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).

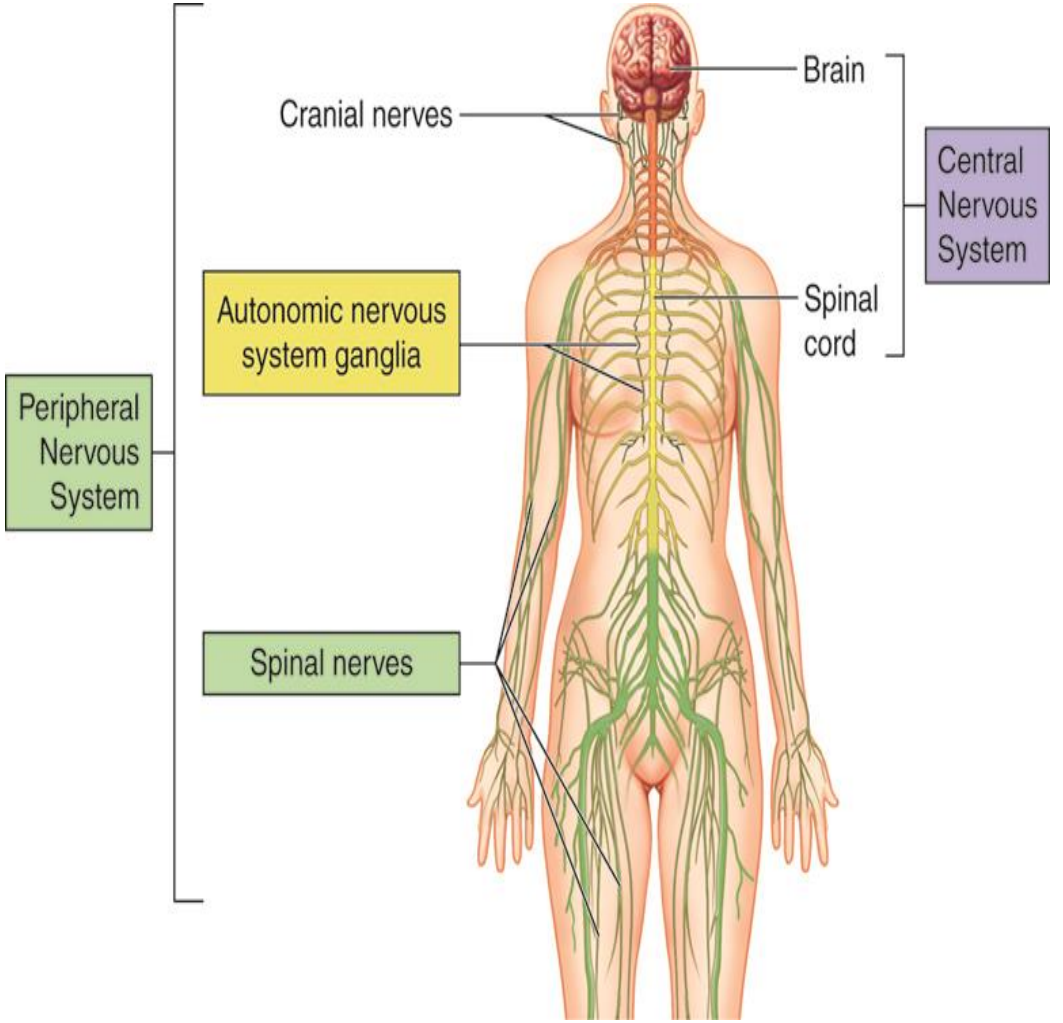
General Overview

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).

synapse الذي يفرز neurotransmitter إلى

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.

لا يتضمن انتقال السيال العصبي دائما وجود neurotransmitter في بعض الأحيان يكون هناك روابط بين cells'body بتنقل السيال electrical synapse العصبي مباشرة بيسمى اسمها Gap junctions لأن الإستجابات في بعض يجب أن تكون سريعة جدًا في بعض organ زي الدماغ والقلب لأن أسرع من chemical synapse

ELECTRICAL SYNAPSES

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

عبارة عن فتحات داخلها
أنابيب بين الأغشية البلازمية (tubular connexons)
الخلايا تعمل كقنوات (tunnles)

- 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**.

- السيالات العصبية في هذه المناطق تكون electrical

- أي Synapse بين الجنين والأم هو electrical

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

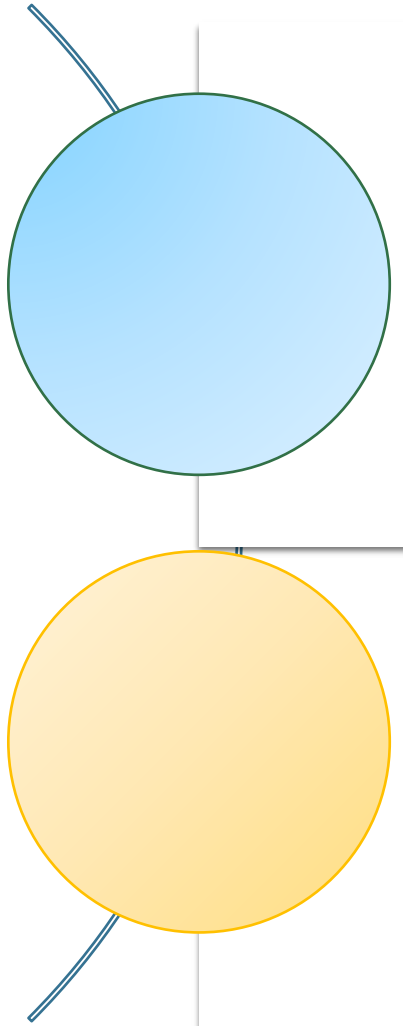
The **plasma membranes of presynaptic and postsynaptic neurons** in a chemical synapse are separated by the **synaptic cleft**, a space of 20–50 nm that is filled with interstitial fluid.

