بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

HISTOLOGY

وَلَقَدْ خَلَقْنَا الْإِنسَانَ وَنَعْلَمُ مَا تُوَسْوِسُ بِهِ نَفْسُهُ ۖ وَنَحْنُ أَقْرَبُ إِلَيْهِ مِنْ حَبْلِ الْوَرِيدِ

Final | Lecture 6

Nervous Tissue Pt.1

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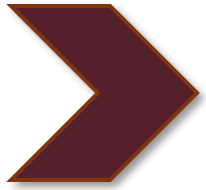
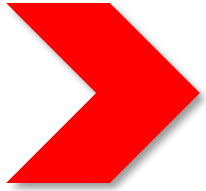
Color coding used in the modified:

Black: the original slides



Maroon: the doctor's explanation/words

Gray: additional information and explanation



Red: important information

NERVOUS TISSUE

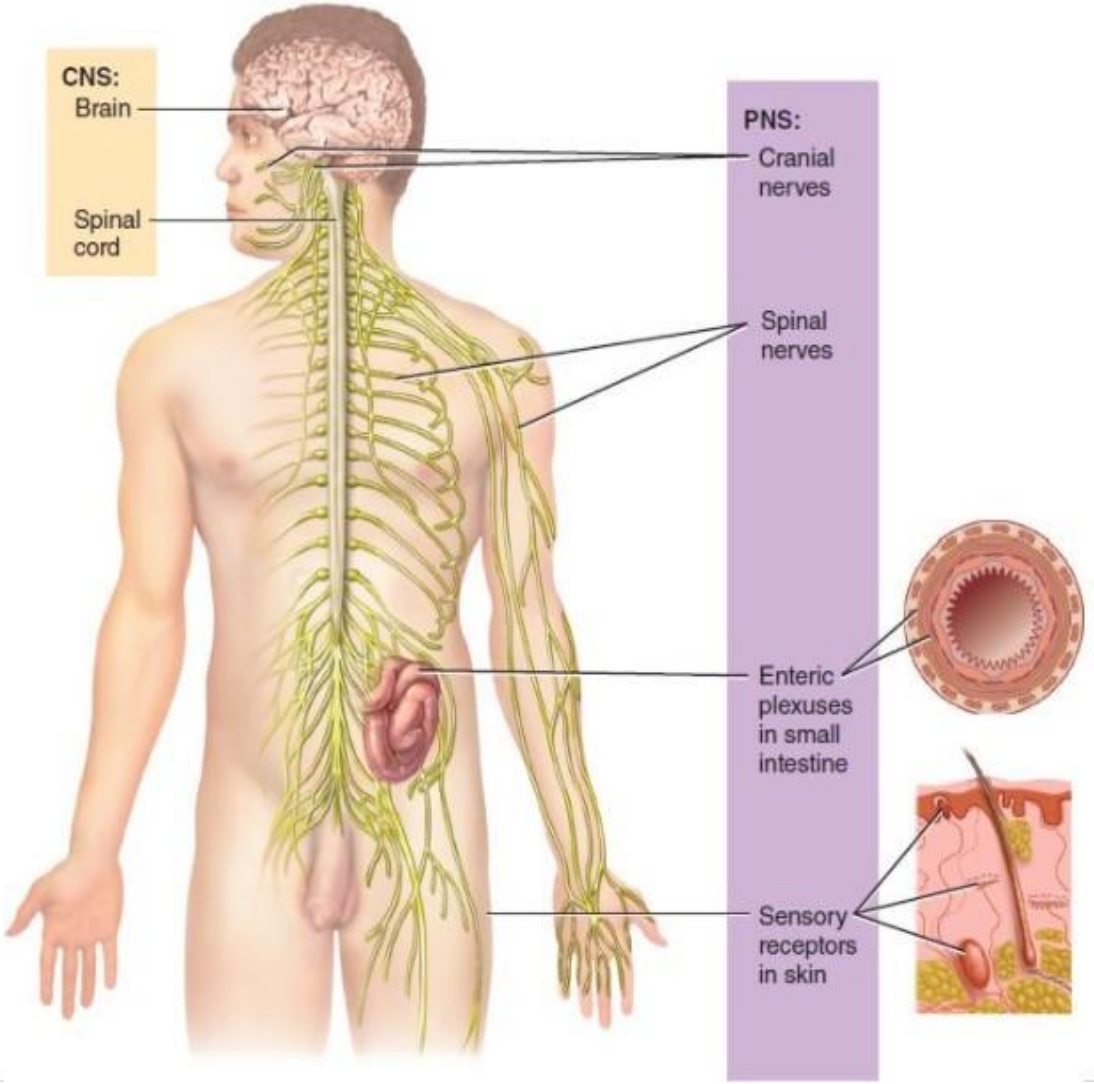
JANQUEIRA'S BASIC HISTOLOY

STRUCTURE AND ORGANIZATION

1. **Central nervous system** (CNS): brain and spinal cord
2. **Peripheral nervous system** (PNS): cranial, spinal, and Ganglia: small aggregates of nerve cells outside the CNS.

Attached to the brain

Attached to the spinal cord



Cells in both central and peripheral:

- Neurons: have numerous long processes, responsible for neural synapses
- Glial cells: short processes: support and protect neurons.

and nourish the neurons

Classification of Neuroglia
Since the nervous system is divided into:
-Central Nervous System (CNS)
-Peripheral Nervous System (PNS)
Neuroglia are also classified accordingly:
In the **CNS**, there are **four types**
In the **PNS**, there are **two types**

The nervous system is functionally divided into three main parts: **Sensory (afferent) part ,motor (efferent) part ,integration part**

Nerves can be classified according to their function into:
Sensory nerves: carry only sensory information.
Motor nerves: carry only motor commands.
Mixed nerves: carry both sensory and motor fibers.

Cranial nerves can be:
-Pure sensory nerves: they carry only sensory information. Examples include: **Optic nerve (CN II):** vision , **vestibulocochlear nerve (CN VIII):** hearing and balance
-Pure motor nerves: they carry only motor commands to muscles. Example: **Abducens nerve (CN VI):** supplies the **lateral rectus muscle of the eye**
-Mixed nerves: carry both sensory and motor fibers.

Spinal nerves are **all mixed nerves**, meaning: They carry **sensory fibers ,** they carry **motor fibers,** they also carry **autonomic fibers**

When we take a section from the **brain**, **spinal cord**, or **nerves**, their microscopic appearance is different from other tissues we studied.
In **epithelium**, the cells are **similar and tightly adherent to each other**, forming layers that **cover surfaces or line cavities** , in **connective tissue**, the cells are **scattered and surrounded by an extracellular matrix**. However, in **nervous tissue**, the organization is different.

In the nervous system, there are **two main types of cells**:
Neurons (nerve cells): These are the **main functional cells ,** they are responsible for: receiving stimuli ,initiating signals and conducting (transmitting) impulses.
Neurons can be classified into **sensory neurons, motor neurons, and interneurons**.
However, neurons alone are **not sufficient ,** we need something to support them.

(Glial cells): These are **supporting cells** that: provide structural support , and protect neurons.
In the **central nervous system (CNS)**, neuroglia perform a **supportive role similar to connective tissue**.
In other words, you **do not have typical connective tissue within the CNS parenchyma**, because it is not compatible with neural function. Instead, specialized supporting cells (neuroglia) are present.
There are also **specialized cells that provide additional functions**, which you will study later in more detail.

SENSORY AND MOTOR

Functionally the nervous system consists of:

