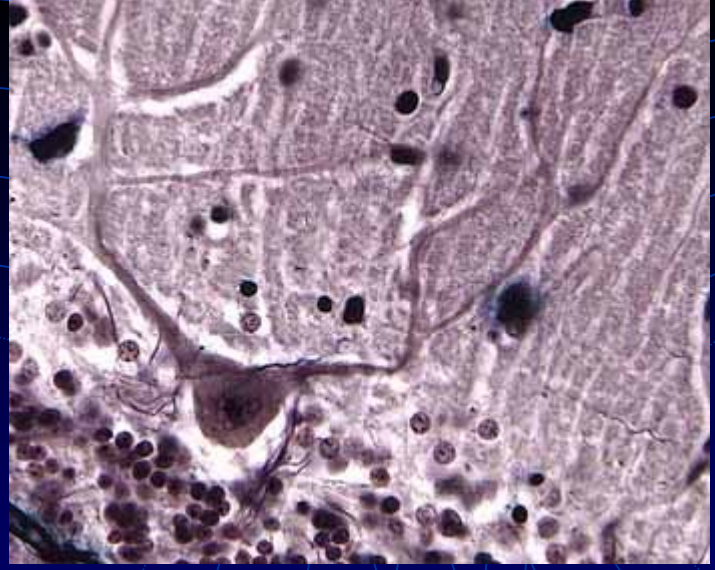
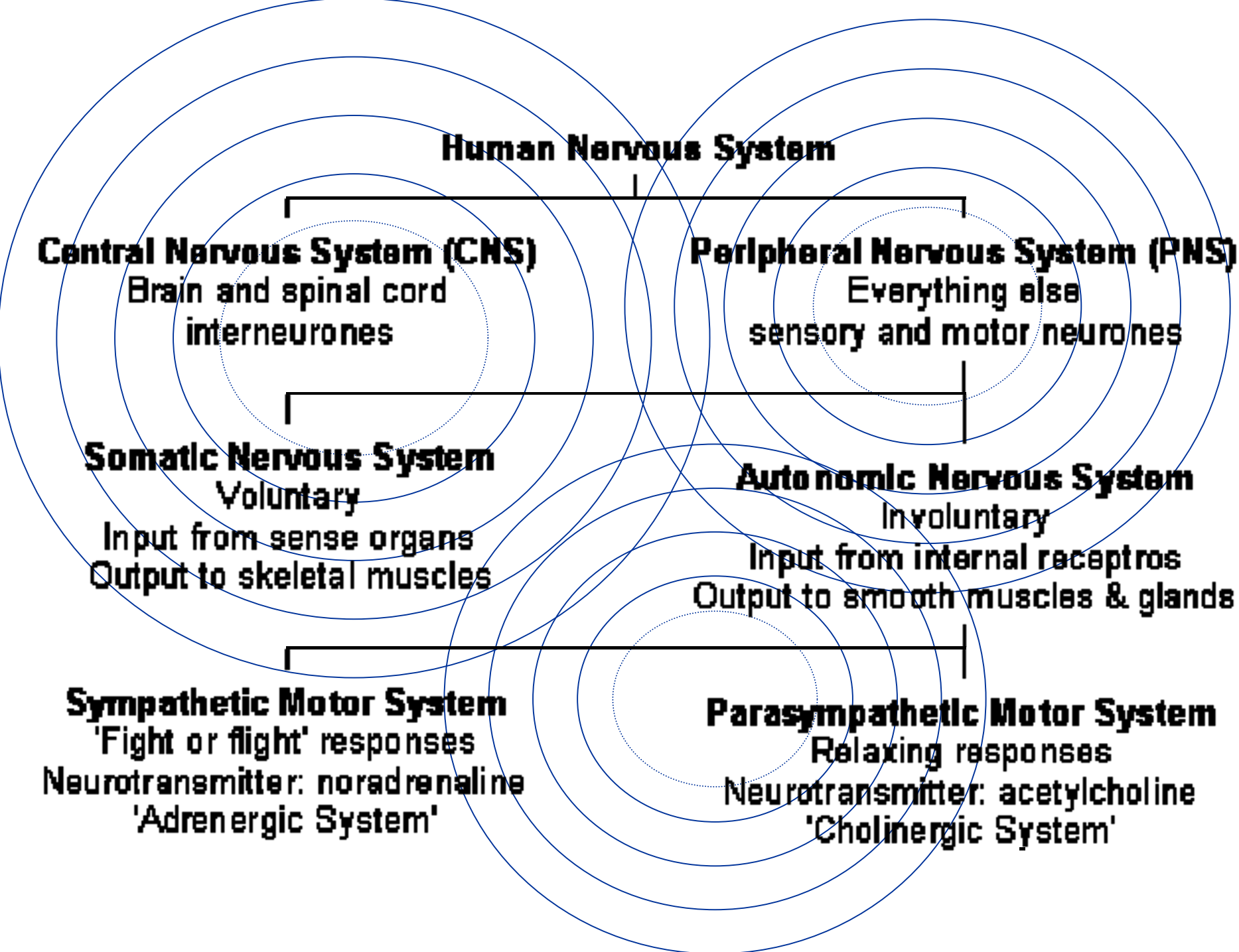


Nervous system part 1

Danil Hammoudi.MD


Human Nervous System
Central Nervous System (CNS)
Brain and spinal cord
interneurones
Peripheral Nervous System (PNS)
Everything else
sensory and motor neurones
Somatic Nervous System
Voluntary
Input from sense organs
Output to skeletal muscles
Autonomic Nervous System
Involuntary
Input from internal receptros
Output to smooth muscles & glands
Sympathetic Motor System
'Fight or flight' responses
Neurotransmitter: noradrenaline
'Adrenergic System'
Parasympathetic Motor System
Relaxing responses
Neurotransmitter: acetylcholine
'Cholinergic System'

The central nervous system (CNS) is formed by :

- the brain
- spinal cord.

- These elements are enclosed within the skull and spinal vertebral canal.