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

لا ينتقل AP لل synaptic cleft الذي يخرج هو neurotransmitter فيكون indirect communication

يصير فيه تأخير

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**.

- إذا استقبلت الـ sensory receptors الـ neurotransmitter يكون اسم الـ graded potential
(receptor potential)

- إذا راحت الـ neurotransmitter على sensory neuron يكون اسم الـ graded potential
(generator potential)

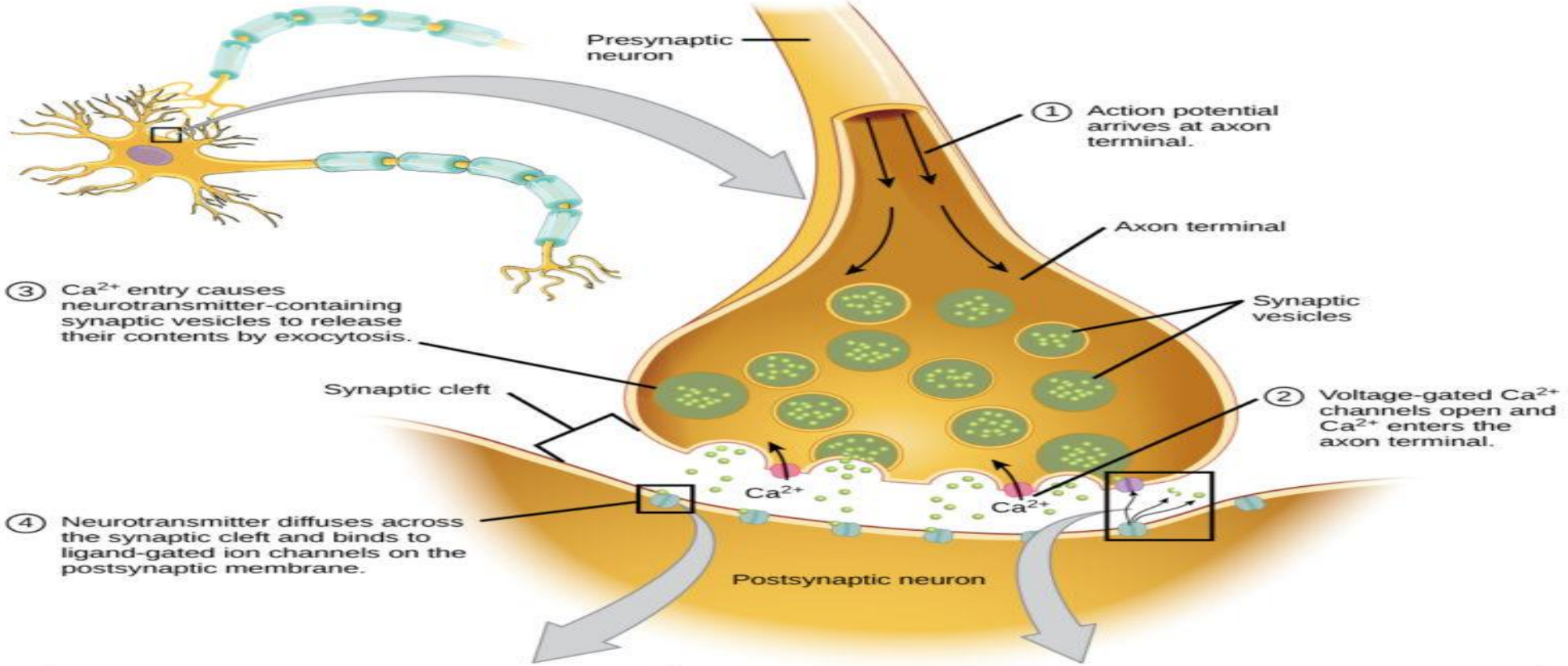
- إذا راحت الـ neurotransmitter على dendrites أو cell body يكون اسم الـ graded potential
(post synaptic potential)

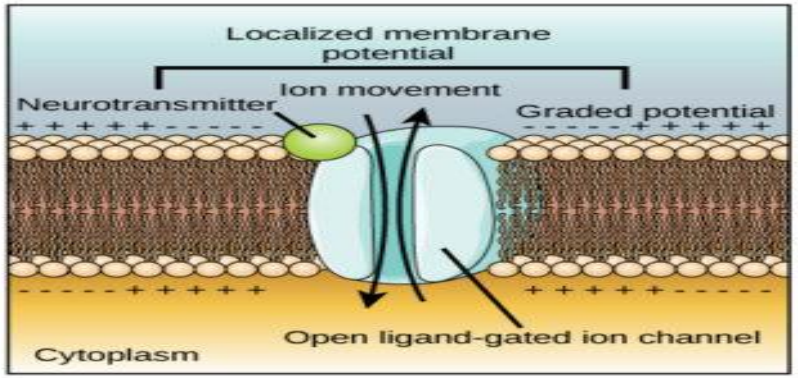
CHEMICAL SYNAPSES

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

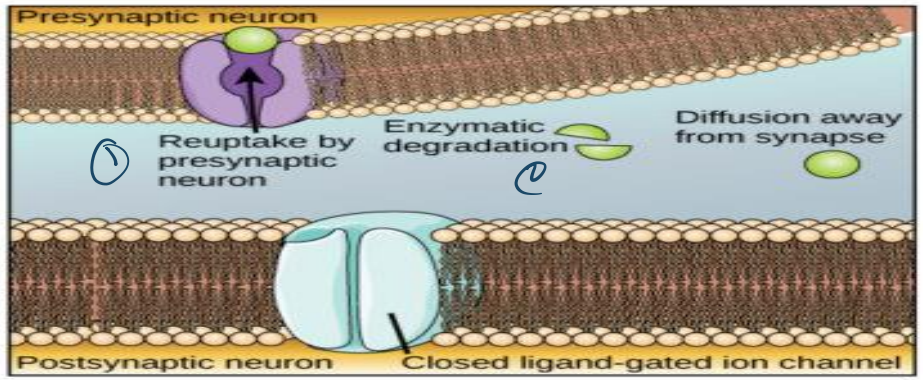
- The time required for these processes at **a chemical synapse**, a synaptic delay of about 0.5 msec, is the reason that chemical synapses relay signals more slowly than electrical synapses.

