Human Physiology

Lecture 8 – Monday 7/3/2016

"Graded Potential & Synaptic Transmission" with

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(Slides are on e-learning)

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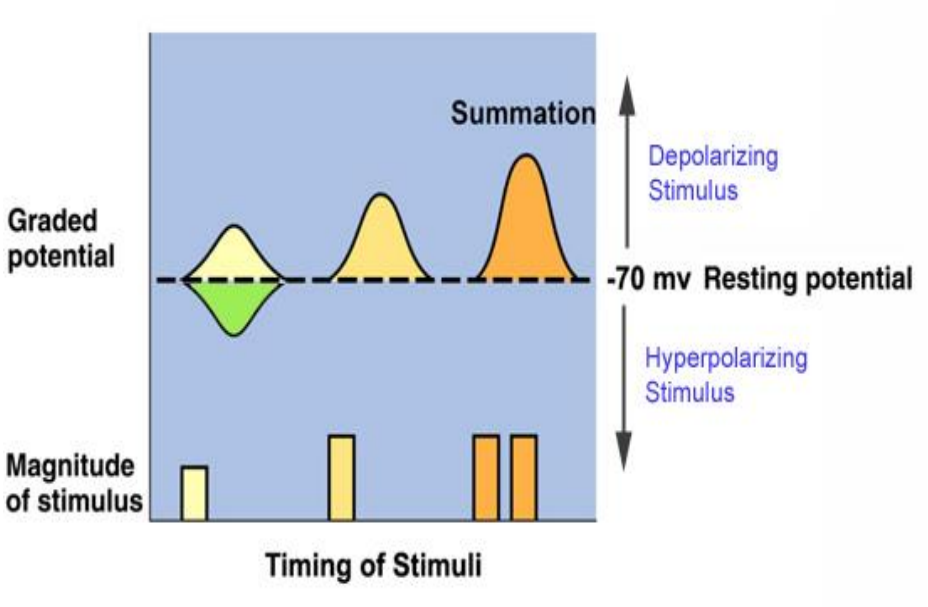
PSU

Reminder: There are 2 types of membrane potential, action potential & graded potential.

Graded potential

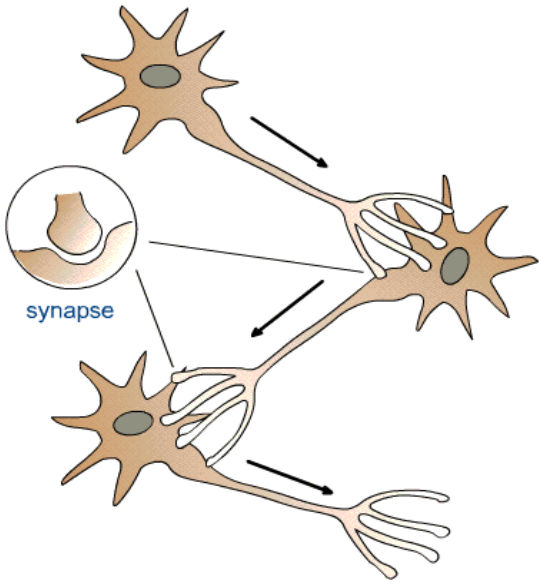


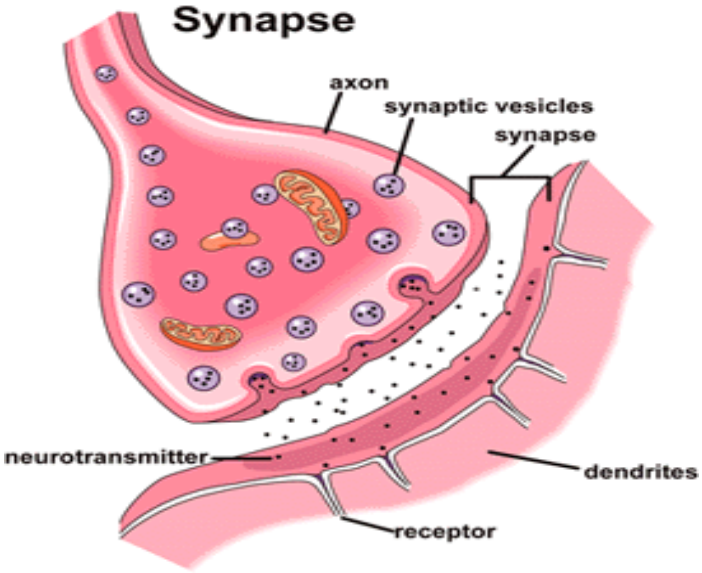
- Is a <u>small</u> change in membrane potential without reaching threshold potential.
- Is related to strength of triggering event; A stronger stimulus leads to larger magnitude of graded potential.
- Has no refractory period
- Is propagated/transmitted in a **<u>decremental</u>** fashion (the magnitude of the potential decreases as you move further from the initial active area)
- Is propagated/transmitted in two directions

