PHYSIOLOGY

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LECTURE 5- PARTS (1) & (2)

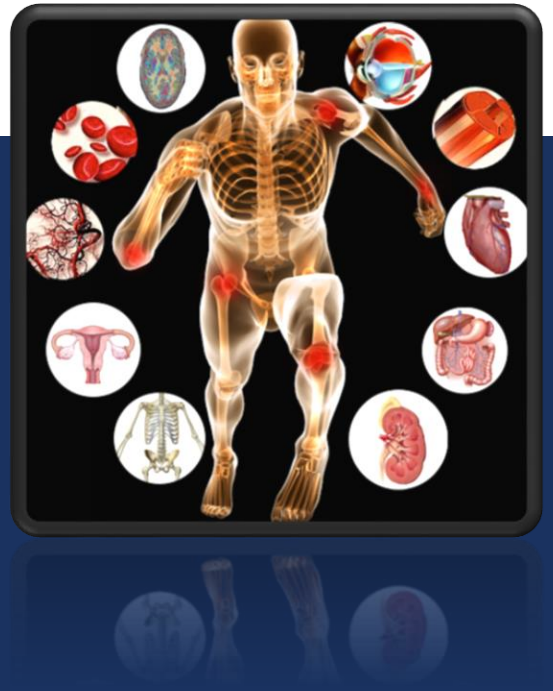
Objectives

1. Discuss **signal transmission at synapses**.

2. Distinguish **spatial and temporal summation of postsynaptic potentials.**

(Pages 424-436 of the reference).

General Overview

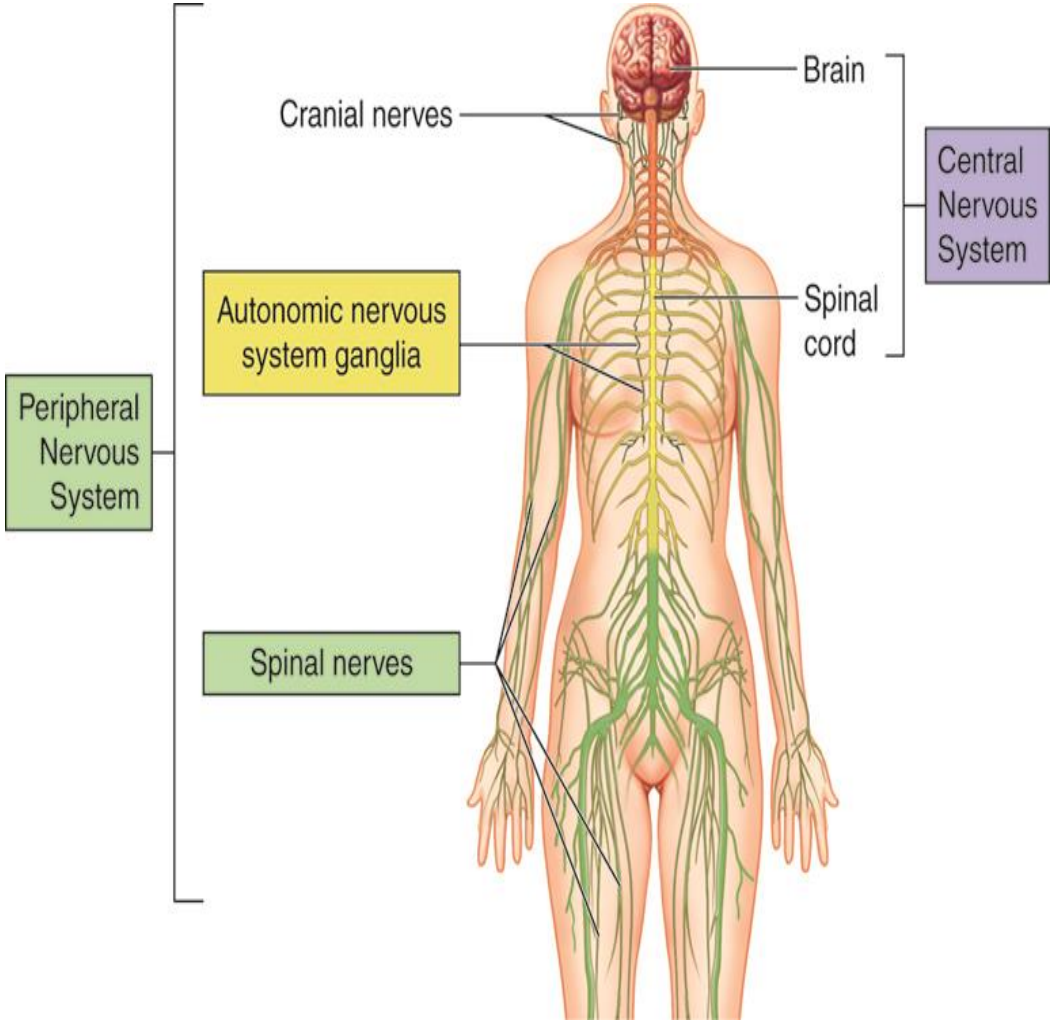


NERVOUS SYSTEM

- It consists of **central nervous system (CNS)** and **peripheral nervous system (PNS).**

- The **CNS** consists of brain (85 billion neurons) and spinal cord (100 million neurons.).

- The **PNS** consists of all nervous tissue outside the CNS, which include nerves, ganglia, enteric plexuses, and sensory receptors.



SIGNAL TRANSMISSION AT SYNAPSES

- ✓ Recall from lecture 3 that **a synapse** is a region where communication occurs between two neurons or between a neuron and an effector cell.
- ✓ The term **presynaptic neuron** refers to a nerve cell that carries a nerve impulse toward a synapse (sends a signal).

