Introduction into the central nervous system anatomy

Lecture I

OrSMU
Human anatomy
Department
2020

Plan of the lecture

- Anatomical-and-functional characteristic of the nervous system.
- Basic morphological elements of the nervous system.
- Concept of gray and white matter, nucleus, ganglions, conductive tracts.
- Reflex arches

Functions of the nervous system

- The nervous system ensures the relationship of the body with the external environment by perception of stimuli, analysis of these stimuli and subsequent adequate response.

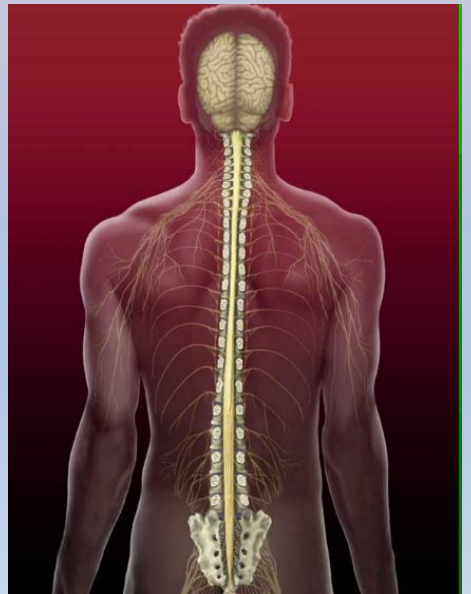
- The nervous system provides the interconnection of organs within a single system and the integration of the work of different systems of the body

Nervous system

I. Anatomical classification

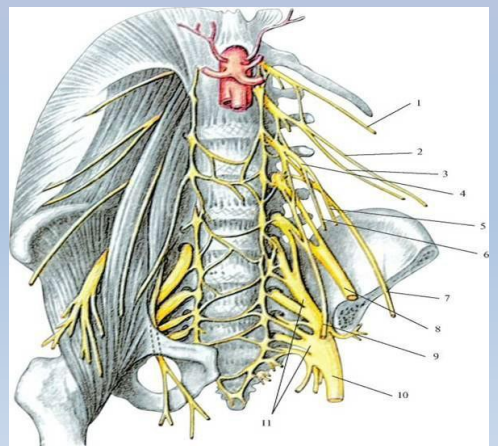
Central nervous system (CNS)

- Brain
- Spinal cord



Peripheral nervous system (PNS)