	Action potential	Graded potential
Magnitude	<u>Large</u> change in potential	<u>Small</u> change in potential
Refractory period	Has a refractory period	Has no refractory period
Direction of propagation	In one direction only	In two directions
Effect of stimulus	Stronger stimulus does not affect action potential	Stronger stimulus leads to stronger graded potential
Type of propagation	<u>Non-decremental</u>	<u>Decremental</u>

A neuron may terminate (ينتهي) at a muscle, or a gland, or another neuron.

Synapse (تشابك)

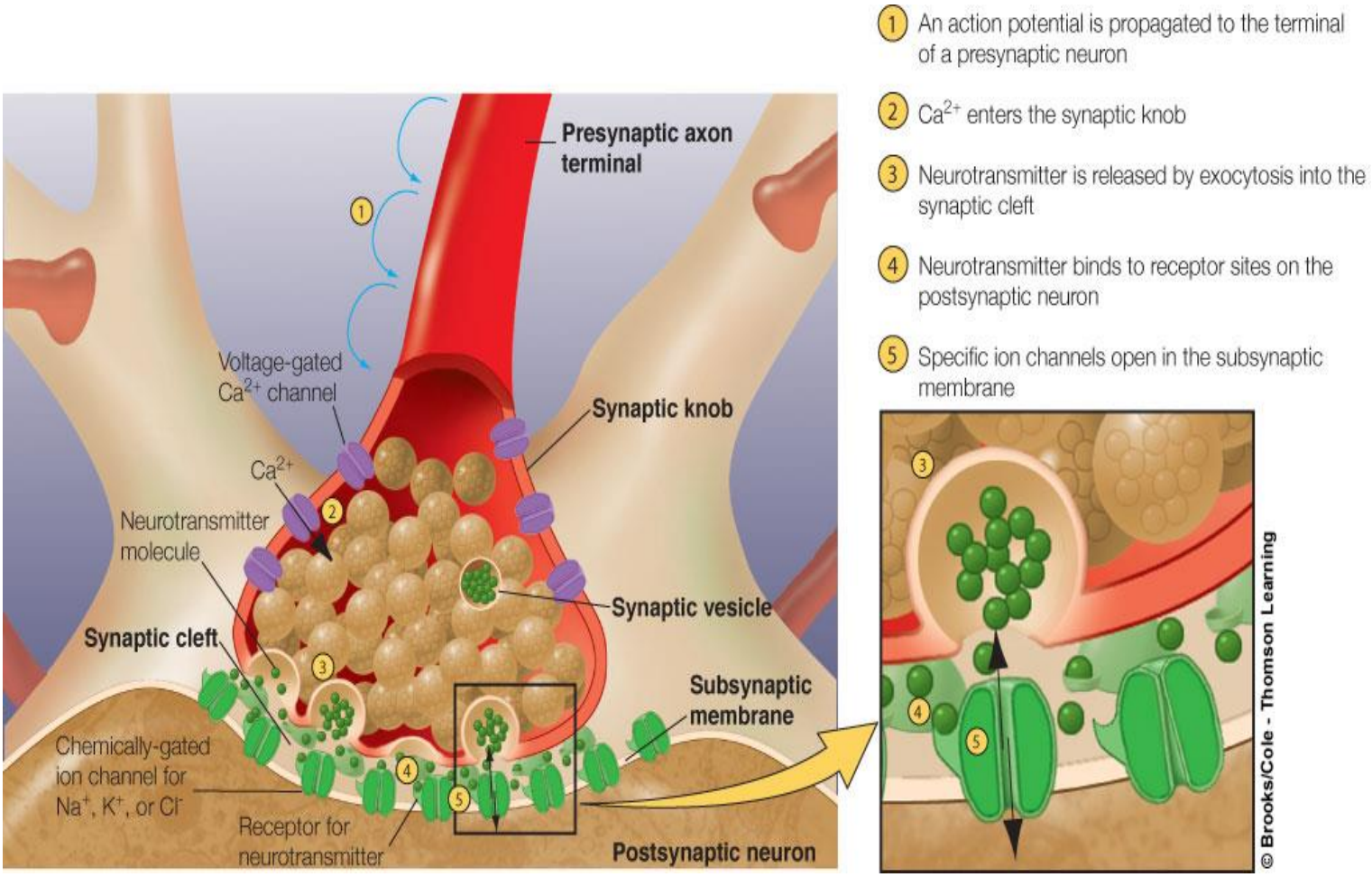




- A synapse is a junction (تقاطع) between two neurons.
- The neuron before synapse is called the **presynaptic neuron** (العصبون قبل التشابك)
- The neuron after synapse is called the **postsynaptic neuron** (العصبون بعد التشابك)
- So, a synapse is a junction between the output zone (axon terminals) of the presynaptic neuron, and the input zone (dendrites & cell body) of the postsynaptic neuron.
- The axon terminal of the presynaptic neuron is terminated as a swelling (إنتفاخ) and this swelling is known as synaptic knob.
- The membrane right below the synaptic knob is called a sub-synaptic membrane.
- The space between the synaptic knob & the sub-synaptic membrane is known as a synaptic cleft (الشق التشابكي).
- A synapse is only transmitted in one direction (from presynaptic to postsynaptic)
