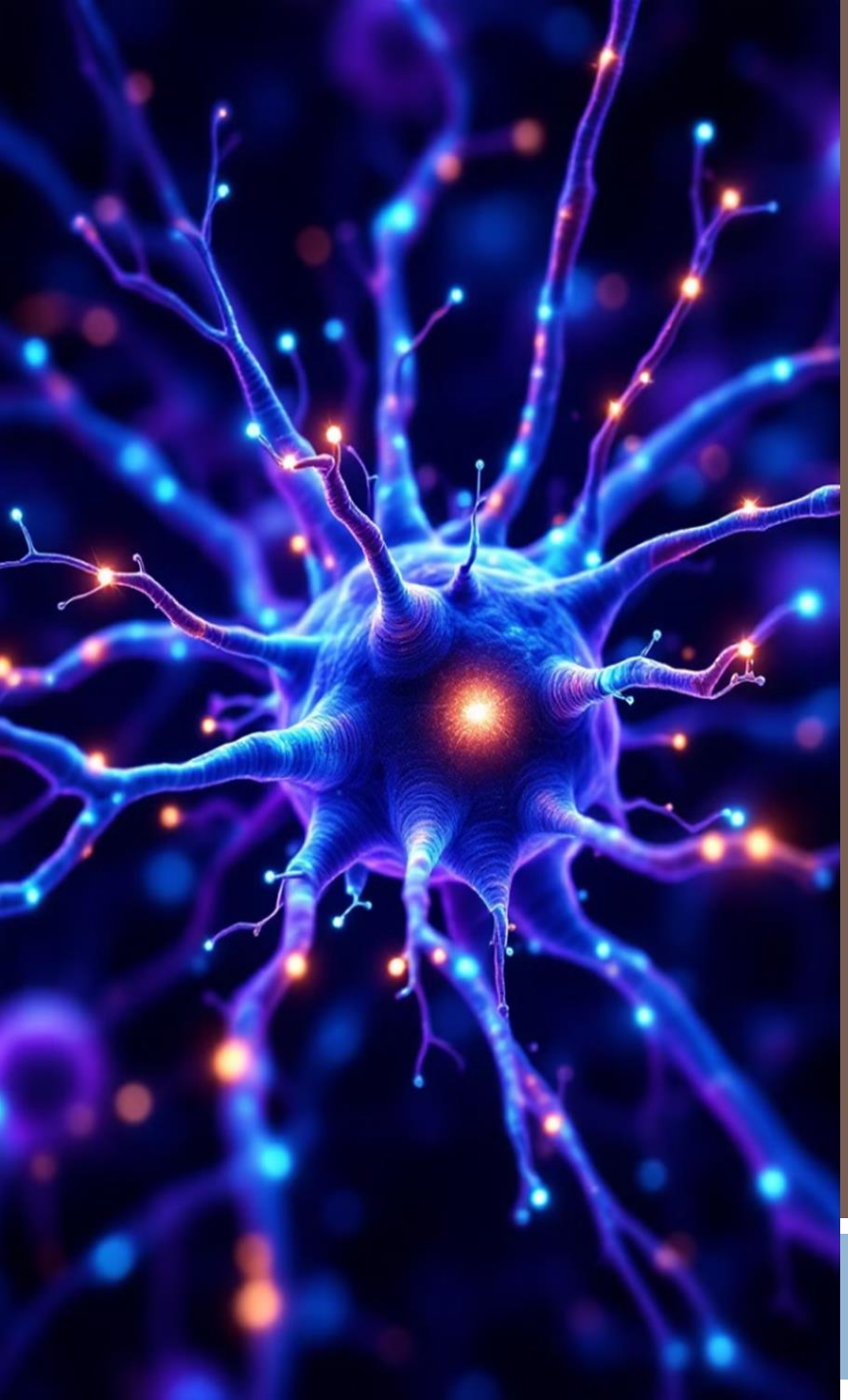

Synaptic & Junctional Transmission

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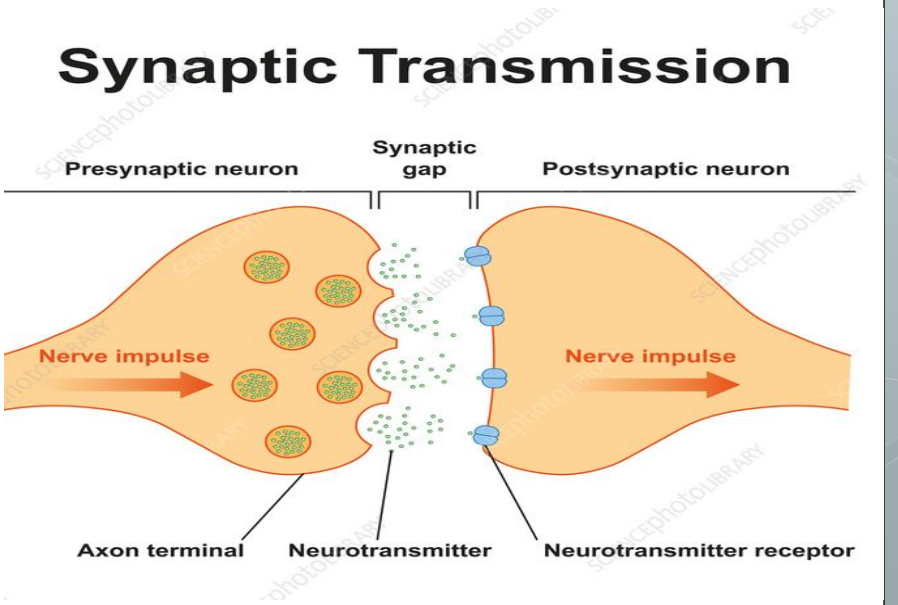
- The term "synapse" comes from Greek, meaning "connection." These junctions transfer information between neurons.
- Each synapse consists of:
- Presynaptic terminal
- Synaptic cleft
