Synapse

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 (Fig. 140.1).

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.

However, generally the word synapse refers to a chemical synapse.

1. *Electrical Synapse*

Electrical synapse is the synapse in which the physiological continuity between the presynaptic and the post-

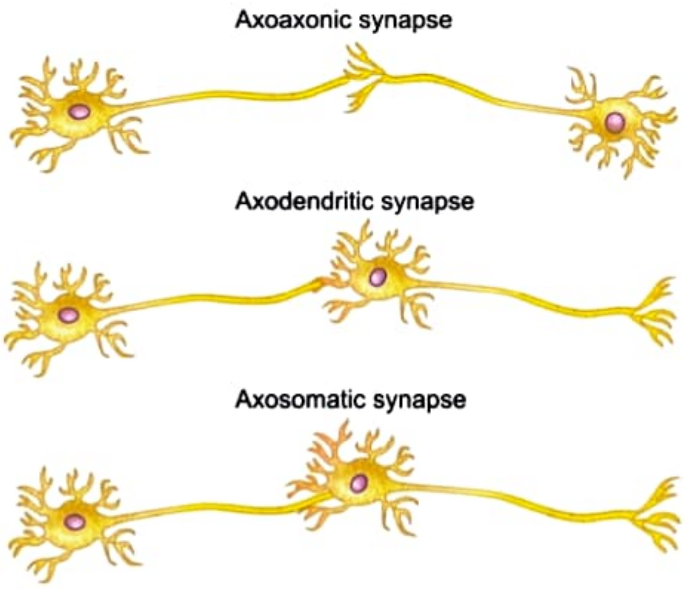


FIGURE 140.1: Anatomical synapses

synaptic neurons is provided by gap junction between the two neurons (Fig. 140.2). 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.

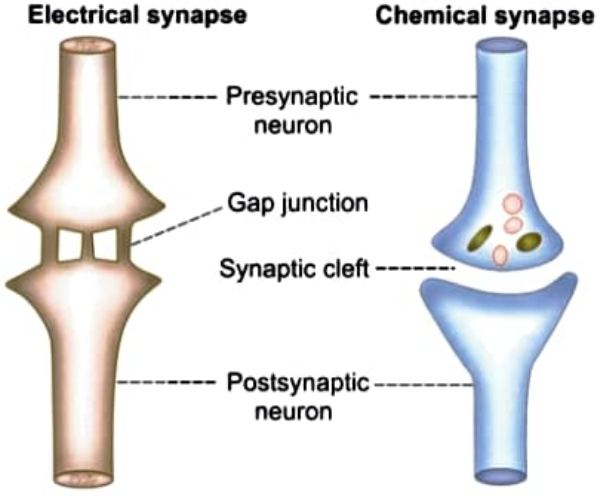


FIGURE 140.2: Electrical and chemical synapse

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. Structure and functions of the chemical synapse are given here.

■ FUNCTIONAL ANATOMY OF CHEMICAL SYNAPSE

Functional anatomy of a chemical synapse is shown in Figure 140.3. Neuron from which the axon arises is called the presynaptic neuron and the neuron on which the axon ends is called postsynaptic neuron. Axon of the presynaptic neuron divides into many small branches before forming the synapse. These branches are known as presynaptic axon terminals.

Types of Axon Terminals

1. *Terminal knobs*

Some of the terminals are enlarged slightly like knobs called terminal knobs. Terminal knobs are concerned with excitatory function of the synapse.