- Cranial nerves
- Spinal nerves
- Ganglia
- Plexuses



Nervous system

II. Functional classification

Sensory =afferent division

Motor = efferent division

Autonomic=vegetative ***(unvoluntary)***

Somatic=animal ***(voluntary)***

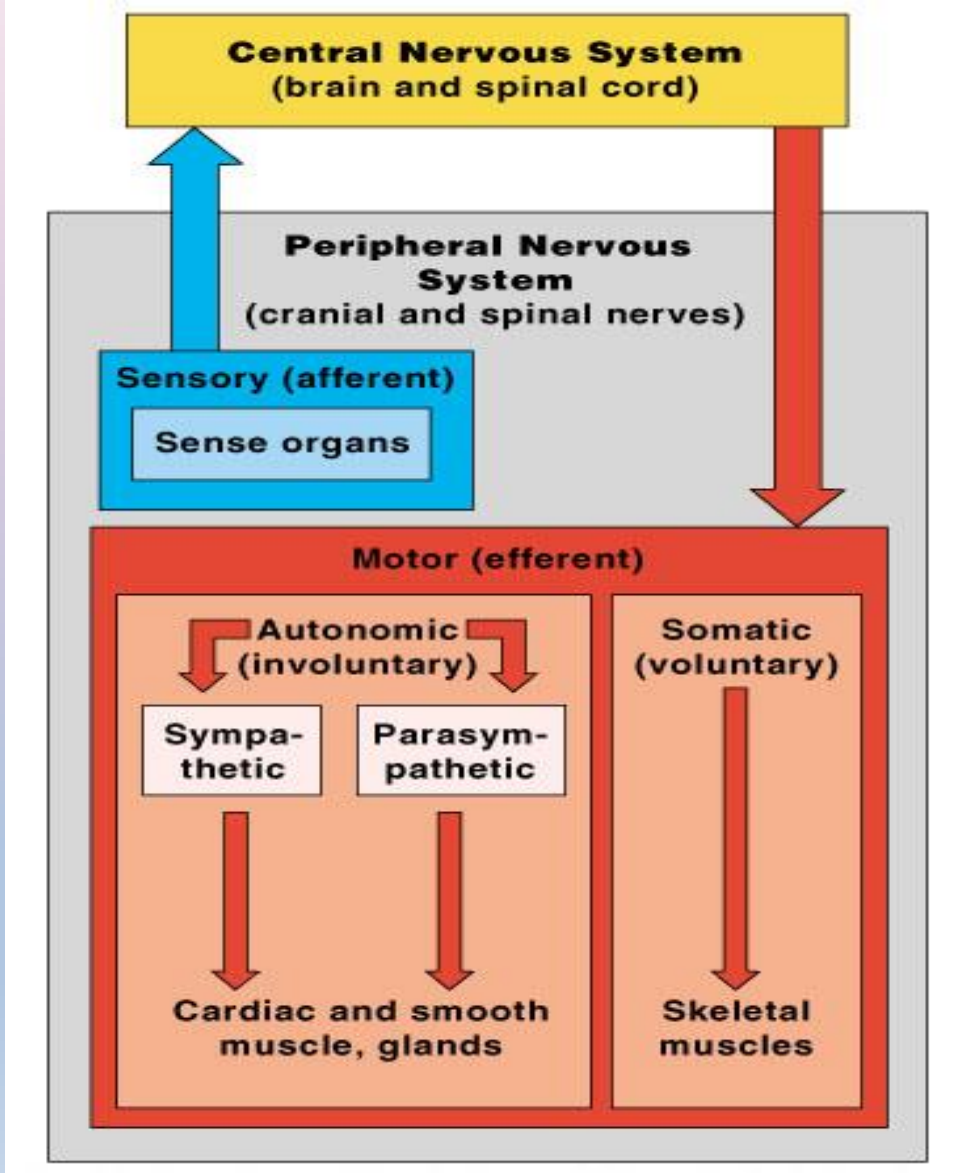
Sympathetic

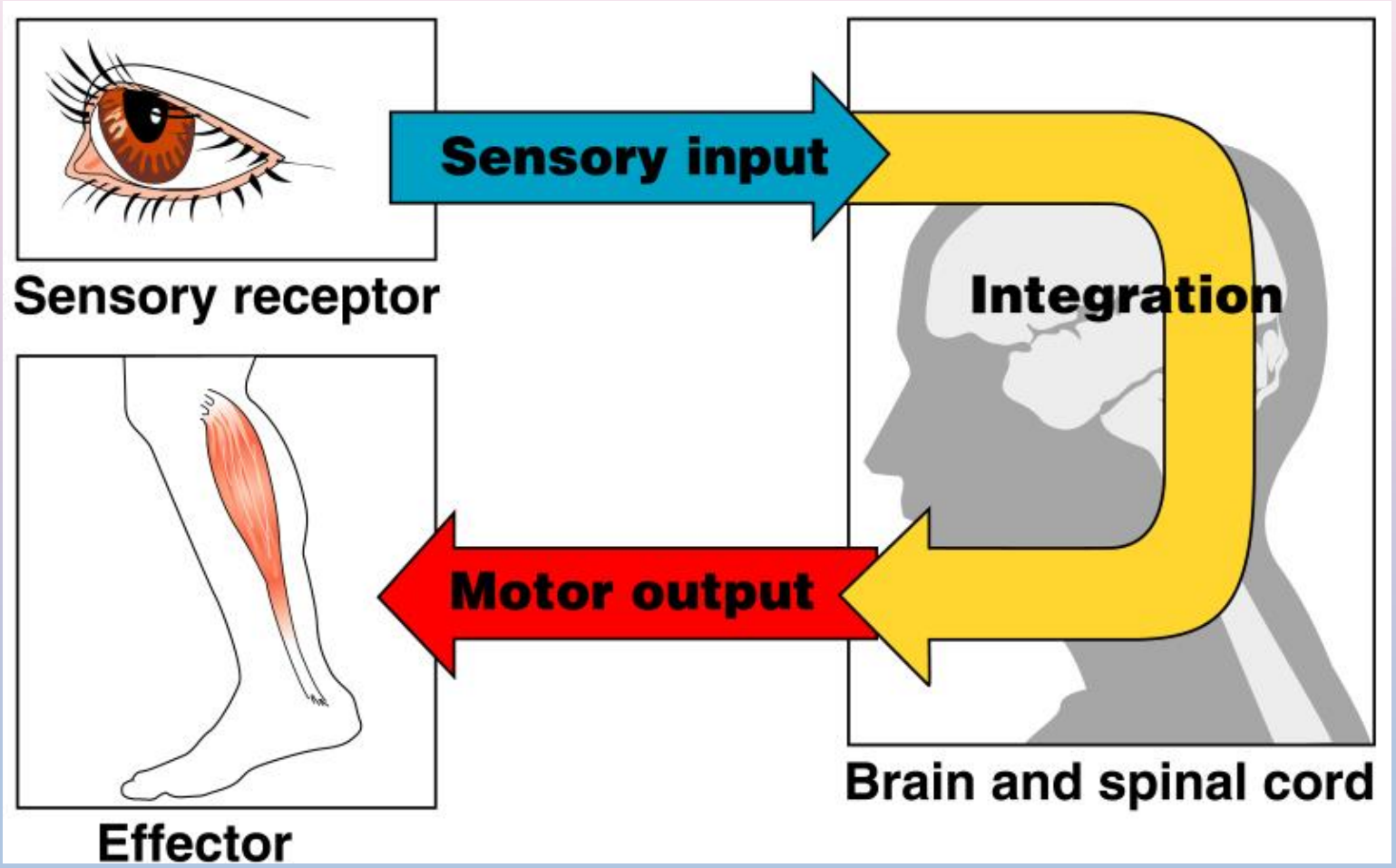
Parasympathetic

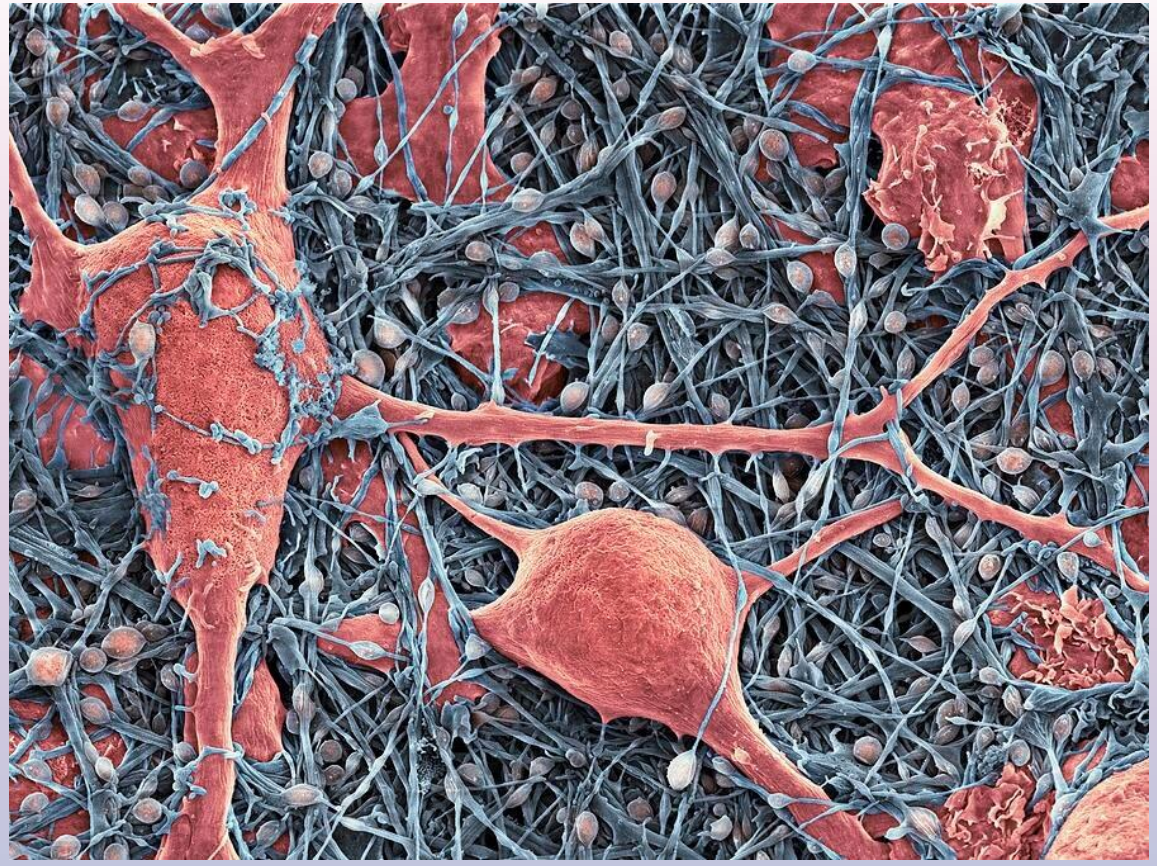
- ***THE SOMATIC PART*** is the part of the NS that goes to the ***Soma (locomotor system+ skin)***
- The «working organ» is ***striated musculature***,
- Type of innervation is ***voluntary***.

- ***The AUTONOMIC PART*** is the part of the NS that goes to ***the internal organs***.
- The «working organ» - smooth muscles of the internal organs and vessels, glands and heart.
- Type of innervation is ***involuntary***

Organization of the nervous system




Sensory input
Sensory receptor
Integration
Motor output
Brain and spinal cord
Effector



The basis of the nervous system is the nervous tissue

- ***Nervous Tissue = Neurons + Neuroglia***

Glia, also called **glial cells** or **neuroglia**, - neuronal cells in the CNS and PNS that don't produce electrical impulses.

In the CNS glial cells include oligodendrocytes, astrocytes, ependymal cells, and microglia, and in the peripheral nervous system glial cells include Schwann cells and satellite cells.

They pave four main functions:

(1) to surround neurons and hold them in place;
(2) to supply nutrients and oxygen to neurons;
(3) to insulat one neuron from another;
(4) to destroy pathogens and remove dead neurons.
+To play a role in neurotransmission and synaptic connections

However glial cells have far more cellular diversity and functions than neurons, and glial cells can respond to and manipulate neurotransmission in many ways.

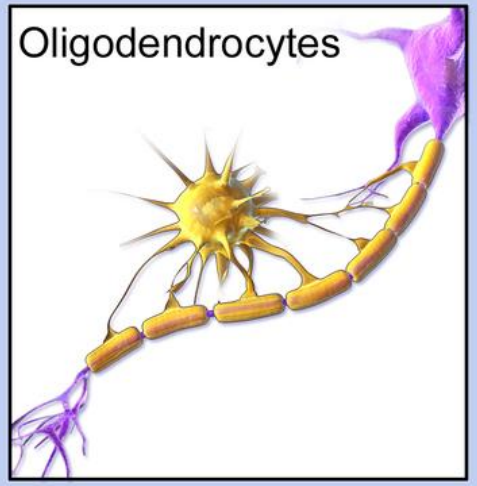
***Glia** were discovered in 1856, by the pathologist Rudolf Virchow in his search for a "connective tissue" in the brain.*

Types of Neuroglia

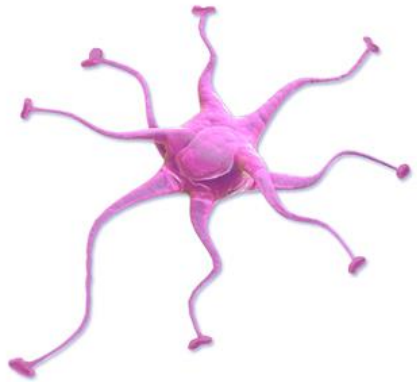
Central Nervous System

Ependymal cells

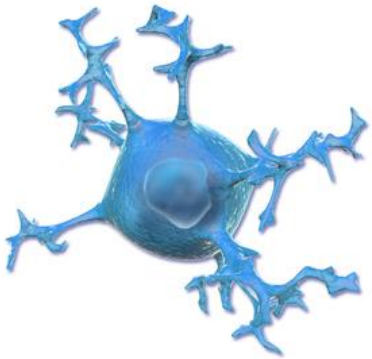
Oligodendrocytes



Astrocytes

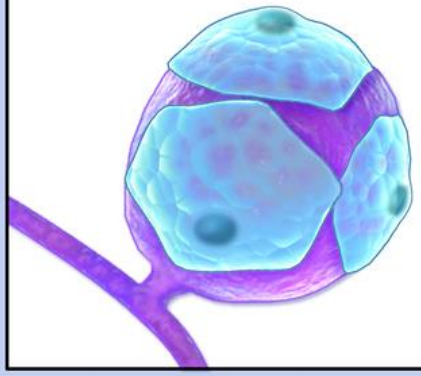


Microglia

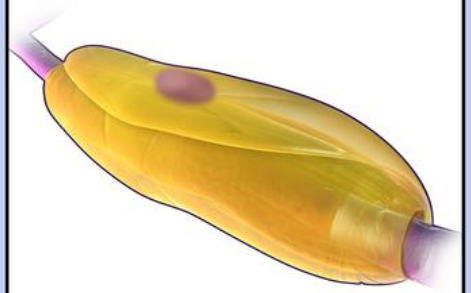


Peripheral Nervous System

Satellite cells

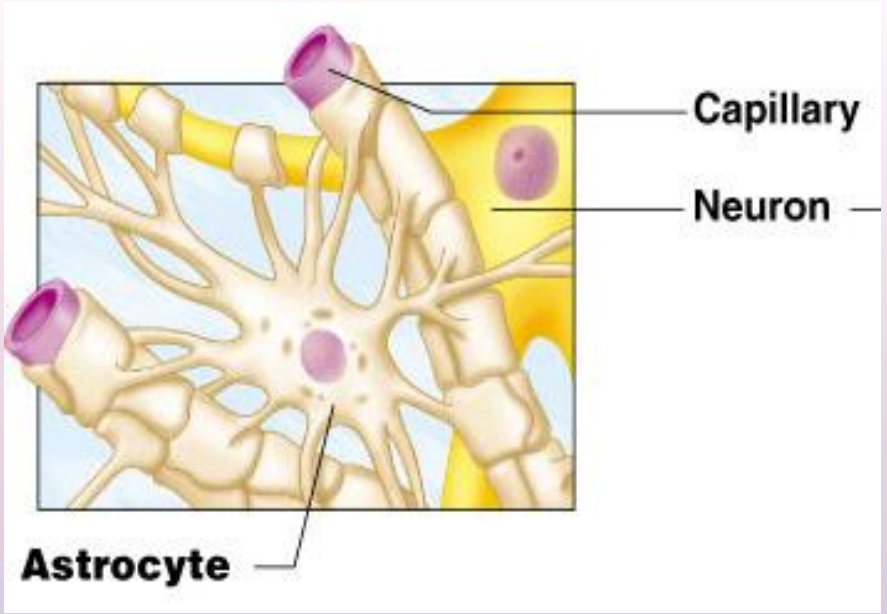


Schwann cells



ASTROCYTES

=ASTROGLIA



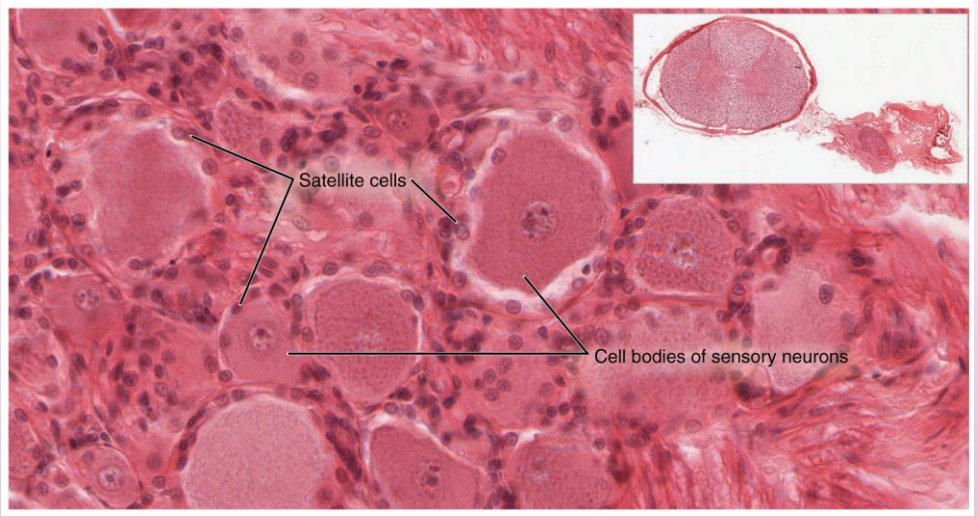
The most abundant type of macroglial cell in the CNS. They have numerous projections that link neurons to their blood supply while forming the blood-brain barrier.

They regulate the external chemical environment of neurons by removing excess potassium ions, and recycling neurotransmitters released during synaptic transmission.

