muscles. Some of the fibers called collaterals fibers terminate on Renshaw cells instead of leaving the spinal cord.

When motor neurons send motor impulses, some of the impulses reach the Renshaw cell by passing through **collaterals. Now, the Renshaw cell** is stimulated.

In turn, it sends inhibitory impulses to α-motor neurons so that, the discharge from motor neurons is reduced.

In this way, Renshaw cell inhibition represents a negative feedback mechanism.

4. Feedforward Inhibition:

Feedforward synaptic inhibition **occurs in cerebellum** and it controls the **neuronal activity in cerebellum.**

During the process of neuronal activity in cerebellum, stellate cells and basket cells, which are activated by granule cells, inhibit the **Purkinje cells by releasing GABA. This type of inhibition is called** feedforward inhibition.

5. Reciprocal Inhibition

Inhibition of antagonistic muscles when a group of muscles are activated is called reciprocal inhibition. It is because of **reciprocal innervation.**

PROPERTIES OF SYNAPSE

1. ONE WAY CONDUCTION – BELL-MAGENDIE LAW

According to Bell Magendie law, the impulses are transmitted only in **one direction in synapse, i.e. From** presynaptic neuron to postsynaptic neuron.

2. SYNAPTIC DELAY

Synaptic delay is a short delay that occurs during the transmission of impulses through the synapse.

It is due to the time taken for:

i. Release of neurotransmitter

ii. Passage of neurotransmitter from axon terminal to postsynaptic membrane

iii. Action of the neurotransmitter to open the ionic channels in postsynaptic membrane.

Normal duration of synaptic delay is **0.3 to 0.5 millisecond**. Synaptic delay is one of the causes for **reaction time of reflex activity.**

3. FATIGUE

During continuous muscular activity, synapse becomes the seat of fatigue along with **Betz cells present in motor** area of frontal lobe of cerebral cortex.

Fatigue at synapse is due to the **depletion of neurotransmitter substance, acetylcholine.**

4. SUMMATION:

Summation is the fusion of effects or progressive increase in the excitatory postsynaptic potential in post synaptic neuron when many presynaptic excitatory terminals are stimulated simultaneously or when single presynaptic terminal is stimulated repeatedly.

Increased EPSP triggers the axon potential in the initial segment of axon of postsynaptic neuron.

Summation is of two types:

