Learning objectives

1- Type of ion channel

2- explain how an action potential is produced

3- Describe the structure and function of electrical and chemical synapses.

4- Identify the nature of excitatory and inhibitory postsynaptic potentials.

Functions of the Nervous System

1- **Sensory function**. Sensory receptors detect internal stimuli, such as an increase in blood pressure, or external stimuli (for example, a raindrop landing on your arm), This sensory information is then carried into the brain and spinal cord through cranial and spinal nerves.

2 • *Integrative function*. The nervous system **processes** sensory information by analyzing it and making decisions for appropriate responses—an activity known as integration.

• **Motor function**. Once sensory information is integrated, the nervous system may elicit an appropriate motor response by activating effectors (muscles and glands) through cranial and spinal nerves. Stimulation of the effectors causes muscles to contract and glands to secrete

Ion Channels

When ion channels are open, they allow specific ions to move across the plasma membrane, down their **electrochemical gradient**—a concentration (chemical) difference plus an electrical difference. As ions move, they create a flow of electrical current that can change the membrane potential. Ion channels open and close due to the presence of "gates."

types of gate channels:

1- A **ligand or chemical gated channel** opens and closes in response to the binding of a ligand (chemical) stimulus. A wide variety of chemical ligands—including neurotransmitters, hormones, and particular ions—can open or close ligand-gated channels.

Ligand-gated channels are located in the dendrites of some sensory neurons, such as pain receptors, and in dendrites and cell bodies of interneurons and motor neurons

2. A **mechanically-gated channel** opens or closes in response to

mechanical stimulation in the form of vibration (such as sound waves), touch, pressure, or tissue stretching The force distorts the channel from its resting position, opening the gate. Examples of mechanically-gated channels are

those found in auditory receptors in the ears, in receptors that monitor stretching of internal organs, and in touch receptors

and pressure receptors in the skin.

3. A **voltage-gated channel** opens in response to a change in membrane potential (voltage) Voltage-gated channels participate in the generation and conduction of action potentials in the axons of all types of neurons.

The **non gated leak channels are open channel** Typically, plasma membranes have many more potassium ion (K) leak channels than sodium ion (Na) leak channels, and the potassium ion leak channels are leakier than the sodium ion leak channels. Thus, the membrane's permeability to K is much higher than its permeability to Na. Leak channels are found in nearly all cells, including the dendrites, cell bodies, and axons of all types of neurons

resting membrane potential

Extracellular fluid is rich in Na and chloride ions (Cl^-). In cytosol, however, the main cation

is K, and the two dominant anions are phosphates attached to molecules, such as the three phosphates in ATP, and amino acids in proteins.

3 factors contribute to resting membrane potential

1- Because the plasma membrane typically has more K leak channels than Na leak channels, the number of potassium ions that diffuse down their concentration gradient out of the cell into the ECF is greater than the number of sodium ions that diffuse down their concentration gradient

from the ECF into the cell. As more and more positive potassium ions exit, the inside of the membrane becomes increasingly negative, and the outside of the membrane becomes increasingly positive.

2) Trapped anions cannot follow K out of the cell because they are attached to non-diffusible molecules such as ATP and large proteins.

(3) The electrogenic Na–K ATPase expels 3 Na ions for every 2 K ions imported

Graded Potentials

A **graded potential** is a small deviation from the resting membrane potential that makes the membrane either more polarized (inside more negative) or less polarized (inside less negative). When the response makes the membrane more polarized (inside more negative), it is termed a **hyperpolarizing graded potential**

A graded potential occurs when a stimulus causes mechanically-gated or ligand-gated channels to open or close in an excitable cell's plasma membrane . Typically, mechanically-gated channels and ligand-gated channels can be present in the dendrites of sensory neurons, and ligand-gated channels are numerous in the dendrites and cell bodies of interneurons and motor neurons. Hence, graded potentials occur mainly in the dendrites and cell body of a neuron.