SIGNAL TRANSMISSION AT SYNAPSES

- ✓ A **postsynaptic cell** is the cell that receives a signal. It may be a nerve cell called **a postsynaptic neuron** that carries a nerve impulse away from a synapse or an **effector cell** that responds to the impulse at the synapse.

SYNAPSES BETWEEN NEURONS

- Synapses may be **electrical or chemical** and they differ both structurally and functionally.

ELECTRICAL SYNAPSES

- At an electrical synapse, **action potentials (impulses) conduct directly** between the plasma membranes of adjacent neurons through structures called **gap junctions**.

- Each gap junction contains a **hundred or so tubular connexons**, which act like tunnels to connect the cytosol of the two cells directly.

ELECTRICAL SYNAPSES

- Gap junctions are common in **visceral smooth muscle, cardiac muscle, and the developing embryo**. They also occur in the **brain**.

ELECTRICAL SYNAPSES HAVE TWO MAIN ADVANTAGES:

Faster communication (At an electrical synapse, the action potential **passes directly from the presynaptic cell to the postsynaptic cell**. The events that occur at a chemical synapse take some time and delay communication slightly).

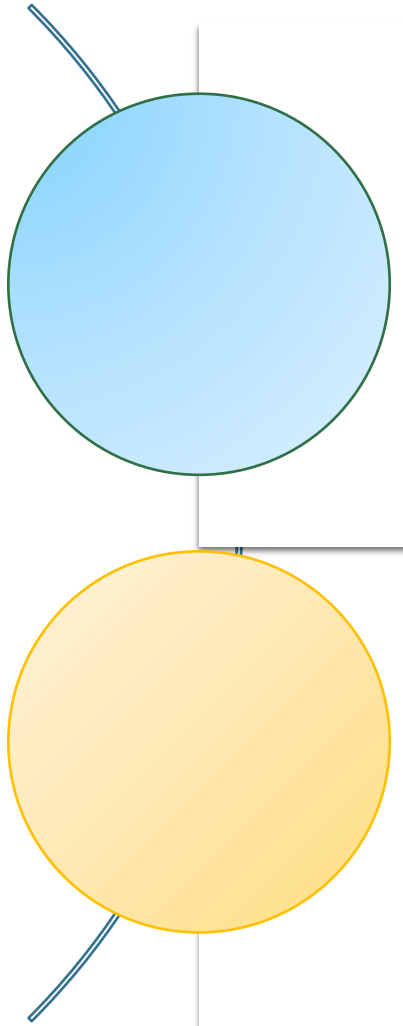
Synchronization (large number of neurons or muscle fibers can **produce action potentials in unison** if they are connected by gap junctions).

CHEMICAL SYNAPSES

The **plasma membranes of presynaptic and postsynaptic neurons** in a chemical synapse are separated by the **synaptic cleft**, a space of 20–50 nm that is filled with interstitial fluid.

Nerve impulses cannot conduct across the synaptic cleft (**indirect form of communication**).

CHEMICAL SYNAPSES



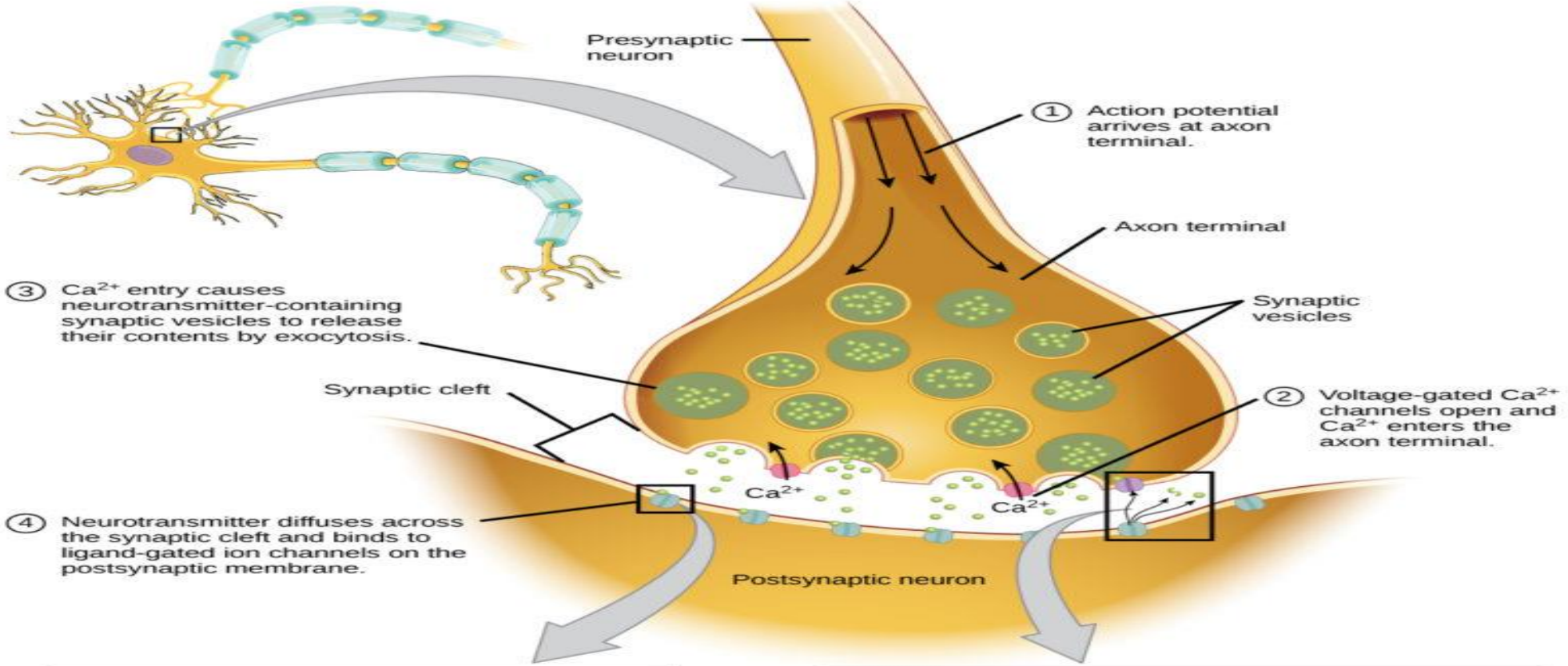
In **response to a nerve impulse**, the presynaptic neuron releases a **neurotransmitter** that diffuses through the fluid in the synaptic cleft and binds to receptors in the plasma membrane of the postsynaptic neuron.