i. *Spatial Summation*

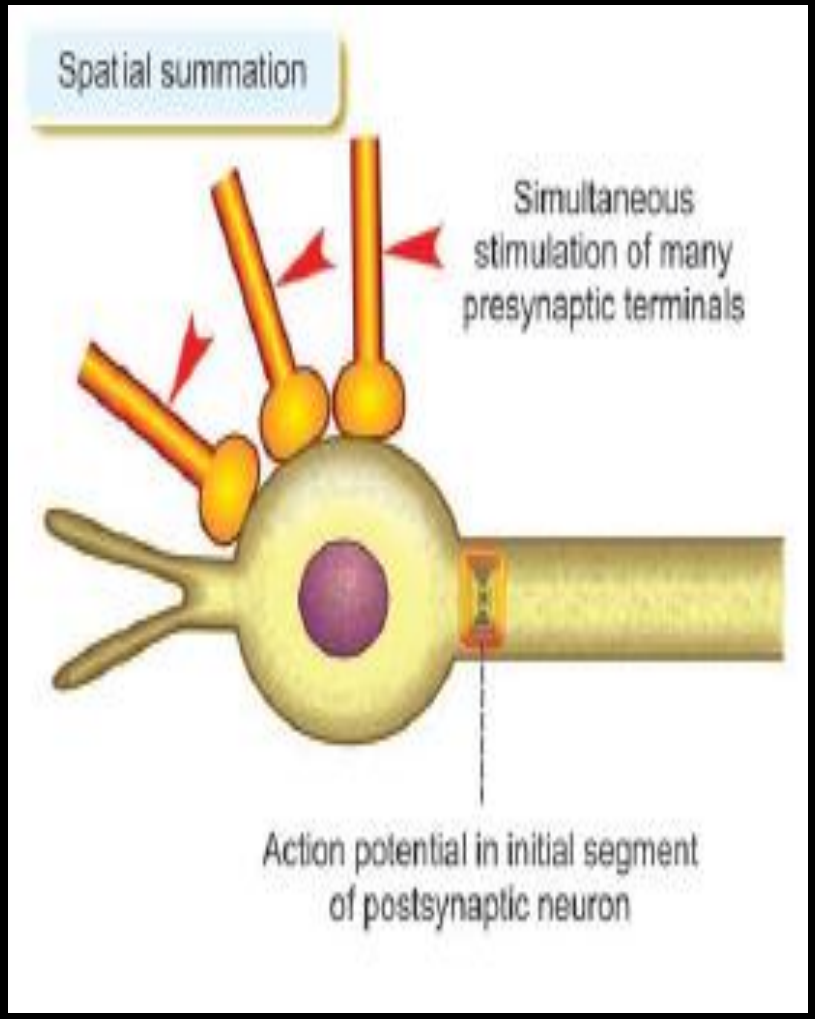
ii. *Temporal Summation*

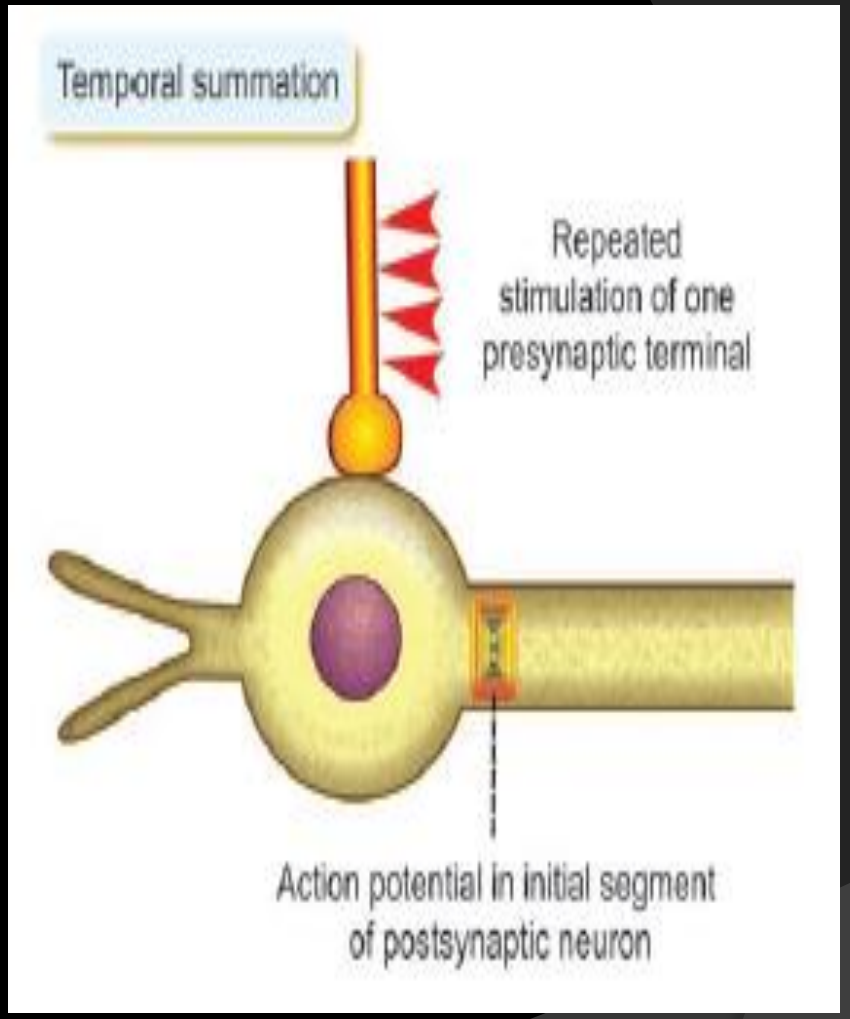
i. *Spatial Summation*

Spatial summation occurs when many presynaptic terminals are stimulated simultaneously.

ii. *Temporal Summation*

Temporal summation occurs when one presynaptic terminal is stimulated repeatedly.