- In the synaptic knob there are vesicles that contain chemicals called **neurotransmitters** (نواقل عصبية)
  (There are many types of neurotransmitters, like Acetylcholine, norepinephrine, histamine, glycine, GABA)
- This means that a synapse is transmitted chemically (by neurotransmitters)

- The neurotransmitters from the synaptic knob bind to the receptors in the subsynaptic membrane, changing the permeability of the membrane. This changes resting membrane potential.

Synaptic transmission

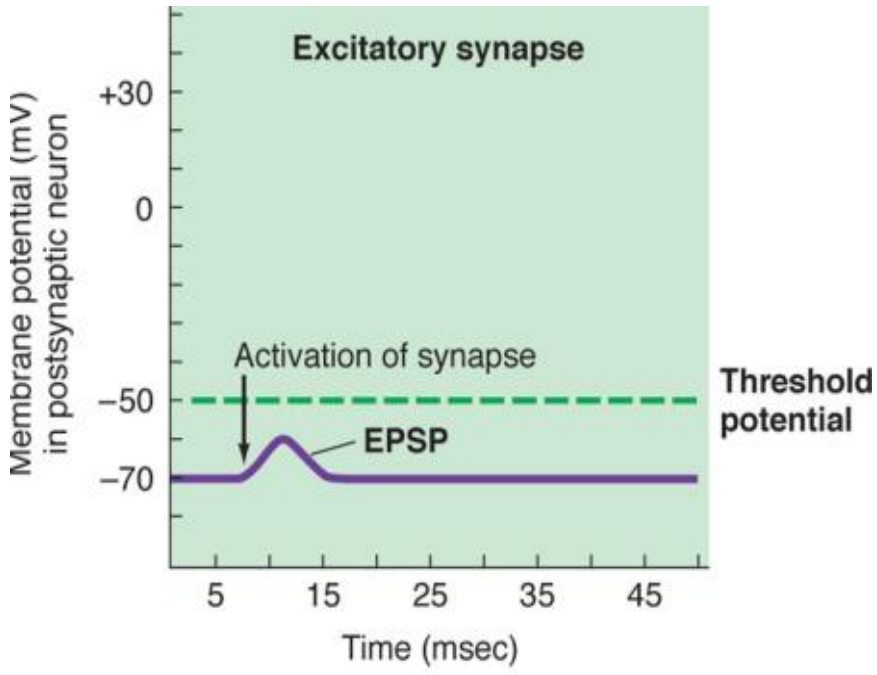


- Once action potential reaches the axon terminal of presynaptic neuron, it causes an influx of Calcium ions (Ca^{+2}) by opening the voltage-dependent calcium ion channels.
  Calcium ions move from the outside to the inside, as their concentration outside is higher than inside.
- Influx of Ca^{+2} ions causes the release (exocytosis) of neurotransmitters in the synaptic cleft. These neurotransmitters will bind to the receptors in the subsynaptic membrane, causing specific ion channels to open (and these channels are called "**chemical messenger-gated channels**")

- The changes in the postsynaptic neuron are either **excitatory (تحفيز)** or **inhibitory (تثبيط)**. Inhibitory means moving away from threshold potential (hyperpolarization), and excitatory means moving towards threshold potential (depolarization).