سبب التأخير عن electrical synapse
هو ان chemical synapse تستغرق 0.5 msec





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

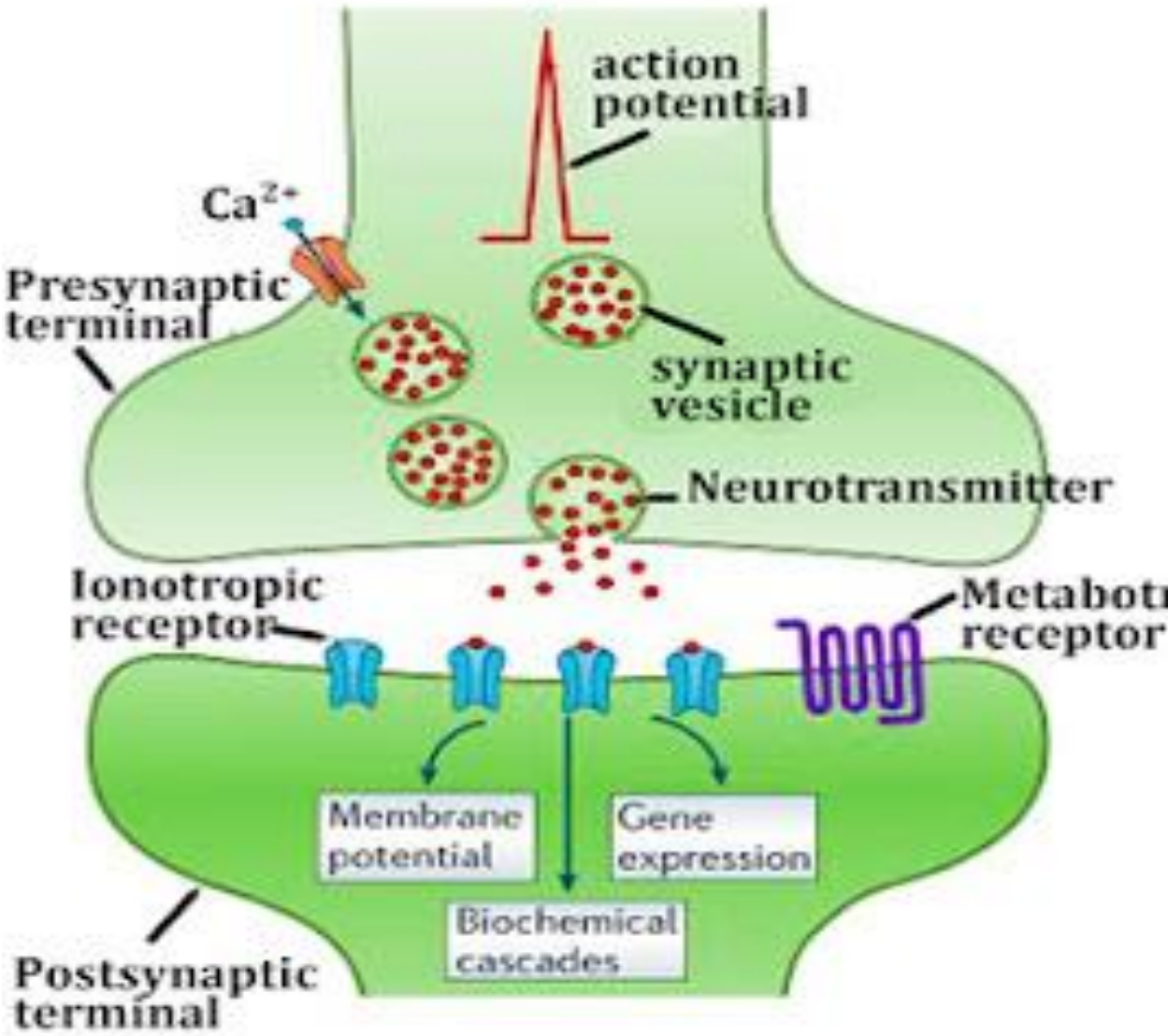


6 Reuptake by the presynapic neuron, enzymatic degradation and diffusion reduce neurotransmitter levels, terminating the signal.