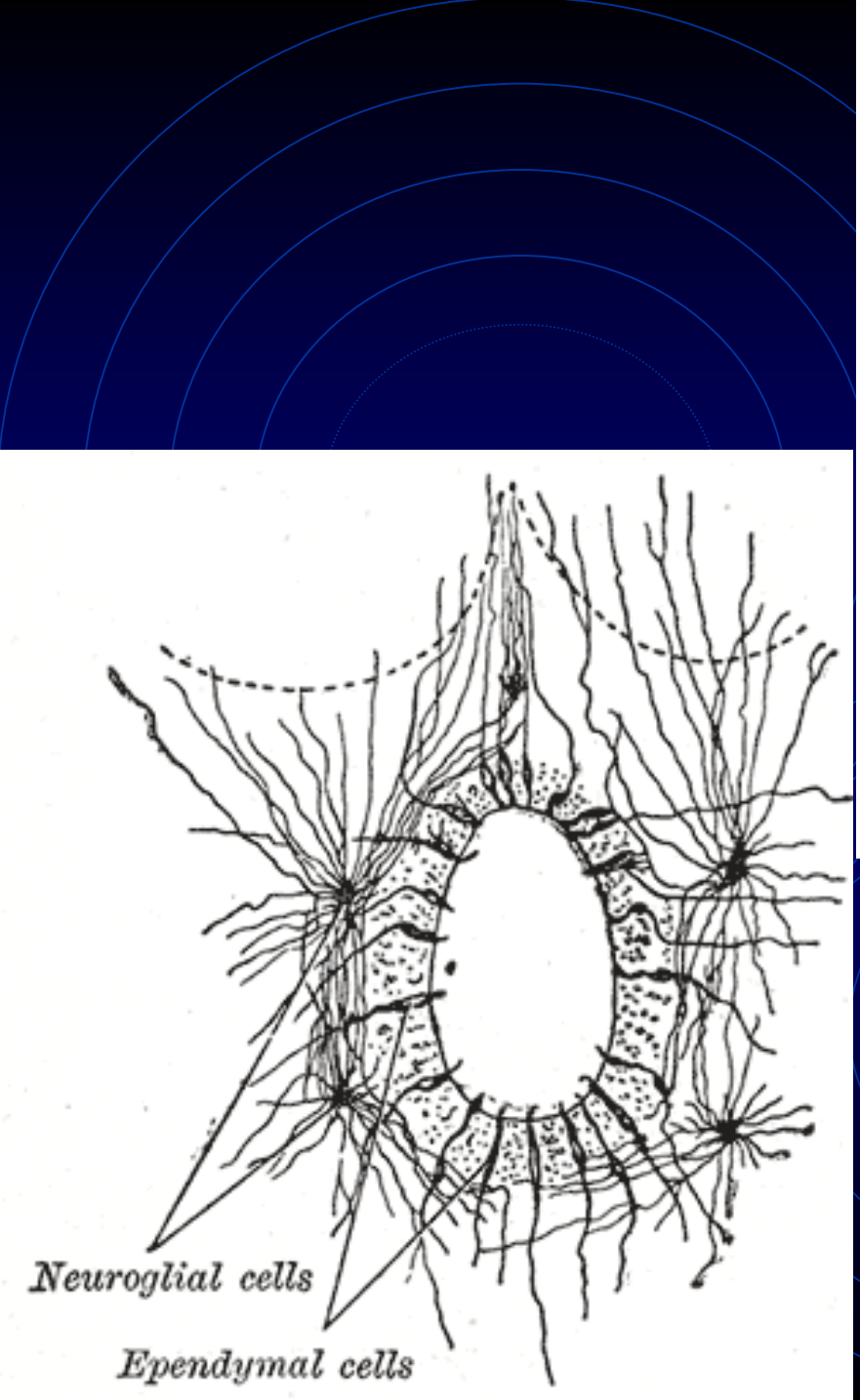
- They are covered by the meninges,
  - the dura,
  - arachnoid
  - pia.
- Cerebrospinal fluid flows over the surface and fills the chambers (ventricles, central canal of the spinal cord).
- Two primary cell types make up the CNS - the neurons, and the glia [NEUROGLIA].

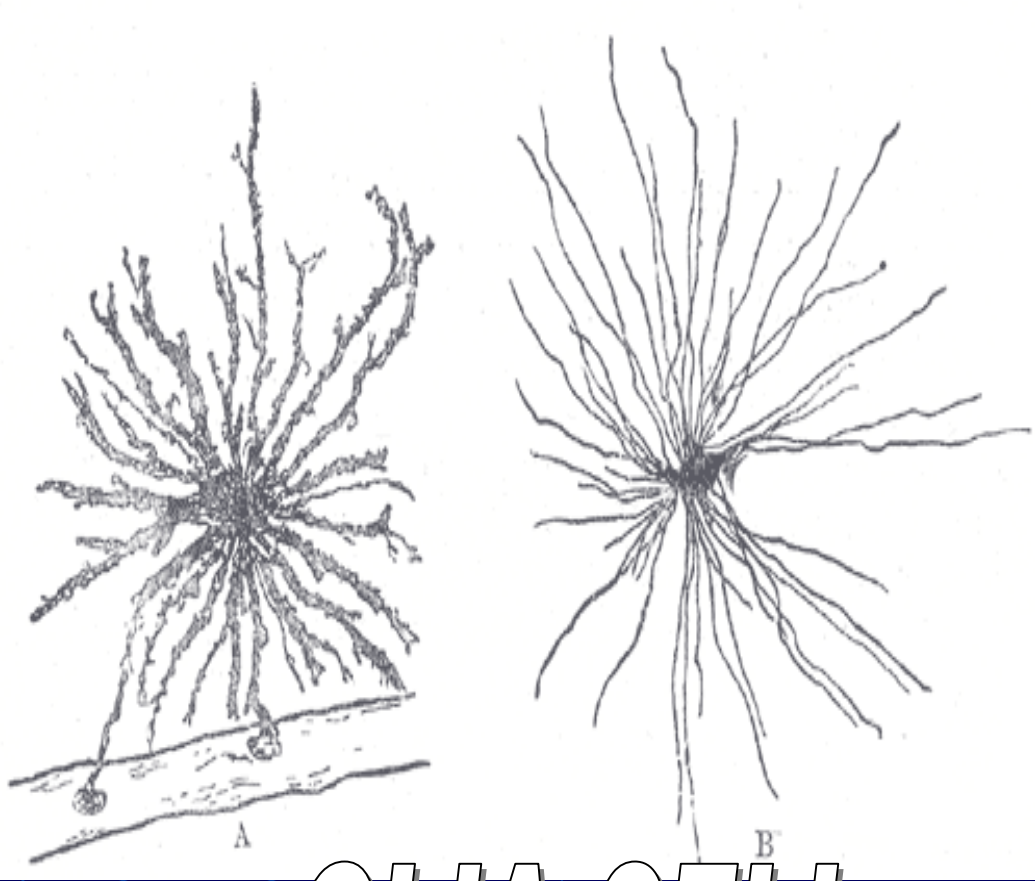
NEUROGLIA OR GLIA

- **Glial cells**, commonly called **neuroglia** or simply **glia**, are non-neuronal cells that provide
  - support and nutrition,
  - maintain homeostasis,
  - form myelin,
  - and participate in signal transmission in the nervous system.