To say that these electrical signals are *graded* means that they

vary in amplitude (size), depending on the strength of the stimulus

They are larger or smaller depending on how

many ligand-gated or mechanically-gated channels have opened

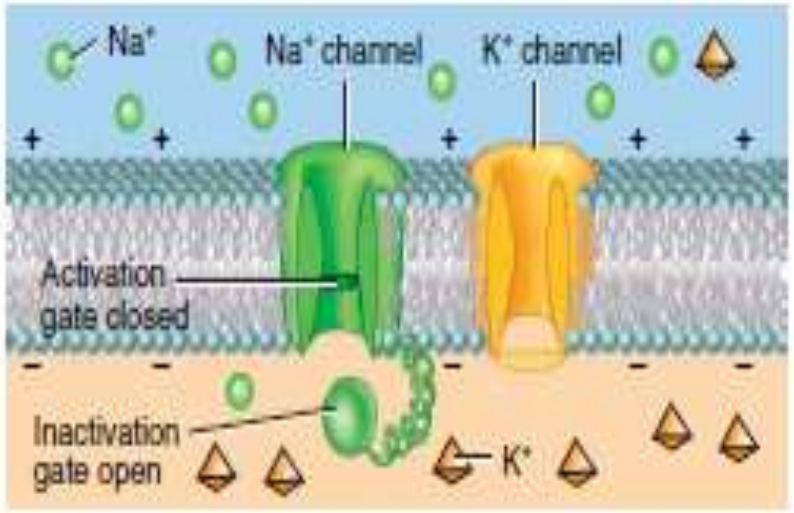
(or closed) and how long each remains open.

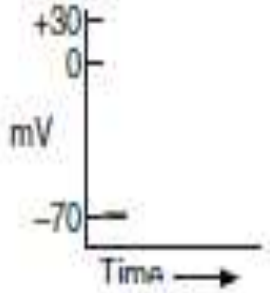
individual graded potential undergoes **decremental conduction** which mean it dies out with time as they spread through membrane it can become stronger and last longer by summating

with other graded potentials **Summation(temporal or spatial) .**

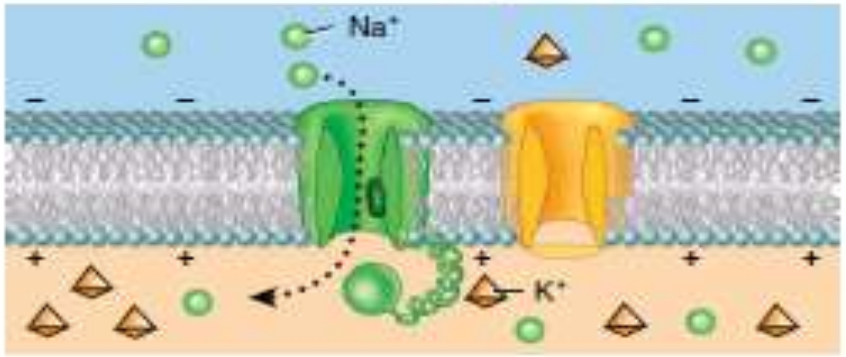
Action potential

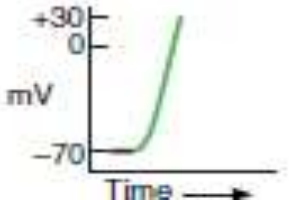
1. **Resting state:**
All voltage-gated Na^+ and K^+ channels are closed. The axon plasma membrane is at resting membrane potential: small buildup of negative charges along inside surface of membrane and an equal buildup of positive charges along outside surface of membrane.

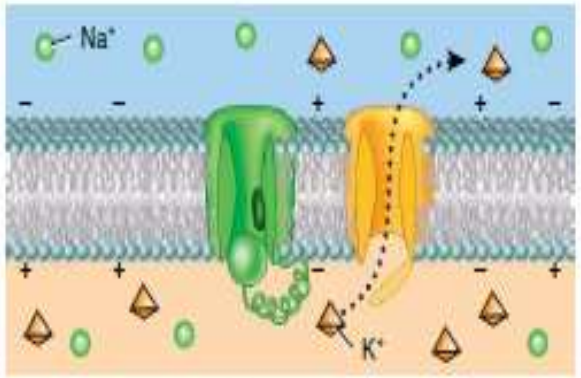


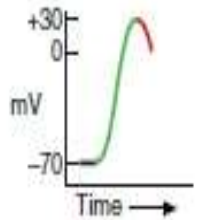


2. **Depolarizing phase:**
When membrane potential of axon reaches threshold, the Na^+ channel activation gates open. As Na^+ ions move through these channels into the neuron, a buildup of positive charges forms along inside surface of membrane and the membrane becomes depolarized.