Anything moving towards the CNS

1. Sensory division (afferent)

sensations that I'm aware of

A. Somatic – sensory input perceived consciously (eg, from eyes ears, skin, musculoskeletal structures)

B. Visceral – sensory input not perceived consciously (eg, from Internal organs and cardiovascular structures)

Anything moving away from CNS

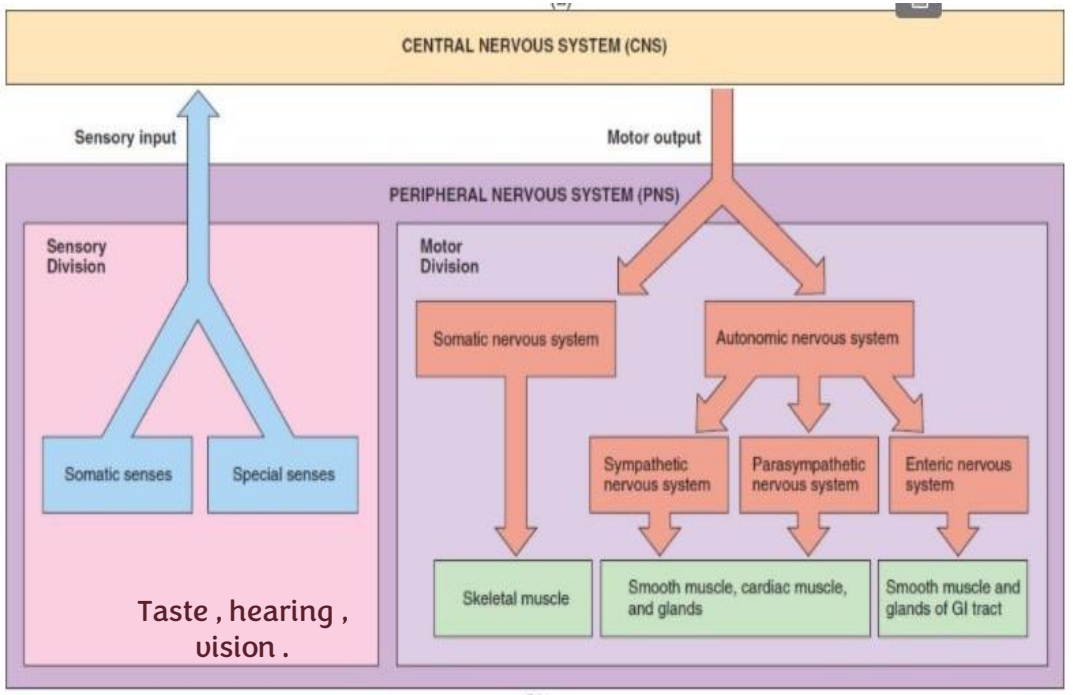
2. Motor division (efferent)

A. Somatic – motor output controlled consciously or voluntarily (eg, by skeletal musde effectors)

This involves things that I can control voluntarily. For example, when I move a joint, the muscles in that area contract in an **intended and voluntary** way. I choose to do this movement.This is called **somatic motor commands**.

B. Autonomic – motor output not controlled consciously (eg, by heart or gland effectors)

Visceral sensations are not consciously perceived in detail. For example, we do not know the exact degree of contraction of the smooth muscles in the stomach. The body regulates this automatically in the background.
This function is carried out by the **autonomic nervous system**, which works on its own without conscious control. It is responsible for handling these visceral sensations.
The autonomic nervous system carries visceral sensations and delivers them to their specialized areas. If there is a problem, it sends orders and performs correction automatically by itself.
Normally, this process happens in the background. However, if a problem occurs, symptoms may appear later.



On the other hand, there are structures that I **do not control voluntarily**, such as: smooth muscles , cardiac muscle , glands
I cannot control the contraction of my heart or decide to increase its rate. This happens automatically in the background. It is like a "background controller" that I cannot control by my will.
These are considered **visceral (autonomic)**.
Glands also require **motor autonomic commands** to increase their secretions.
For example, while I am speaking, the amount of saliva increases, and I cannot consciously control its amount.

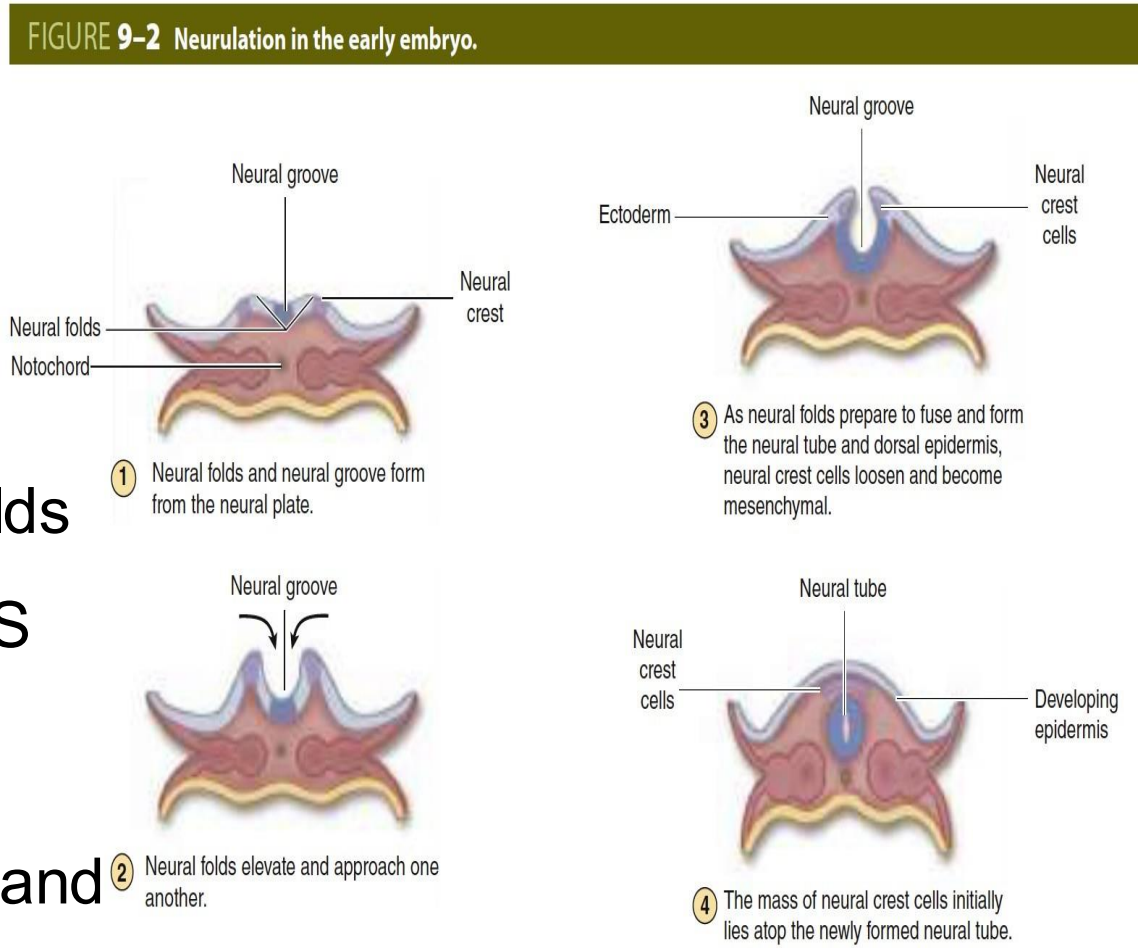
DEVELOPMENT OF NERVE TISSUE

Epithelium

Ectoderm : nervous tissue
Mesoderm : connective tissue, muscles
Endoderm

Embryology

- Nervous tissue develops from the ectoderm.
- Beginning in the third week of development.
- Ectoderm--thickening--epithelial neural plate---folds and forms the **Neural tube**– gives rise to entire CNS (neurons and most glial cells).
- **Neural crest**--migrate--- gives rise to cells of PNS and several other tissues. & a part of the neuralgia cells



NEURONS

- The functional unit in both the CNS and PNS

Parts of a neuron:

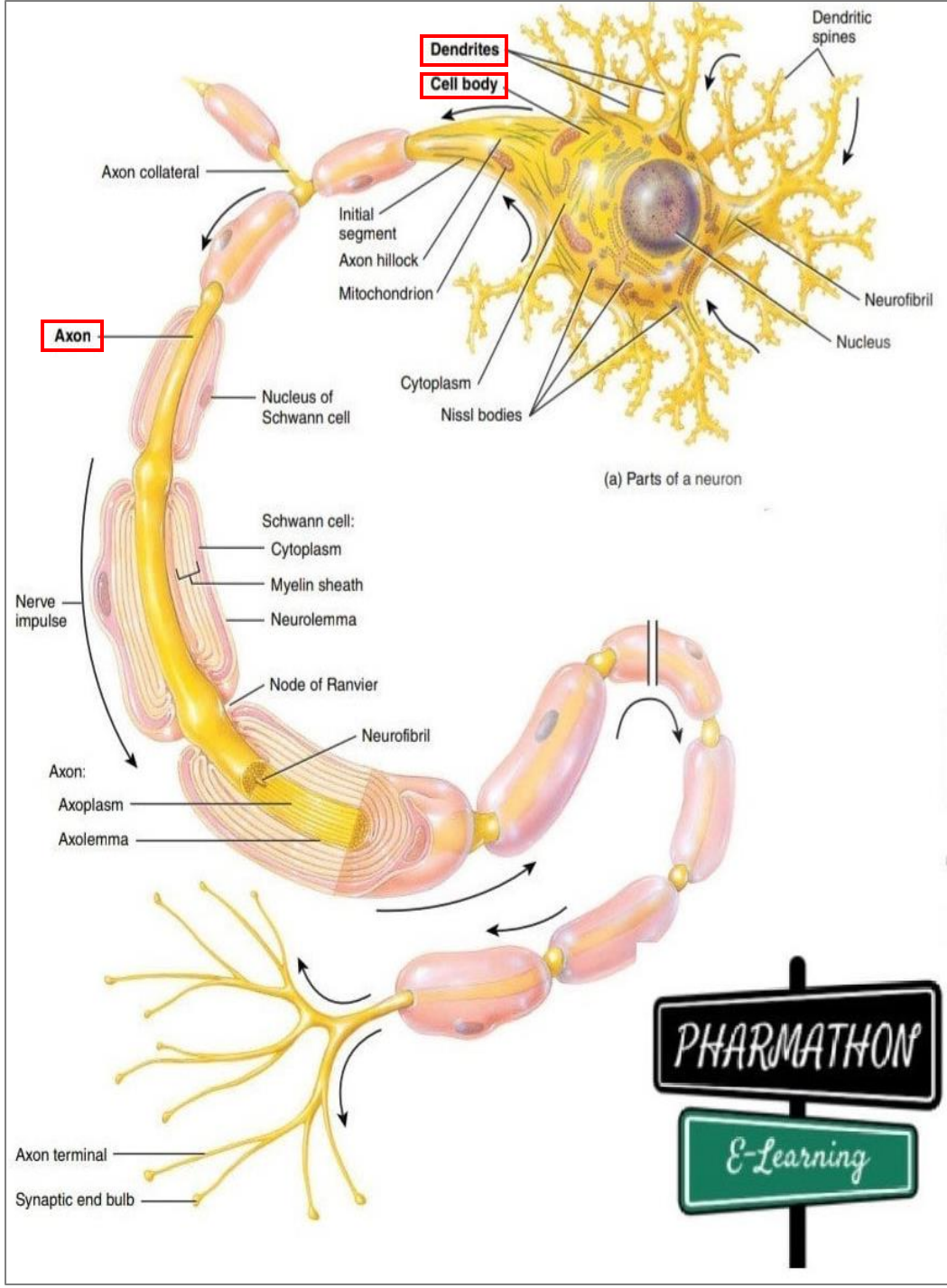
1. Cell body (perikaryon or soma)