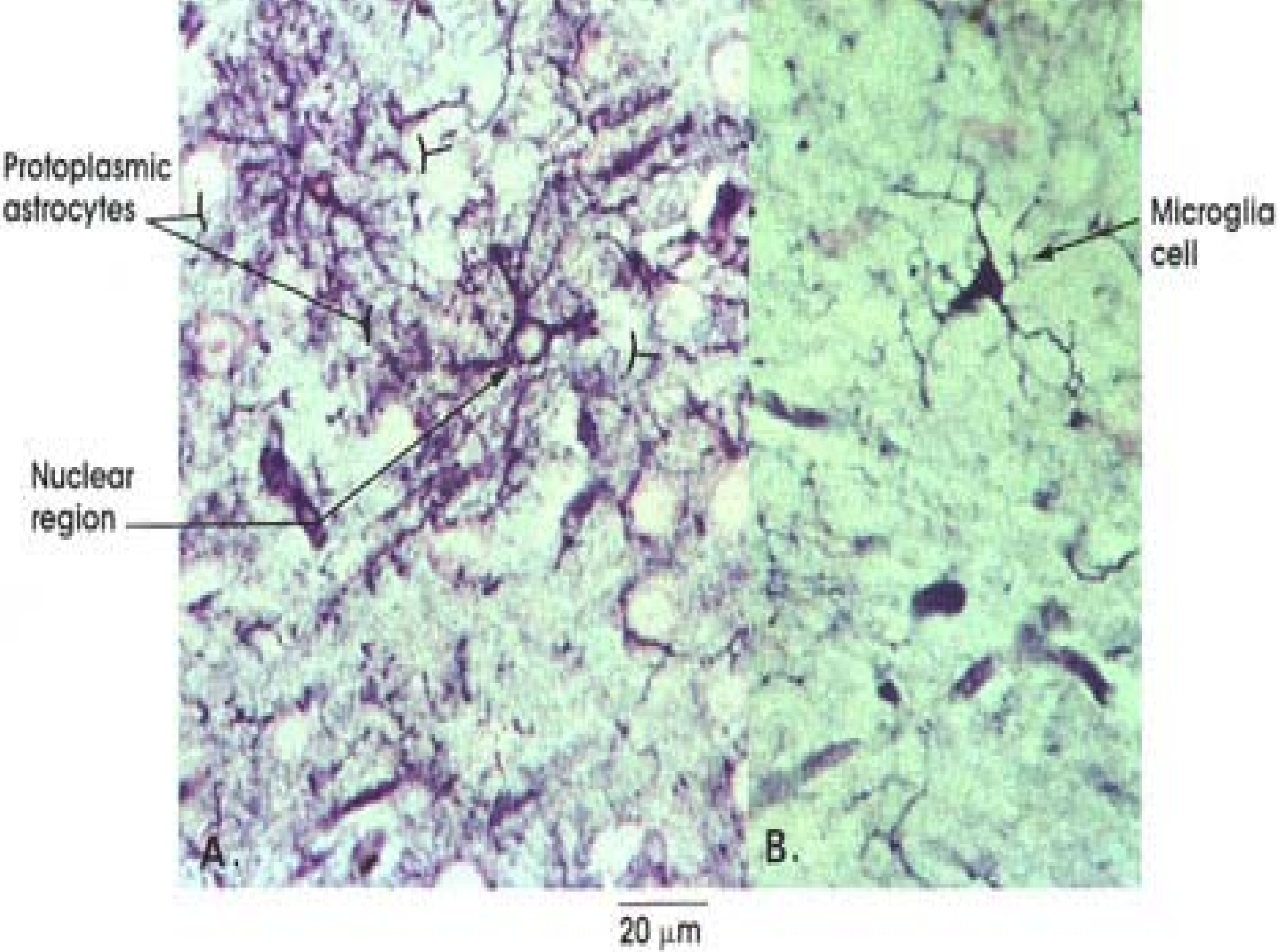
TYPE OF NEUROGLIA

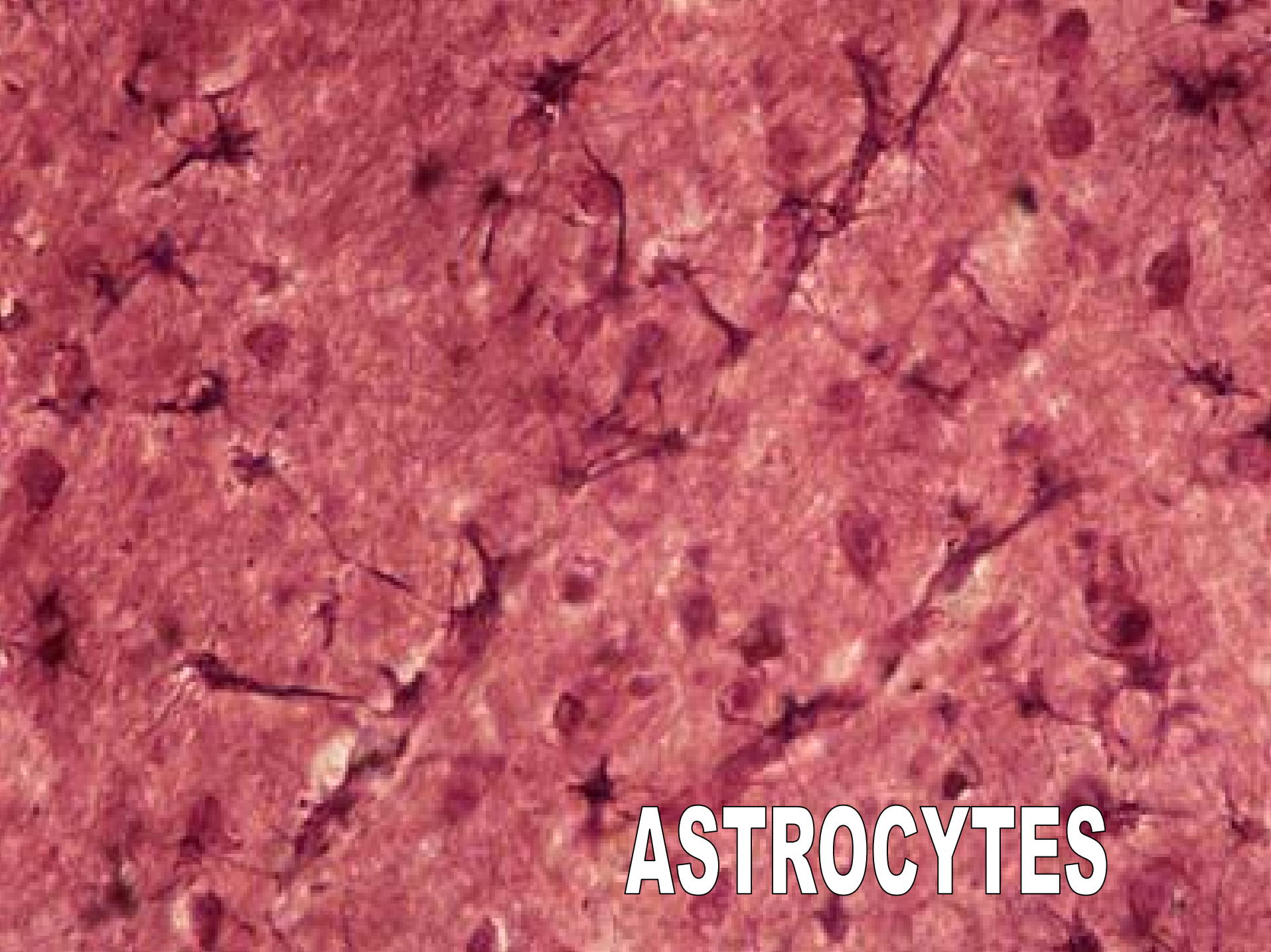
- **Microglia [Microglia are specialized macrophages capable of phagocytosis that protect neurons of the CNS.]**
- **Macroglia FOR CNS**
  - **Astrocytes: The most abundant type of glial cell, astrocytes (also called *astroglia*)**
  - **Oligodendrocytes**
  - **Ependymal cells**
  - **Radial glia**
- **FOR PNS [PERIPHERIC NERVOUS SYSTEM**
  - **Schwann cells**
  - **Satellite cells**