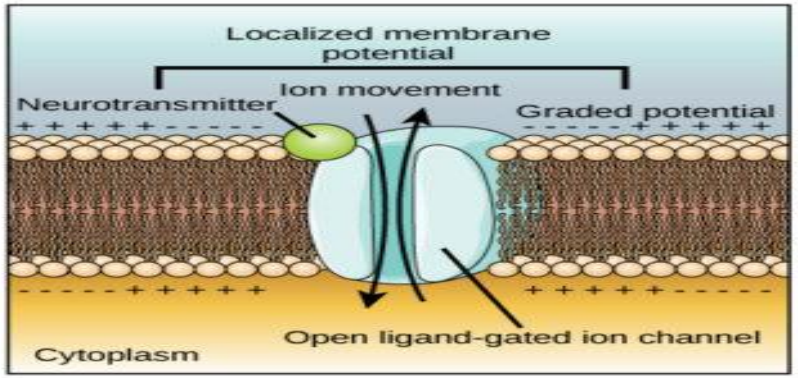
The **postsynaptic neuron** receives the chemical signal and in turn produces a **postsynaptic potential**, a type of **graded potential**.

CHEMICAL SYNAPSES

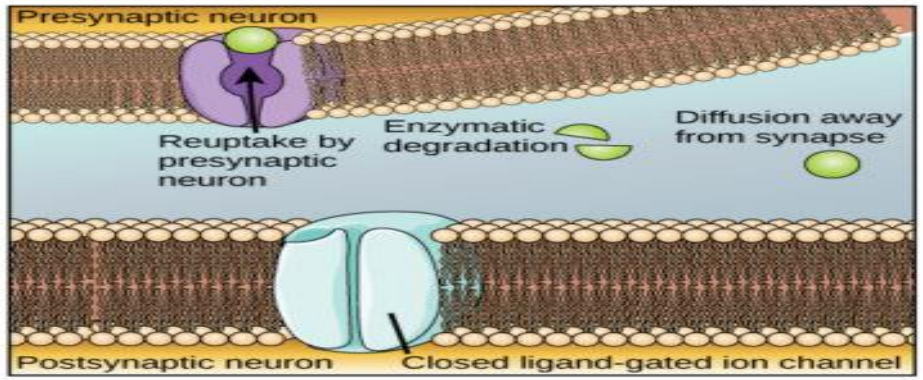
- **Thus, the presynaptic neuron converts an electrical signal (nerve impulse) into a chemical signal (released neurotransmitter).**

- The time required for these processes at **a chemical synapse**, a synaptic delay of about 0.5 msec, is the reason that chemical synapses relay signals more slowly than electrical synapses.