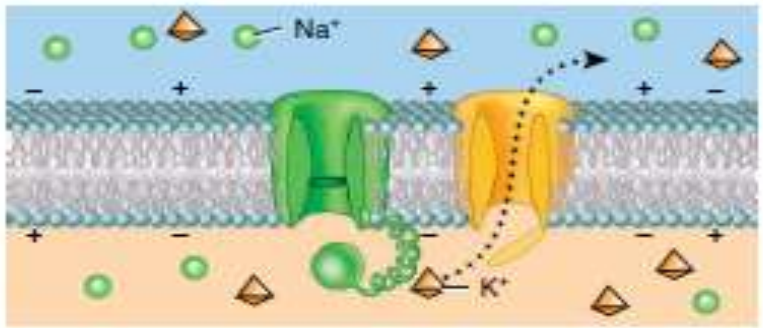


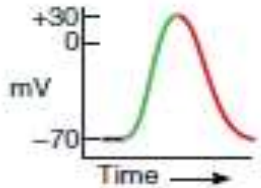






3. **Repolarizing phase begins:** Na^+ channel inactivation gates close and K^+ channels open. The membrane starts to become repolarized as some K^+ ions leave the neuron and a few negative charges begin to build up along the inside surface of the membrane.





4. **Repolarization phase continues:** K^+ outflow continues. As more K^+ ions leave the neuron, more negative charges build up along inside surface of membrane. K^+ outflow eventually restores resting membrane potential. Na^+ channel activation gates close and inactivation gates open. Return t resting state when K^+ gates clos

• *Refractory Period*

The period of time after an action potential begins during which an excitable cell cannot generate another action potential in response to a *normal* threshold stimulus is called the **refractory Period**

Absolute refractory period, even a very strong stimulus cannot initiate a second action potential.

relative refractory period is the period of time during which a second action potential can be initiated, but only by a larger than normal stimulus

Classification of Nerve Fibers

A fibers are the largest diameter axons (5–20 m) and are myelinated. A fibers have a brief absolute refractory period and conduct nerve impulses (action potentials) at speeds of 12 to 130 m/sec . The axons of sensory neurons that propagate impulses associated with touch, pressure, position of joints, and some thermal and pain sensations are A fibers, as are the axons of motor neurons that conduct impulses to skeletal muscles.

• **B fibers** are axons with diameters of 2–3 m. Like A fibers, B fibers are myelinated and exhibit saltatory conduction at speeds up to 15 m/sec . B fibers have a somewhat longer absolute refractory period than A fibers. B fibers conduct sensory nerve impulses from the viscera to the brain and spinal cord. They also constitute all of the axons of the autonomic motor neurons that extend from the brain and spinal cord to the ANS relay stations called autonomic ganglia.

C fibers are the smallest diameter axons (0.5–1.5 m) and all are unmyelinated. Nerve impulse propagation along a C fiber ranges from 0.5 to 2 m/sec . C fibers exhibit the longest absolute refractory periods. These unmyelinated axons conduct some sensory impulses for pain, touch, pressure, heat, and cold from the skin, and pain impulses from the viscera. Autonomic motor fibers that extend from autonomic ganglia to stimulate the heart, smooth muscle, and glands are C fibers. Examples of motor functions of B and C fibers are constricting and dilating the pupils, increasing and decreasing the heart rate, and contracting and relaxing the urinary bladder