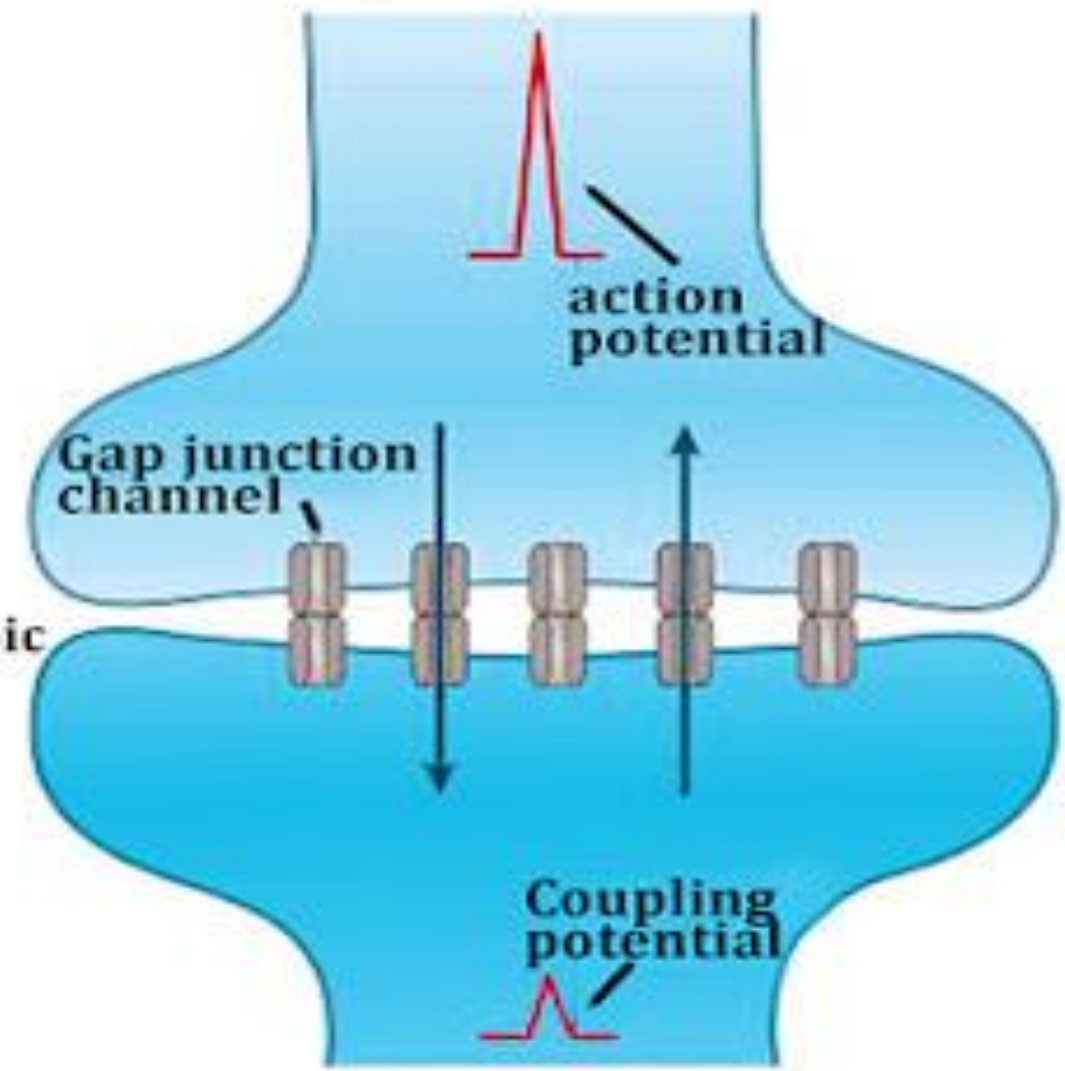
Postsynaptic potential

- 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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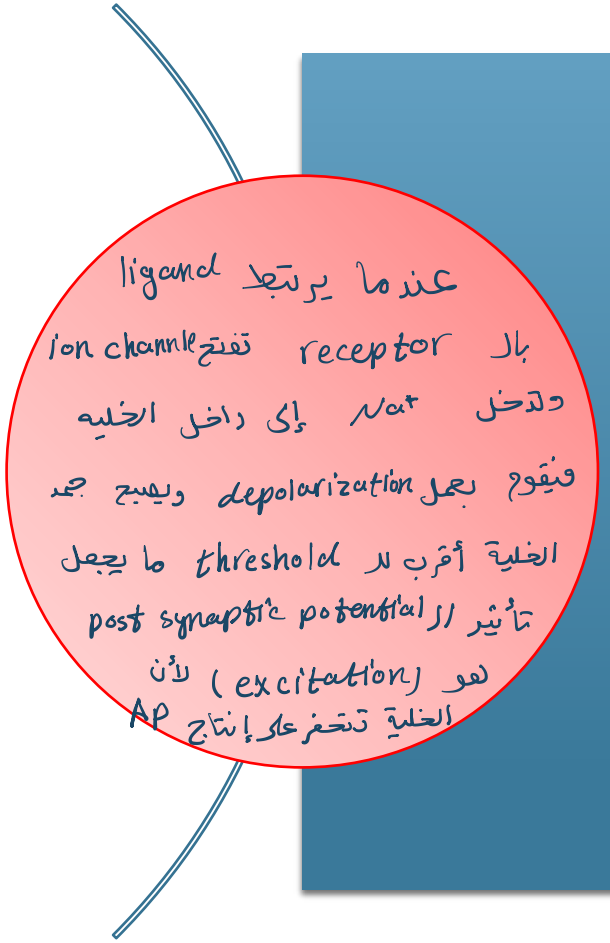
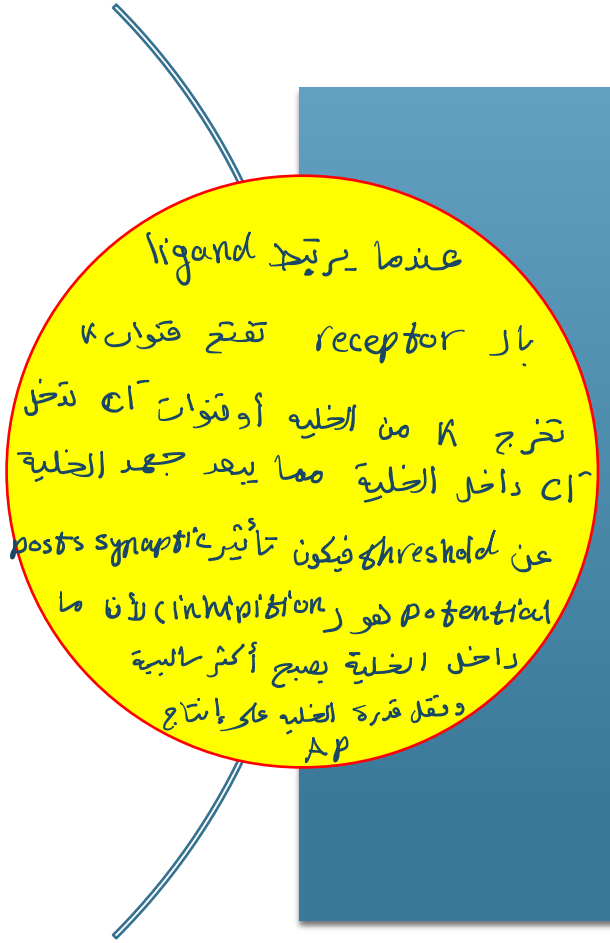
EXCITATORY AND INHIBITORY POSTSYNAPTIC POTENTIALS



