1 Synapses and Synaptic Transmission

Sources

-Male slides
-Female slides
-Guyton & Hall Text book p1022

(تنبيه)

- سيتم إيضاح مصادر السلايدات في بداية كل محاضرة
- لن تكون هناك أسئلة نهاية كل محاضرة بل سيتم وضع أسئلة للمراجعة شاملة قبل كل اختبار بإذن الله
- ينصح بمتابعة محاضرات الدكتور نجيب لهذا البلوك

http://www.ksums.net/files/2nd/Archive/01%20CNS%20BLOCK/Female/Physiology/Dr.%20Najeeb%20lectures/

Objectives

(1) define synapses and show where they are located.
(2) describe the parts of a synapse , & what does each part contain .
(3) know how to classify synapses .
(4) define synaptic transmitters , give examples of excitatory & inhibitory ones ; explain how they are released
(5) explain ionic channels that mediate actions on synaptic receptors .
(6) explain : EPSP , IPSP , LTP .
(7) describe properties of synapses such as convergence , divergence , spatial & temporal sunmmation , subliminal fringe , types of inhibition and their physiological significance .
(8) expalin how acidosis and alkalosis can affect synaptic transmission

New Terms

Soma = cell body of neuron
EPSP = excitatory postsynaptic potential
IPSP = inhibitory postsynaptic potential
GABA = gamma-aminobutyric acid
RMP = Resting membrane potential

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Synapses

It is a n area of communication between 2 neurons

Types of Synapses

two major types of synapses:

(1) chemical synapse (2) electrical synapse

(3) Conjoint synapses (both chemical & electrical)

it founds in lateral vestibular nucleus.

Almost all the synapses used for signal transmission in CNS of the human being are chemical synapse

Electrical synapses are faster than the chemical because of gap junctions between the neurons

They are important in CNS in :

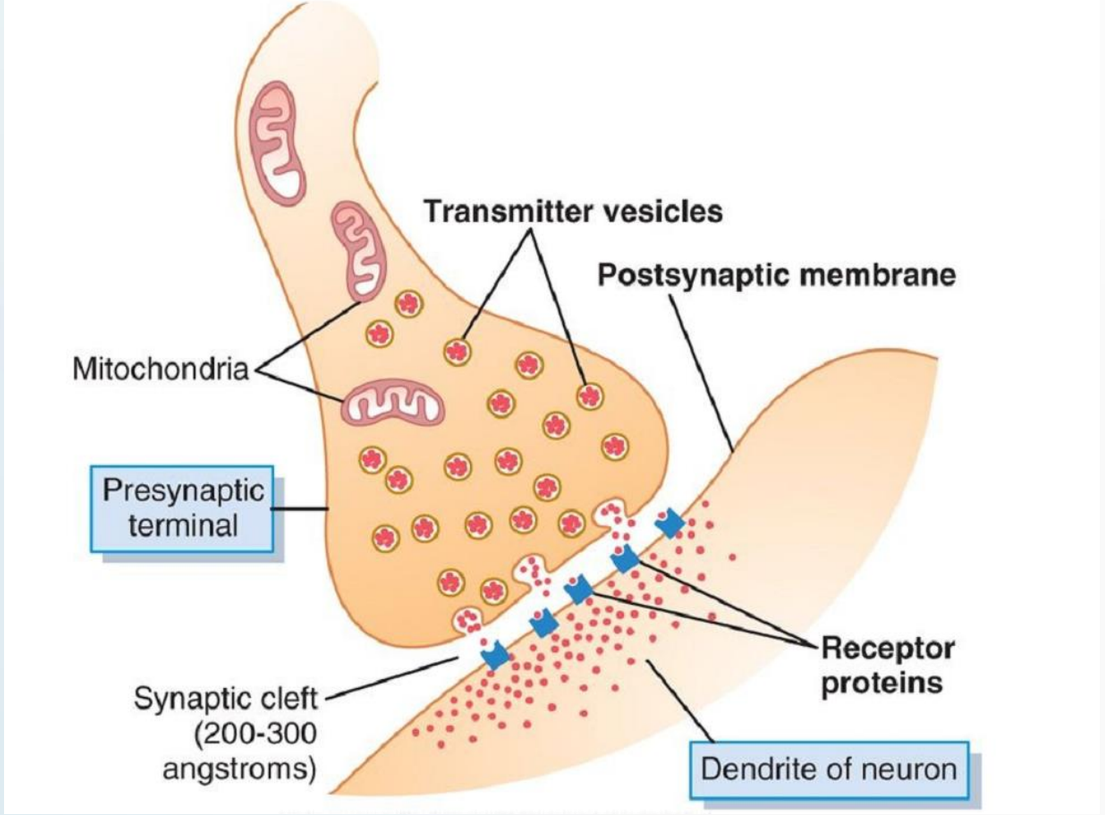
- Mental attention
- Emotions and memory
- Arousal from sleep
- Ion and water homeostasis