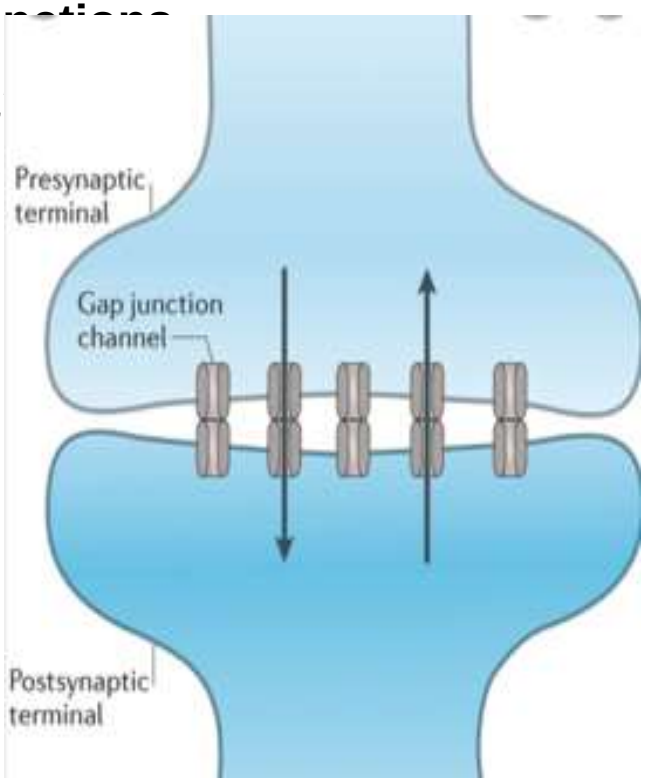
synapse is a region where communication occurs between two neurons or between a neuron and an effector cell (muscle cell or glandular cell). The term **presynaptic neuron** (*pre-* before) refers to a nerve cell that carries a nerve impulse toward a synapse. It is the cell that sends a signal. A **postsynaptic cell** is the cell that receives a signal. It may be a nerve cell called a **postsynaptic neuron** (*post-* after) that carries a nerve impulse away from a synapse or an **effector cell** that responds to the impulse at the synapse.

Most synapses between neurons are **axodendritic** while others are **axosomatic** or **axoaxonic**

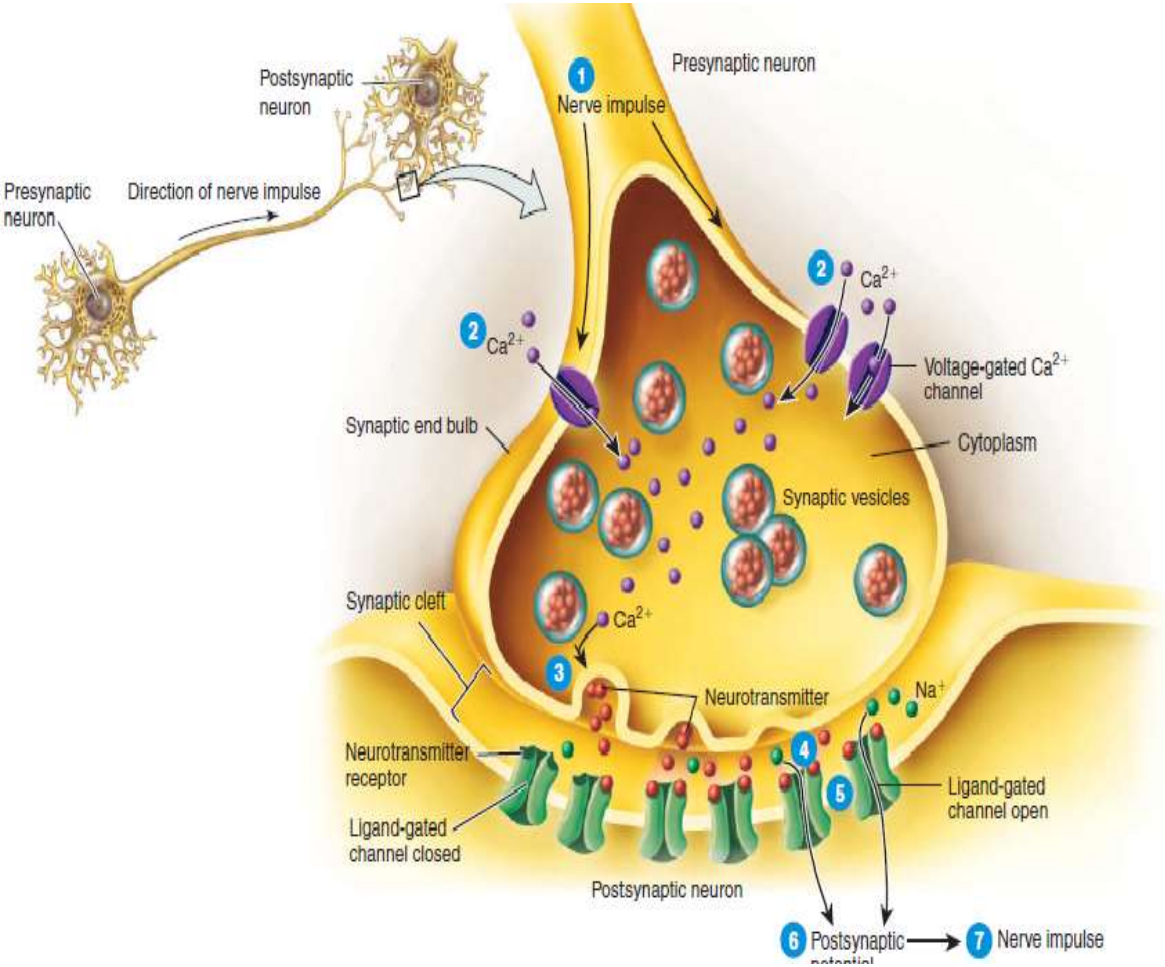
In addition, synapses may be electrical or chemical and they differ both structurally and functionally.