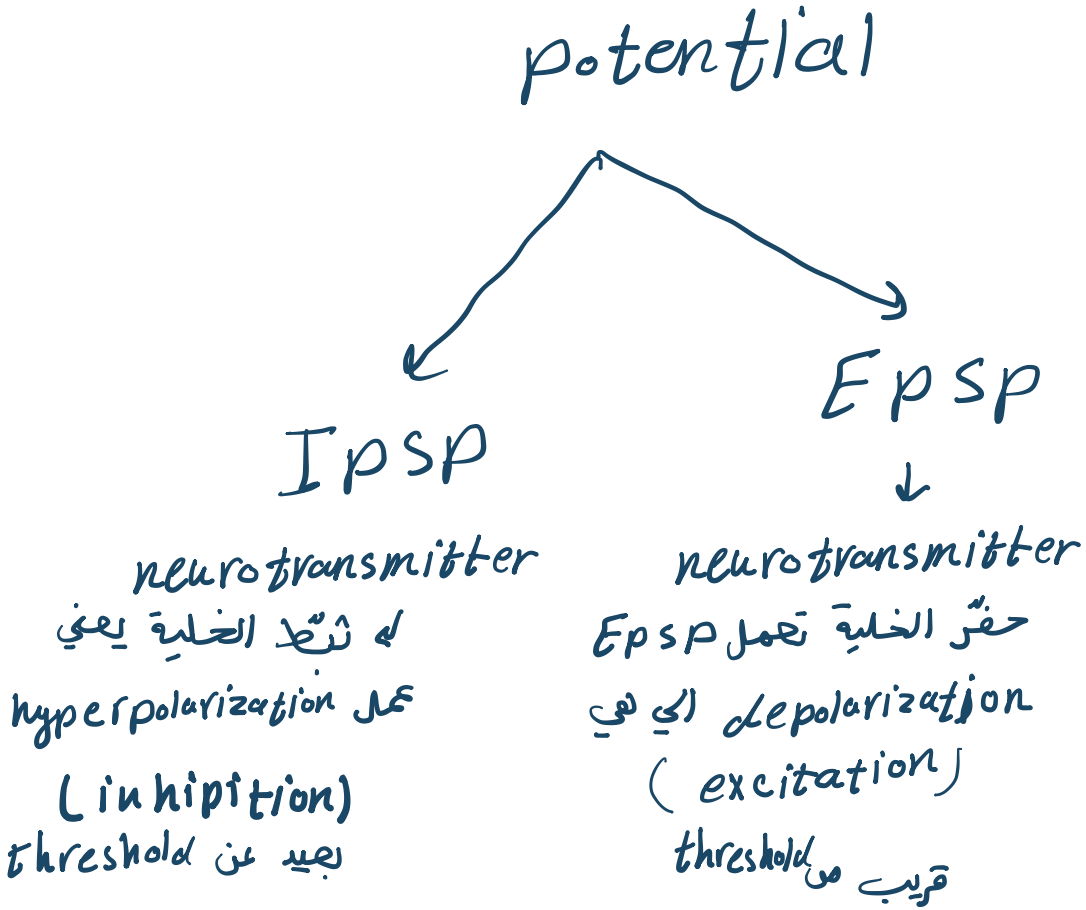
Depolarization of the postsynaptic membrane is excitatory because it brings the membrane closer to threshold. A **depolarizing postsynaptic potential** is called an **excitatory postsynaptic potential (EPSP)**.