Components of Synapses

1- Synaptic knob of the pre-synaptic cell
(contains neurotransmitter)

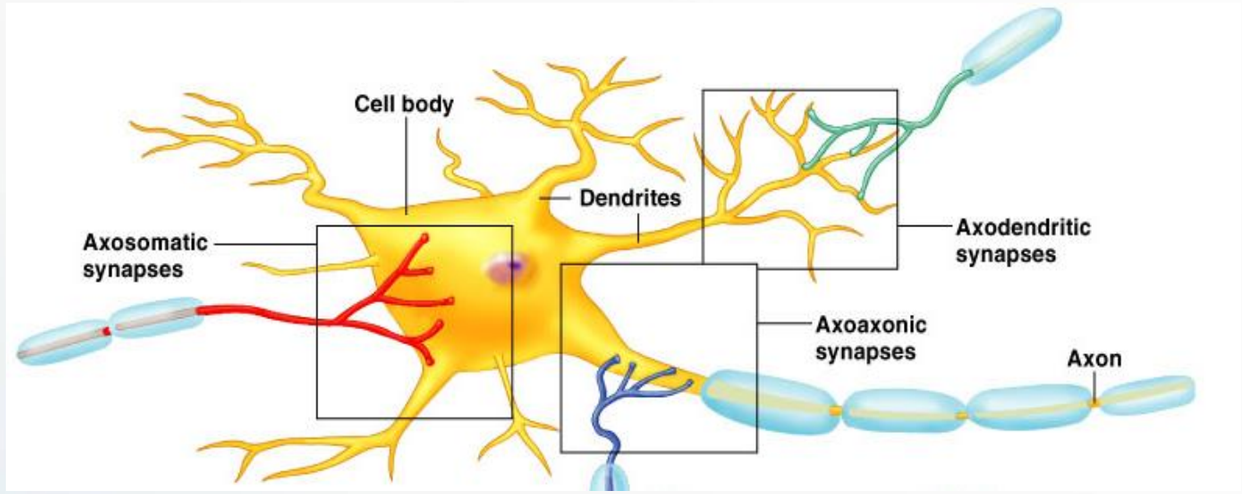
2- Synaptic cleft
(contains enzyme that destroys the transmitter)

3- Post-synaptic membrane
(contains receptors for the transmitter)



Types of Synapses (classification according to location)

1- Axodendritic (axon to dendrite)
2- Axosomatic (axon to soma)
3- Axoaxonic (axon to axon)
4- Dendrodendritic (dendrite to dendrite)
5- Dendrosomatic (dendrites to soma)



Neurotransmitter of Pre-synaptic terminals

A neurotransmitter is a **chemical substances** that is released by a neuron (called pre-synaptic cell) , crosses the synaptic cleft , and binds to a receptor located on the membrane (post-synaptic membrane) of another cell.

Types if Neurotransmitters

1- Excitatory neurotransmitter :

a transmitter that produces **excitatory postsynaptic potential** (EPSP) on the postsynaptic neuron .

2- Inhibitory neurotransmitter :

a transmitter that produces **inhibitory postsynaptic potential** (IPSP) on the postsynaptic neuron .

Differences between EPSP,IPSP and action potentials

	EPSP	IPSP	Action potentials
Type	Graded Potentials	Graded Potentials	Not Graded
Responses	Local “unpropagated”	Local “unpropagated”	Go to far distance Local “propagated”
Summation	Can be summated **(proportional to the strength of the stimulus)**	Can be summated **(proportional to the strength of the stimulus)**	Can not be summated **(All or none law)**
Function	makes the postsynaptic membrane more excitable **(Produce action potential)**	makes the postsynaptic membrane less excitable **(Inhibit action potentials)**	Transmit impulses to other neurons
Examples	**1-Acetylcholine** (Open sodium channels) **2- Glutamate** (Open calcium channels)	**1-GABA** (opens chloride or potassium channels) **2- Enkephalin** (Found in the GIT and spinal cord . It exerts analgesic activity, reducing the feeling of pain) **3- Glycine** (mainly in spinal cord)	