5 Binding of neurotransmitter opens ligand-gated ion channels, resulting in graded potentials.

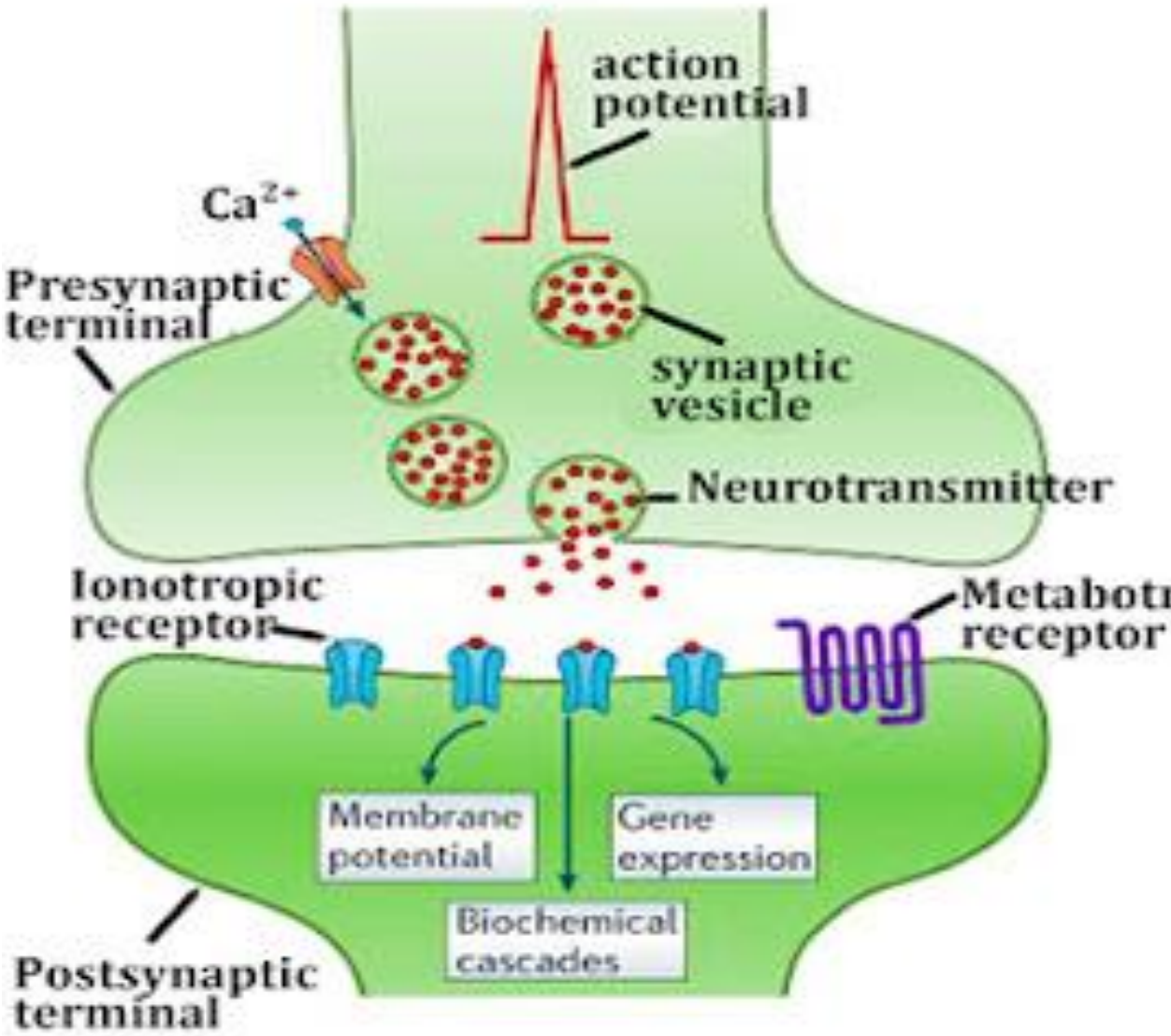


6 Reuptake by the presynapic neuron, enzymatic degradation and diffusion reduce neurotransmitter levels, terminating the signal.

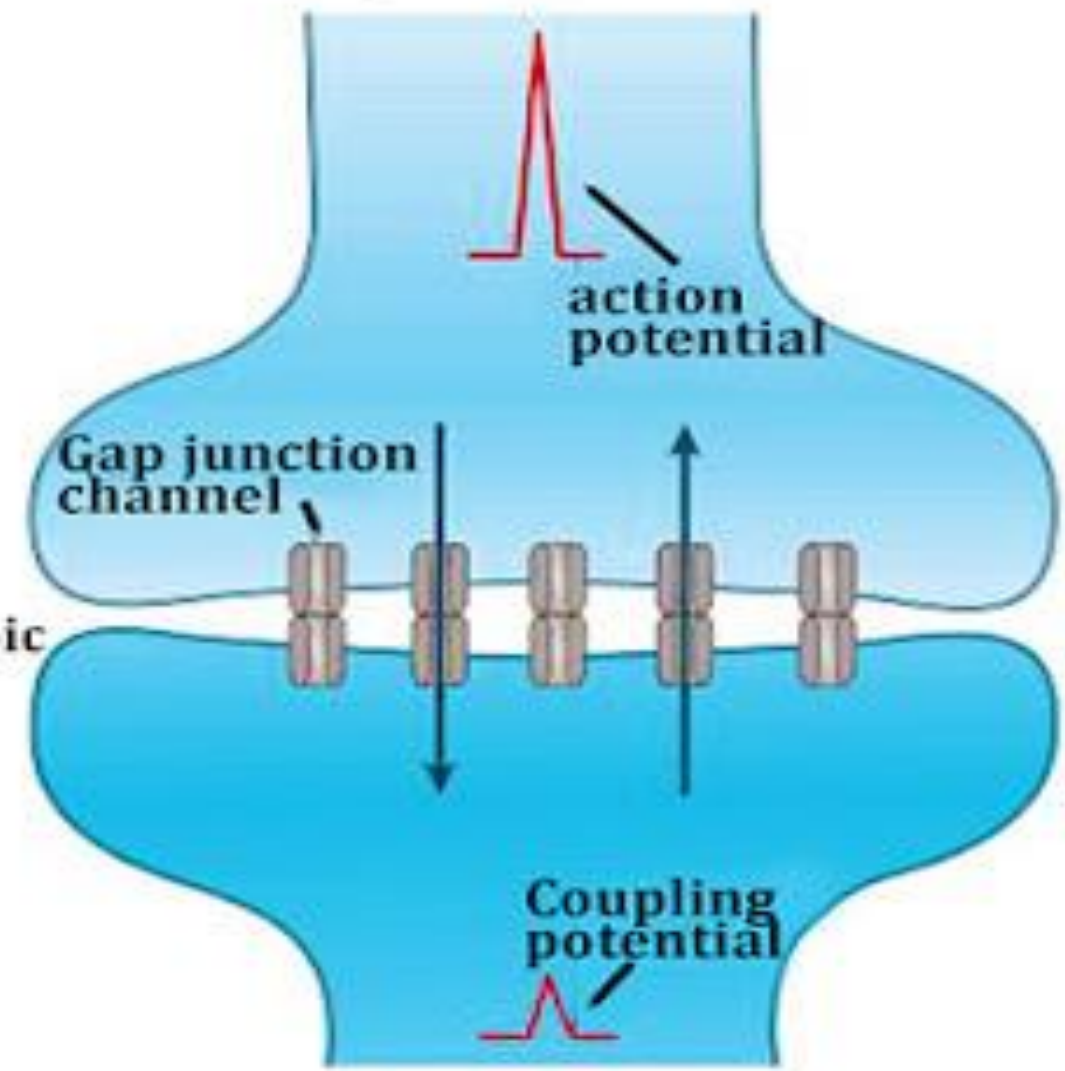
Postsynaptic potential

- Opening of Na ions channels allows inflow of Na ions, which causes depolarization.
- However, opening of Cl– or K ions channels causes hyperpolarizaion.
- When a depolarizing postsynaptic potential reaches threshold, it triggers an action potential in the axon of the postsynaptic neuron.