Astrocytes may regulate vasoconstriction and vasodilation

SATELLITE

GLIAL CELLS

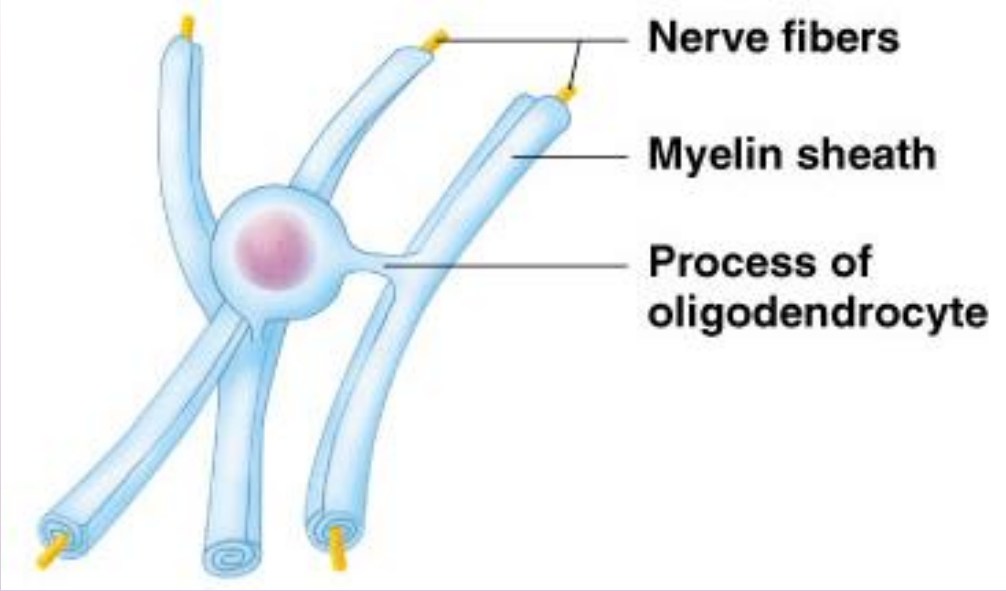


Satellite glial cells are small cells that surround neurons in sensory, sympathetic, and parasympathetic ganglia.

These cells help regulate the external chemical environment. Like astrocytes, they are interconnected by gap junctions.

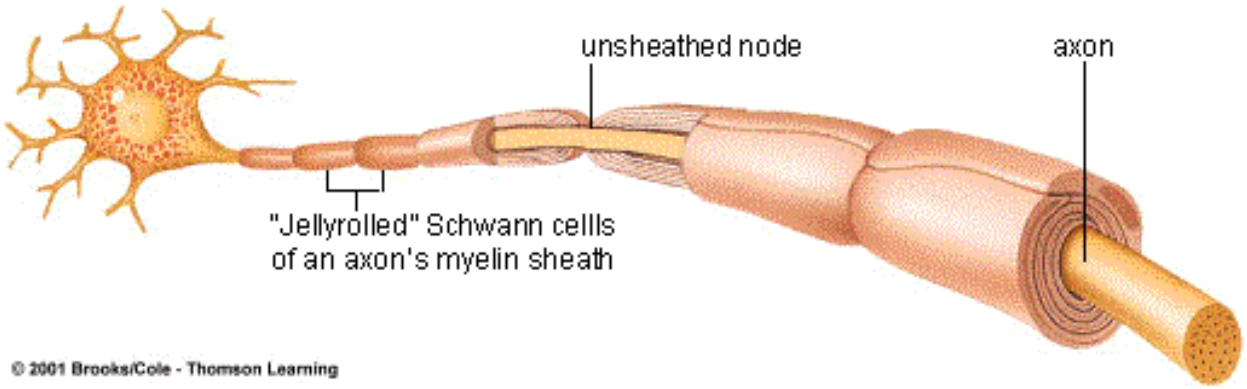
They are highly sensitive to injury and inflammation, and appear to contribute to pathological states, such as chronic pain

OLIGODENDROCYTES

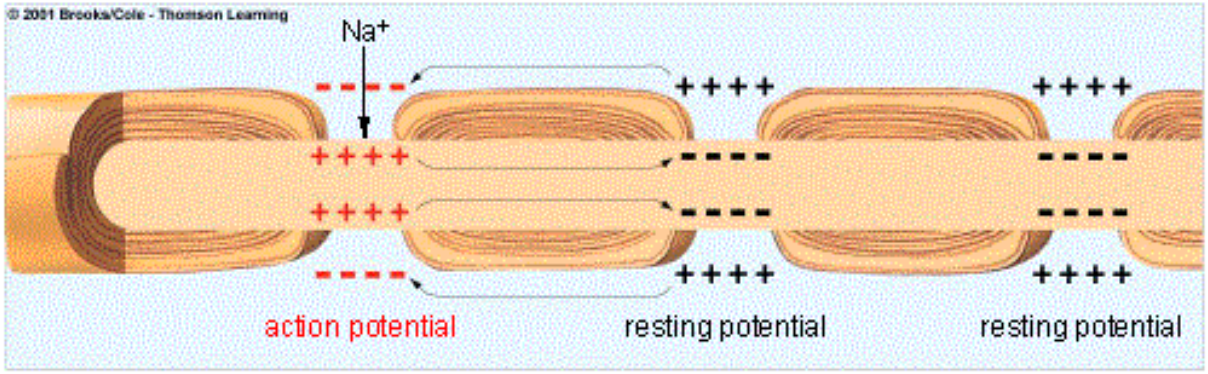


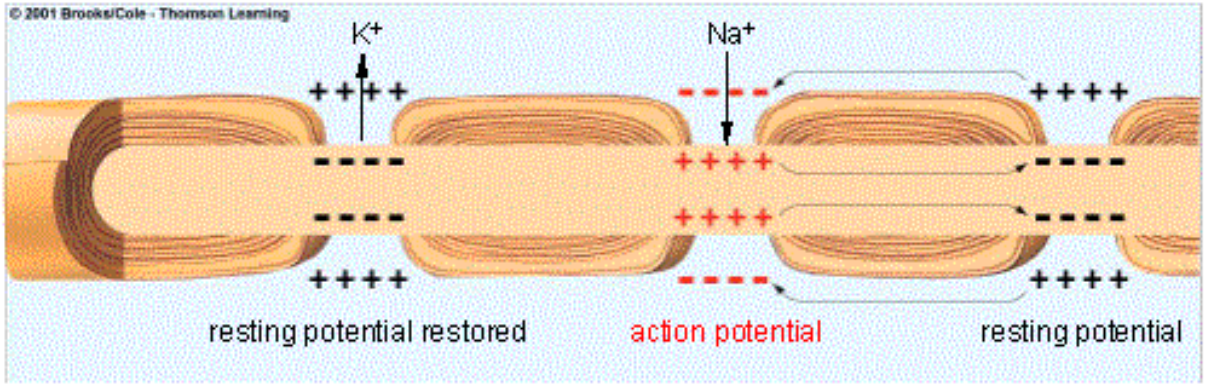
They coat axons in the central nervous system (CNS) with their cell membrane, forming a specialized membrane differentiation called myelin, producing the myelin sheath.

The myelin sheath provides insulation to the axon that allows electrical signals to propagate more efficiently



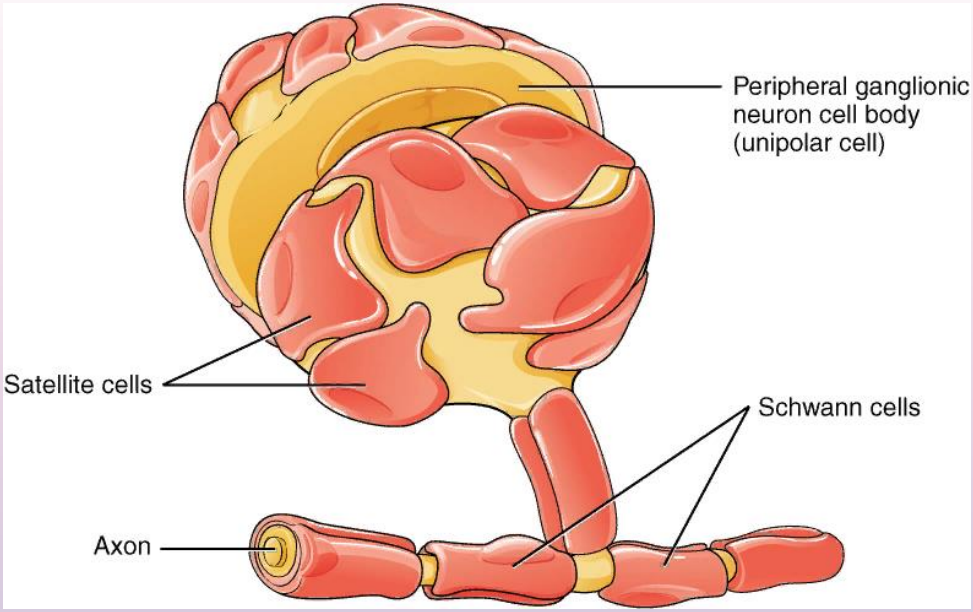
Myelin Sheath





- A series of Schwann cells
- Sheath blocks ion movements
- Action potential must "jump" from node to node

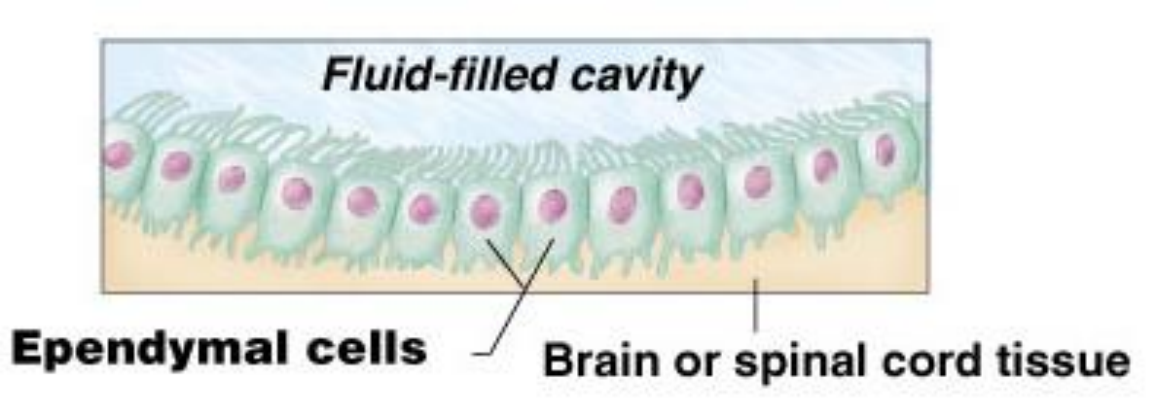
SCHWANN CELLS



Similar in function to oligodendrocytes, Schwann cells provide myelination to axons in the peripheral nervous system (PNS).