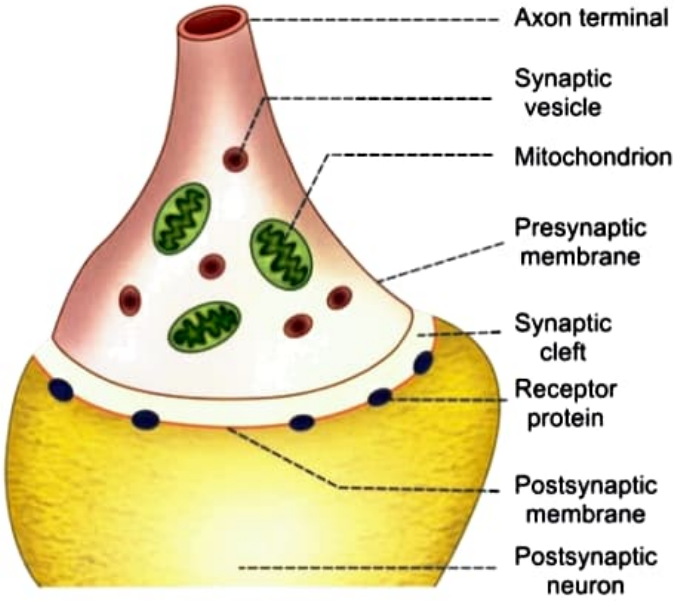


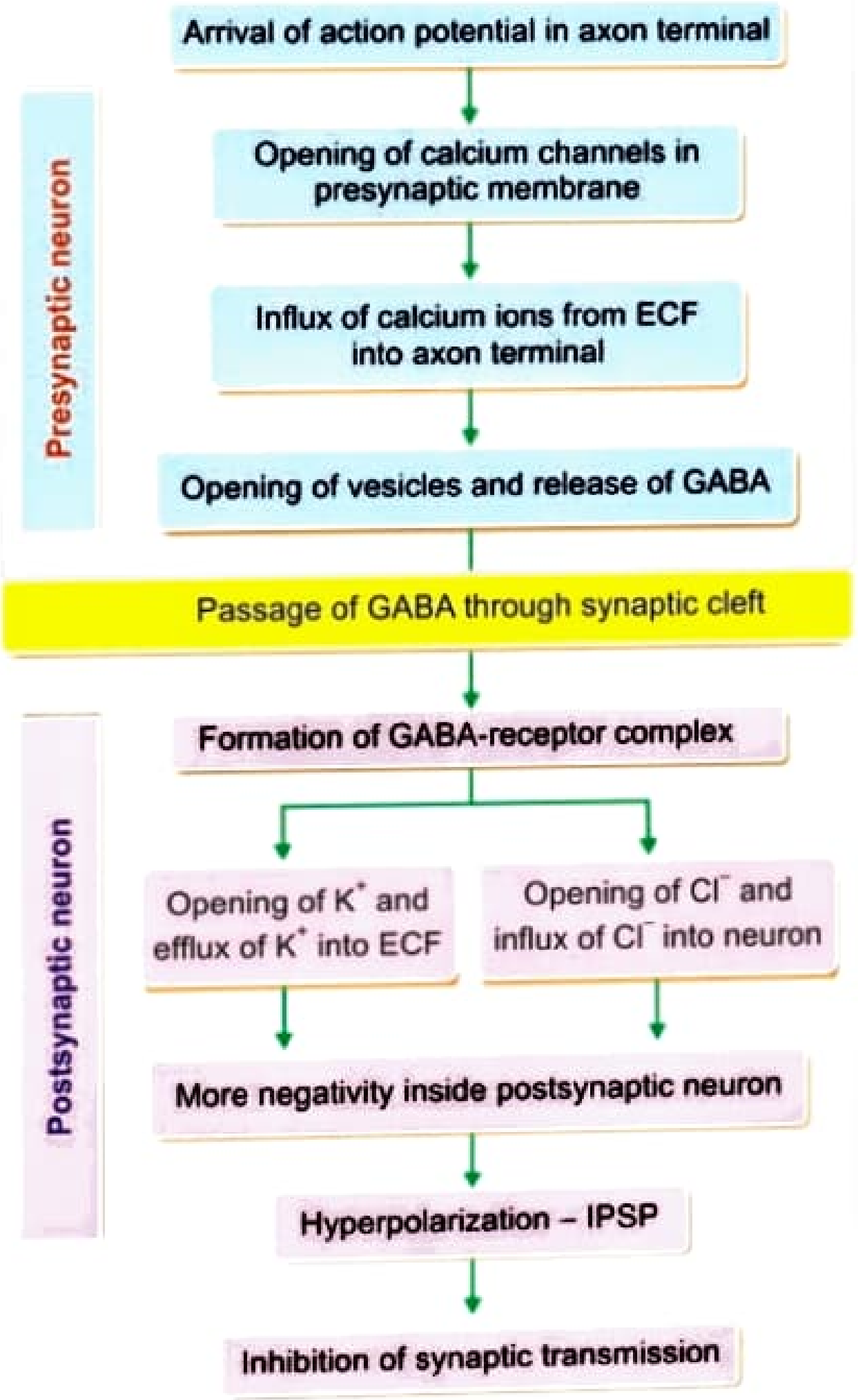
FIGURE 140.3: Structure of chemical synapse