If we lose a part of the axon, this doesn't mean that we've lost the whole neuron, because the soma will eventually regenerate & initiate the regrowth the lost part of the axon

- Contains the nucleus and most of the cell's organelles
- The synthetic or trophic center for the entire neuron.

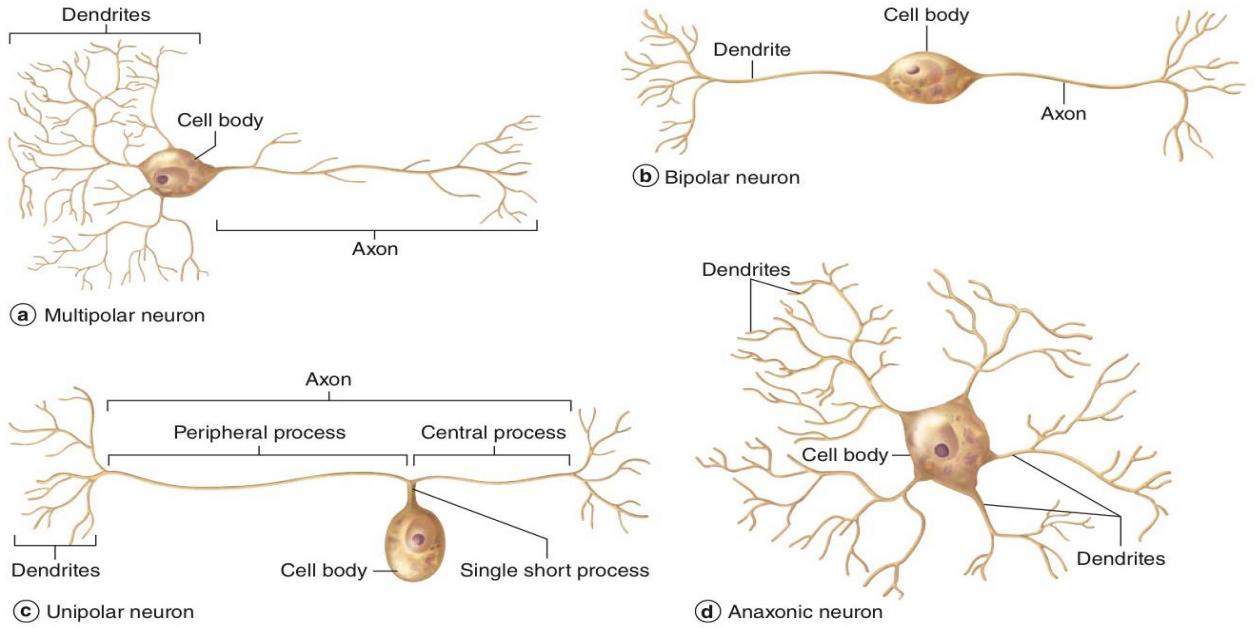
2. Dendrites: (Usually go through extensive **arborization** which means **branching**) numerous elongated processes extending from the perikaryon and specialized to receive stimuli from other neurons (input) .

3. Axon: **Neural cells USUALLY have an axon (one or none)** which is a single long process ending at synapses specialized to generate and conduct nerve impulses to other cells (nerve, musde, and gland cells) (output) .



4-types NEURON CLASSIFICATION-STRUCTURALLY Each structure has a function.

1. Multipolar neurons: one axon and two or more dendrites, most common. functional-wise: found in motor neurons and interneurons.
2. Bipolar neurons: one dendrite and one axon, sensory neurons of the retina, the olfactory epithelium, and the inner ear. In the retina there are photoreceptors (rods and cones) and at their ends there is a dendrite that will carry the action potential that was generated in the photoreceptors to the cell body of the neuron. And then the signal will be transmitted to another neuron because there is not a one neuron order "sensation is not carried by just a single neuron" there are multiple neurons, but the first one is bipolar.



Shown are the four main types of neurons, with short descriptions. **(a)** Most neurons, including all motor neurons and CNS interneurons, are **multipolar**. **(b)** **Bipolar neurons** include sensory neurons of the retina, olfactory mucosa, and inner ear. **(c)** All other sensory neurons are **unipolar** or **pseudounipolar**. **(d)** **Anaxonic** neurons of the CNS lack true axons and do not produce action potentials, but regulate local electrical changes of adjacent neurons.

3. Unipolar or pseudounipolar neurons: single process that bifurcates (divides) close to the perikaryon; longer branch extending to a peripheral ending and the other toward the CNS; all other sensory neurons. One process that is shortly divided into two processes.

Single short process → Peripheral / central

4. Anaxonic neurons: many dendrites but no true axon, do not produce action potentials, but regulate electrical changes of adjacent CNS neurons.

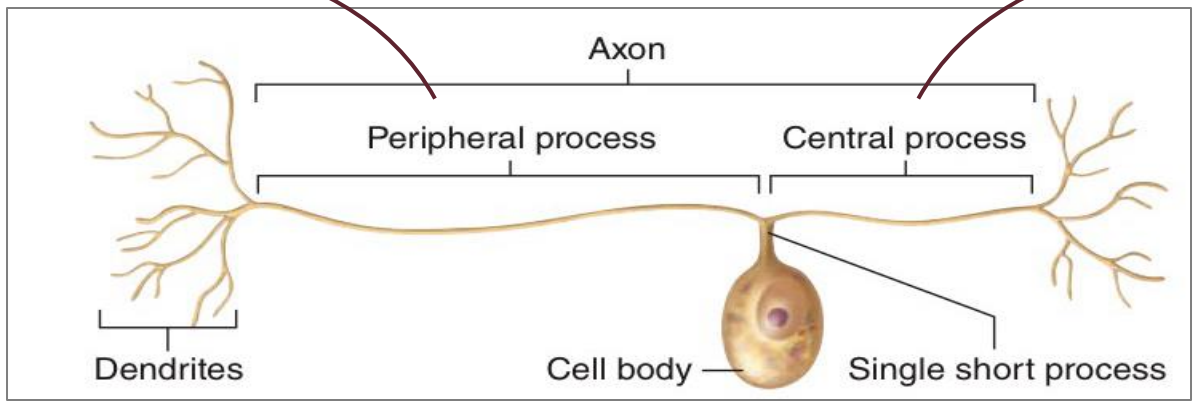
Where did the peripheral and central processes come from?? (in the unipolar neurons)

Recall the DORSAL ROOT GANGLIA (cell bodies of sensory unipolar neurons).
When a sensation happens, Afferent fibers in pain receptors transmit the sensation through the nerve (peripheral process).
A spinal nerve is formed by the joining of two separate roots: the dorsal root and the ventral root.
The dorsal root carries sensory information toward the spinal cord, while the ventral root carries motor commands away from the spinal cord.

Before entering the spinal cord, the sensory neuron is a pseudounipolar neuron with two processes. One is called the peripheral process, because it lies outside the central nervous system and carries signals from the body toward the neuron's cell body in the dorsal root ganglion.

The other extension is called the central process, because it enters the central nervous system (the spinal cord).
So, sensation is not carried by a single neuron that "finishes everything," but rather by a chain of connected neurons that relay the signal step by step until it reaches the sensory areas of the brain and this neuron is the first one.