They also have phagocytotic activity and clear cellular debris that allows for regrowth of PNS neurons

EPENDYMAL CELLS

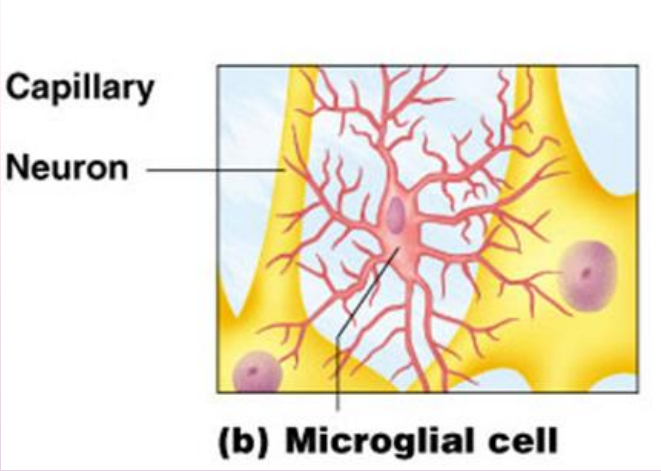


They also named **ependymocytes**, line the spinal cord and the ventricular system of the brain.

These cells are involved in the creation and secretion of cerebrospinal fluid (CSF) and beat their cilia to help circulate the CSF and make up the blood-CSF barrier.

They are also thought to act as neural stem cells.

MICROGLIA



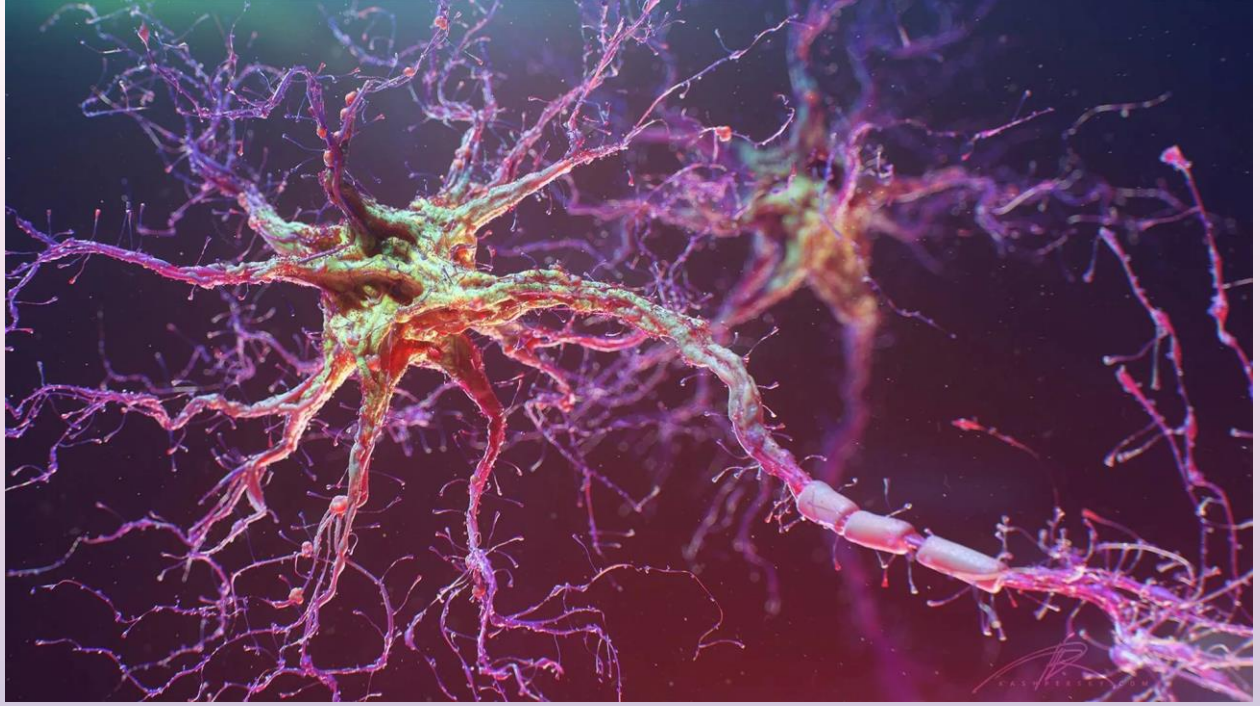
Microglia are specialized macrophages capable of phagocytosis that protect neurons of the central nervous system. These cells are found in all regions of the brain and spinal cord.

Microglial cells are small relative to macroglial cells, with changing shapes and oblong nuclei. They are mobile within the brain and multiply when the brain is damaged. In the healthy central nervous system, microglia processes constantly sample all aspects of their environment (neurons, macroglia and blood vessels).

In a healthy brain, microglia direct the immune response to brain damage and play an important role in the inflammation that accompanies the damage.

Many diseases and disorders are associated with deficient microglia, such as Alzheimer's disease, Parkinson's disease.

NEURONS

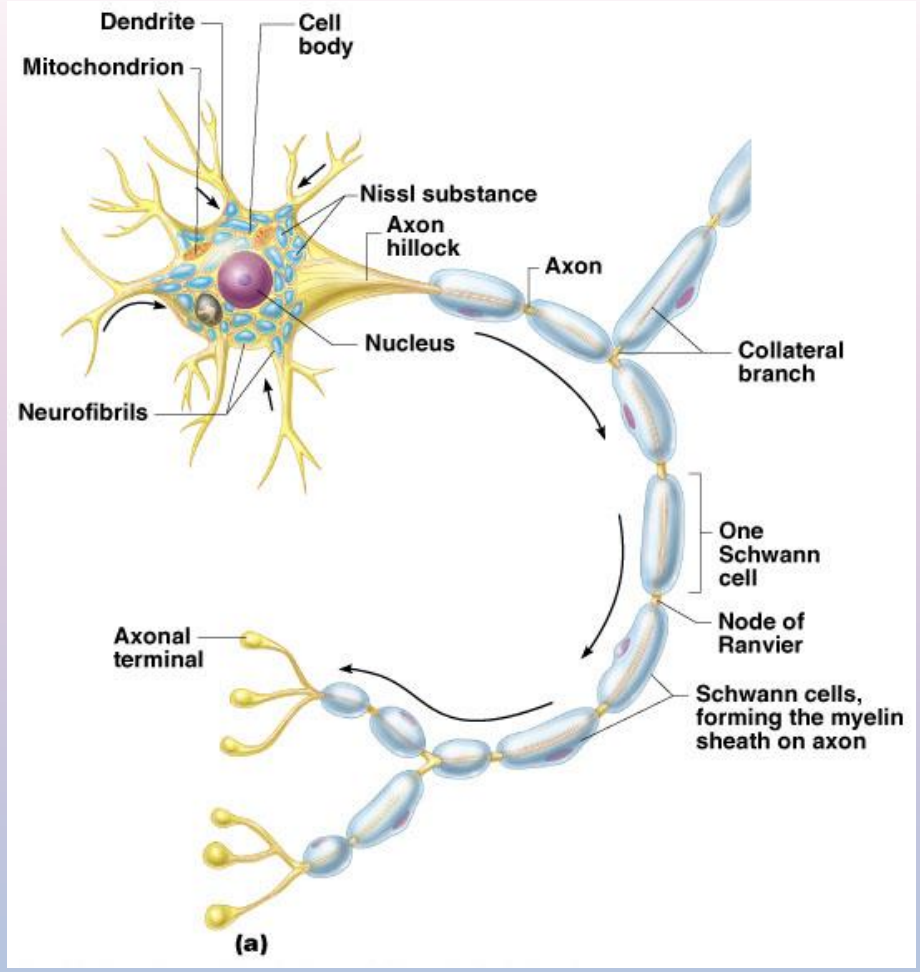


Neurons are functionally different from other cells by two properties:

- **Excitability = the ability to form the electric impulse**
- **Conductivity = the ability to carry out nervous impulses.**

NEURON ANATOMY

- **Body of the neuron (soma)**
- **Processes: dendrites and axon**

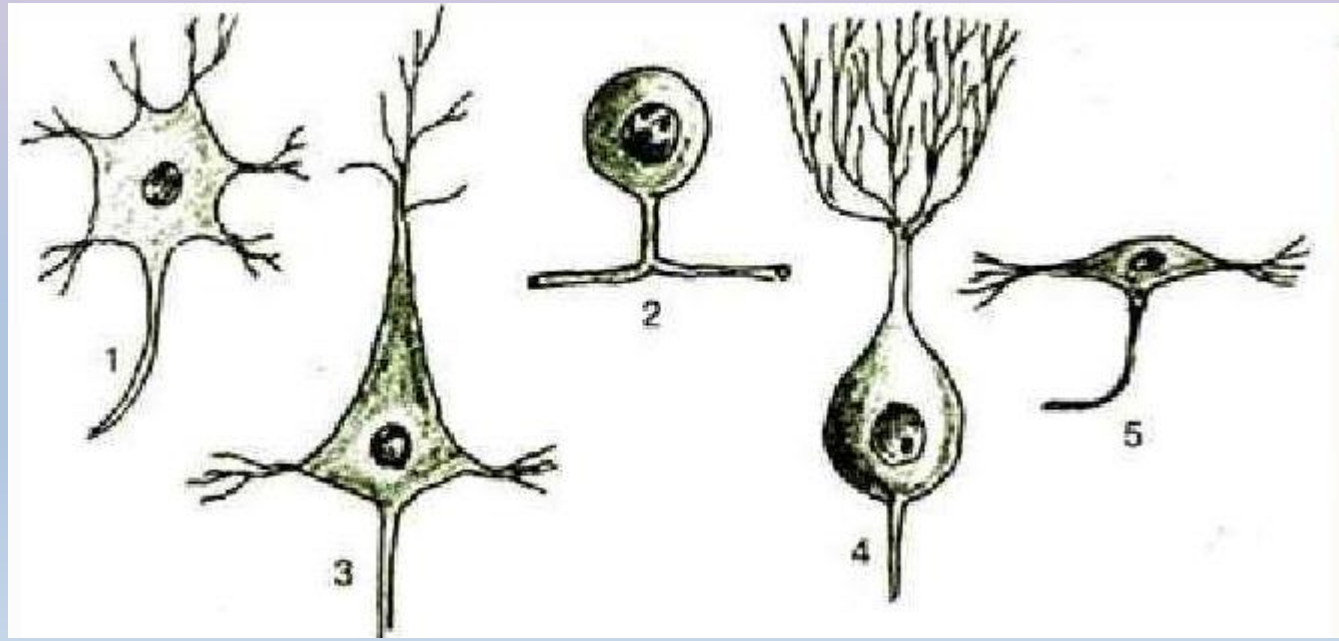


- Dendrites conduct impulses **<u>to</u>** the neuron body
- Axon (only 1!) conducts impulses **<u>from</u>** the neuron body

CLASSIFICATION OF THE NEURONS

According to the body shape:

- pyramidal,
- pear-shaped,
- fusiform,
- polygonal,
- star,
- etc.