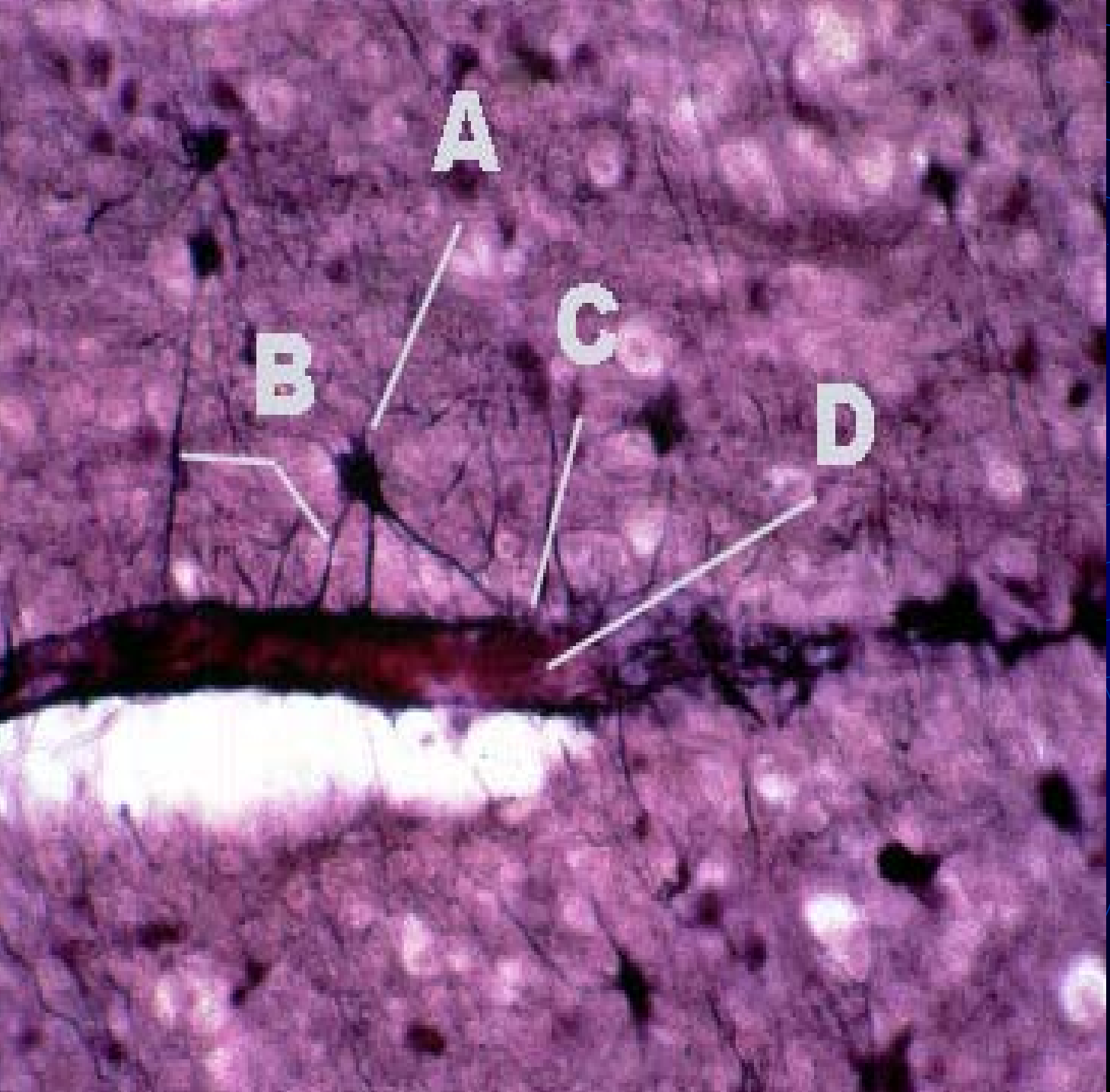




GLIA CELL


Protoplasmic astrocytes
Nuclear region
Microglia cell
A.
B.
20 μm

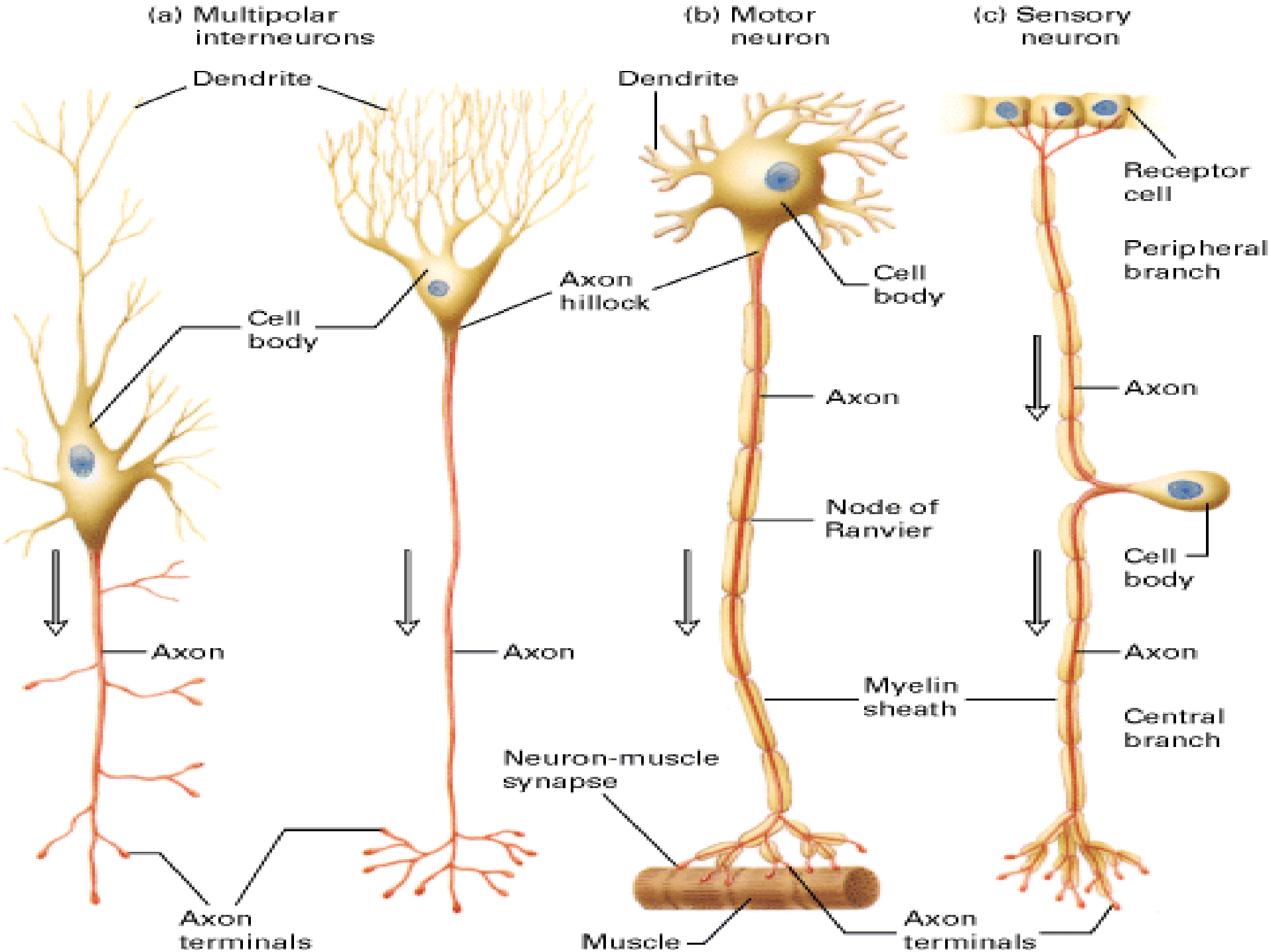

ASTROCYTES

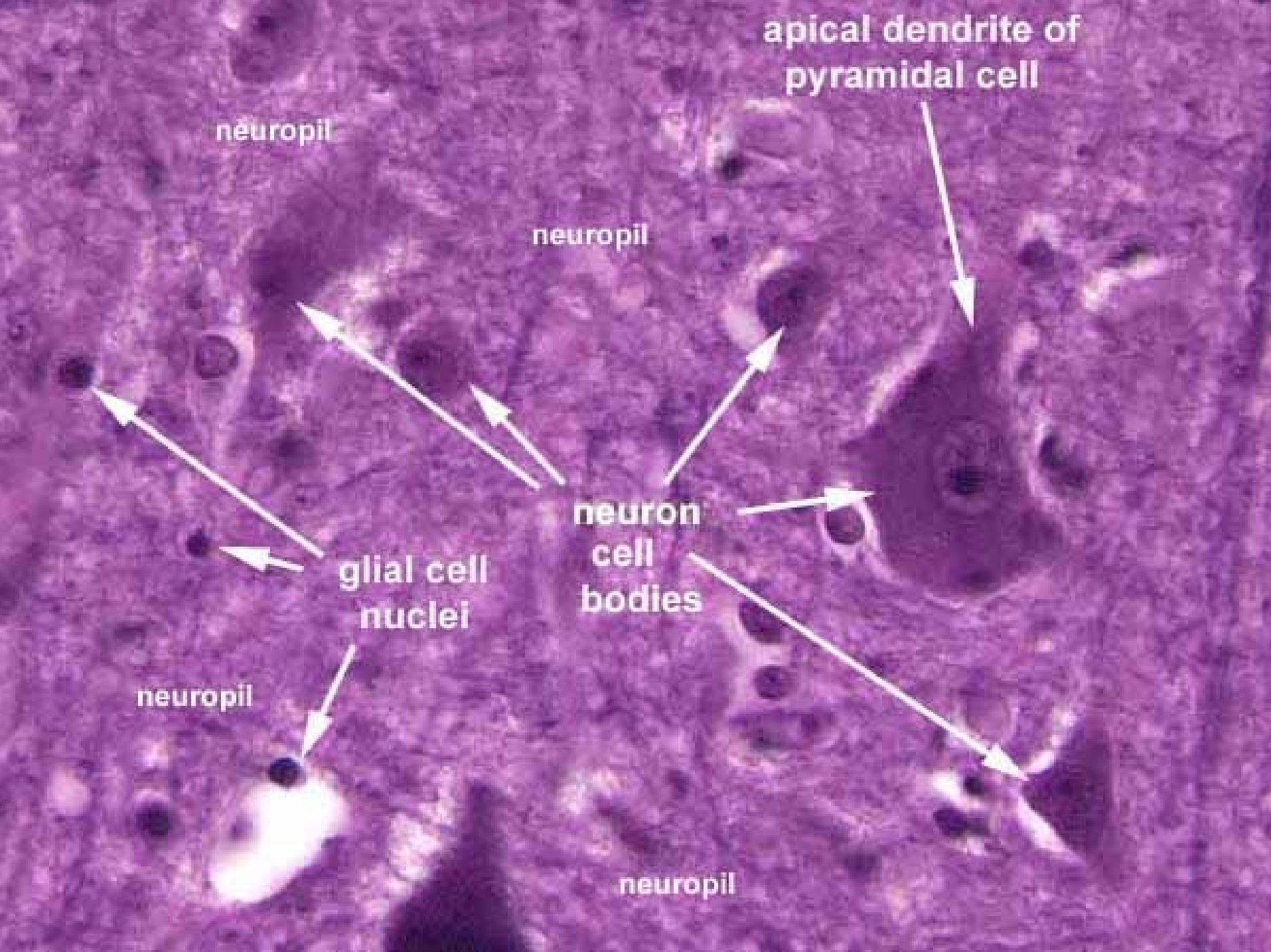


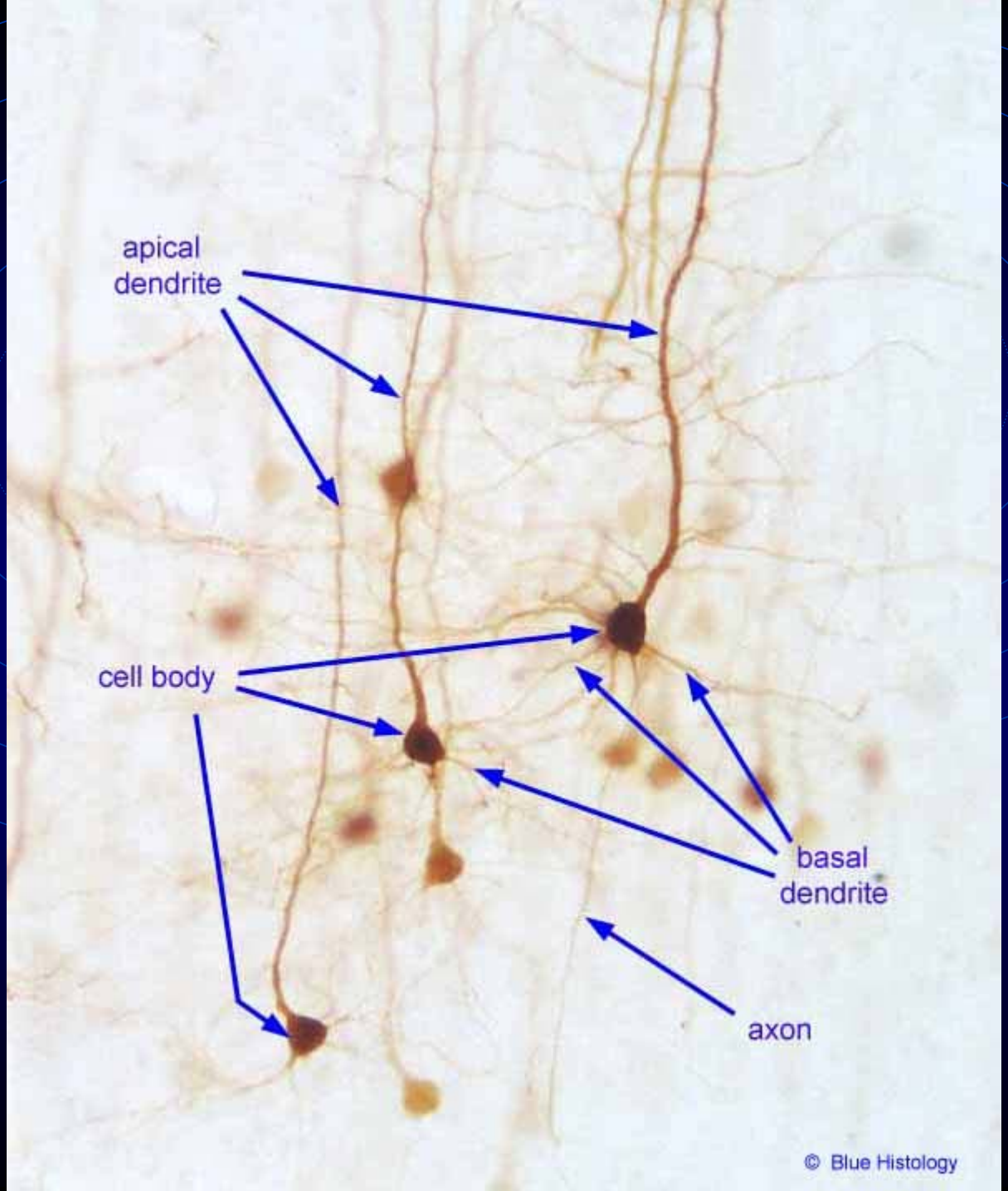
numerous processes (B), some astrocytic processes are in contact with nerve fibers. Other astrocytic processes surround capillaries (D) forming perivascular end-feet (C).

Neurons

- There are many types of neuron based on the size and shape of the cell body and the arrangement of the processes.
- Based on their staining neurons could be seen to be unipolar, bipolar or multipolar.
- Most of the neurons within the CNS are multipolar.
- The processes extending from the cell body are either axons or dendrites.
- Neurons usually have only one axon but many dendrites.