Chemical synapse



Electrical synapse



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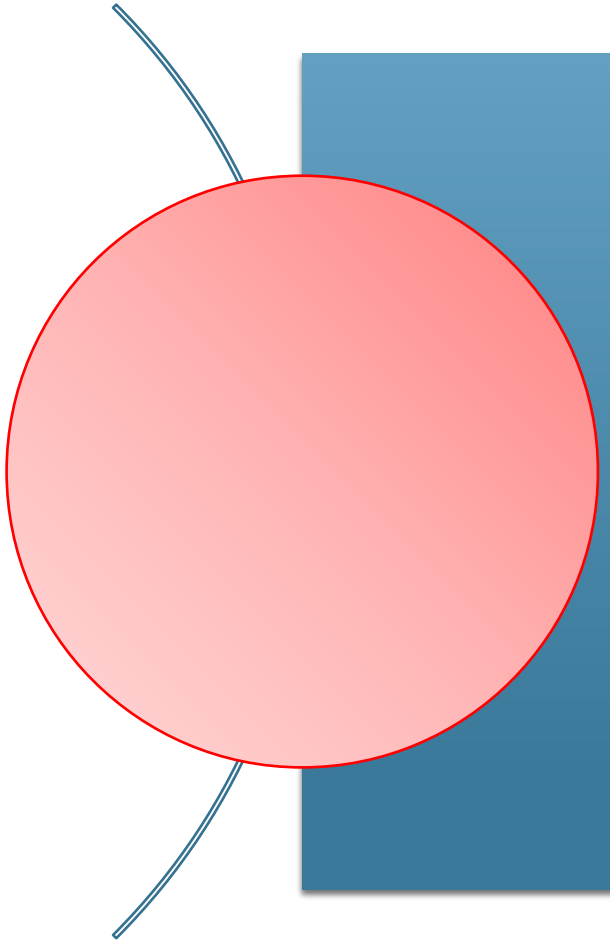
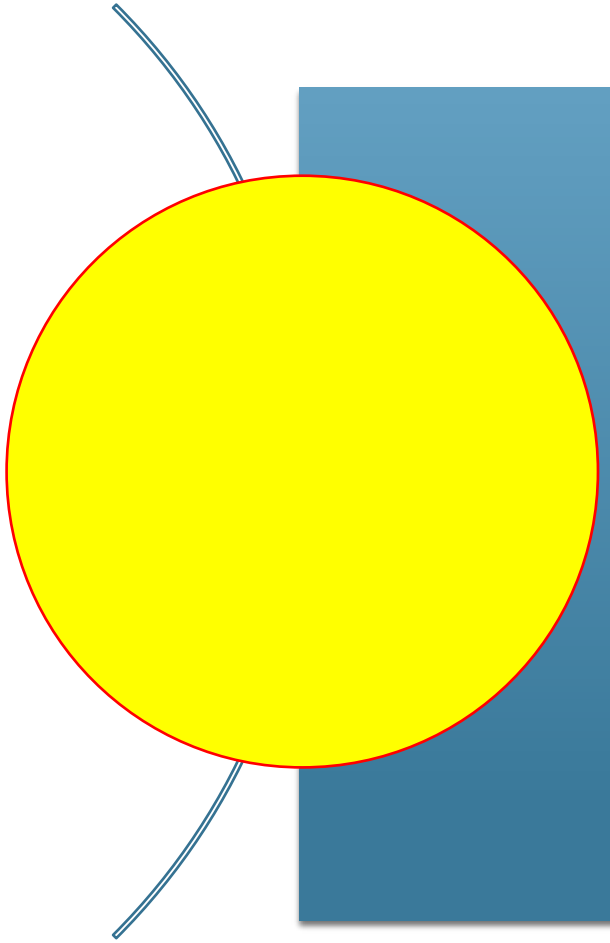
EXCITATORY AND INHIBITORY POSTSYNAPTIC POTENTIALS



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)**.

EXCITATORY AND INHIBITORY POSTSYNAPTIC POTENTIALS



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).**

STRUCTURE OF NEUROTRANSMITTER RECEPTORS

Neurotransmitter receptors are classified as either **ionotropic receptors or metabotropic receptors** based on whether the neurotransmitter binding site and the ion channel are components of the same protein or are components of different proteins.

IONOTROPIC vs METABOTROPIC RECEPTORS

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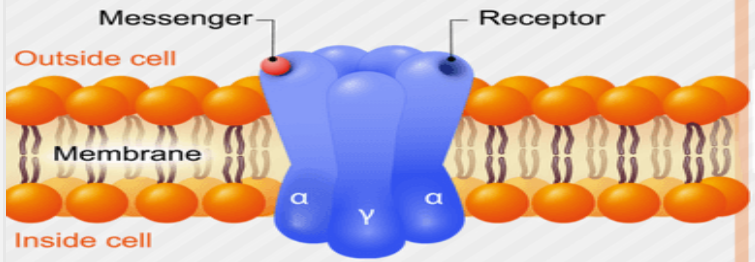
IONOTROPIC RECEPTORS

METABOTROPIC RECEPTORS

both are ligand-gated transmembrane proteins

Acts quicky.

Takes a little longer depending on the number of steps required to produce a response.