CLASSIFICATION OF THE NEURONS

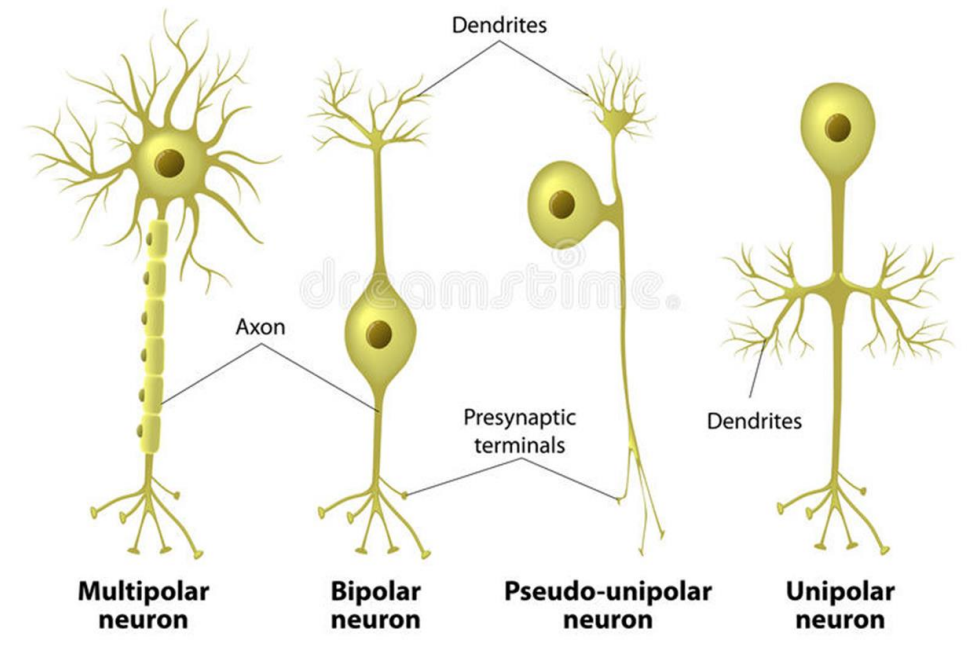
By body size:

- small (4-20 microns),
- medium (20-60 microns),
- large (60-130 microns).

CLASSIFICATION OF THE NEURONS

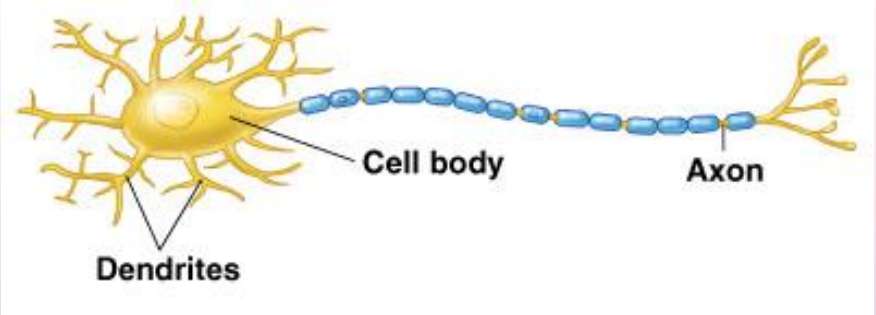
By the number of the processes:

- **unipolar neurons-** do not occur in humans (? or in fetal period, nucleus of trigeminal nerve)
- **pseudodnopolar neurons** - in the sensitive ganglia of the cranial and spinal nerves
- **bipolar neurons** - in the sensitive nodes of those nerves that are responsible for specific types of sensitivity (smell, hearing, vestibular sense, vision)
- **multipolar neurons** - in the central nervous system and in the autonomic ganglia.



Multipolar neurons –

many dendrites+1 axon

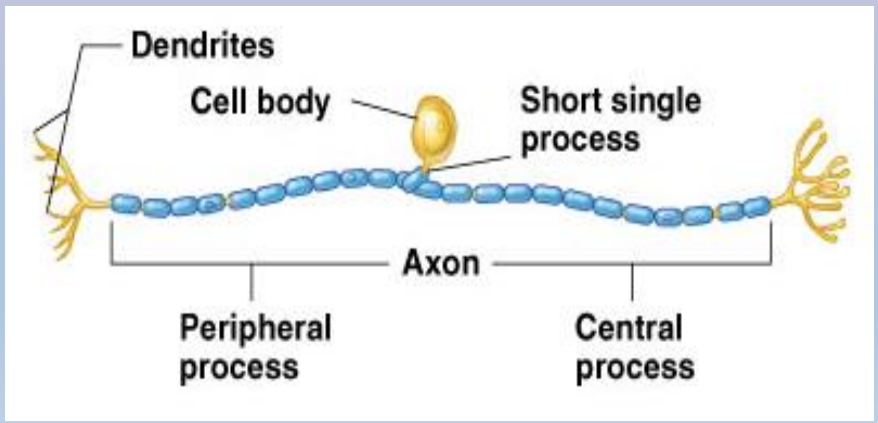


Bipolar neurons –

one axon and one dendrite

Pseudounipolar neurons –

axon and denrites are started together and than isolated



NB!! We distinguish grey and white matter in any department of the brain and the spinal cord

Grey matter is a set of the **neuron's bodies** which are united in **nucleus and ganglia**.

White matter is a set **of the axons** with the same function, which are united into **conducting pathway or tracts**.

Grey matter forms nuclea and ganglia

NUCLEUS is the aggregation of the neuron's bodies , which have the **same function and development** and are located **inside of CNS.**

Types of nuclea:

- sensory
- motor
- autonomic

GANGLION is the aggregation of neuron's bodies, which have the **same function and development** and are located **outside of CNS**. It has capsule.

Types of ganglia:

- sensory
- autonomic

White matter

White matter is a cluster of neuronal processes.

- White matter forms **conducting pathways (tracts) within the central nervous system**

- White matter forms **peripheral nerves (spinal, cranial, vegetative) outside of the central nervous system**

Processes of nerve cells are covered by layers of connective tissue and glial cells and they are called neural fibers.

According to structure of the layers there are:

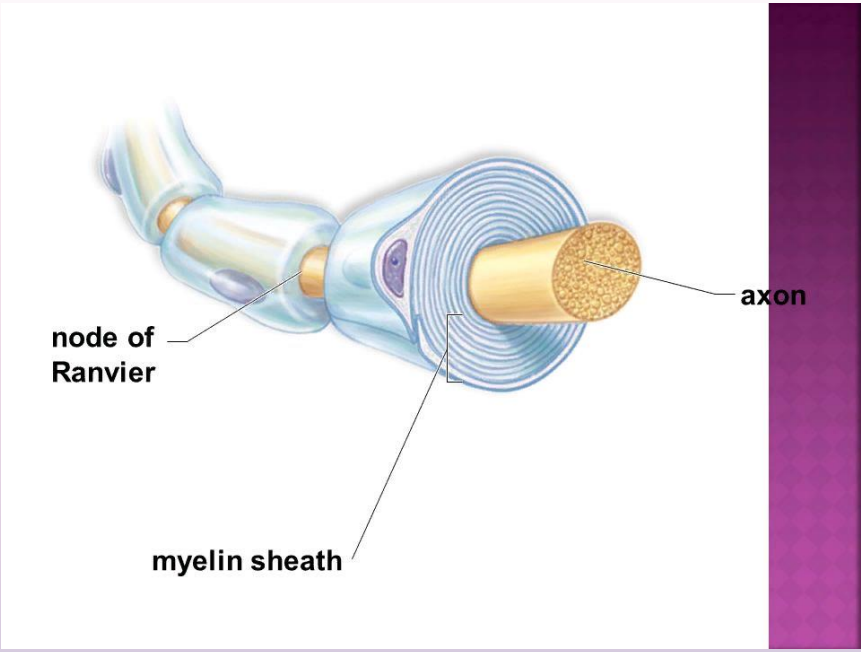
1.myelinated

2.non-myelinated

Processus of nerve cell in the nerve fiber is called **axial cylinder**

Non-myelinated nerve fiber consists of a few axial cylinders and layers are formed by neurolemmocytes.

MYELINATED NERVE FIBRES



- Myelinated nerve fibers are present both in CNS and PNS.
- They are thicker, than non-myelinated.
- Myelinated fiber consists of one axial cylinder, myelin sheath and neurilemma.
- Myelin sheath contains great number of lipids.
- Through definite intervals (1-2milimeters) parts of fiber are without myelin sheath **-nodes of Ranvier**
- Part of fiber between two nodes is **called internode segment.**

Classification of the nerve fibers by direction:

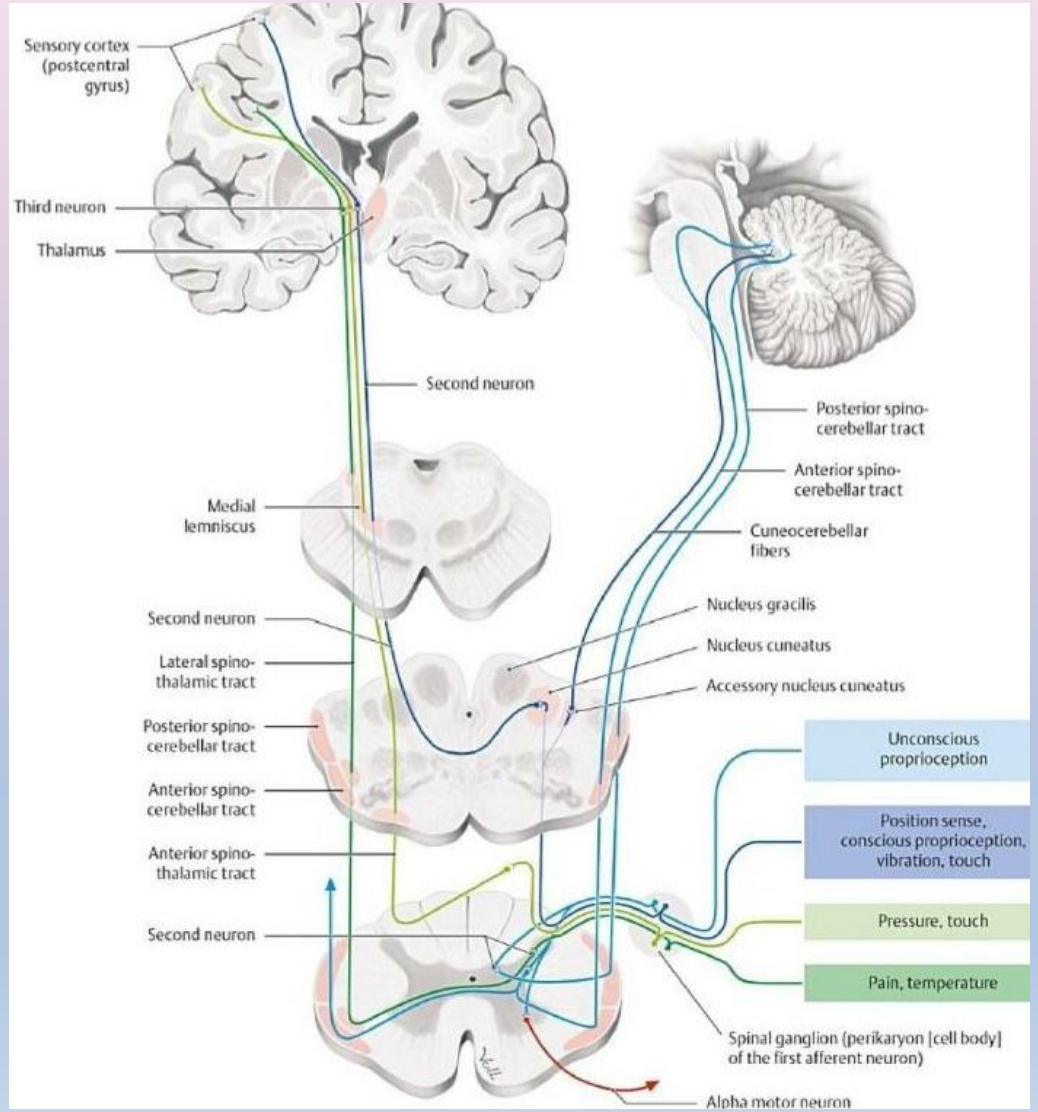
- Those nerve fibers that are directed **TO** the central nervous system (spinal cord or brain) are called **sensitive = afferent =ascending= centripetal.**

- Fibers that carry impulses **FROM** the central nervous system to the working organs are called **motor= efferent =descending =centrifugal.**

Classification of the nerve fibers by attitude to the brain cortex:

- **conscious**-fibers reach or start in the cortex of the brain

- **unconscious**-fibers reach or start in subcortical structures



- *There are 3 groups of nerve endings:*
- 1. **synapse** (for connection of neurons with each other);
- 2.**effector endings (effectors)** passing impulse into tissues of «working organ»;
- 3.**receptor** (sensitive).

RECEPTORS

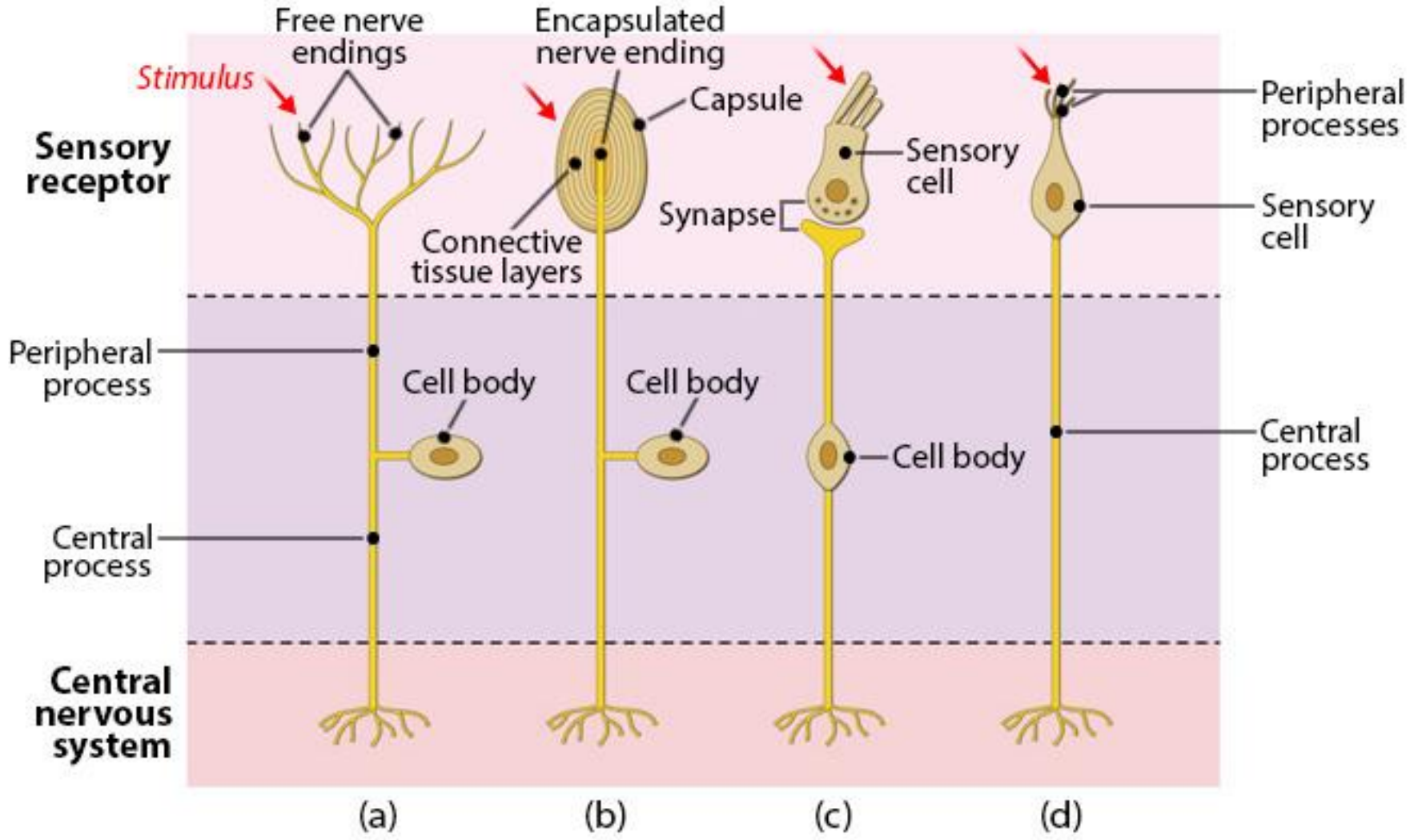
Receptor nerve endings are in whole body. They percept different irritations from external environment and from internal organs.

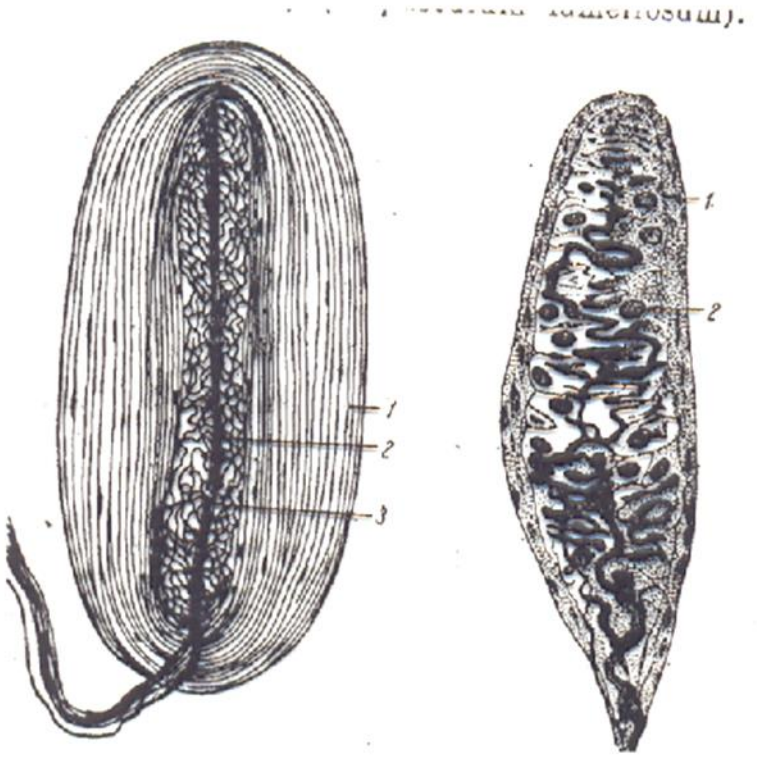
Types of receptors by localization:

- **exteroreceptors** – (in the skin and the mucous membrane);
- **interoreceptors** – internal –visceroreceptors (they signalize about condition of the internal organs)
- **proprioreceptors** (receptors of the elements of the locomotor apparatus).

Types of receptors by structure:

- **free nerve endings**
- **encapsulated nerve endings**
- **sensory cells**


Free nerve endings
Encapsulated nerve ending
Stimulus
Capsule
Sensory receptor
Sensory cell
Peripheral processes
Synapse
Sensory cell
Connective tissue layers
Peripheral process
Cell body
Cell body
Central process
Cell body
Central process
Central nervous system
(a)
(b)
(c)
(d)