Long-term-potentiation (LTP)

Means the response will remains after action potential finished. For example, Glutamate in some animals is important for memorial functions

Mechanisms of Action potentials producing

1- Neuronal soma will be in RMP (-65 mV)

2- Excitatory Transmitters will release from presynaptic cell and binds to receptors of postsynaptic cell → Depolarization → Make it less negative to reach threshold level → Produce action potential at axon hillock (Which called trigger zone)

3- Inhibitory Transmitters will release from presynaptic cell and binds to receptors of postsynaptic cell → Hyperpolarization → Make it more negative → Be away from threshold level

Final Fate of Transmitter

It will be destroyed

1-Diffusion out of synaptic cleft into surrounding fluid

2- In case of Acetylcholine (Ach) destroyed by Acetylcholinesterase (Ach-esterase)

3- In case of Norepineohrine (Noradrenaline) destroyed by

- Monoamine Oxidase (MAO) intracellularly (more important)
- Catechol-O-Methyl Transferase (COMT) extracellularly .

Properties of Synapses & Synaptic Transmission

1- One Direct conduction

It allows signals to be directed from presynaptic cell to postsynaptic cell only. That allows the nervous system to perform its various functions of sensation, motor control, memory , and many others.

2- SYNAPTIC DELAY

- Is the minimum time required for transmission across the synapse. **It is 0.5 ms for transmission across one synapse.**
- Caused due to discharge transmitters from presynaptic cell, then pass synaptic cleft to the receptors in postsynaptic membrane.
- We can determine the number of synapses through equation :-

Overall time \ 0.5 = Number of synapses

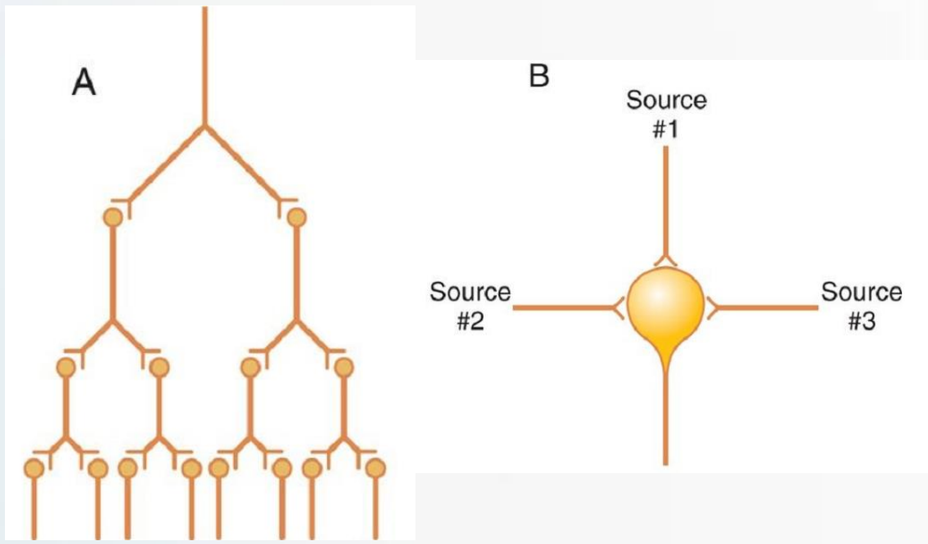
3- Divergence and Convergence

Divergence

Axons of pre-synaptic neurons divide into many branches that diverge to end on many post-synaptic neurons **to help to spread a single stimulus to a wide area of the spinal cord**

Convergence

When many pre-synaptic neurons converge on any single post-synaptic neuron **to help the process of spatial summation**