(a) Multipolar interneurons
(b) Motor neuron
(c) Sensory neuron
Dendrite
Cell body
Axon hillock
Axon
Axon terminals
Dendrite
Axon hillock
Cell body
Axon
Node of Ranvier
Myelin sheath
Neuron-muscle synapse
Muscle
Axon terminals
Receptor cell
Peripheral branch
Axon
Cell body
Axon
Central branch

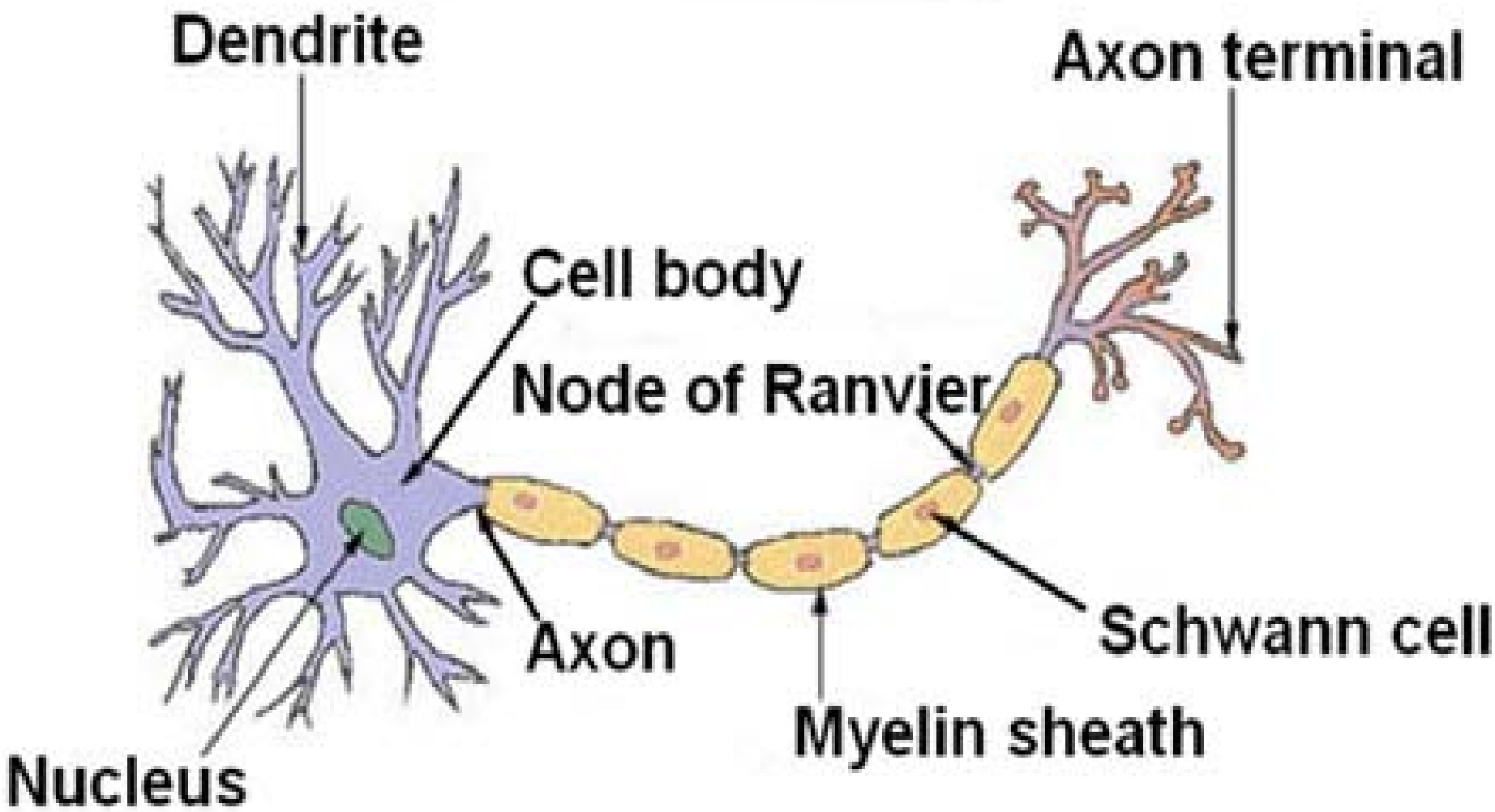

apical dendrite of
pyramidal cell
neuropil
neuropil
neuron
cell
bodies
glial cell
nuclei
neuropil
neuropil


apical
dendrite
cell body
basal
dendrite
axon
© Blue Histology

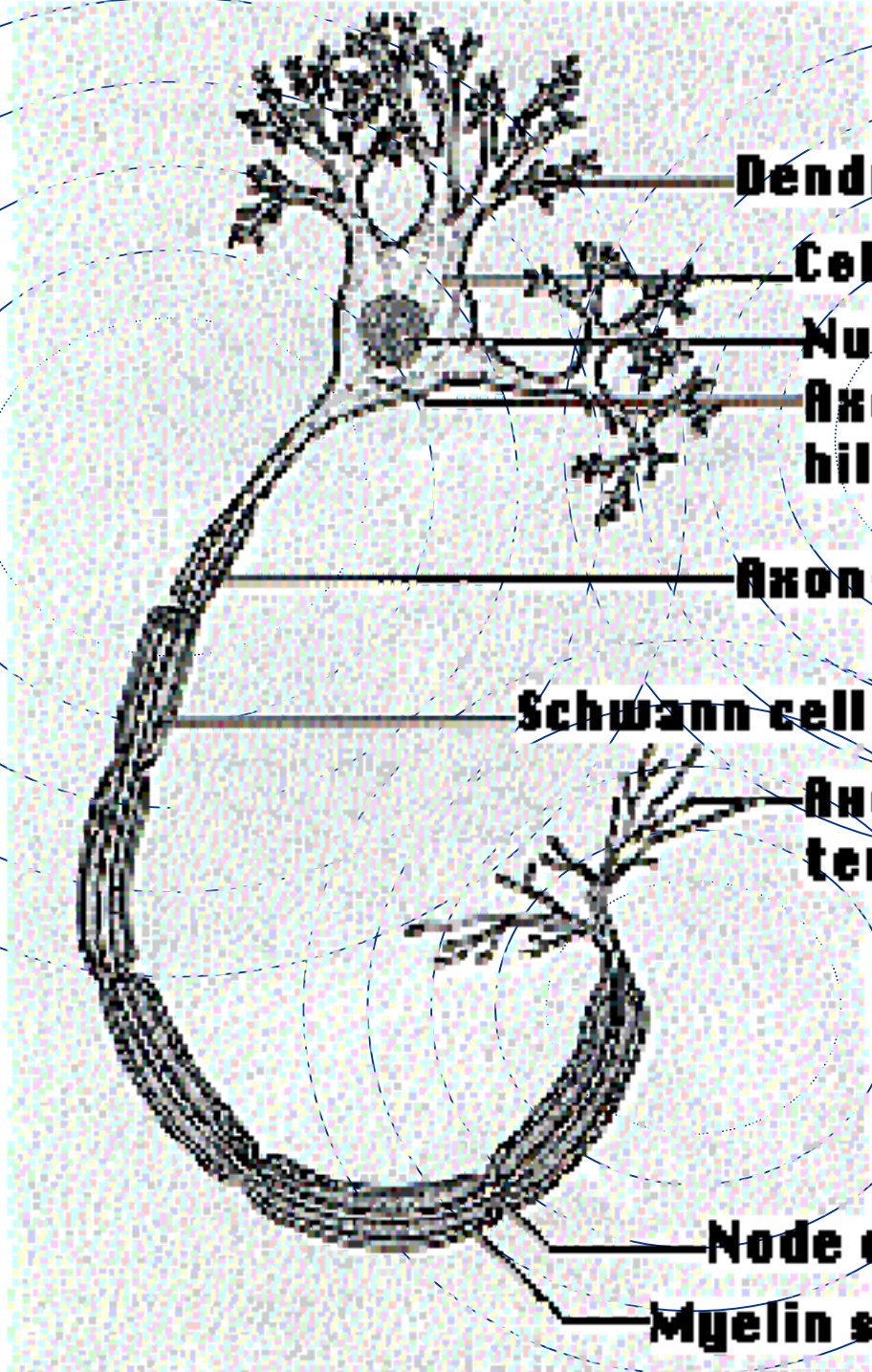
NEURONS

- Main role is to process and transmit information.
- neurons are found in the brain, the spinal cord and in the nerves and ganglia of the peripheral nervous system.
- Neurons are typically composed of a cell body, a dendritic tree and an axon.