Encapsulated and non-encapsulated

Free nerve endings

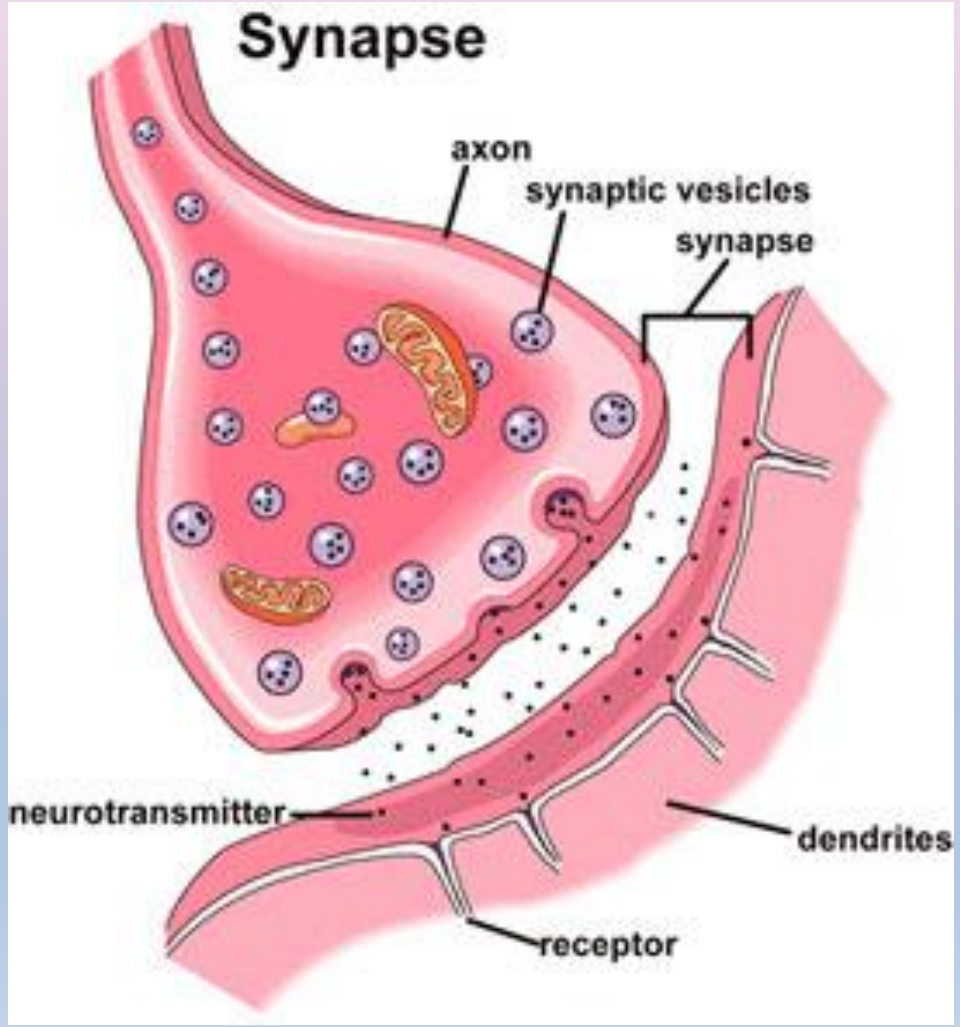
Effector nerve endings are of 2 types:

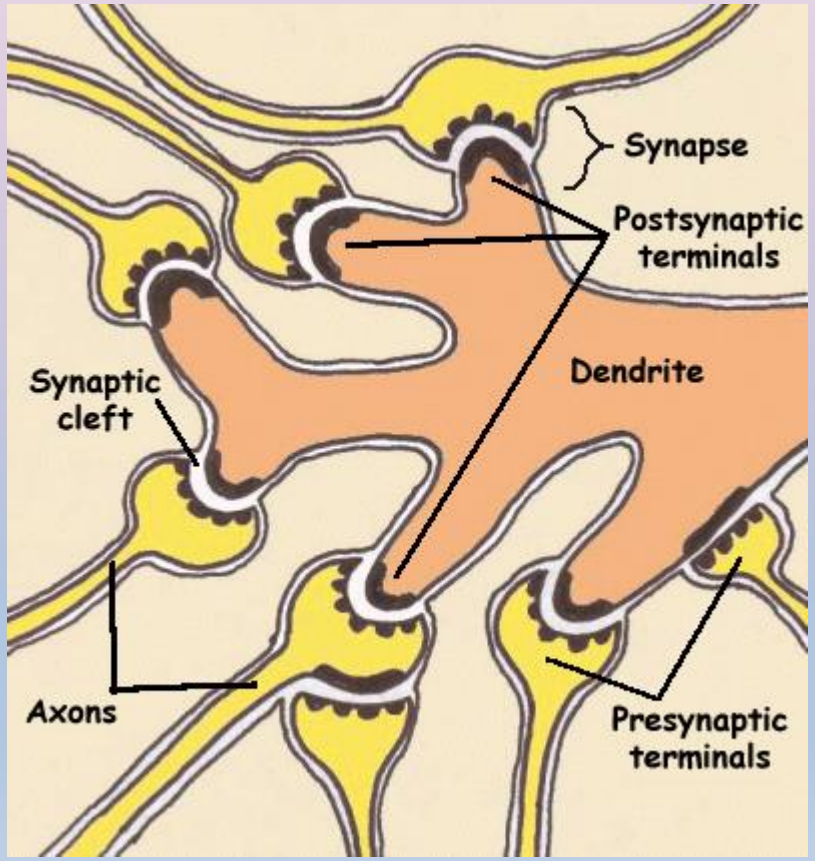
1.**motor** – this is terminal apparatus of the motor cells axons of the somatic or vegetative nervous system.

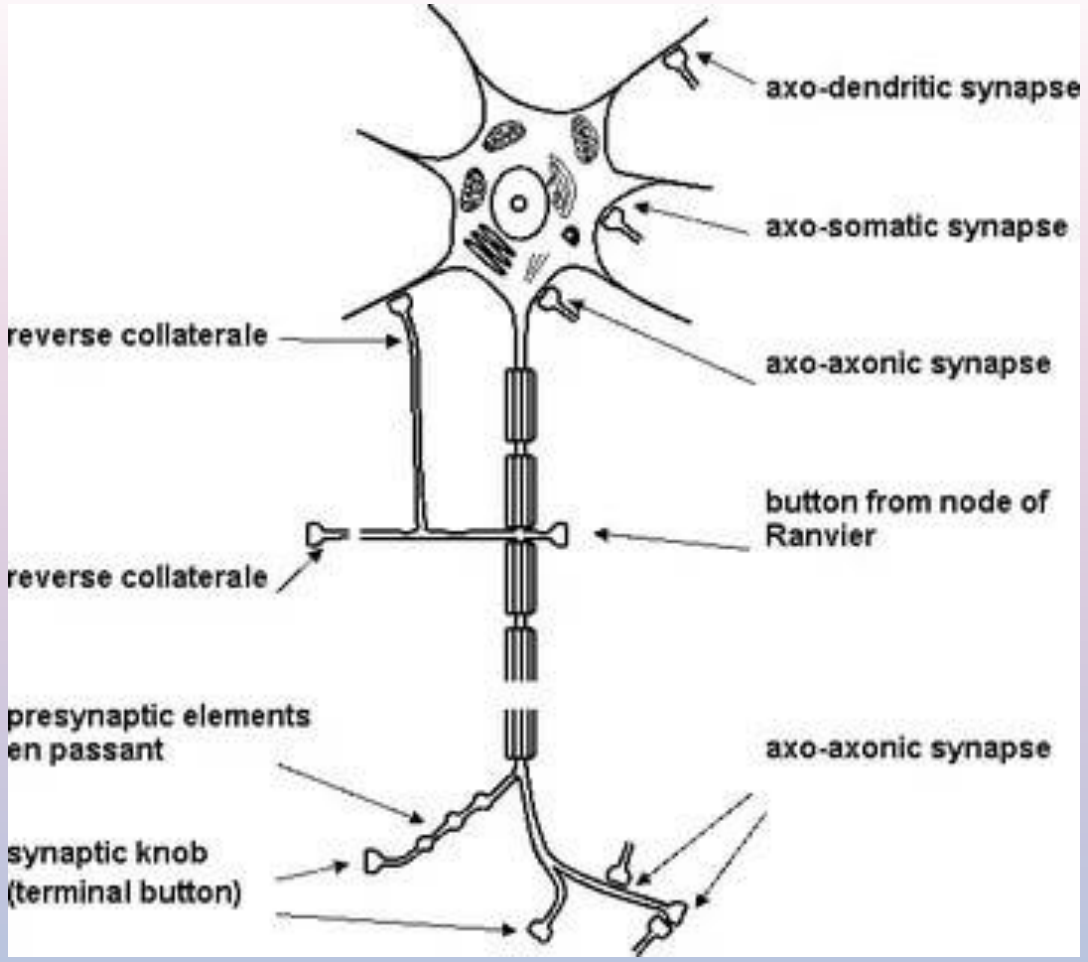
With their help nerve impulse is passed onto tissues of working organs (nerve-muscular endings in striated muscles, motor nerve endings in smooth muscles);

2.**secretory** – they represent terminal thickenings of terminals or thickenings along nerve fiber containing synaptic vesicles.

Polarization of passing of nerve impulse along chain of neurons is determined by their specialized contacts – synapses.







According to localization synapses are:

1.axo-dendritic;

2.axo-somatic;

3.axo-axonic.

SYNAPSE

According to the type of impulse passage:

1. Chemical synapse

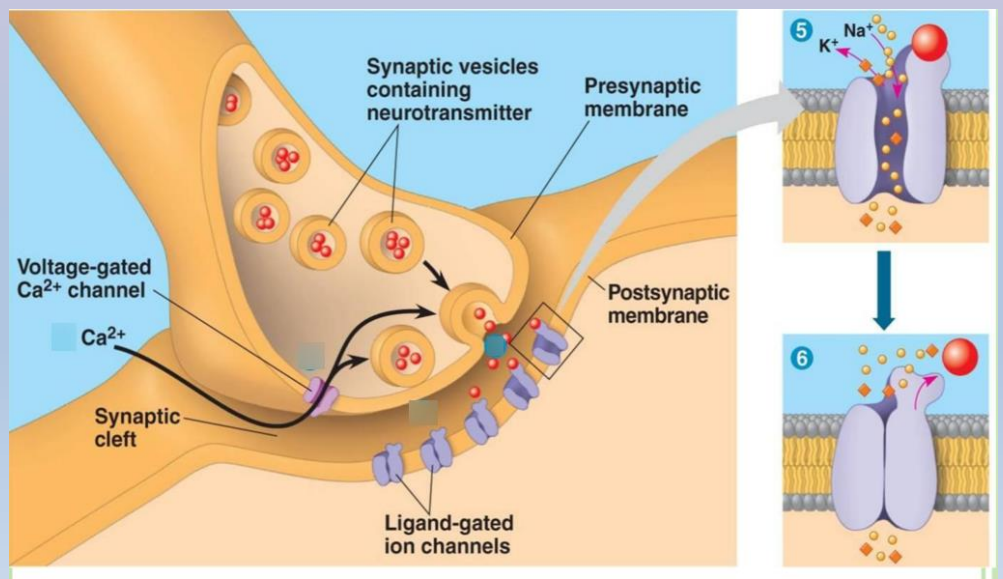
Impulses pass by the help of special biologically active substances– **neuromediators** placed in synaptic vesicles (acetylcholin, noradrenalin, dophamin, serotonin, histamine).

2. Electrical synapse

Electrical synapses in the nervous system of the mammals are present rarely. Their structure corresponds to fissure-shaped contact.