Properties of Synapses & Synaptic Transmission

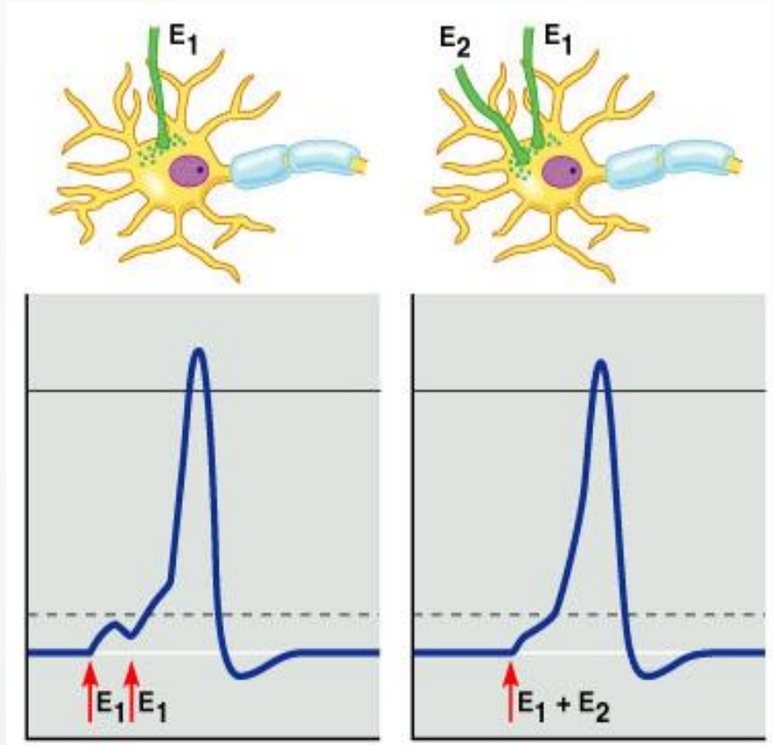
4- Summation

1- Spatial summation.

When EPSP occurs in **more than one** synaptic knob **at the same time.**

2- Temporal summation.

If EPSPs in a pre-synaptic knob(**even if from a single