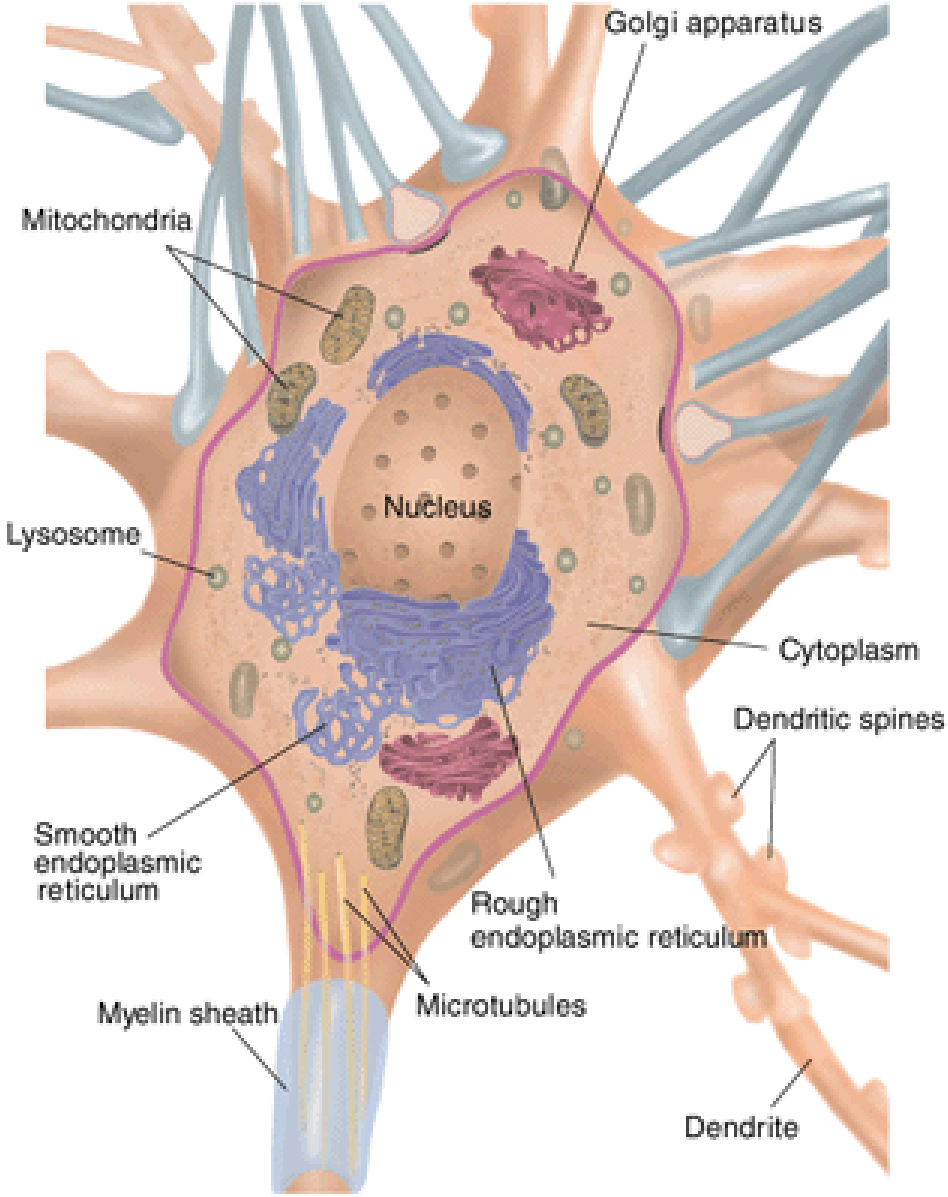
Structure of a Typical Neuron



Axons	Dendrites
•Take information away from the cell body •Smooth Surface •Generally only 1 axon per cell •No ribosomes •Can have myelin •Branch further from the cell body	•Bring information to the cell body •Rough Surface (dendritic spines) •Usually many dendrites per cell •Have ribosomes •No myelin insulation •Branch near the cell body


Dendrite
Cell body
Nucleus
Axon hillock
Axon
Schwann cell
Axon terminals
Node of Ranvier
Myelin sheath

▶ Principal Internal Structures of a Multipolar Neuron



Neurons are similar to other cells in the body because:

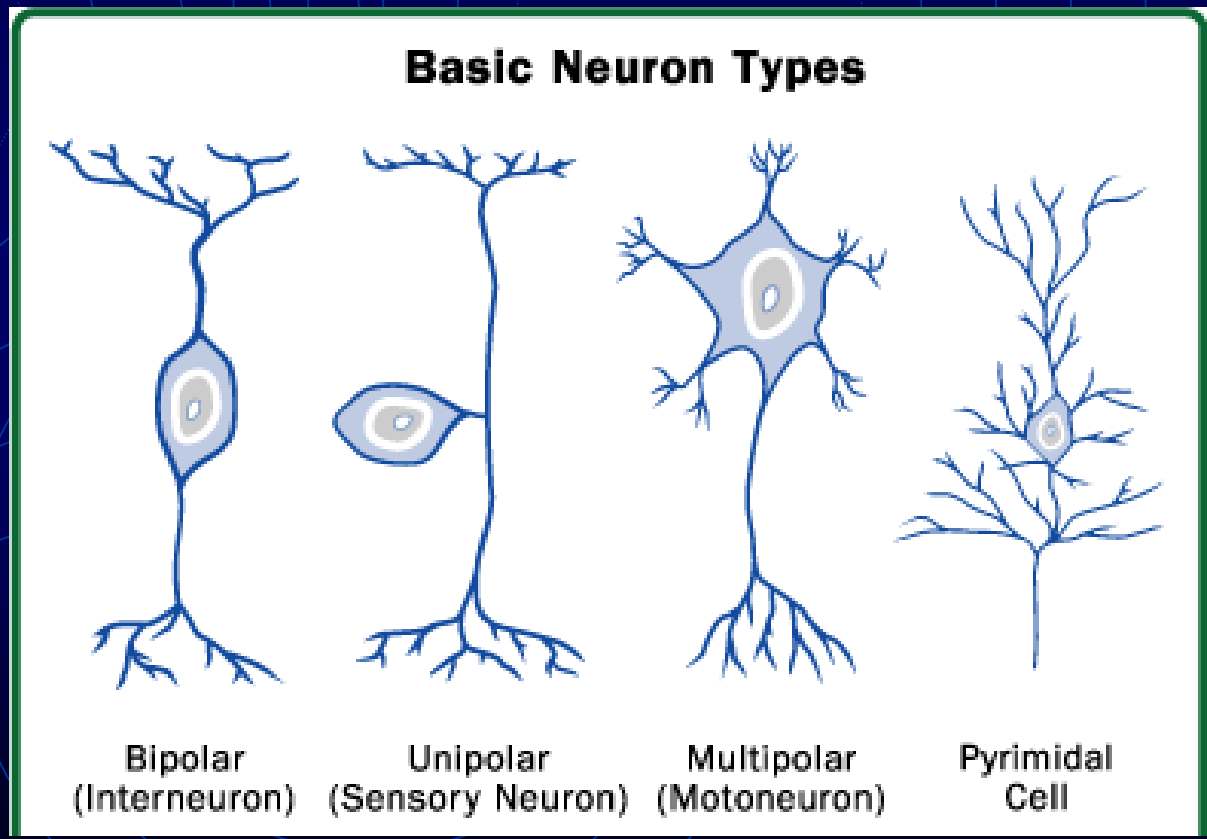
1. Neurons are surrounded by a cell membrane.
2. Neurons have a nucleus that contains genes.
3. Neurons contain cytoplasm, mitochondria and other organelles.
4. Neurons carry out basic cellular processes such as protein synthesis and energy production.