Signal Transmission at Synapses At an **electrical synapse,** action potentials (impulses) conduct directly between the plasma membranes of adjacent neurons through structures called **gap ju**

2 main advantage of gap junction are Faster communication. & Synchroniza



Chemical synapse

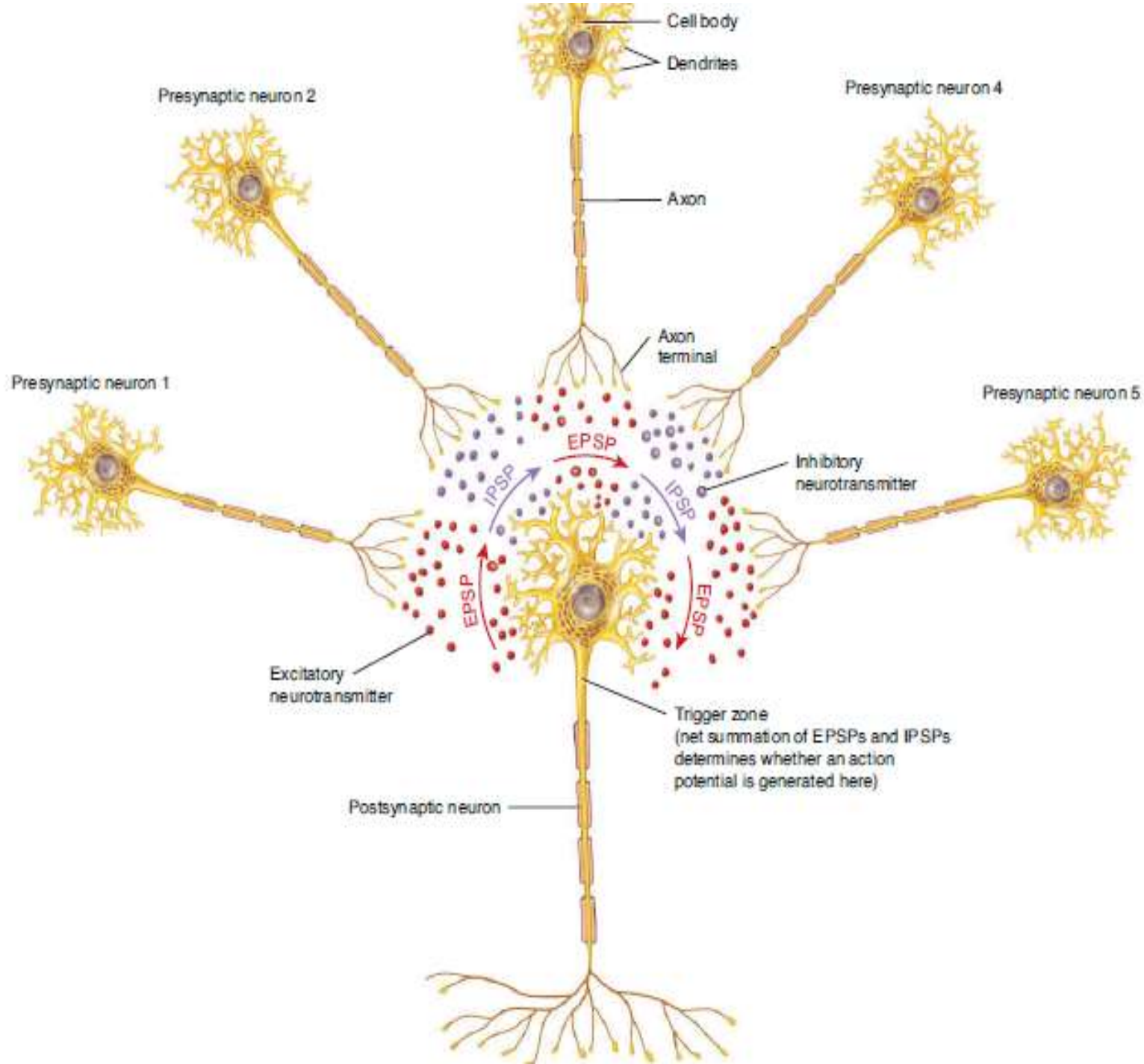


Excitatory and Inhibitory Postsynaptic Potentials

A neurotransmitter causes either an excitatory or an inhibitory graded potential. A neurotransmitter that causes *depolarization* of the postsynaptic membrane is excitatory because it brings the membrane closer to threshold A depolarizing postsynaptic potential is called an **excitatory postsynaptic potential (EPSP).**

Although a single EPSP normally does not initiate a nerve impulse, the postsynaptic cell does become more excitable. Because it is partially depolarized, it is more likely to reach threshold when the next EPSP occurs.