synaptic knob)** are **successively repeated** without significant delay so the effect of the previous stimulus is **summated to the next**.



(b) Temporal summation (c) Spatial summation

5- Fatigue

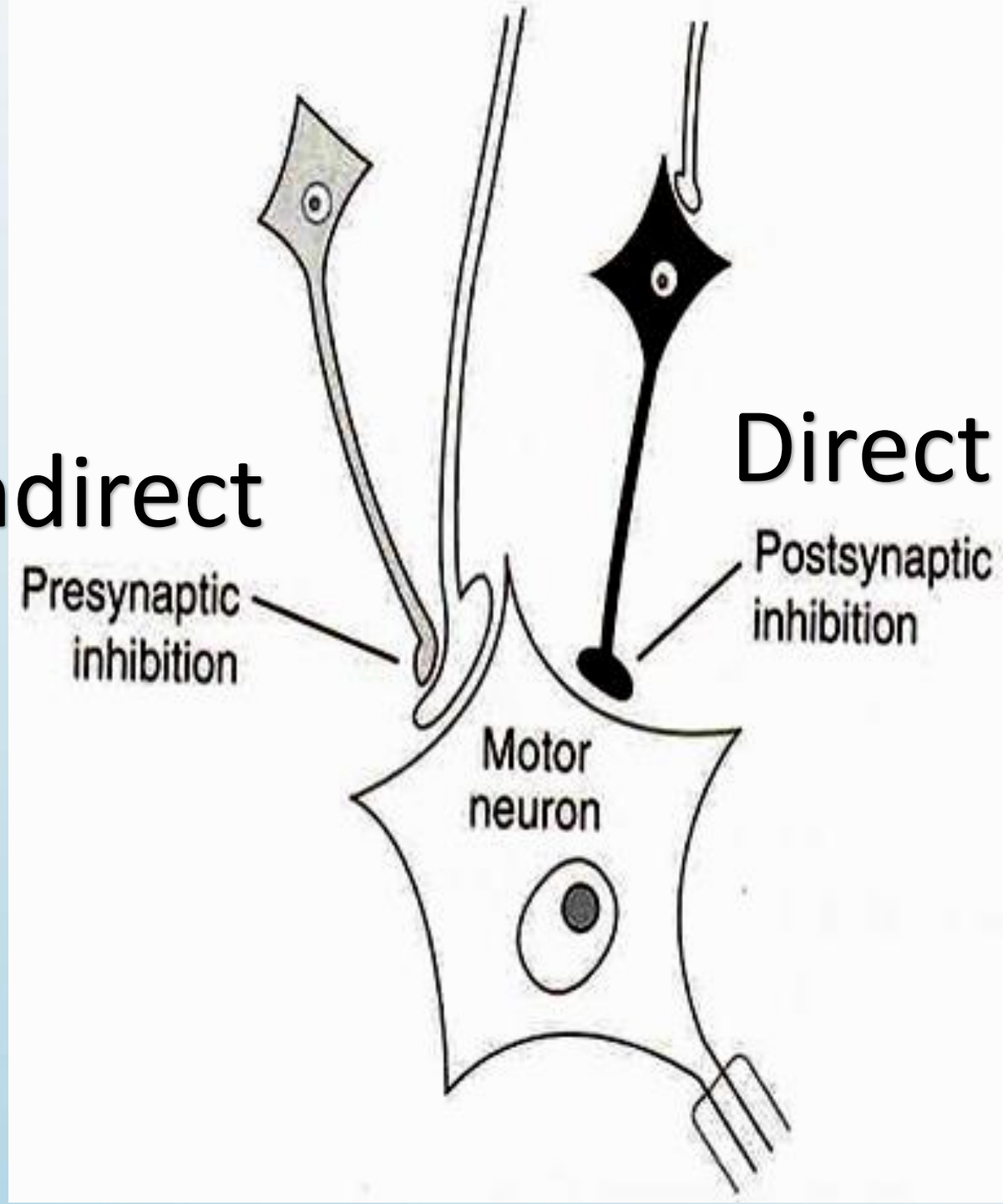
It is due to exhaustion of neurotransmitter.