Outside the spinal cord (PNS)



Will enter the spinal cord (CNS)

In anaxonic neurons:

A typical axon is a single long extension of the neuron that begins at the axon hillock and continues through the initial segment, with a uniform length and diameter.

An anaxonic neuron doesn't have a process with these characteristics so one of the processes must act as an axon but we can't tell which one is it.

They used to think that anaxonic neuron is a neuroglial. But the anxonic neuron helps other neurons in the regulation of action potential but it doesn't initiate it or transmit it. but it's still a neuron based on the function as the neuroglial can't do this.

NEURON CLASSIFICATION-FUNCTIONALLY

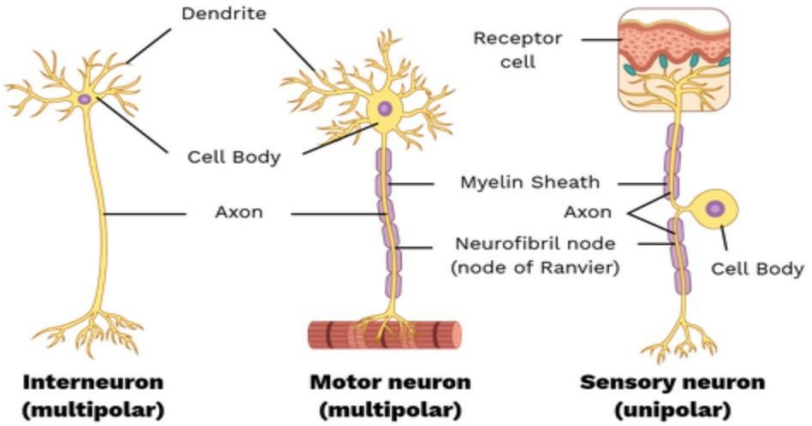
- **Sensory** neurons (afferent):

1. Sensory input perceived consciously (eyes ears, skin, musculoskeletal structures).
2. Visceral – sensory input NOT perceived consciously (Internal organs and cardiovascular structures).

- **Motor** neurons(efferent): sending impulses to effector organs muscle fibers and glands.

3. Somatic motor nerves–- voluntary -- skeletal muscle.

4. Autonomic motor nerves– involuntary or unconscious–- glands, cardiac musde, and smooth muscle.

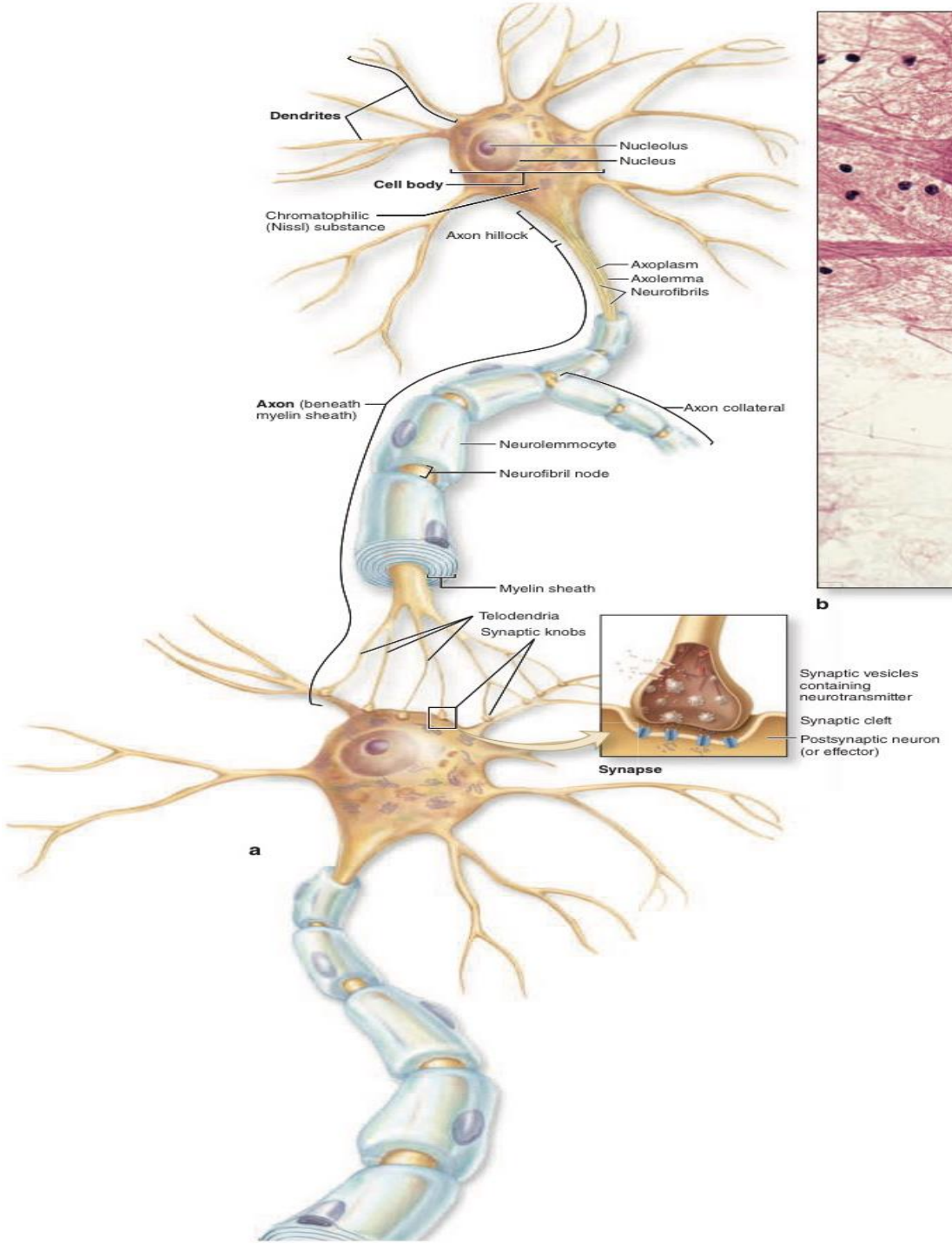


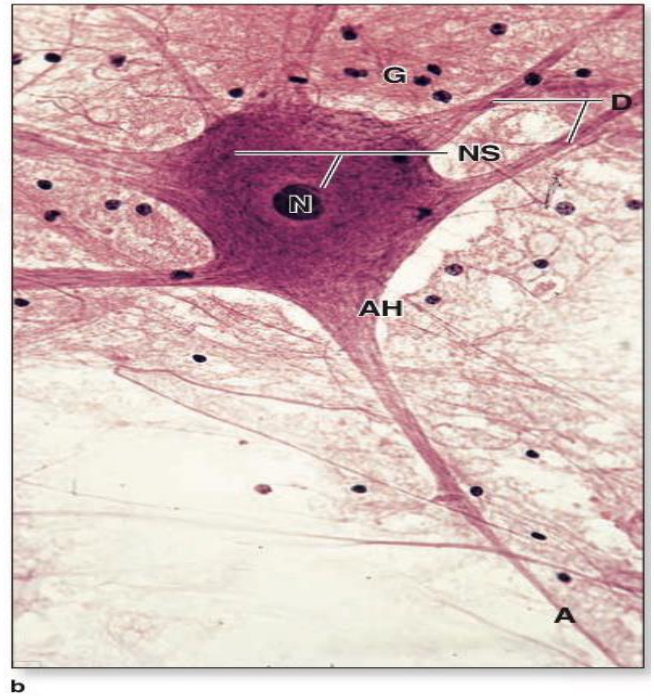
Interneurons interlock: (complex functional networks)
1)the motor with the sensory
2)motors with each other
3)different hemispheres
4)within the hemispheres

- **Interneurons** establish relationships among other neurons, forming complex functional networks or circuits in the CNS. Interneurons are either multipolar or anaxonic and comprise 99% of all neurons in adults.

Complexity of us humans comes from the interneurons and their number.
The size of your brain comes from the number of interneurons you have.