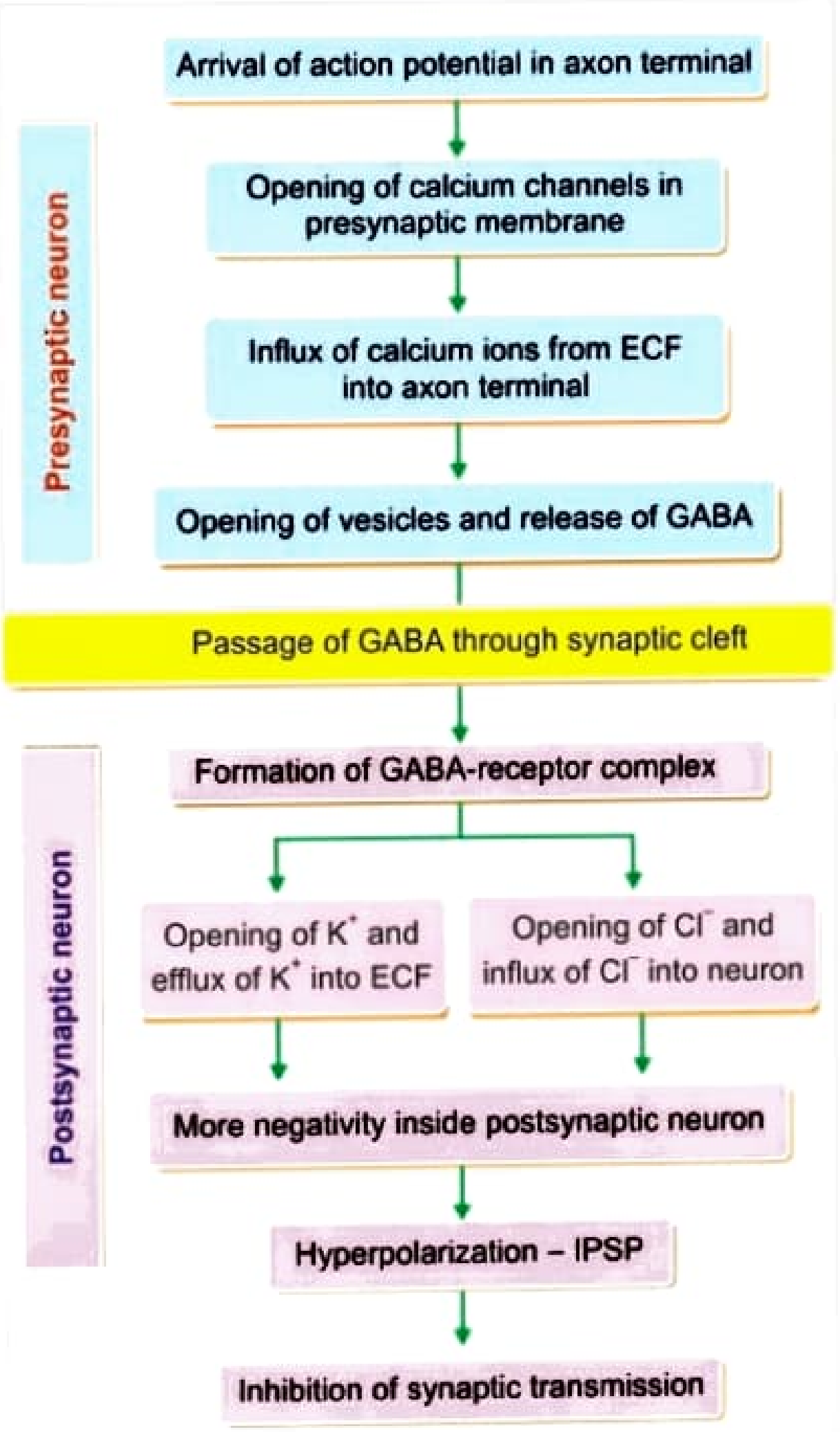
FUNCTIONS OF SYNAPSE

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 (excitatory function)
2. Inhibitory synapses, which inhibit the transmission of impulses (inhibitory function).