If the pre synaptic neurons are continuously stimulated there may be an exhaustion of the neurotransmitter. Resulting in stoppage of synaptic transmission.

Properties of Synapses & Synaptic Transmission

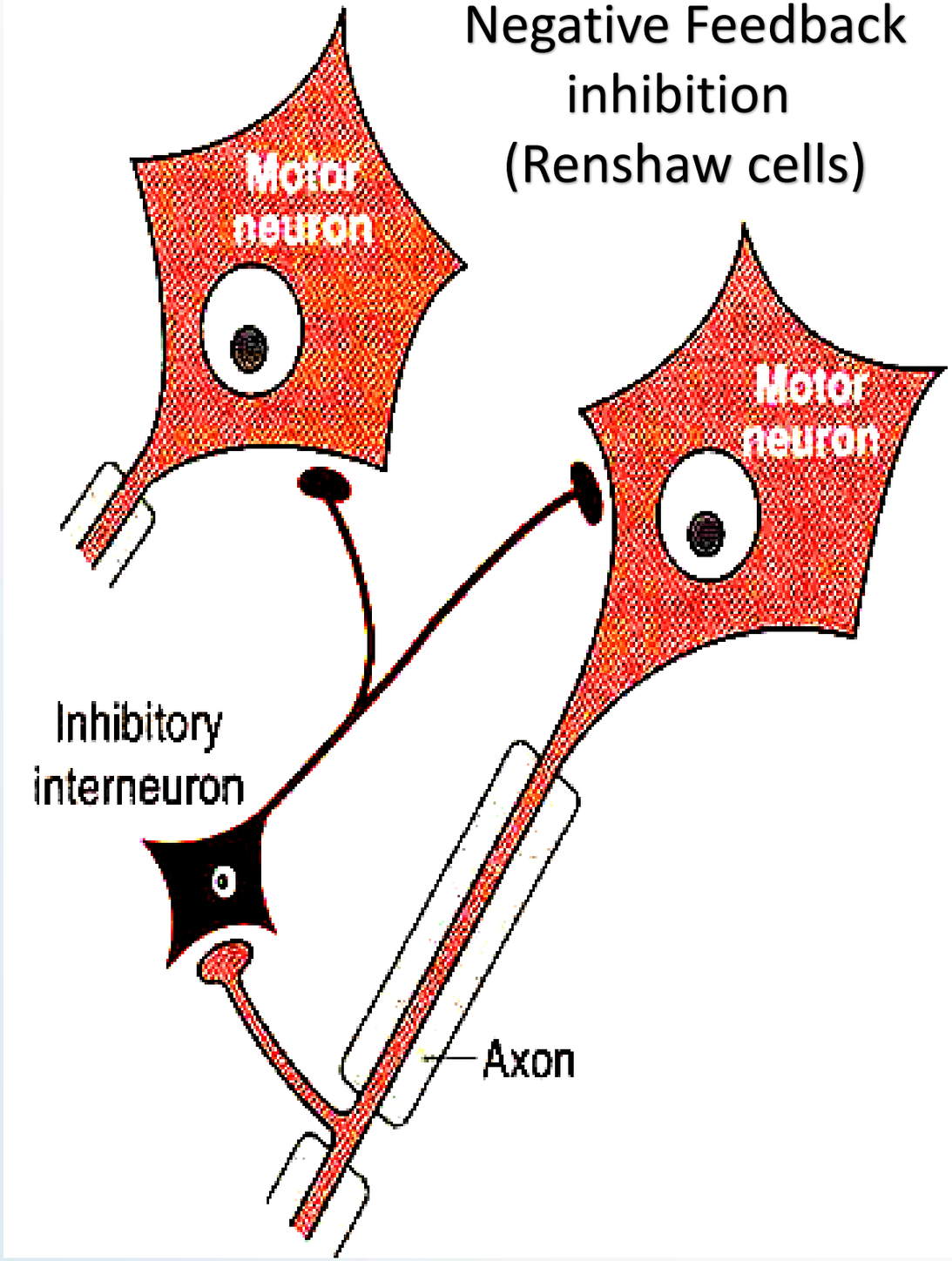
Direct inhibition	Indirect inhibition	Reciprocal Inhibition	Inhibitory interneuron (Renshaw cells)
Occurs when an inhibitory neuron (releasing inhibitory substance) acts on a post-synaptic neuron	This happens when an inhibitory synaptic knob lie directly on the termination of a pre-synaptic excitatory fiber. The inhibitory synaptic knob release a transmitter which inhibits the release of excitatory transmitter from the pre-synaptic fiber.	Inhibition of antagonist activity is initiated in the spindle in the agonist muscle. Impulses pass directly to the motor neurons supplying the same muscle and via branches to inhibitory interneurones that end on motor neurones of antagonist muscle.	1. Neurons may also inhibit themselves in a negative feedback fashion (Negative Feedback inhibition). 2. A spinal motoneuron gives a collateral that synapses Renshaw cell which is inhibitory interneuron , located in the anterior horn of spinal cord . 3. Then Renshaw cell , in turn , sends back axons that inhibit the spinal motoneuron . 4. These axons secrete an inhibitory transmitter that produces IPSPs on cell-bodies of motoneurons and inhibit them
Example : Glycine at the level of the spinal cord to **block pain impulses.**	Example: The transmitter released at the inhibitory knob is GABA. The inhibition is produced by Increasing Cl^- to postsynaptic receptors and lead to move K+ outward. e.g. occurs in dorsal horn.	Example: if you contract your elbow flexors (biceps) an impulses to this muscle has a branch which go to the inhibitor neuron for elbow extensors (triceps) and it will inhibited.	