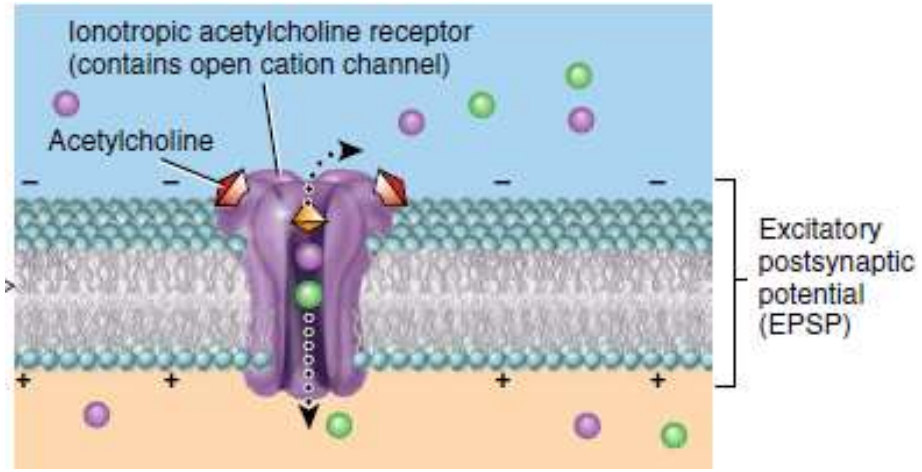
A neurotransmitter that causes *hyperpolarization* of the postsynaptic membrane is inhibitory. During hyperpolarization, generation of an action potential is more difficult than usual because the membrane potential becomes inside more negative and thus even farther from threshold than in its resting state. A hyperpolarizing postsynaptic potential is termed an **inhibitory postsynaptic potential (IPSP).**


Cell body
Dendrites
Presynaptic neuron 2
Presynaptic neuron 4
Axon
Axon terminal
Presynaptic neuron 1
Presynaptic neuron 5
EPSP
IPSP
IPSP
Inhibitory neurotransmitter
EPSP
EPSP
Excitatory neurotransmitter
Trigger zone (net summation of EPSPs and IPSPs determines whether an action potential is generated here)
Postsynaptic neuron

Neurotransmitter Receptors

An **ionotropic receptor** is a type of neurotransmitter receptor that contains a neurotransmitter binding site and an ion channel. the ion channel opens,