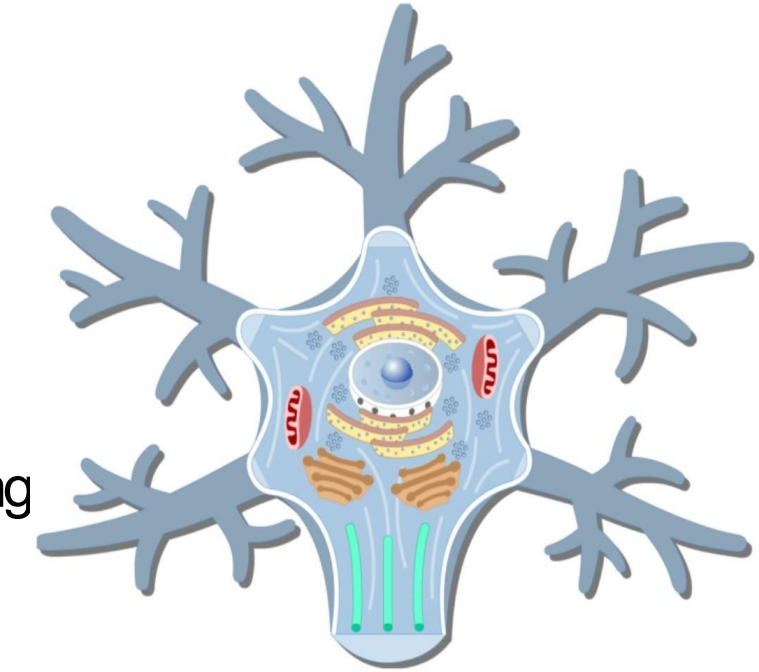
NEURON PARTS

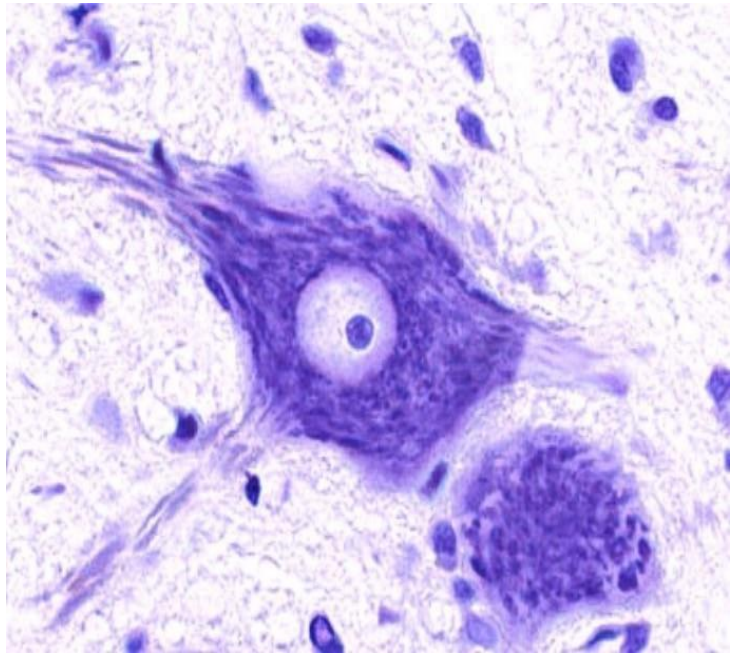




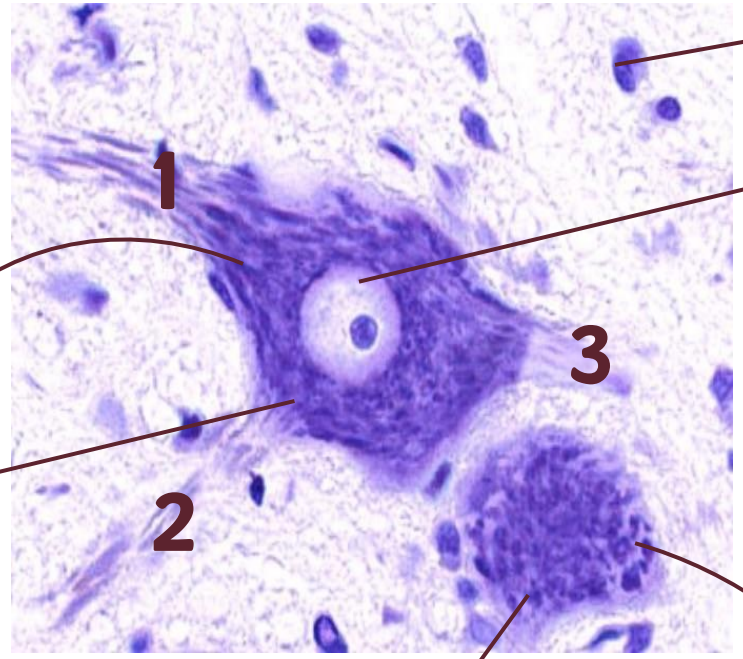
CELL BODY (PERIKARYON OR SOMA)

- Contains the nucleus and surrounding cytoplasm.
- It acts as a trophic center.
- Most are in contact with a great number of nerve endings conveying excitatory or inhibitory stimuli.
- Large, euchromatic nucleus with a prominent nucleolus (intense synthetic activity)





- **Nissl bodies** NB (Nissl substance, chromatophilic substance): numerous free polyribosomes and highly developed RER. Produce neurotransmitters
- The amount of NB varies with the type and functional state of the neuron–-abundant in large motor neurons.
- The Golgi apparatus is located only in the cell body.
- Mitochondria can be found throughout the cell and are usually abundant in the axon terminals.



Neuroglial

nucleus

Neuron (1)

Cell body/ soma/ perikaryon

Neuron (2)
Its nucleus has gone with sectioning.

These clumps are called Nissl bodies

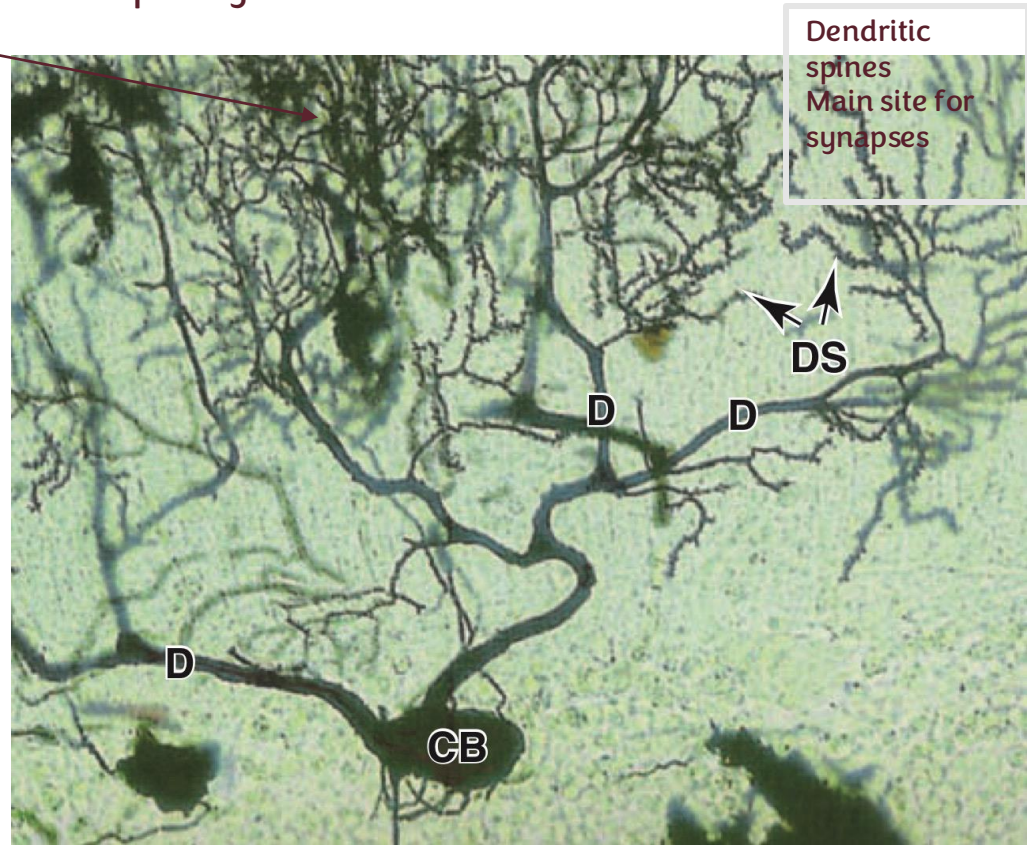
-Multipolar neuron
-Neurons are humongous (an eye looking at you)
-(1) and (2) are dendrites.(they have nissl bodies)
-(3) is an axon followed by an initial segment.(doesn't have nissl bodies)

DENDRITES

- **Short**, small processes emerging and branching off the soma.
- Covered with **many synapses.** Because the massages reached the cell body or dendrites or axons – in unique type -
- Are the principal signal reception and processing sites on neurons.
- The large number and extensive arborization--- signals from many other nerve cells.
- Dendrites become much thinner as they branch.
- **Dendritic spines:** dynamic membrane protrusions along the dendritic branches

Massive area contains many dendrites , most of them receive synapses. So as much you see , it shows the complexity of the function of this neurons .