hyper-polarizing inhibition

EXCITATORY AND INHIBITORY POSTSYNAPTIC POTENTIALS

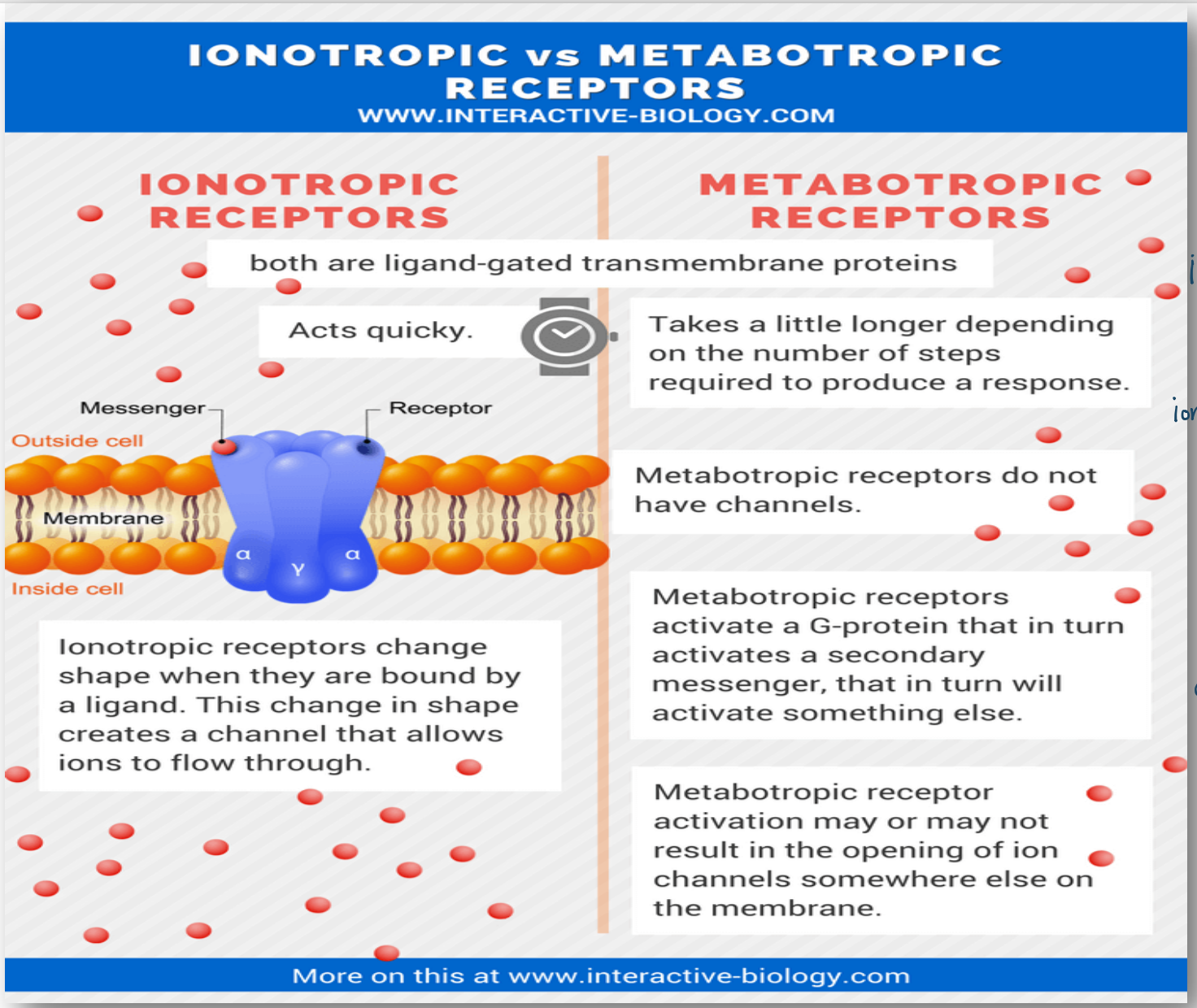


During hyperpolarization, generation of an action potential is more difficult than usual because the membrane potential becomes inside more negative and thus even farther from threshold than in its resting state. A **hyperpolarizing postsynaptic potential** is termed an **inhibitory postsynaptic potential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


potential
Ipsp
neurotransmitter
لا تنشط الخلية يعني
hyperpolarization عمل
(inhipition)
بعيد عن threshold
Epsp
neurotransmitter
حفّز الخلية تعمل Epsp
depolarization اللي هي
(excitation)
قريب من threshold

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.



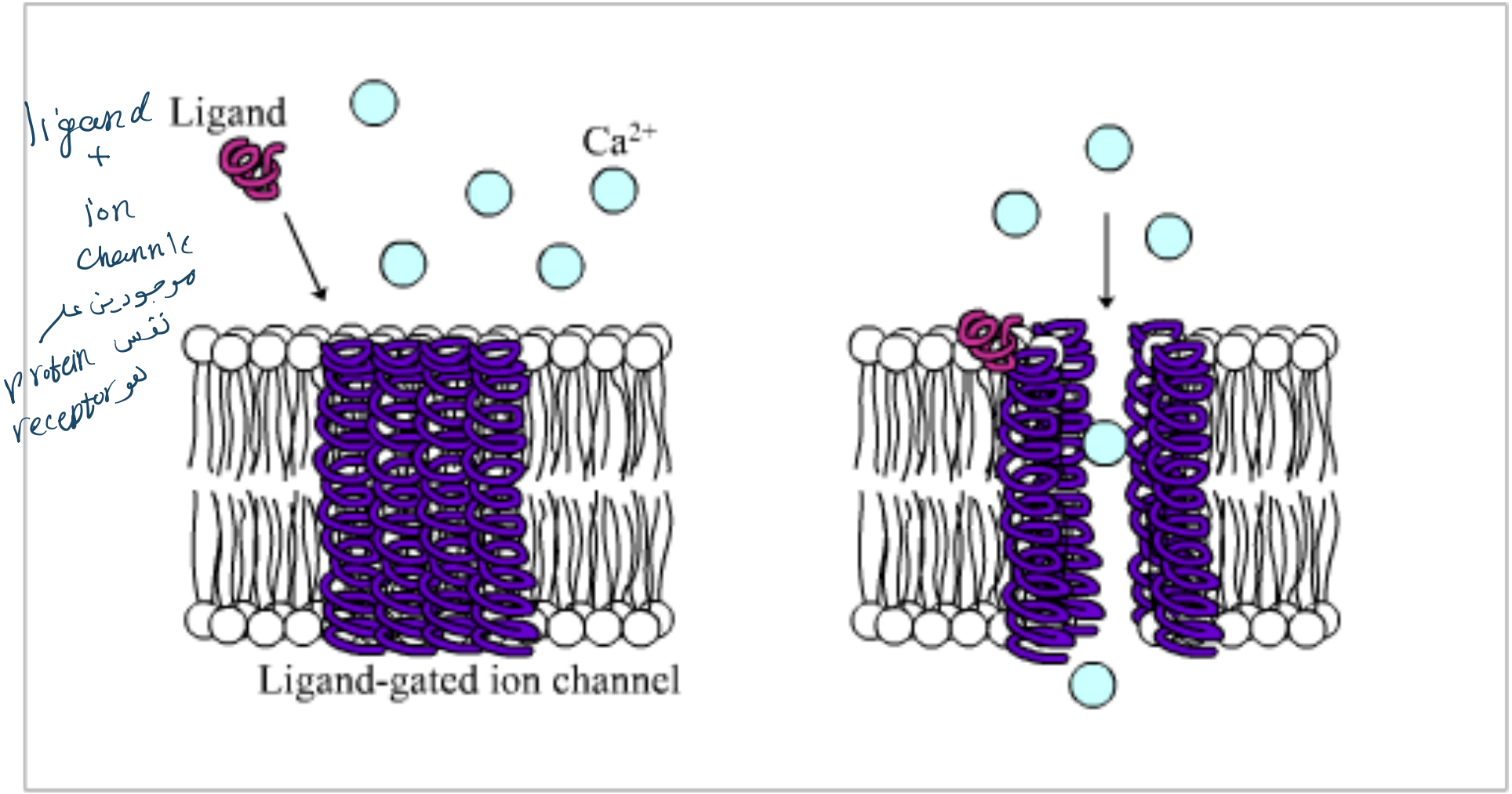
- مش دائما ion channels بتكون بجانب receptors مرات بتكون بعيدة عنها