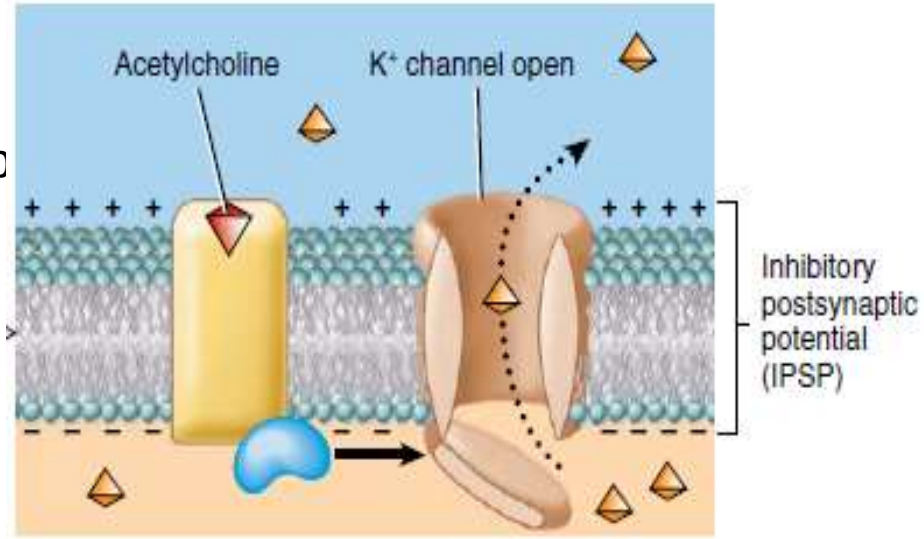
and an EPSP or IPSP occurs in the postsynaptic cell



Metabotropic Receptors

A **metabotropic receptor** is a type of neurotransmitter receptor that contains a neurotransmitter binding site but lacks an ion channel as part of its structure. However, a metabotr receptor is coupled to a separate ion channel by a type of membrane protein called a *G protein.* the G protein either **directly** op (or closes) the ion channel **or it may act indirectly** by activating another molecule, a “second messenger,” in the cytosol

Metabotropic acetylcholine receptor



• . ***Acetylcholine***

is secreted by neurons in many areas of the nervous system but specifically by (1) the terminals of the large pyramidal cells from the motor cortex, (2) several different types of neurons in the basal ganglia, (3) the motor neurons that innervate the skeletal muscles, (4) the preganglionic neurons of the autonomic nervous system, (5) the postganglionic neurons of the parasympathetic nervous system, and (6) some of the postganglionic neurons of the sympathetic nervous system. In most instances, acetylcholine has an excitatory effect; however, it is known to have inhibitory effects at some peripheral parasympathetic nerve endings, such as inhibition of the heart by the vagus nerves.

• ***Norepinephrine***

is secreted by the terminals of many neurons whose cell bodies are located in the **brain stem and hypothalamus**.

. norepinephrine probably activates excitatory receptors, but in a few are activate inhibitory receptors

- *Dopamine* is secreted by neurons that originate in the **substantia nigra**. The termination of these neurons is mainly in the striatal region of the basal ganglia. The effect is inhibitory *Glycine* is secreted mainly at synapses in the spinal cord. It is believed to always act as an inhibitory transmitter.
- *GABA (gamma-aminobutyric acid)* is secreted by nerve terminals in the spinal cord, cerebellum, basal ganglia, and many areas of the cortex. It is believed to always cause inhibition.
- *Glutamate* is secreted by the presynaptic terminals in many of the sensory pathways entering the central nervous system, as well as in many areas of the cerebral cortex. It probably always causes excitation.
- *Serotonin* is secreted brain stem and project to many brain and spinal cord areas, especially to the dorsal horns of the spinal cord *Serotonin acts as an inhibitor of pain pathways* , and an inhibitor action in the higher regions of the nervous system is believed to help

- **Nitric oxide** is an important excitatory neurotransmitter secreted in the brain, spinal cord, Unlike all previously known neurotransmitters, NO

is not synthesized in advance and packaged into synaptic vesicles.

Rather, it is formed on demand and acts immediately. Its action is

brief because NO is a highly reactive free radical

Removal of Neurotransmitters

1. *Diffusion.* Some of the released neurotransmitter molecules diffuse away from the synaptic cleft.

2. *Enzymatic degradation.* For example, the enzyme acetylcholinesterase breaks down acetylcholine in the synaptic cleft.

3. *Uptake by cells.* Many neurotransmitters are actively transported back into the neuron that released them (reuptake)