Presynaptic neuron
Arrival of action potential in axon terminal
Opening of calcium channels in presynaptic membrane
Influx of calcium ions from ECF into axon terminal
Opening of vesicles and release of GABA
Passage of GABA through synaptic cleft
Postsynaptic neuron
Formation of GABA-receptor complex
Opening of K+ and efflux of K+ into ECF
Opening of Cl- and influx of Cl- into neuron
More negativity inside postsynaptic neuron
Hyperpolarization – IPSP
Inhibition of synaptic transmission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Formation of GABA-receptor complex
Opening of K+ and efflux of K+ into ECF
Opening of Cl- and influx of Cl- into neuron
More negativity inside postsynaptic neuron
Hyperpolarization – IPSP
Inhibition of synaptic transmission

■ DEFINITION

Neurotransmitter is a chemical substance that acts as a mediator for the transmission of nerve impulse from one neuron to another neuron through a synapse.

TABLE 141.1: Neurotransmitters

Group	Name	Site of secretion	Action
Aminoacids	GABA	Cerebral cortex, cerebellum, basal ganglia, retina and spinal cord	Inhibitory
	Glycine	Forebrain, brainstem, spinal cord and retina	Inhibitory
	Glutamate	Cerebral cortex, brainstem and cerebellum	Excitatory
	Aspartate	Cerebellum, spinal cord and retina	Excitatory
Amines	Noradrenaline	Postganglionic adrenergic sympathetic nerve endings, cerebral cortex, hypothalamus, basal ganglia, brainstem, locus coeruleus and spinal cord	Excitatory and inhibitory
	Adrenaline	Hypothalamus, thalamus and spinal cord	Excitatory and inhibitory
	Dopamine	Basal ganglia, hypothalamus, limbic system, neocortex, retina and sympathetic ganglia	Inhibitory
	Serotonin	Hypothalamus, limbic system, cerebellum, spinal cord, retina, gastrointestinal (GI) tract, lungs and platelets	Inhibitory
	Histamine	Hypothalamus, cerebral cortex, GI tract and mast cells	Excitatory
Others	Nitric oxide	Many parts of CNS, neuromuscular junction and GI tract	Excitatory
	Acetylcholine	Preganglionic parasympathetic nerve endings Postganglionic parasympathetic nerve endings Preganglionic sympathetic nerve endings Postganglionic sympathetic cholinergic nerve endings Neuromuscular junction, cerebral cortex, hypothalamus, basal ganglia, thalamus, hippocampus and amacrine cells of retina	Excitatory

GABA = Gamma-aminobutyric acid, CNS = Central nervous system.

■ NEUROMODULATORS

Definition

Neuromodulator is the chemical messenger, which modifies and regulates activities that take place during the synaptic transmission.

These peptides do not propagate nerve impulses like neurotransmitters.