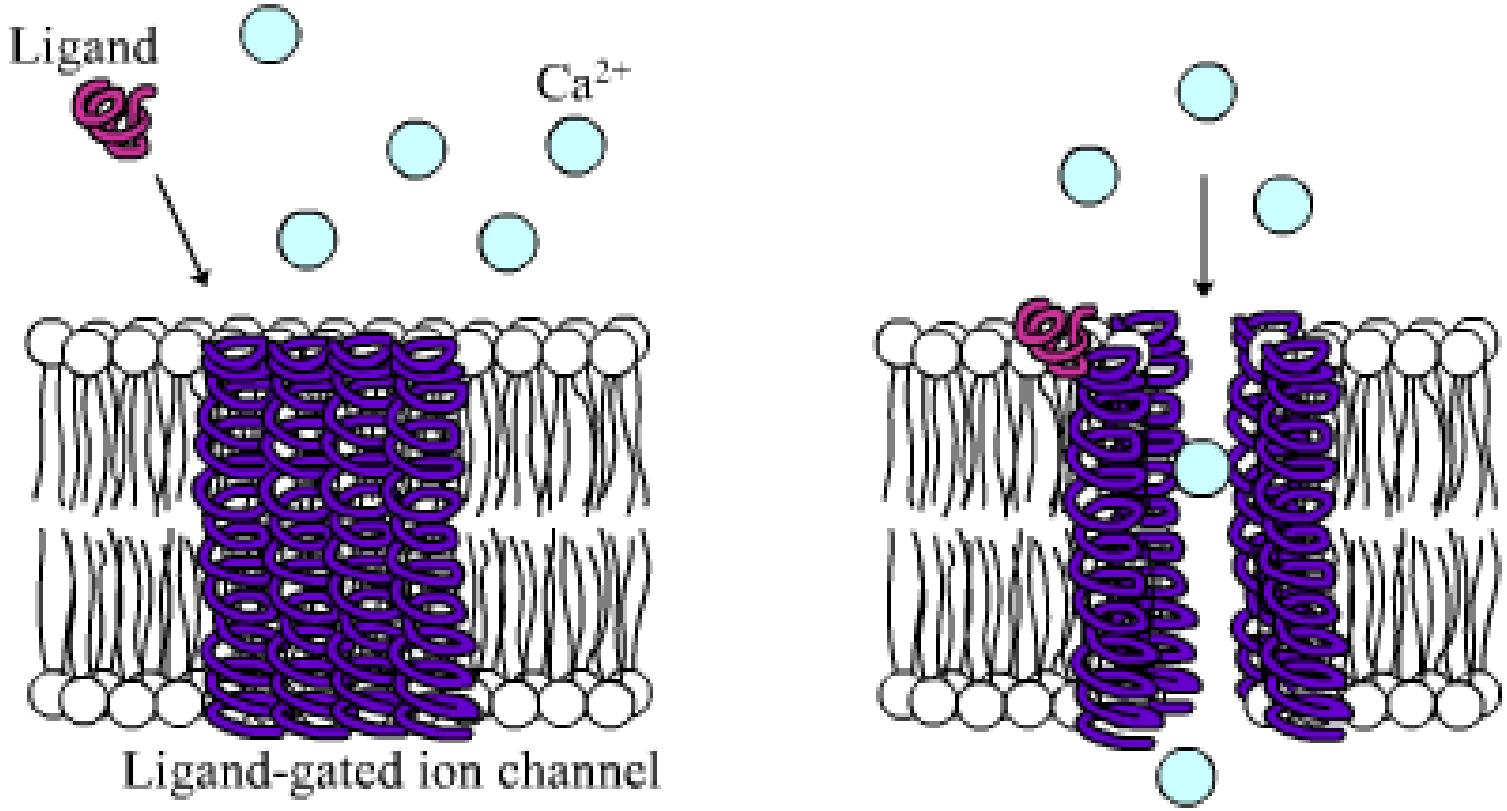
Metabotropic receptors do not have channels.

Ionotropic receptors change shape when they are bound by a ligand. This change in shape creates a channel that allows ions to flow through.

Metabotropic receptors activate a G-protein that in turn activates a secondary messenger, that in turn will activate something else.

Metabotropic receptor activation may or may not result in the opening of ion channels somewhere else on the membrane.

IONOTROPIC RECEPTORS



IONOTROPIC RECEPTORS

- is a type of **neurotransmitter receptor** that contains **a neurotransmitter binding site and an ion channel** (i.e neurotransmitter binding site and the ion channel are components of the **same protein**).

IONOTROPIC RECEPTORS

- ***When the correct neurotransmitter binds to the ionotropic receptor, the ion channel opens, and an EPSP or IPSP occurs in the postsynaptic cell.***

METABOTROPIC RECEPTORS

is a type of neurotransmitter receptor that contains a **neurotransmitter binding site** but **lacks an ion channel** as part of its structure. However, a metabotropic receptor **is coupled to a separate ion channel by** a type of membrane protein called **a G protein**.

METABOTROPIC RECEPTORS

- When a neurotransmitter binds to a metabotropic receptor, the **G protein either directly** opens (or closes) the ion channel or it may act **indirectly** by activating another molecule, **a "second messenger**," in the cytosol, which in turn opens (or closes) the ion channel.

- Thus, a metabotropic receptor differs from an ionotropic receptor in that the neurotransmitter binding site and the ion channel are components of **different proteins**.

REMOVAL OF NEUROTRANSMITTER

- is essential for **normal synaptic function**. If a neurotransmitter could linger in the synaptic cleft, it would influence the postsynaptic neuron, muscle fiber, or gland cell indefinitely.