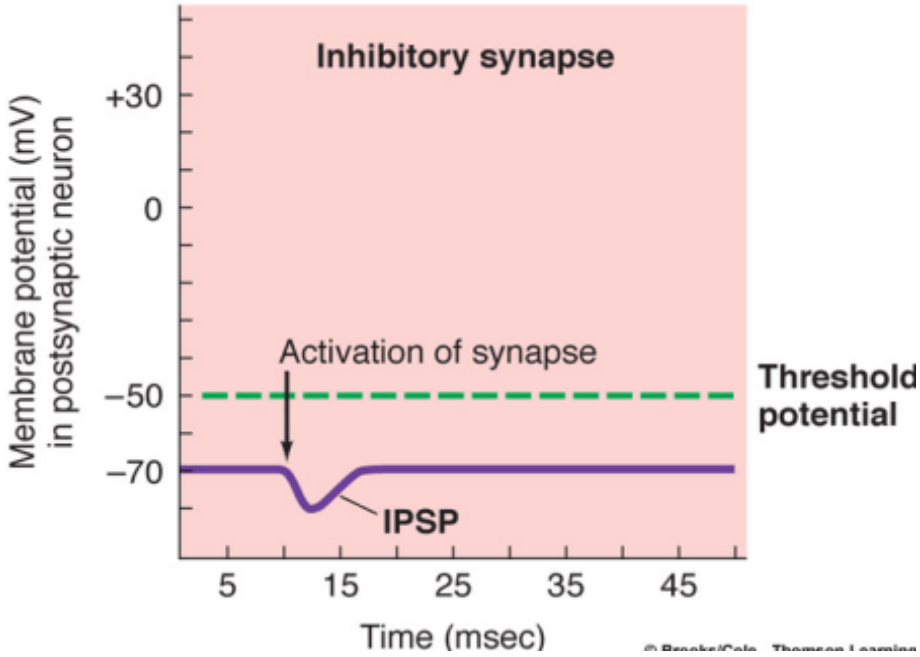
Types of synapses: a synapse is either excitatory or inhibitory

Excitatory synapse



- Binding of neurotransmitters to receptors in subsynaptic membrane causes opening of certain ion (Na^+ & K^+) channels in the membrane.
- Na^+ moves to the inside of the postsynaptic neuron & K^+ moves to the outside of the postsynaptic neuron. However, more Na^+ moves inside than K^+ outside due to the electrical gradient // the inside of the cell is negative, causing more Na^+ to move inside as the positive ions are attracted to the negativity of the membrane.
- This greater influx of Na+ causes a decrease in negativity of the cell membrane (depolarization) & this decrease in negativity is called **EPSP – Excitatory PostSynaptic Potential**
- Even though the negativity decreases (depolarizing), this is still not enough to reach threshold potential. Since it does not reach threshold potential, EPSP is a type of graded potential.