TABLE 141.4: Non-opioid neuromodulators

Name	Site of secretion	Action
Bradykinin	Blood vessels, kidneys	Vasodilator
Substance P	Brain, spinal cord, retina peripheral nerves and intestine	Mediates pain. Regulates anxiety, stress, mood disorders, neurotoxicity, nausea and vomiting. Causes vasodilatation.
Secretin	Cerebral cortex, hypothalamus, thalamus, olfactory bulb, brainstem and small intestine	Inhibits gastric secretion and motility
CCK	Cerebral cortex, hypothalamus, retina and small intestine	Contracts gallbladder Inhibits gastric motility Increases intestinal motility
Gastrin	Hypothalamus, medulla oblongata, posterior pituitary and gastrointestinal (GI) tract	Increases gastric secretion and motility Stimulates islets in pancreas
VIP	Cerebral cortex, hypothalamus, retina and intestine	Causes vasodilatation
Motilin	Cerebral cortex, cerebellum, posterior pituitary and intestine	Stimulates intestinal motility
Neurotensin	Hypothalamus and retina	Inhibits pain sensation Decreases food intake
Vasopressin	Posterior pituitary, medulla oblongata and spinal cord	Causes vasoconstriction
Oxytocin	Posterior pituitary, medulla oblongata and spinal cord	Stimulates milk ejection and uterine contraction
CRH	Hypothalamus	Stimulates release of ACTH
GHRH	Hypothalamus	Stimulates release of growth hormone
GHRP	Hypothalamus	Stimulates release of GHRH
TRH	Hypothalamus, other parts of brain and retina	Stimulates release of thyroid hormones
Somatostatin	Hypothalamus, other parts of brain, substantia gelatinosa and retina	Inhibits growth hormone secretion Decreases food intake
GnRH	Hypothalamus, preganglionic autonomic nerve endings and retina	Inhibits gonadotropin secretion
Endothelin	Posterior pituitary, brainstem and endothelium	Causes vasoconstriction
Angiotensin II	Hypothalamus, brainstem and spinal cord	Causes vasoconstriction
ANP	Hypothalamus, brainstem and heart	Causes vasodilatation Increases sodium excretion
BNP	Hypothalamus and heart	Causes vasodilatation Increases sodium excretion
CNP	Brain, myocardium, endothelium of blood vessels, GI tract and kidneys	Causes vasodilatation Increases sodium excretion
Neuropeptide Y	Medulla, hypothalamus and small intestine	Increases food intake Causes vasoconstriction Increases enteric blood flow
Ghrelin	Hypothalamus, stomach, pituitary, kidney and placenta	Promotes GH release Induces appetite and food intake Stimulates gastric emptying

ACTH = Adrenocorticotropic hormone, ANP = Atrial natriuretic peptide, BNP = Brain natriuretic peptide, CCK = Cholecystokinin, CNP = C-type natriuretic peptide, CRH = Corticotropin-releasing hormone, GHRH = Growth hormone-releasing hormone, GHRP = Growth hormone-releasing polypeptide, GnRH = Gonadotropin-releasing hormone, TRH = Thyrotropin-releasing hormone, VIP = Vasoactive intestinal polypeptide.

TABLE 141.5: Opioid neuromodulators

Name	Site of secretion	Action
Enkephalins	Many parts of brain, substantia gelatinosa and retina	Inhibit pain sensation
Dynorphins	Hypothalamus, posterior pituitary and duodenum	
β-endorphin	Thalamus, hypothalamus, brainstem and retina	

TABLE 141.3: Differences between neurotransmitters and neuromodulators

Sl No	Neurotransmitters	Neuromodulators
1	Propagate nerve impulse through synapse	Modify and regulate synaptic transmission
2	Packed in small synaptic vesicles	Packed in large synaptic vesicles
3	Found only in axon terminals	Found in all parts of the body
4	Generally, neuron has only one neurotransmitter	Neuron may have one or more neuromodulators
5	Act by changing the electric potential – depolarization or repolarization	Have diverse actions
6	Chemically, neurotransmitters are amino acids, amine or others	Chemically, neuromodulators are only peptides

■ COTRANSMISSION AND COTRANSMITTERS

Cotransmission is the release of many neurotransmitters from a single nerve terminal. Cotransmitters are the

neurotransmitter substances that are released in addition to primary transmitter at the nerve endings.

For many years, it was believed that each neuron releases only one neurotransmitter substance from its terminals. Now it is known that some of the neurons release many neurotransmitter substances. It is also believed that the additional neurotransmitters, i.e. the cotransmitters modulate the effects of primary neurotransmitters.

Some of the primary neurotransmitters act as cotransmitters in other nerve endings.

Examples of cotransmitters:

1. Calcitonin
2. Dopamine
3. Dynorphin
4. GABA
5. Gene-related peptide
6. Glutamate
7. Glycine
8. Neuropeptide Y
9. Substance P
10. Vasoactive intestinal polypeptide (VIP).