- Postsynaptic membrane.



They create the neural networks enabling all brain functions.

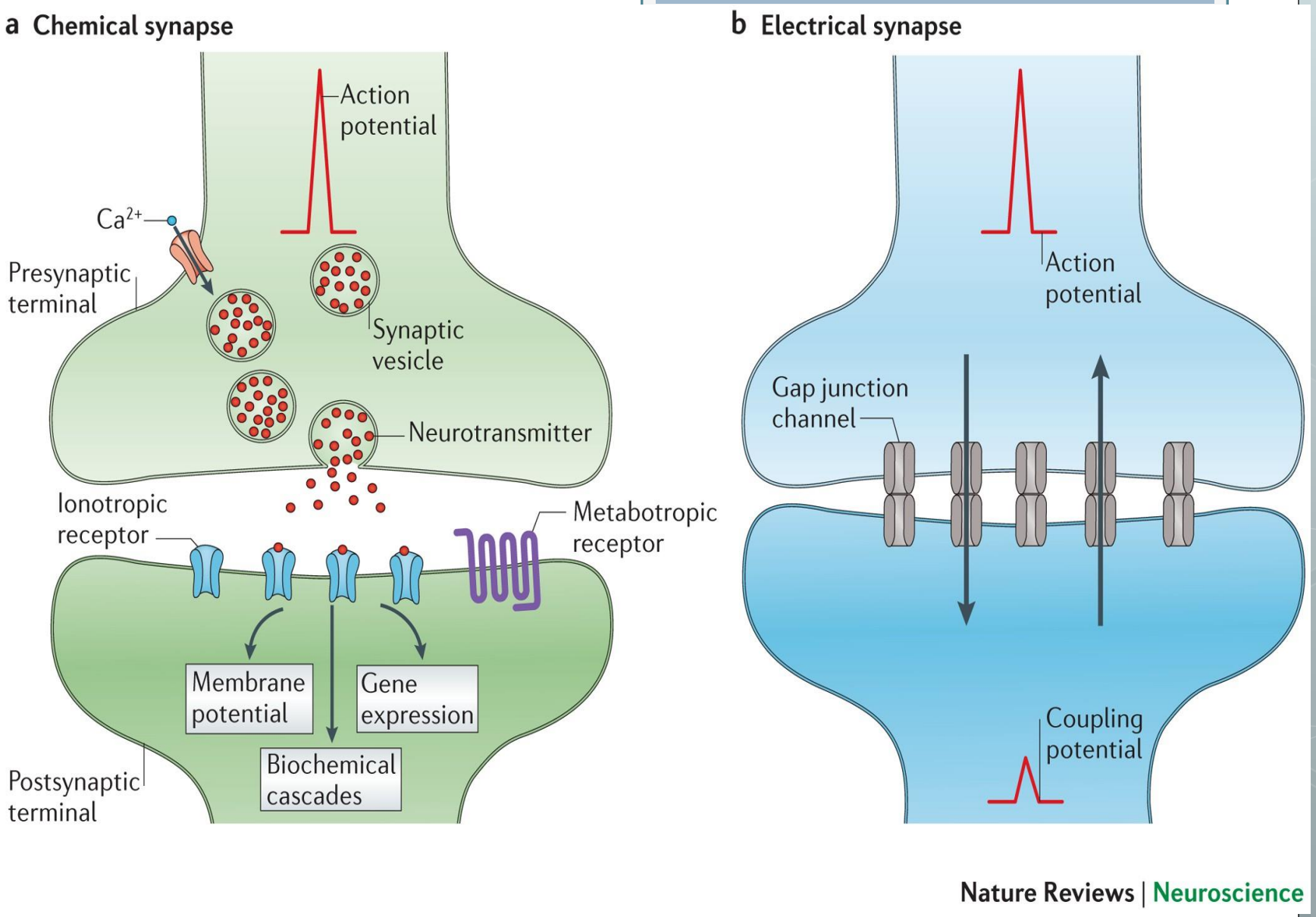
- Impulses are transmitted from one nerve cell to another cell at synapses .
- Cell-to-cell communication occurs across synapse. Every thought, memory, and sensation depends on these microscopic junctions.
- **Types of synapse**:

- Electrical synapse
- Chemical Synapse
- Mixed synapse.

- **Electrical Synapses:**
- Electrical synapses exist between neurons and either other neurons or glial cells. The membranes of the presynaptic and postsynaptic neurons come close together, allowing direct bidirectional flow between neurons, which is important in synchronized neural activities.
- Gap junctions(connect neighboring cells via intercellular channels that allow direct electrical communication as well as sharing of ions and small molecules) form between the cells. These junctions will form a low-resistance bridge through which ions can pass with relative ease.
- Electrical synapses have been identified in the retina of the eye and certain areas of the cortex, areas of the brainstem that regulate breathing.

Chemical Synapse:

- Most common type.
- Uses neurotransmitters to send signals across a small gap between neurons. Allows for complex signal modulation
- At chemical synapses, a synaptic cleft separates the terminal of the presynaptic cell from the postsynaptic cell.
- An impulse in the presynaptic axon causes secretion of a chemical(neurotransmitter) that diffuses across the synaptic cleft and binds to receptors on the surface of the postsynaptic cell.
- This triggers events that open or close channels in the membrane of the postsynaptic cell mediating excitation or inhibition.


a Chemical synapse
Action potential
Ca2+
Presynaptic terminal
Synaptic vesicle
Neurotransmitter
Ionotropic receptor
Metabotropic receptor
Membrane potential
Gene expression
Biochemical cascades
Postsynaptic terminal
b Electrical synapse
Action potential
Gap junction channel
Coupling potential
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Mixed Synapses

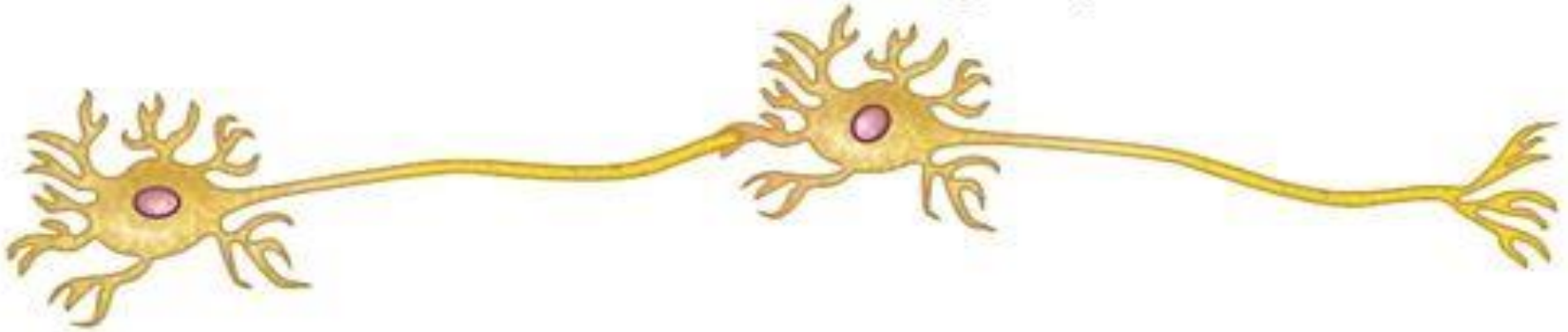
- There are also a few conjoint synapses in which transmission is both electrical and chemical.
- Regardless of the type of synapse, transmission is not a simple jumping of an action potential from the presynaptic to the postsynaptic cell.
- The effects of discharge at individual synaptic endings can be excitatory or inhibitory.