Inhibitory Synapse



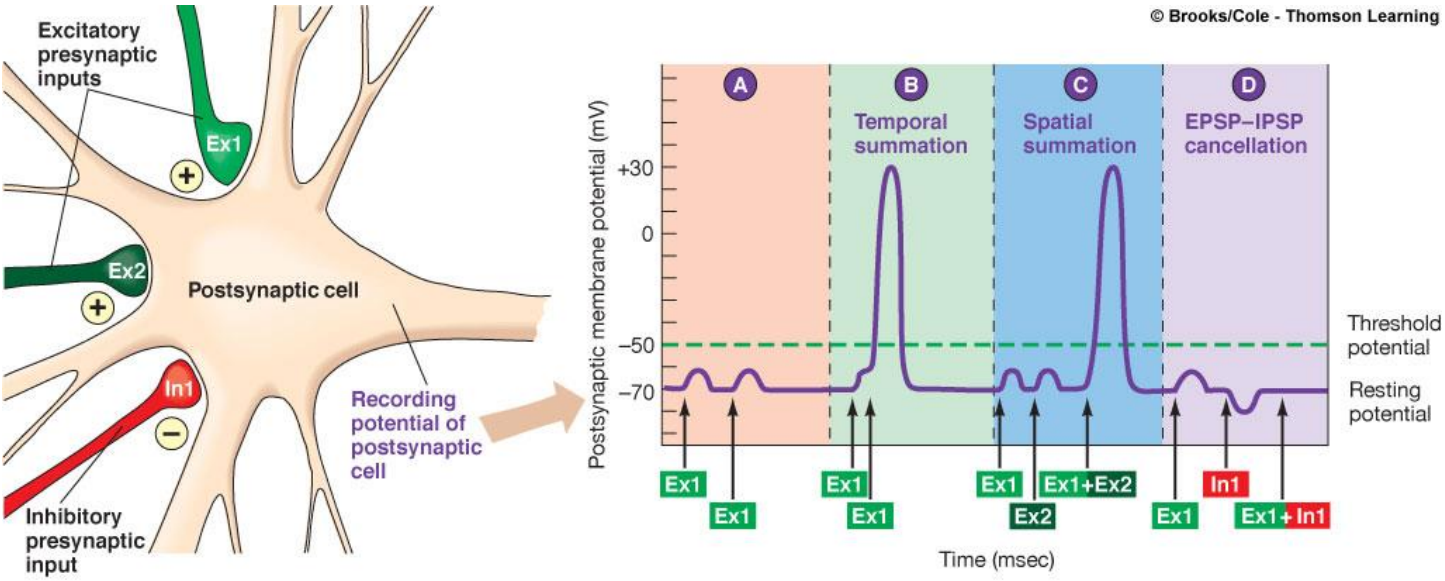
- Binding of neurotransmitters to receptors in the subsynaptic membrane causes opening of certain ion (K^+ & Cl^-). K^+ moves to the outside, and Cl^- moves to the inside – this causes a small increase in negativity (hyperpolarization).
- The increase in negativity moves the cell far from threshold potential, and this type of change is called **IPSP – Inhibitory PostSynaptic Potential**. It is also a type of graded potential, because like EPSP it does not reach threshold potential.

Synaptic delay

- The time taken for the neurotransmitters to be released to the synaptic cleft (and produce the effect of opening the ion channels) is known as **synaptic delay** & it takes about 0.5 to 1ms (millisecond)

What happens to neurotransmitters after they finish their effect? They are either

- Broken down by an enzyme // for example, the neurotransmitter "acetylcholine" is broken down by the enzyme acetylcholinesterase
- Actively moved by pumps to the inside of the synaptic knob, where they are the repackaged in order to be used again.



Panel A If an excitatory presynaptic input (Ex1) is stimulated a second time after the first EPSP in the postsynaptic cell has died off, a second EPSP of the same magnitude will occur.

Panel B If, however, Ex1 is stimulated a second time before the first EPSP has died off, the second EPSP will add onto, or sum with, the first EPSP, resulting in *temporal summation*, which may bring the postsynaptic cell to threshold.

Panel C The postsynaptic cell may also be brought to threshold by *spatial summation* of EPSPs that are initiated by simultaneous activation of two (Ex1 and Ex2) or more excitatory presynaptic inputs.

Panel D Simultaneous activation of an excitatory (Ex1) and inhibitory (In1) presynaptic input does not change the postsynaptic potential, because the resultant EPSP and IPSP cancel each other out.

- **GPSP – Grand PostSynaptic Potential** is the summation (مجموع) of all potentials (IPSP & EPSP). There are two types of summation:
    - **Temporal (زمني) Summation:** Achieving action potential [reaching threshold potential] by the summation of EPSPs occurring very close together in time because of <u>one presynaptic neuron firing</u>. In the picture above, if Ex1 fires (انطلاق) then Ex2 will fire & their sum results in temporal summation.
    - **Spatial (مكاني) Summation:** Achieving action potential [reaching threshold] by the summation of EPSPs coming from <u>many presynaptic inputs</u>.
    - Note: If IPSP & EPSP fire together, there will be <u>no</u> change in postsynaptic potential as the inhibitory potential & excitatory will cancel each other out.

- Note: Why does summation happen? Summation happens because the potential is graded – and graded potential does not have refractory period (this means that presynaptic neurons can fire several times)