Spatial summation
Simultaneous stimulation of many presynaptic terminals
Action potential in initial segment of postsynaptic neuron


Temporal summation
Repeated stimulation of one presynaptic terminal
Action potential in initial segment of postsynaptic neuron

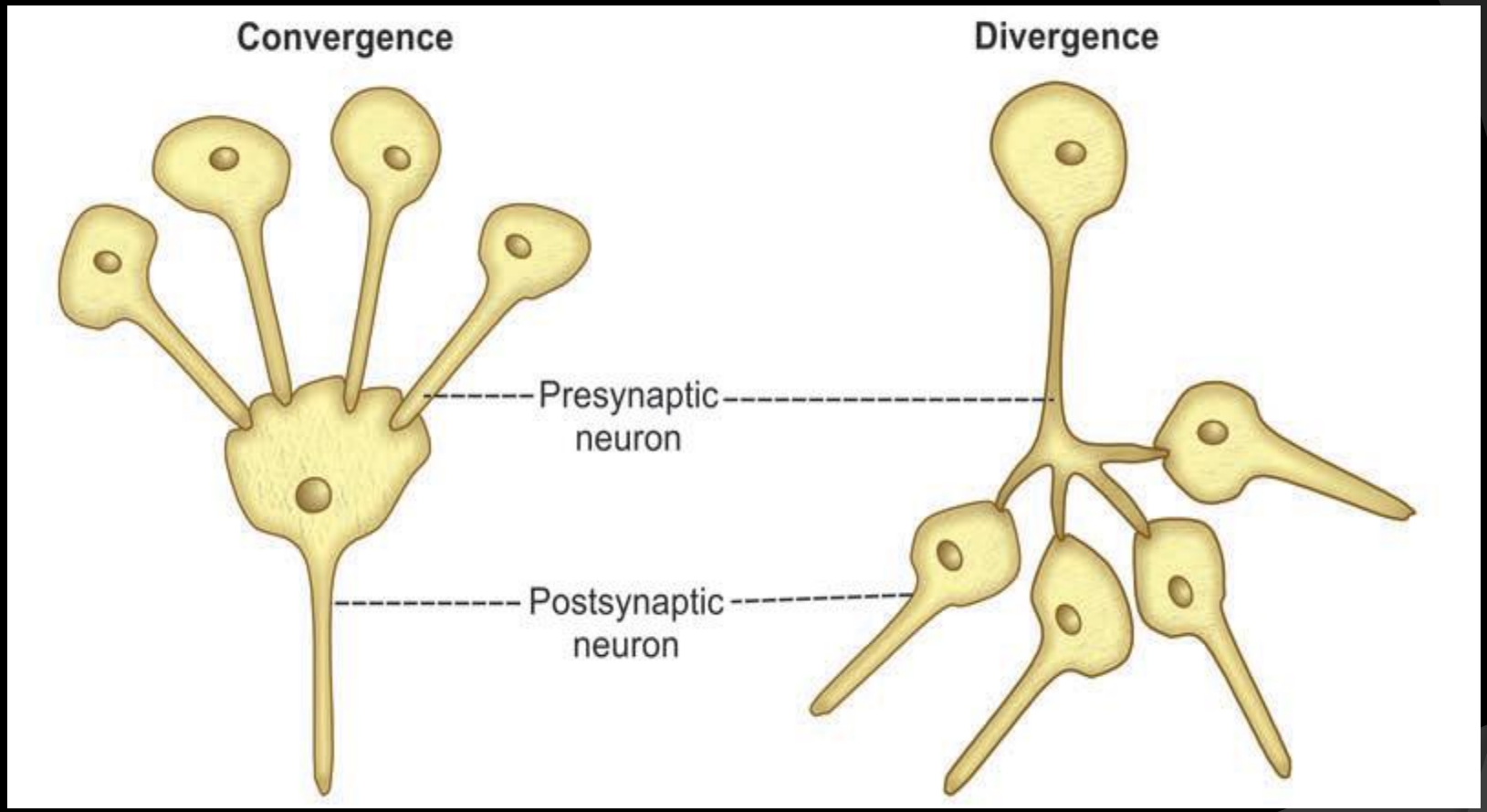
CONVERGENCE AND DIVERGENCE

CONVERGENCE

Convergence is the process by which many presynaptic neurons terminate on a single postsynaptic neuron.

DIVERGENCE

Divergence is the process by which one presynaptic neuron terminates on many postsynaptic neurons.


Convergence
Divergence
Presynaptic neuron
Postsynaptic neuron