- في منها بتكون ion channels بجانب receptor (بتكون على نفس البروتين) فبمجرد ما يرتبط ligand بال receptor بتغير شكل ion channle وتغير شكلها بسمح بمرور الأيونات وهاي (ionotropic receptor) بسميها receptors

- إذا كانت ion channles منفصلة عن receptor (موجودين على بروتينات مختلفة) بترتبط ببعض عن طريق بروتين يسمى G protein والذي عند ارتباط ligand بال receptor يتحفّز ويقوم بتحفيز ion channle بشكل مباشر أو بشكل غير مباشر عن طريق تحفيز بروتين آخر في Cytocol يسمى G protein يتحفّز messenger protein والذي عند تحفّزه يحفّز ion channle وهاي (metabotropic receptor) بسميها

ionotropic تعد مثال على nicotonic receptor باستثناء adrenergic و cholinergic تعد metabotropic مثال على receptor

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**.

بكون receptor مرتبط بقناة أيونية منفصلة عن طريق 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.

يجب إزالة neurotransmitter من synaptic cleft لأن بقاءها لفترة أطول يؤدي إلى تحفيز مستمر للخلية العصبية أو العضلية أو الغدد مما يؤدي إلى أضرار

REMOVAL OF NEUROTRANSMITTER

1. ***Diffusion:*** Neurotransmitters diffuse away from the synaptic cleft.

يروح لمكان آخر بعيد عن مكانه الأول

مسؤول عن الأدوية side effect

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).

يروح لمكان قريب

الفرق بين uptake و diffusion ؟

uptake بتكون عن طريق active transport ← تحتاج طاقة

diffusion بتكون عن طريق passive transport ← لا تحتاج طاقة

SPATIAL AND TEMPORAL SUMMATION OF POSTSYNAPTIC POTENTIALS

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

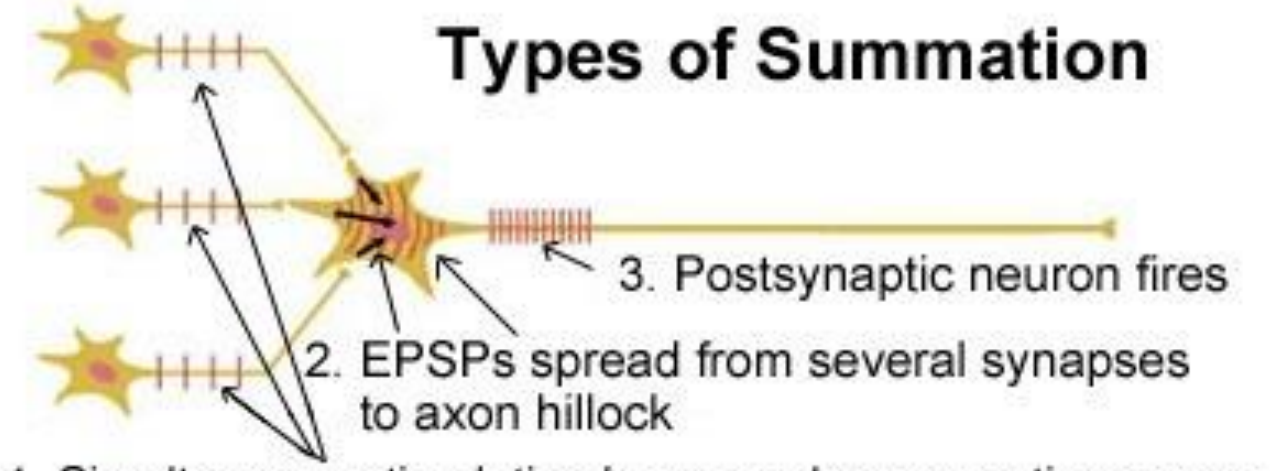
- **Integration of these inputs** involves summation of the postsynaptic potentials that form in the postsynaptic neuron. Recall that **summation** is the process by which graded potentials add together.

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.