Indirect



Direct

Negative Feedback inhibition (Renshaw cells)



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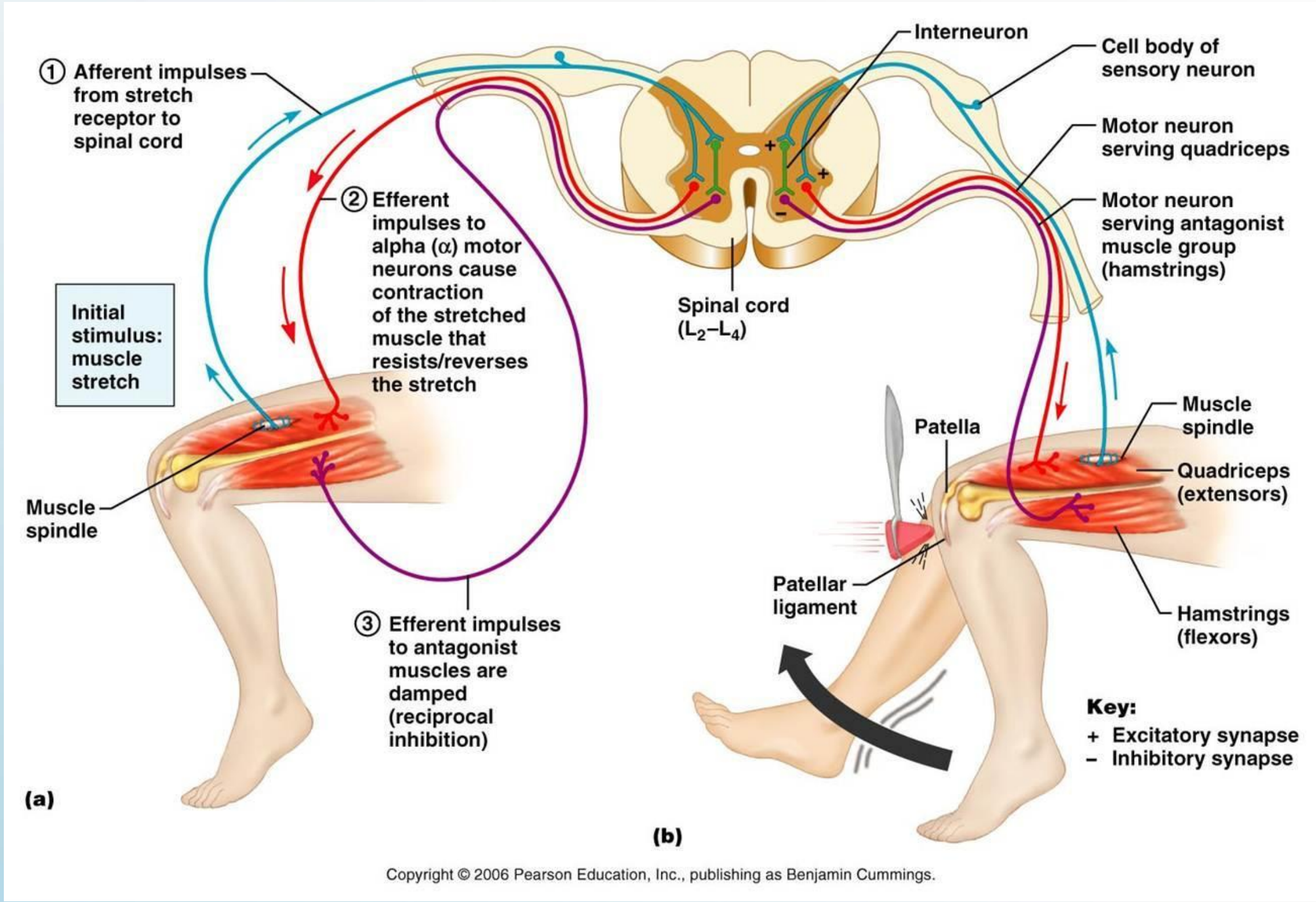
Reciprocal Inhibition



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Factors that Affect Neurotransmission

Alkalosis

alkalosis greatly increases neuronal excitability.

For instance, a rise in arterial blood pH from the 7.4 norm to 7.8 to 8.0 often causes cerebral epileptic seizures because of increased excitability of some or all of the cerebral neurons.

Acidosis

acidosis greatly depresses neuronal activity;.

A fall in pH from 7.4 to below 7.0 usually causes a comatose state.

Hypoxia

Depression of neurons

Drugs:

Many drugs are known to increase the excitability of neurons, and others are known to decrease excitability.

-Caffeine found in coffee, tea, increases neuronal excitability, by reducing the threshold for excitation of neurons.

Strychnine:

Is one of the best known of all agents that increase excitability of neurons.

It inhibits the action of some normally inhibitory transmitter substances, especially glycine in the spinal cord.

Therefore, the effects of the excitatory transmitters become overwhelming, and the neurons become so excited that they go into rapidly repetitive discharge, resulting in severe tonic muscle spasms.

Summary

What is synapse? And what its types ?
It is a n area of communication between 2 neurons and has three types chemical, electrical and conjoint

What are the components of synapses?
1- Synaptic knob (Nerve ending) 2- Synaptic cleft 3- Postsynaptic membrane

What is the most common type of synapses according to their location?
Axodendritic (axon to dendrite)

What are the types of neurotransmitters?
1-Excitatory neurotransmitter 2- inhibitory neurotransmitter

How graded potentials can reach to threshold and produce action potentials?
By Summation of local responses (proportional to the strength of the stimulus)

What does Long-term potentiation mean?
Means the response will remains after action potential finished.
For example, Glutamate in some animals is important for memorial functions

Where the action potential is produced?
Axon hillock (trigger zone)

How much is the minimum time required for transmission across the synapse?
0.5 ms per synapse

What are the Renshaw cells?
Inhibitory cells that transmit inhibitory signals to the surrounding motor neurons.

What are the factors that increase neuronal excitability?
Alkalosis, Caffeine and Strychnine

What are the factors the decrease neuronal excitability?
Acidosis and Hypoxia

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