3 parts of the chemical synapse:

1. **Presynaptic membrane**
   - Presynaptic part is formed by area of plasmalemma of the first neuron.
   - It contains accumulations of mitochondria and synaptic vesicles.
   - Synaptic vesicles are filled by neuromediator excreted into synaptic fissure and taking part in passing of excitation to postsynaptic part.
2. **Synaptic cleft**
   - Synaptic fissure is located between pre- and postsynaptic parts of synapse.
   - Its width is 20-30 nanometers.
3. **Postsynaptic membrane**
   - Postsynaptic part is area of plasmalemma of the second neuron which percepts neuromediators.
   - It contains receptor zones for perception of corresponding mediator.



The work of the central nervous system is based on **reflex**.

Reflex is the body's response to external or internal irritation.

There are two types of reflexes:

1. **unconditioned = congenital = hereditary**

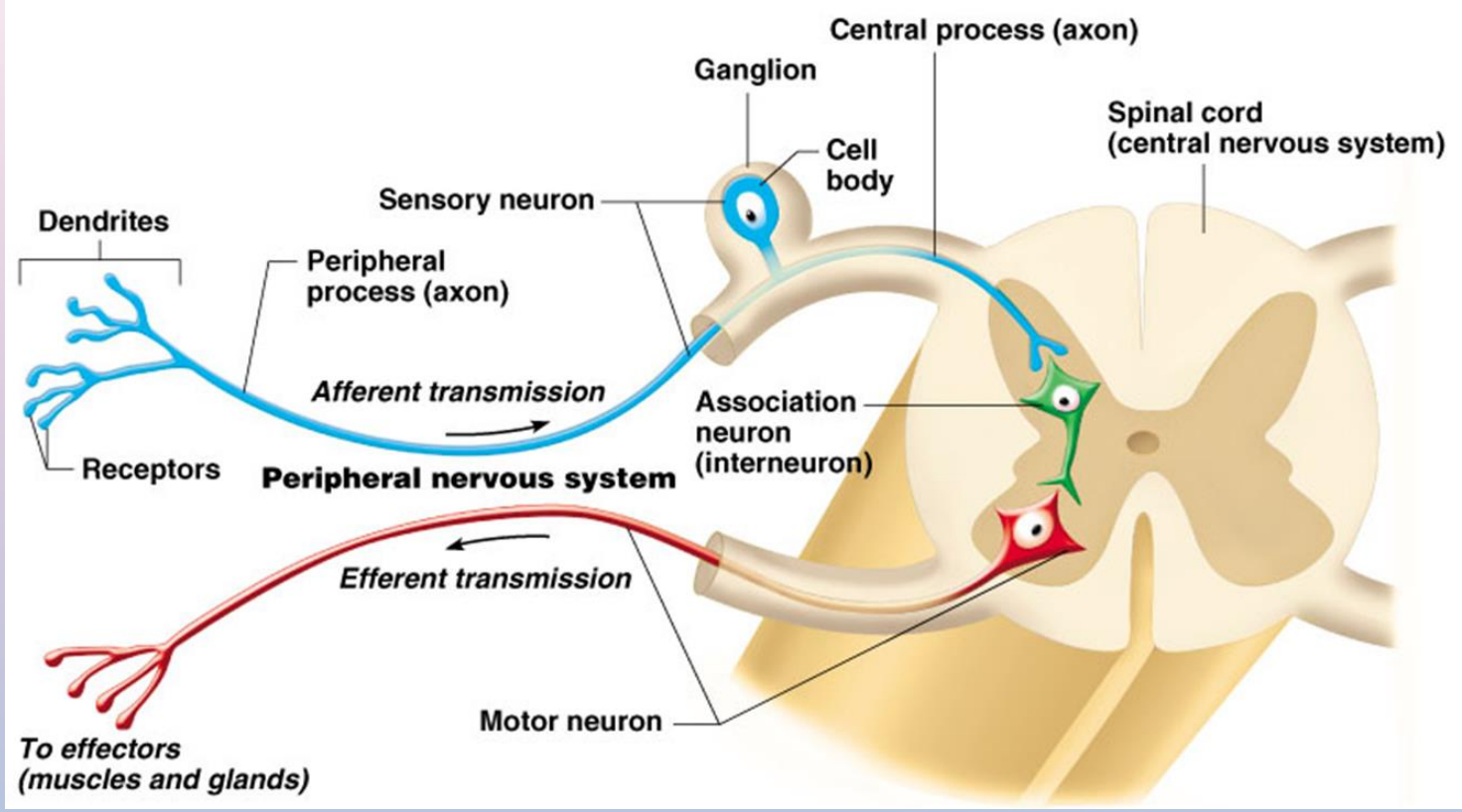
They are carried out with the participation of the spinal cord or brainstem.

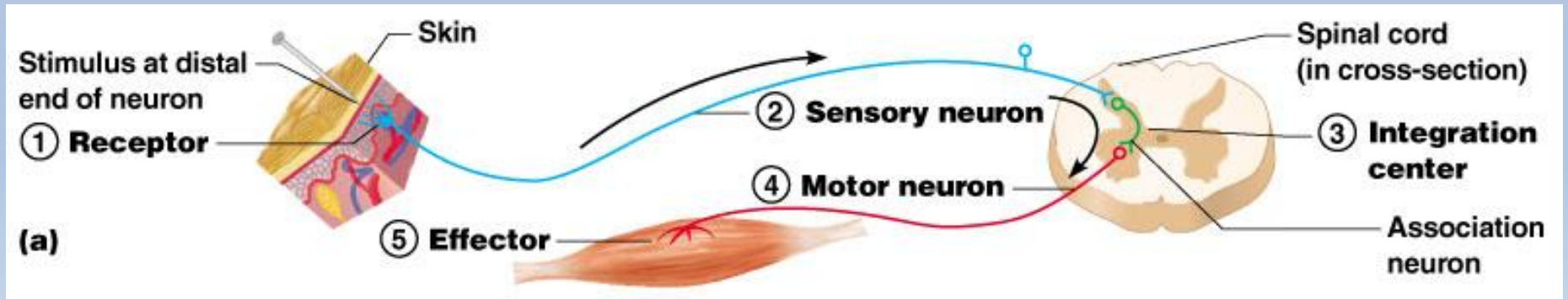
2. conditioned

They are acquired and carried out with the obligatory participation of the cortex of brain.

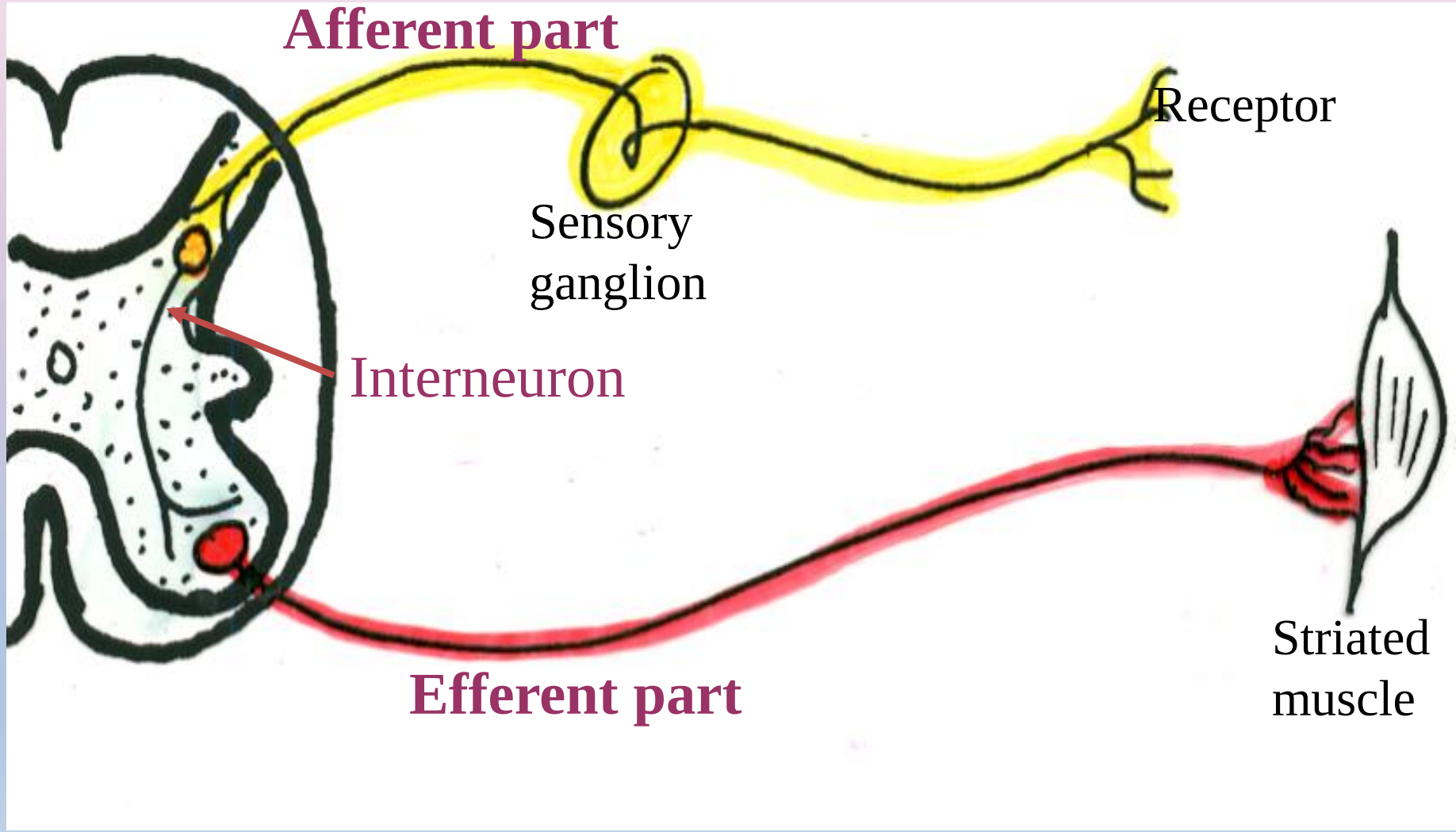
The morphological basis of the reflex is the reflex arch.

Reflex arch


Central process (axon)
Ganglion
Spinal cord
(central nervous system)
Cell
body
Sensory neuron
Dendrites
Peripheral
process (axon)
Afferent transmission
Association
neuron
(interneuron)
Receptors
Peripheral nervous system
Efferent transmission
Motor neuron
To effectors
(muscles and glands)


Stimulus at distal
end of neuron
Skin
Spinal cord
(in cross-section)
① Receptor
② Sensory neuron
③ Integration
center
④ Motor neuron
(a)
⑤ Effector
Association
neuron

Somatic reflex arc



Autonomic reflex arc