Functional Anatomy of chemical synapse

- **Axodendritic Synapses** when the axon terminal of the presynaptic neuron forms a synapse with a dendrite of the postsynaptic neuron.
- **Axosomatic Synapses**, which are synapses between the axon terminal and soma of the postsynaptic cell.
- An **axoaxonic synapse** occurs when the presynaptic neuron's axon terminal connects to the postsynaptic neuron's. Axoaxonic synapses have a special function in modulating communication at axodendritic and axosomatic synapses. Dendrodendritic synapses have also been identified.

Axoaxonic synapse

Axodendritic synapse



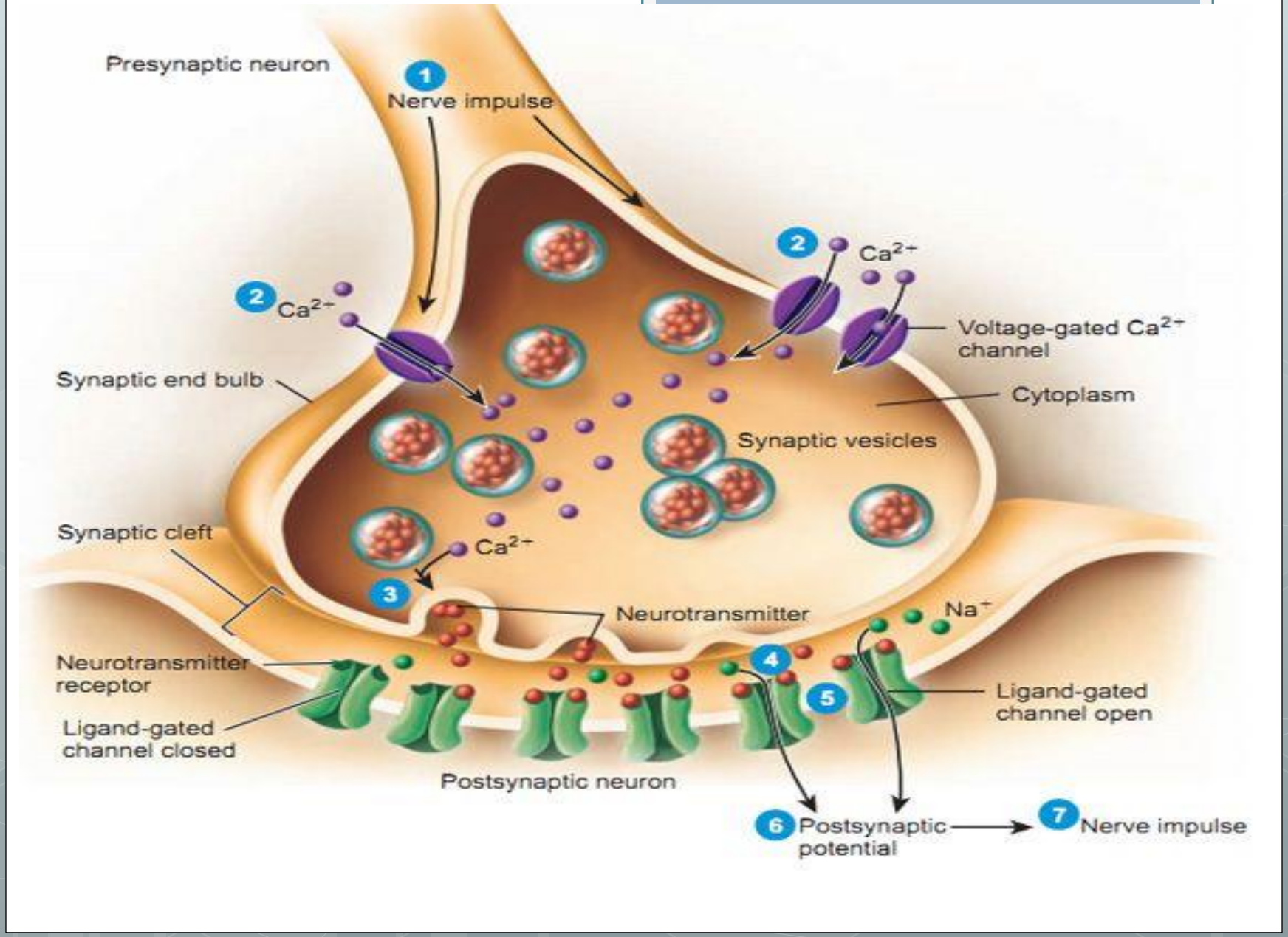
Axosomatic synapse

- In all cases, the axon terminal of the presynaptic neuron releases neurotransmitters into the synaptic cleft. The neurotransmitters diffuse rapidly across the cleft and bind to receptors on the postsynaptic neuron, which produces a response in the postsynaptic neuron.