REMOVAL OF NEUROTRANSMITTER

1. ***Diffusion:*** Neurotransmitters diffuse away from the synaptic cleft.
2. ***Enzymatic degradation:*** Certain neurotransmitters are inactivated through enzymatic degradation.
3. ***Uptake by cells:*** Many neurotransmitters are actively transported back into the neuron that released them (reuptake). Others are transported into neighboring neuroglia (uptake).

SPATIAL AND TEMPORAL SUMMATION OF POSTSYNAPTIC POTENTIALS

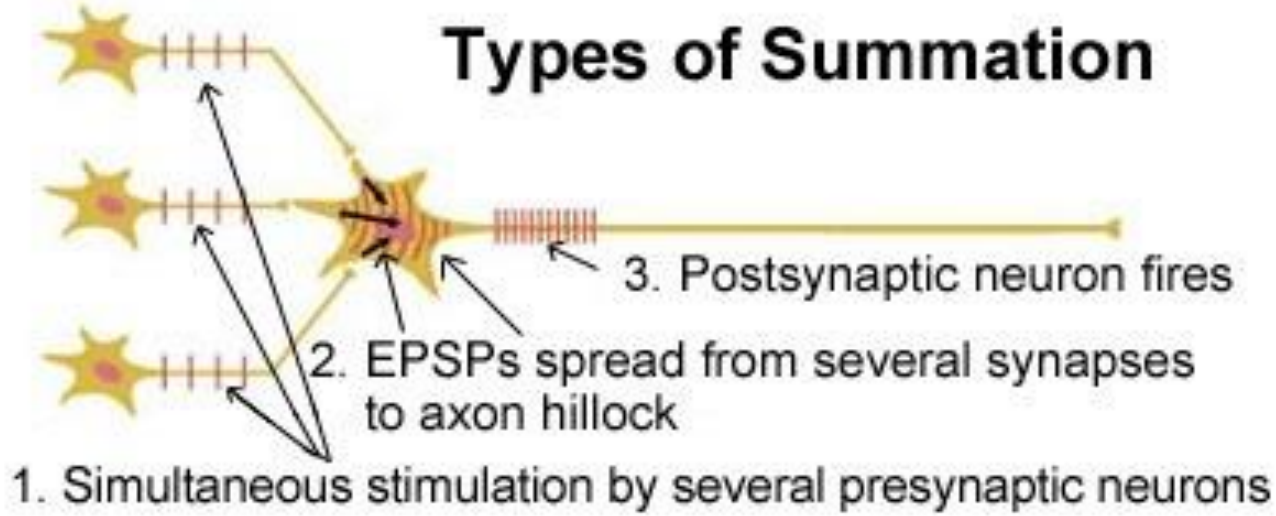
- A **typical neuron** in the CNS receives input from **1000 to 10,000 synapses**.

- **Integration of these inputs** involves summation of the postsynaptic potentials that form in the postsynaptic neuron. Recall that **summation** is the process by which graded potentials add together.

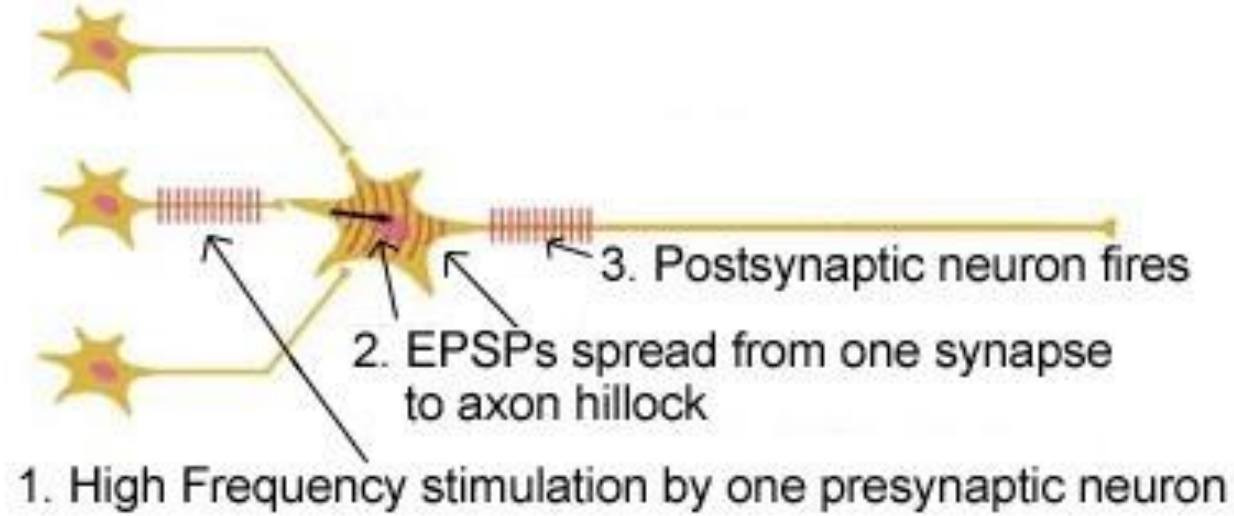
SPATIAL AND TEMPORAL SUMMATION OF POSTSYNAPTIC POTENTIALS

- The **greater the summation of EPSPs**, the **greater the chance that threshold will be reached**. At threshold, one or more nerve impulses **(action potentials)** arise.

Types of Summation



Spatial summation



Temporal summation

SPATIAL AND TEMPORAL SUMMATION OF POSTSYNAPTIC POTENTIALS

- There are two types of summation: **spatial summation and temporal summation**.

- **Spatial summation** is **summation of postsynaptic potentials in response** to **stimuli** that occur at **different locations in the membrane of a postsynaptic cell at the same time**.