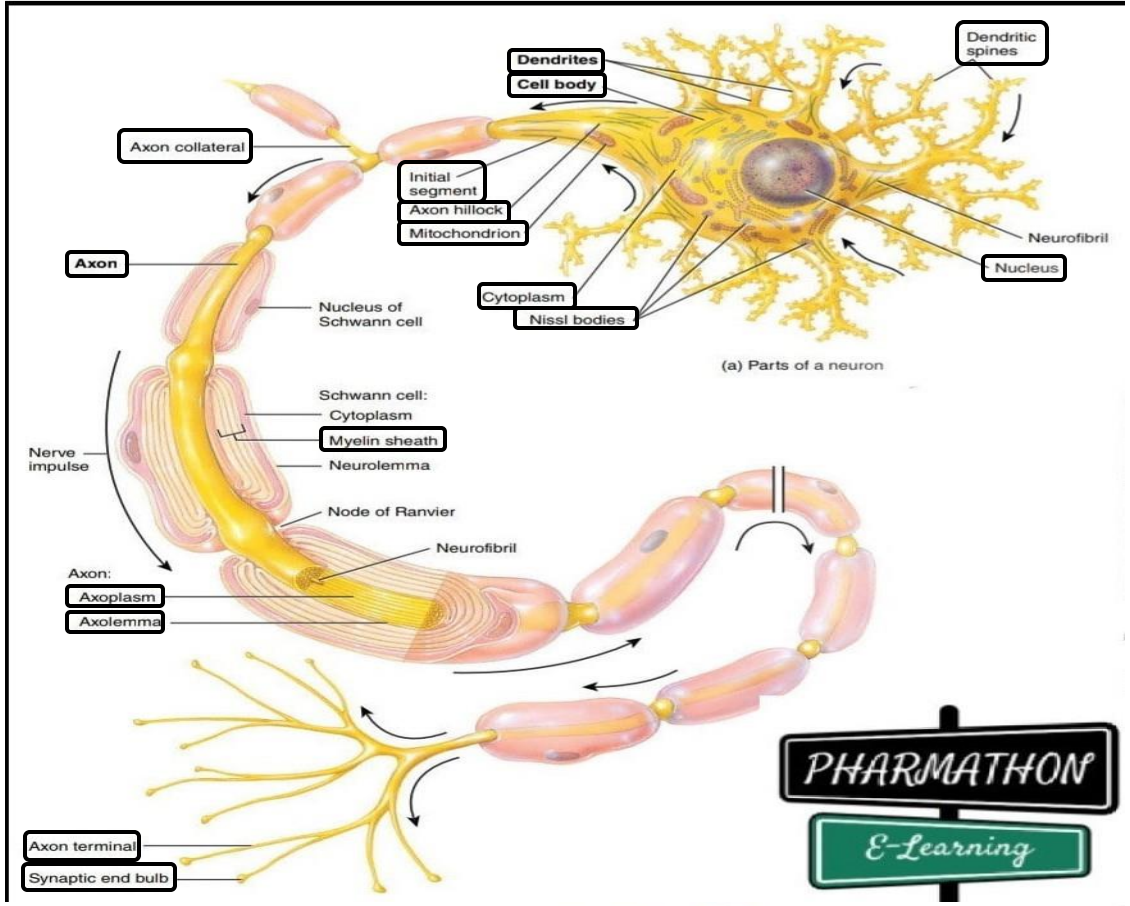
Multipolar neurons

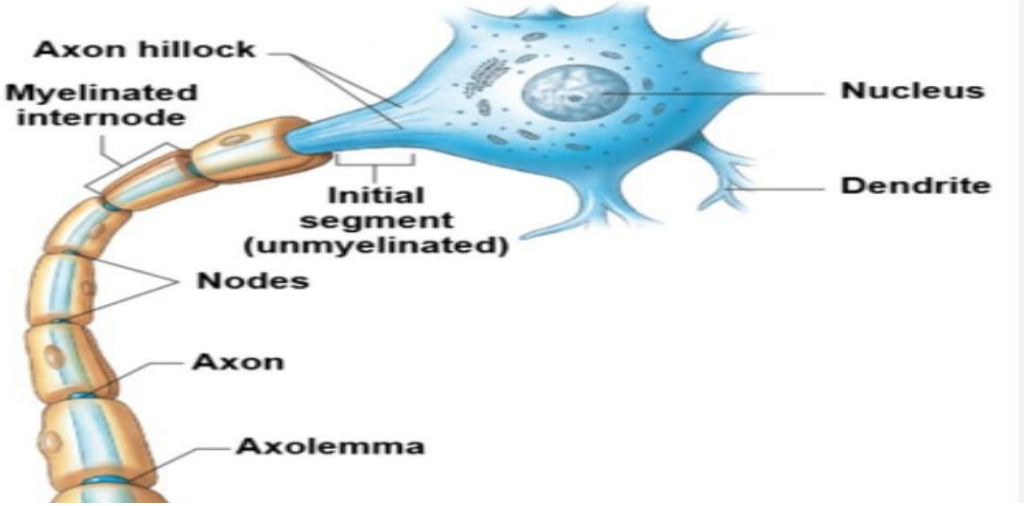


Purkinje cell in the Cerebellum

AXONS

- Most neurons have only one axon. Most and not All because we have exception (anaxonic doesn't have a true axon)
- Axonal processes vary in length and diameter --- Depends on **type of neuron**. For an example : small muscle of the foot controlled by motor neurons in the spinal cord ,run from the ventral root and become a part of the spinal nerve , which divides to reach the foot (long neuron). In contrast , we have a cranial nerves such as Abducens which reaches to one of the extraocular muscle (short neuron).There are a neurons with small diameter and myline sheath and others with large diameter (thicker) with more byline sheath
- Axolemma: plasma membrane.
- Axoplasm: contents of axon. (Its cytoplasm)
- Axon hillock: pyramid-shaped region of the perikaryon where axons originate from.





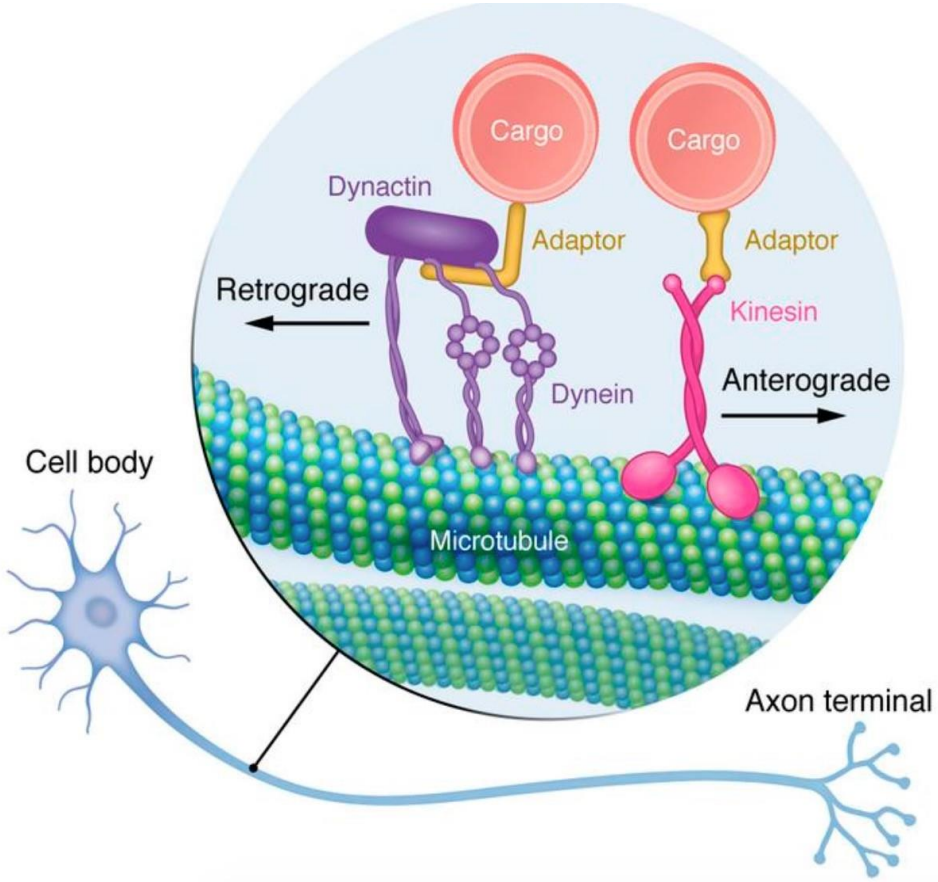
- Initial segment: concentrated ion channels which generate the action potential , at this initial segment of the axon, the various excitatory and inhibitory stimuli impinging on the neuron are algebraically summed, resulting in the decision to propagate—or not to propagate—a nerve impulse (action potential) .
- Axons branch less than dendrites—-but undergo terminal arborization. The name of the branch is axon collateral and we usually see it in the interneurons and motor neurons but at the terminal of the axons there isn't a one terminal end of the axon that goes itself to another neuron , it divides into small branches called axon terminals . At the end of the axon terminals there are a synaptic end bulb or terminal bouton (Fr. bouton, button) that contacts another neuron or non-nerve cell (glands or muscle) at a synapse to initiate an impulse in that cell.
  The number of the axon terminals differs **based on** how **specific** and **precise** the function of the muscle ,the **ratio between the axons and muscle fibers.**

AXONS

- Axons of interneurons and some motor neurons also have major **branches** called **collaterals** that **end** at **smaller branches** with synapses influencing the activity of many other neurons.
- **Terminal bouton**: Small axonal branch ends with a dilation-- contacts another neuron or non-nerve cell.
- **Axoplasm** contains mitochondria, microtubules, neurofilaments, and transport vesides, but very **few** polyribosomes or cisternae of RER (dependence of axoplasm on the perikaryon). But these aren't Nissl bodies which don't exist in the axons .