- The axon terminal of the presynaptic neuron contains numerous small, membrane-bound compartments called synaptic vesicles, which store neurotransmitter molecules. The cytosol of the axon terminal contains the enzymes that synthesize most neurotransmitters.

- Vesicles and proteins are synthesized in the neuronal cell body and transported to the endings by fast axoplasmic transport.
- After synthesis, neurotransmitters are actively transported into synaptic vesicles, where they are stored until their eventual release through the process of exocytosis.
- Calcium ions play an important role in synaptic transmission. Cytosolic calcium triggers the release of neurotransmitter by exocytosis. Calcium channels in the plasma membrane of the presynaptic neuron open when the axon terminal is depolarized.

- Calcium will flow down its electrochemical gradient into the axon terminal, thereby increasing its concentration in the cytosol of the axon terminal. After that, calcium triggers exocytosis, which releases the neurotransmitters into the synaptic cleft, and causes the membranes of synaptic vesicles to fuse with vesicle attachment sites on the inner side of the axon terminal membrane.
- The amount of neurotransmitter released depends on the concentration of calcium in the cytosol of the axon terminal, which depends on the frequency of action potentials in the presynaptic neuron. As a consequence, the concentration of neurotransmitter in the synaptic cleft increases as the frequency of action potentials increases.


Presynaptic neuron
1
Nerve impulse
2
Ca^{2+}
2
Ca^{2+}
Voltage-gated Ca^{2+} channel
Synaptic end bulb
Cytoplasm
Synaptic vesicles
Synaptic cleft
Ca^{2+}
3
Neurotransmitter
Na^{+}
Neurotransmitter receptor
4
5
Ligand-gated channel open
Ligand-gated channel closed
Postsynaptic neuron
6
Postsynaptic potential
7
Nerve impulse

- Following a single action potential, neurotransmitter release stops within a few milliseconds because the voltage-gated calcium channels close soon after opening, and because calcium ions are actively transported out of the axon terminal on a continual basis, bringing the cytosolic calcium concentration back to its resting level.
- If a second action potential arrives before neurotransmitter is cleared from the synaptic cleft, however, then the cytosolic calcium levels increase causing more neurotransmitter to be released from the presynaptic cell, thereby increasing the amount of neurotransmitter in the synaptic cleft.

- The binding of a neurotransmitter molecule to a receptor is a brief and reversible process. Neurotransmitter molecules would bind to receptors repeatedly in the synaptic cleft, causing the postsynaptic neuron to respond continuously.
- Because several processes quickly clear the neurotransmitter from the cleft, the signal is not sustained.
- **The clearance of neurotransmitter molecules:**
- Some of neurotransmitter can be actively reabsorbed into the presynaptic neuron from where they were released, others are broken down by enzymes. Nevertheless, other synaptic cleft neurotransmitter molecules just diffuse out of it.

- **There are two types of neurotransmitters:**
- First, small molecule rapidly acting transmitter like Ach, epinephrine, dopamine, GABA they are synthesized by neurons in CNS and their function either excitatory or inhibitory like in motor function , wakefulness, pain and sleep,
- Second is neuropeptides, Slowly acting transmitters or growth Factors like Hypothalamic-Releasing Hormones Thyrotropin-releasing hormone, Luteinizing hormone–releasing hormone. These transmitter are synthesized in the ribosomes within the soma of neurons and transmitted along the axons by axoplasmic flow, they have more prolonged and potent action than small molecule transmitters where they exert different actions.

- **Electrical Events In Postsynaptic Neurons**
- **Excitatory Synapses**
- An **excitatory synapse** is one that brings the membrane potential of the postsynaptic neuron closer to the threshold for generating an action potential (excitatory synapses depolarize the postsynaptic neuron).
- Following action potential–induced calcium influx, the neurotransmitter(in most cases glutamate)is released from the presynaptic terminal, diffuses across the synaptic cleft, and activates ligand-gated ion channels on the postsynaptic cell surface, causing excitatory postsynaptic currents.

An Inhibitory Synapse

- is a synapse that takes the membrane potential of the postsynaptic neuron away from the action potential threshold by hyperpolarizing the neuron or, alternatively, stabilizes the membrane potential at the resting value.
- After the transmitter opens postsynaptic cell membrane Cl^- channels, Cl^- concentration gradient decreases.
- The net effect is the transfer of negative charge into the cell so that the membrane potential increases; it may be up to -85 mV (below threshold potential). This is called an inhibitory postsynaptic potential (IPSP).
- In the mature brain the majority of synaptic inhibition is mediated by Cl^- permeable $GABA_A$ receptors.