SPATIAL AND TEMPORAL SUMMATION OF POSTSYNAPTIC POTENTIALS

- **Temporal summation** is **summation of postsynaptic potentials in response to stimuli that occur at the same location in the membrane of the postsynaptic cell but at different times.**

SMALL-MOLECULE NEUROTRANSMITTERS

- **Acetylcholine (ACh)**
  - Released by many PNS neurons & some CNS neurons.
  - Excitatory neurotransmitter on neuromuscular junction (NMJ) but inhibitory neurotransmitter at others.
  - Inactivated by acetylcholinesterase.
- **Amino Acids**
  - Glutamate released by nearly all excitatory neurons in the brain - inactivated by glutamate specific transporters
  - Gamma-aminobutyric acid (GABA) is inhibitory neurotransmitter (blocking brain signals) for 1/3 of all brain synapses (Antianxiety drugs such as diazepam (Valium) is a GABA agonist -- enhancing GABA's inhibitory effect).

SMALL-MOLECULE NEUROTRANSMITTERS

- **Biogenic Amines**
  - Certain amino acids are modified and decarboxylated (carboxyl group removed) to produce biogenic amines .
  - They are prevalent in the nervous system include norepinephrine, epinephrine, dopamine, histamine and serotonin.
  - Biogenic amines may cause either excitation or inhibition, depending on the type of metabotropic receptor at the synapse.

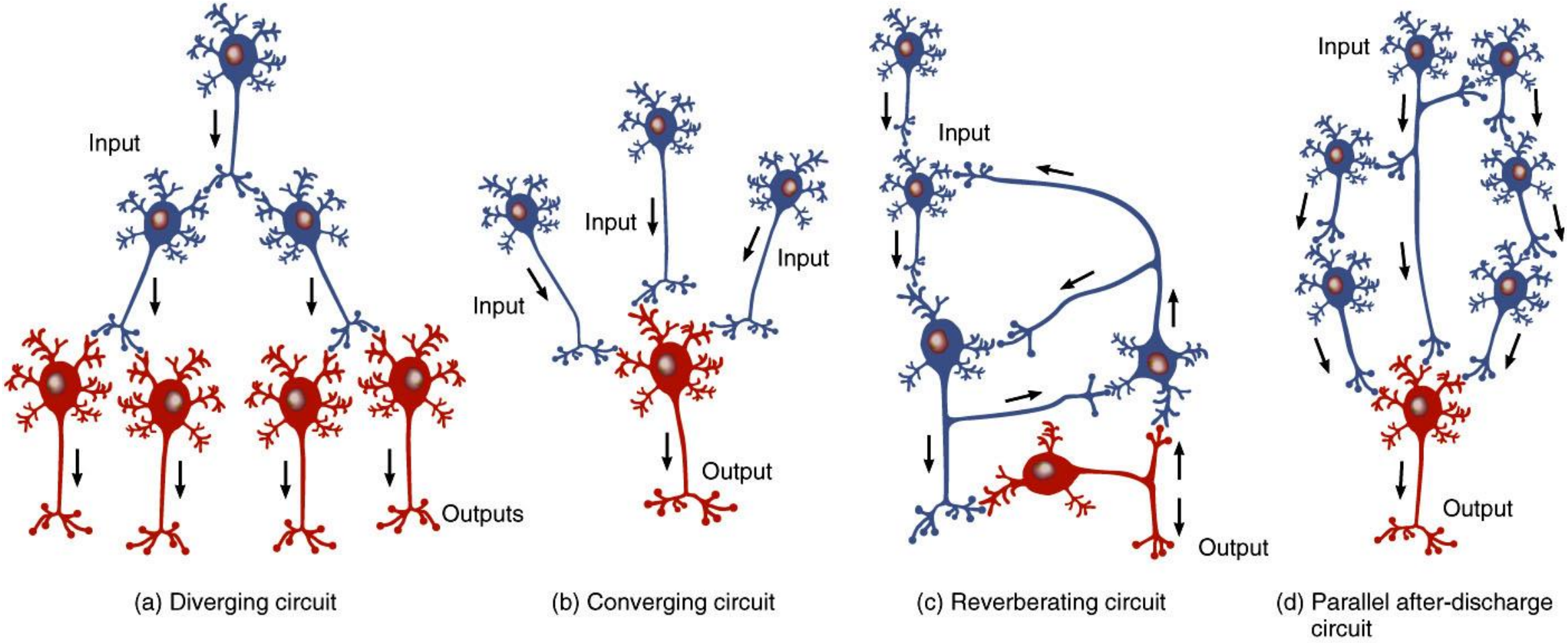
NEURAL CIRCUITS

- The CNS contains **billions of neurons organized into complicated networks** called **neural circuits, functional groups of neurons that process specific types of information**.
- In **a simple series circuit**, a **presynaptic neuron stimulates a single postsynaptic neuron**. The second neuron then stimulates another, and so on.
- The **divergence**, permits one presynaptic neuron to **influence several postsynaptic neurons** (or several muscle fibers or gland cells) at the same time.

NEURAL CIRCUITS

- **Convergence**, several **presynaptic neurons synapse with a single postsynaptic neuron**.
- Stimulation of the presynaptic cell causes the postsynaptic cell to transmit a series of nerve impulses. One such circuit is called **a reverberating circuit**. **This arrangement sends impulses back through the circuit again and again.**
- Fourth type of circuit is the **parallel after-discharge circuit.** In this circuit, a **single presynaptic cell stimulates a group of neurons, each of which synapses with a common postsynaptic cell**. A differing number of synapses between the first and last neurons imposes varying synaptic.

NEURAL CIRCUITS



(a) Diverging circuit

(b) Converging circuit

(c) Reverberating circuit

(d) Parallel after-discharge circuit

THANK YOU

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