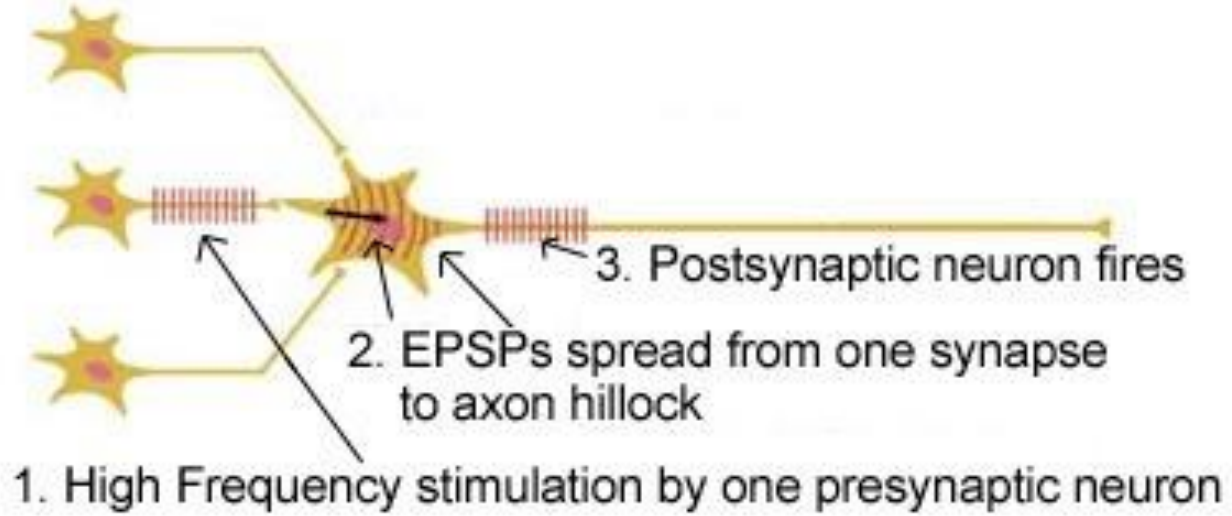
different sensory neurons
بتوصل لنفس اعكان

Types of Summation



من اكثر من خلية متزامن تحفيز

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

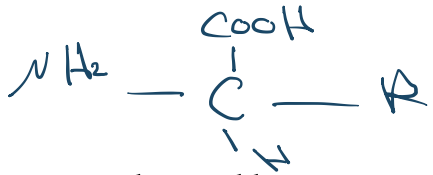
- **Temporal summation** is **summation of postsynaptic potentials in response to stimuli that occur at the same location in the membrane of the postsynaptic cell but at different times.**

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.

الوصل العصبي العضلي
(Neuromuscular Junction) هو
الموقع الذي يحدث فيه الاتصال بين الخلايا
العصبية الحركية والألياف العضلية

- **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

دوائر عصبية

- The CNS contains **billions of neurons organized into complicated networks** called **neural circuits, functional groups of neurons that process specific types of information**.

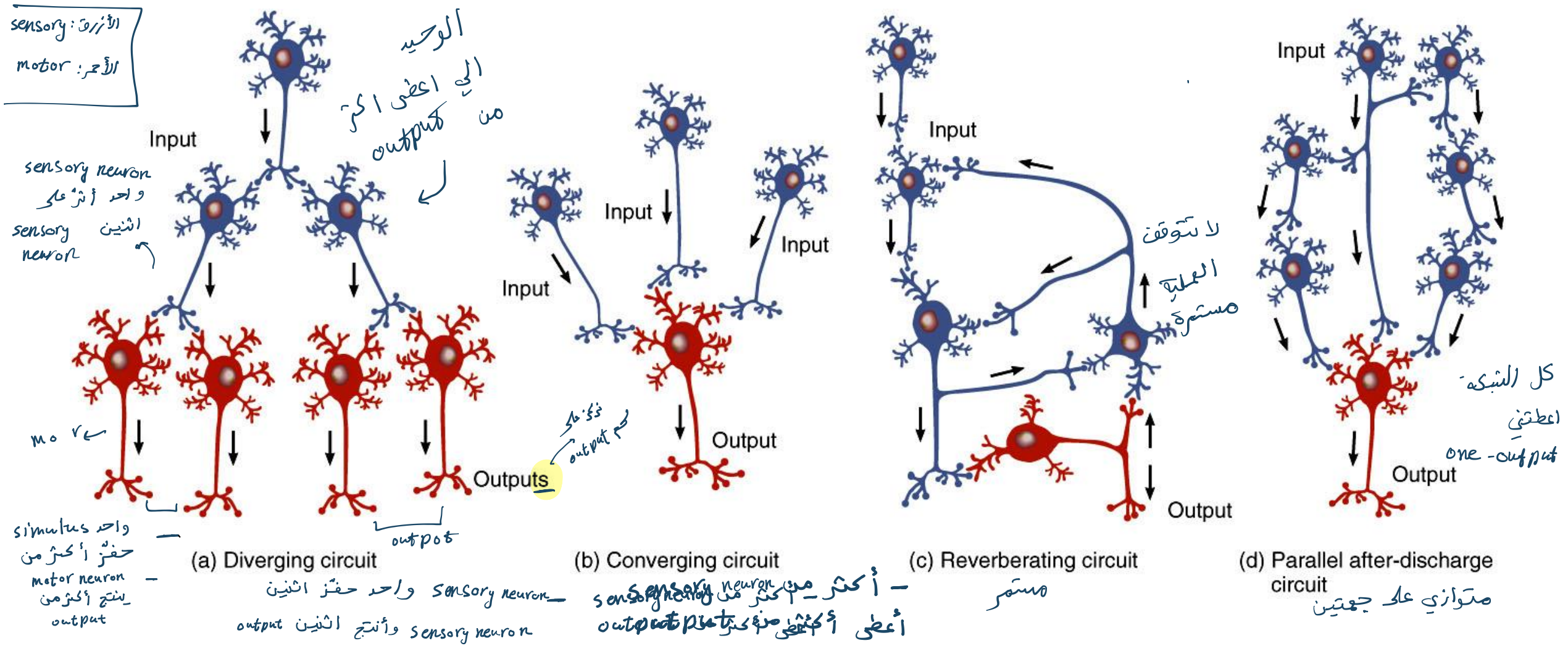
مجموعات وظيفية من الخلايا العصبية تتعاون معا لمعالجة معلومات معينة

- 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 (يسمح) 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



THANK YOU

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