AXON/TRANSPORT

- **Anterograde** transport: **away** from cell body. Organelles and macromolecules synthesized in the cell body move along axonal microtubules via kinesin from the perikaryon to the synaptic terminals. Every thing is specific
- **Retrograde** transport: **toward** cell body. in the opposite direction along microtubules via dynein carries certain other macromolecules–-endocytosis (including viruses and toxins).
- Anterograde and retrograde transports: 50-400 mm/d (just read the number) .



Shingles (Herpes zoster) الحزام الناري :the patient has an itchy feeling usually in the limbs or in the face because one of the types of the virus moves inside neurons using the motor protein dynein in a retrograde direction (from the nerve ending toward the cell body) ,the virus becomes activated and it depression in the immune system and then virus goes periphery and make its effect on the surrface of the skin . This will damage the nerves .

SYNAPSES

The image in the right and the explanation under it are additional from the book

- **Precynaptic cell**

Presynaptic axon terminal (terminal bouton) Neurotransmotter (synaptic vesicles)

Ca^{2+} !!!

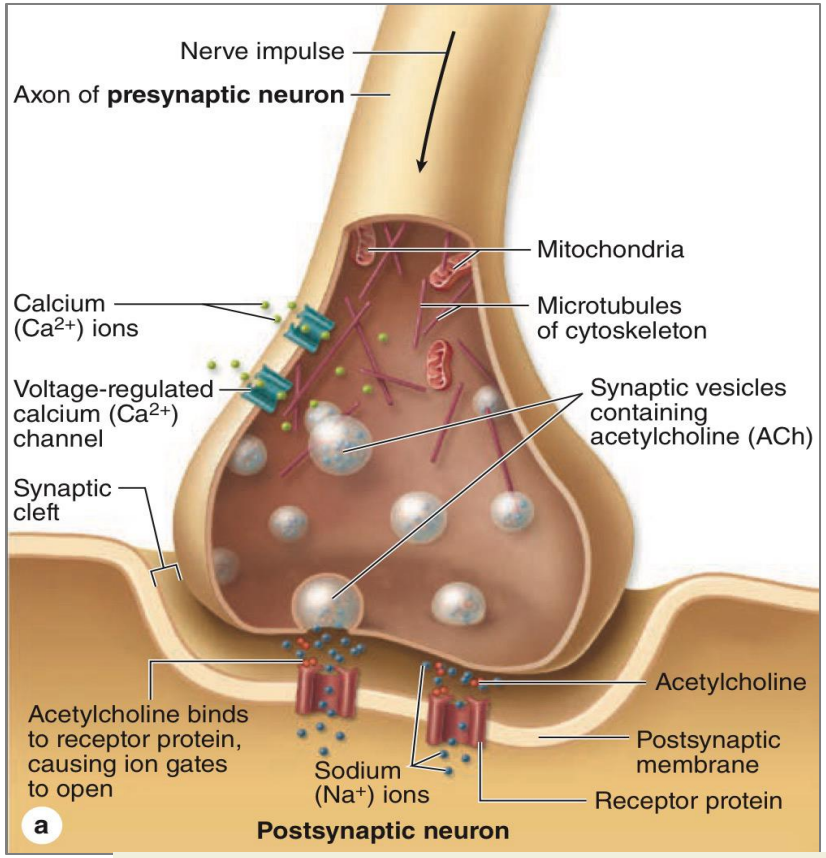
Ca^{+2} , contribute in facilitating the vesicles fusion with the presynaptic membrane ,which leads to the releasing of neurotransmitters to the synaptic cleft , then bind to its receptors on the postsynaptic membrane and that how Action potential is transmitted

- **Synaptic cleft**

20-30 nm-wide intercellular space called the

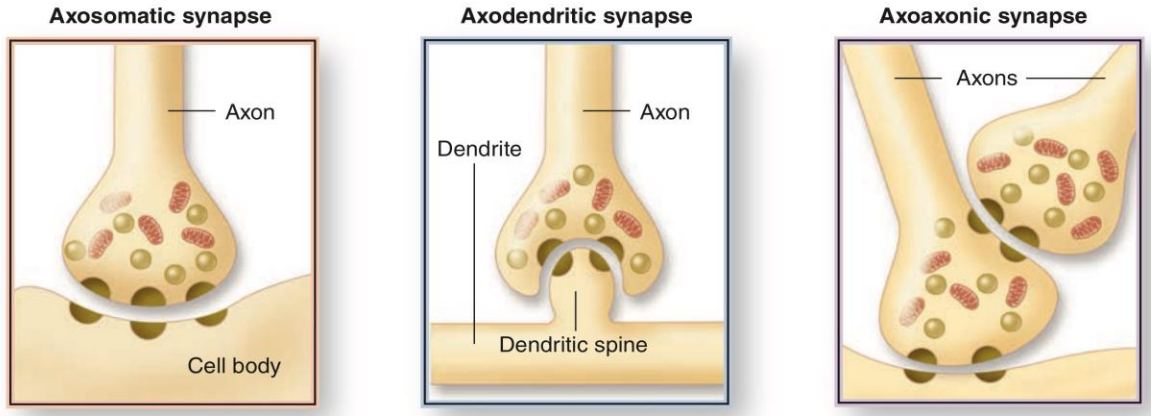
- **Postsynaptic cell**

Postsynaptic cell membrane



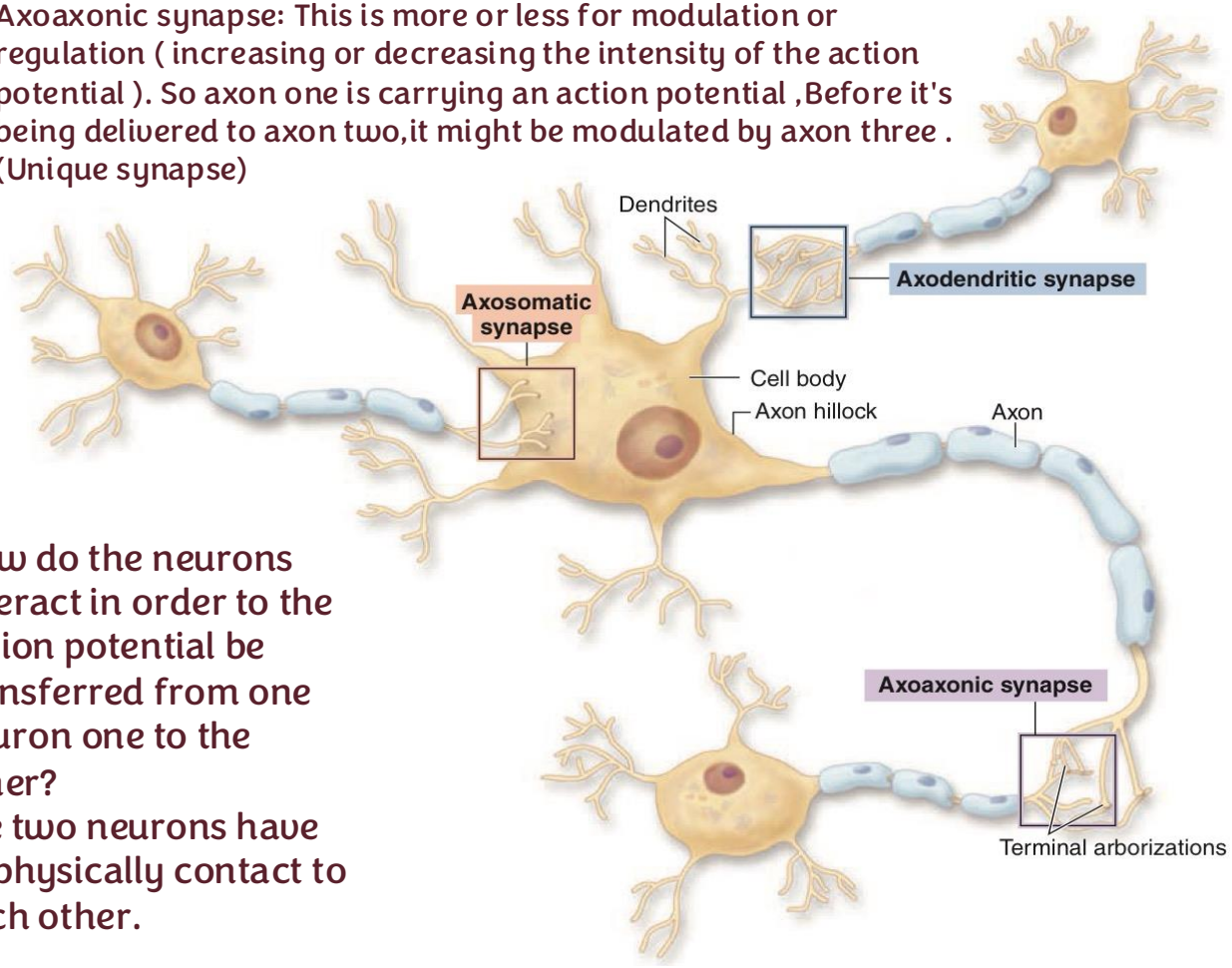
(a) Diagram showing a synapse releasing neurotransmitters by exocytosis from the terminal bouton. Presynaptic terminals always contain a large number of **synaptic vesicles** containing neurotransmitters, numerous **mitochondria**, and smooth ER as a source of new membrane. Some neurotransmitters are synthesized in the cell body and then transported in vesicles to the presynaptic terminal. Upon arrival of a nerve impulse, voltage-regulated Ca^{2+} channels permit Ca^{2+} entry, which triggers neurotransmitter release into the synaptic cleft. Excess membrane accumulating at the presynaptic region as a result of exocytosis is recycled by clathrin-mediated endocytosis, which is not depicted here.

(b) The TEM shows a large presynaptic terminal (T_1) filled with synaptic vesicles and asymmetric electron-dense regions around 20- to 30-nm-wide synaptic clefts (**arrows**). The postsynaptic membrane contains the neurotransmitter receptors and mechanisms to initiate an impulse at the postsynaptic neuron. The postsynaptic membrane on the right is part of a dendrite (**D**), associated with fewer vesicles of any kind, showing this to be an axodendritic synapse. On the left is another presynaptic terminal (T_2), suggesting an axoaxonic synapse with a role in modulating activity of the other terminal. (X35,000)



The diagrams show three common morphologic types of synapses. Branched axon terminals usually associate with and transmit a nerve impulse to another neuron's cell body (or soma) or a dendritic spine. These types of connections are termed an **axosomatic synapse** and an **axodendritic synapse**, respectively. Less frequently, an axon terminal forms a synapse with an axon terminal of another neuron; such an **axoaxonic synapse** functions to modulate synaptic activity in the other two types.

Axoaxonic synapse: This is more or less for modulation or regulation (increasing or decreasing the intensity of the action potential). So axon one is carrying an action potential ,Before it's being delivered to axon two,it might be modulated by axon three . (Unique synapse)



All three morphologic types of synapses have the features of all true synapses: a presynaptic axon terminal that releases a transmitter; a postsynaptic cell membrane with receptors for the transmitter; and an intervening synaptic cleft.

Synaptic structure usually cannot be resolved by light microscopy, although components such as dendritic spines may be shown with special techniques (Figure 9–5).

How do the neurons interact in order to the action potential be transferred from one neuron one to the other?
the two neurons have to physically contact to each other.

TYPES OF SYNAPSES

1. Axo-somatic:
Axo : from the terminals of the axon of the presynaptic neuron
somatic : to the soma (body) of the post synaptic cell(it could be neuron or effector cell)
2. Axo-dendritic :
dendritic: to the dendritic spine on the post synaptic neuron
3. Axo -axonic:
axonic: to the axon of another neuron .

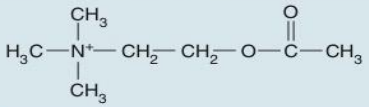
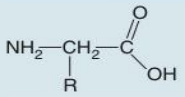
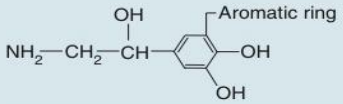
SYNAPSES

- **Excitatory** synapses cause postsynaptic Na^+ channels to open–- depolarization wave in the postsynaptic neuron (or effector).
- **Inhibitory** synapses neurotransmitters open Cl^- (or other anion), causing ---influx of anions -----hyperpolarization-- membrane potential more negative–- resistant to depolarization.
- The response in postsynaptic neurons is determined by the **summation** of activity at hundreds of synapses on that cell.

NEUROTRANSMITTERS (READ ONLY)

Just read it , not required

TABLE 9–1 Common neurotransmitters and their actions.

Neurotransmitter	Description/Action
ACETYLCHOLINE (ACh)	
	Chemical structure significantly different from that of other neurotransmitters; active in CNS and in both somatic and autonomic parts of PNS; binds to ACh receptors (cholinergic receptors) in PNS to open ion channels in postsynaptic membrane and stimulate muscle contraction
AMINO ACIDS	
	Molecules with both carboxyl (—COOH) and amine ($—NH_2$) groups and various R groups; act as important transmitters in the CNS
Glutamate	Excites activity in neurons to promote cognitive function in the brain (learning and memory); most common neurotransmitter in the brain; opens Na^+ channels
Gamma-aminobutyric acid (GABA)	Synthesized from glutamate; primary inhibitory neurotransmitter in the brain; also influences muscle tone; opens or closes various ion channels
Glycine	Inhibits activity between neurons in the CNS, including retina; opens Cl^- channels
MONOAMINES	
	Molecules synthesized from an amino acid by removing the carboxyl group and retaining the single amine group; also called biogenic amines
Serotonin or 5-hydroxytryptamine (5-HT)	Has various functions in the brain related to sleep, appetite, cognition (learning, memory), and mood; modulates actions of other neurotransmitters
Catecholamines	A distinct group of monoamines
Dopamine	Produces inhibitory activity in the brain; important roles in cognition (learning, memory), motivation, behavior, and mood; opens K^+ channels, closes Ca^{2+} channels
Norepinephrine (noradrenaline)	Neurotransmitter of PNS (sympathetic division of autonomic nervous system) and specific CNS regions
Epinephrine (adrenaline)	Has various effects in the CNS, especially the spinal cord, thalamus, and hypothalamus
NEUROPEPTIDES	
	Small polypeptides act as signals to assist in and modulate communication among neurons in the CNS
Enkephalin	Helps regulate response to noxious and potentially harmful stimuli
Neuropeptide Y	Involved in memory regulation and energy balance (increased food intake and decreased physical activity)
Somatostatin	Inhibits activities of neurons in specific brain areas
Substance P	Assists with pain information transmission into the brain
Cholecystokinin (CCK)	Stimulates neurons in the brain to help mediate satiation (fullness) and repress hunger
Beta-endorphin	Prevents release of pain signals from neurons and fosters a feeling of well-being
Neurotensin	Helps control and moderate the effects of dopamine
OTHERS	
Adenosine	Also part of a nucleotide, inhibits activities in certain CNS neurons
Nitric oxide	Involved in learning and memory; relaxes muscle in the digestive tract; important for relaxation of smooth muscle in blood vessels (vasodilation)

Test yourself

Press

For any feedback, scan the code or click on it

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			

Additional Resources:

Reference Used:
(numbered in order as cited in the text)

1. Dr.Ghada’s lecture

Extra References for the Reader to Use:

1. Video: Nervous Tissue
2. Video: Types of Neurons by Structure

Study well everyone and try not to procrastinate ^_^

رسالة من الفريق العلمي:

عن أبي أمامة قال: قال رسول الله صلى الله عليه وسلم: بأيِّ شيءٍ تحرِّكُ شفَتَيكَ يا أبا أمامةَ؟ فقلتُ: أذكرُ اللهَ يا رسولَ اللهِ! فقال: ألا أُخبرُكَ بأكثرَ وأفضلَ من ذِكرِك باللَّيلِ والنَّهارِ؟ قلتُ: بلى يا رسولَ اللهِ!

قال: تقولُ (سبحان اللهِ عدَدَ ما خلق، سبحان اللهِ مِلْءَ ما خلَق، سبحان اللهِ عدَدَ ما في الأرضِ [والسماءِ] سبحان اللهِ مِلْءَ ما في الأرضِ والسماءِ، سبحان اللهِ عدَدَ ما أحصى كتابُه، سبحان اللهِ مِلْءَ ما أحصى كتابُه، سبحان اللهِ عددَ كلِّ شيءٍ، سبحانَ اللهِ مِلْءَ كلِّ شيءٍ، الحمدُ للهِ عددَ ما خلق، والحمدُ لله مِلْءَ ما خلَق، والحمدُ لله عدَدَ ما في الأرضِ والسماءِ، والحمدُ لله مِلْءَ ما في الأرضِ والسماءِ، والحمدُ للهِ عدَدَ ما أحصى كتابُه، والحمدُ لله مِلْءَ ما أحصى كتابُه، والحمدُ للهِ عدَدَ كلِّ شيءٍ، والحمدُ للهِ مِلْءَ كلِّ شيءٍ.)