Neurons differ from other cells in the body because:

1. Neurons have specialised extensions called dendrites and axons. Dendrites bring information to the cell body and axons take information away from the cell body.
2. Neurons communicate with each other through an electrochemical process.
3. Neurons contain some specialized structures (for example, synapses) and chemicals (for example, neurotransmitters).

Type of Neurons

- **Sensory neurons:**
- **Interneurons**
- **Motor neurons**



Sensory neurons

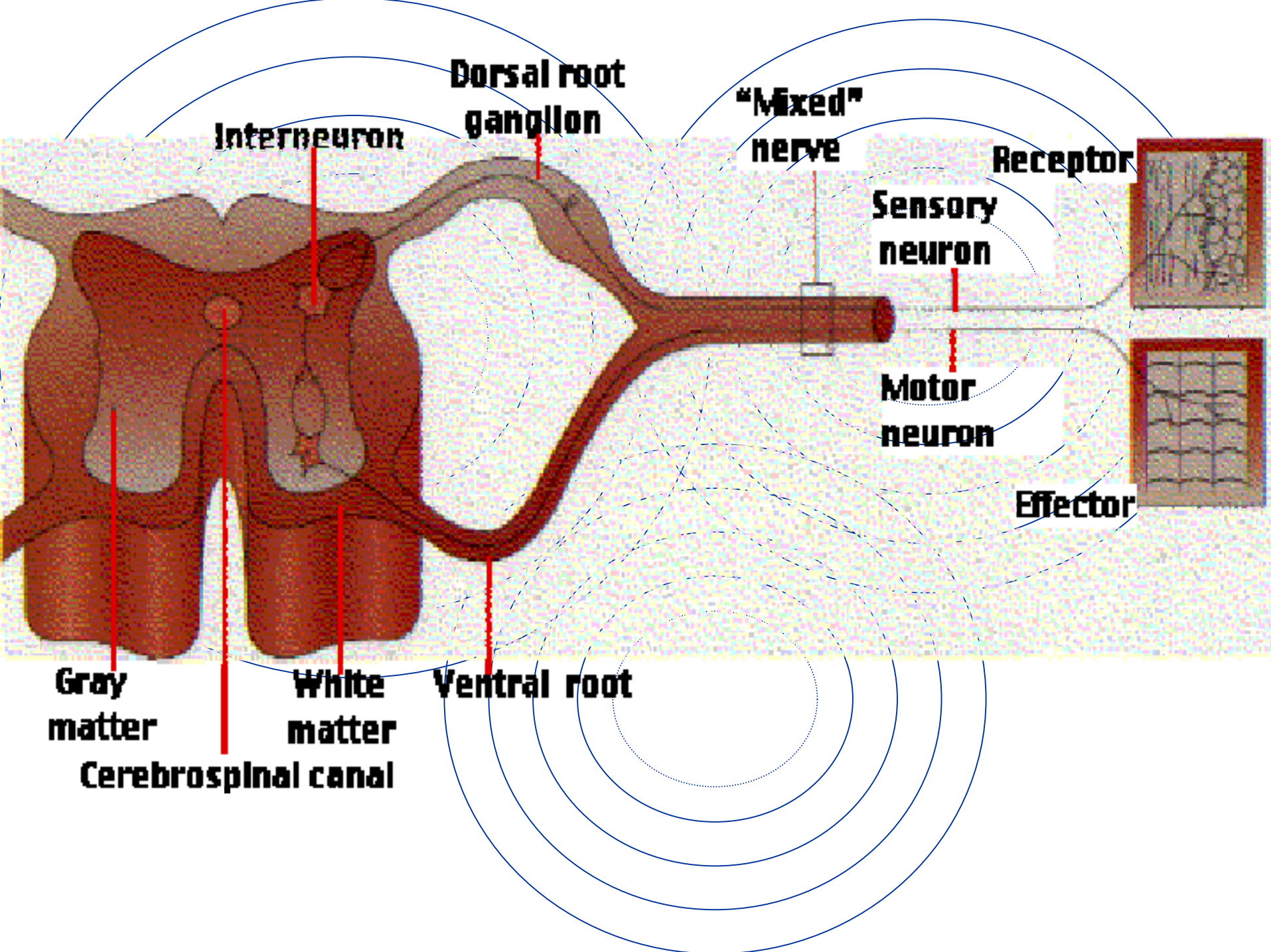
These run from the various types of stimulus receptors, e.g.,

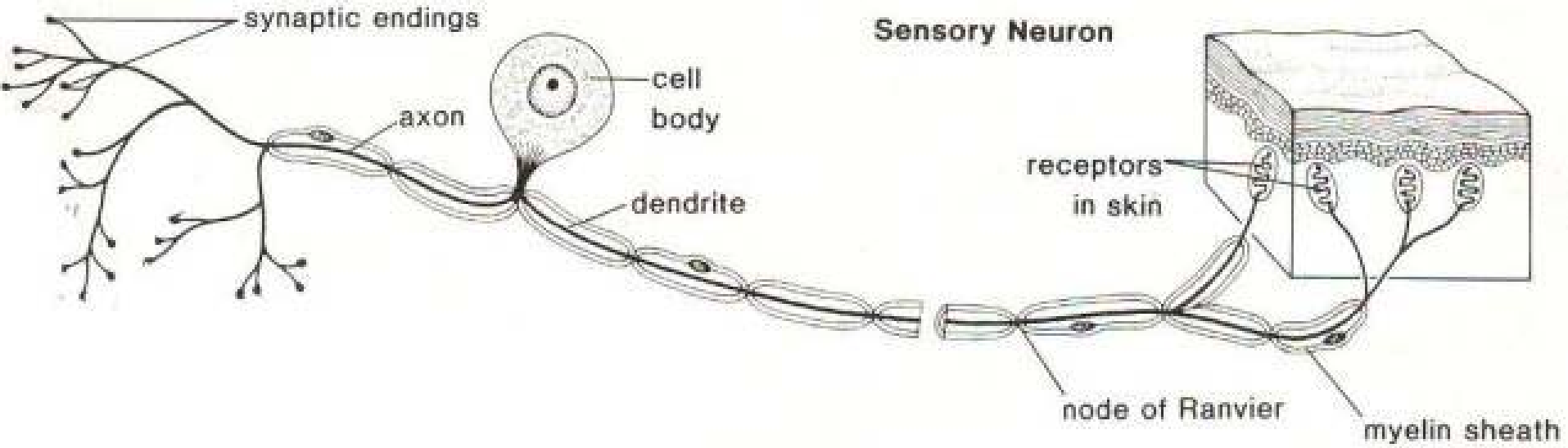
- **touch**
- **odor**
- **taste**
- **sound**
- **vision**

to the central nervous system (CNS), the brain and spinal cord.

The cell bodies of the sensory neurons leading to the spinal cord are located in clusters, called **ganglia**, next to the spinal cord.

The axons usually terminate at interneurons.


Dorsal root ganglion
Interneuron
"Mixed" nerve
Receptor
Sensory neuron
Motor neuron
Effector
Gray matter
White matter
Ventral root
Cerebrospinal canal



Sensory Neurone:

- **Afferent Neuron – Moving away from a central organ or point**
- **Relays messages from receptors to the brain or spinal cord**

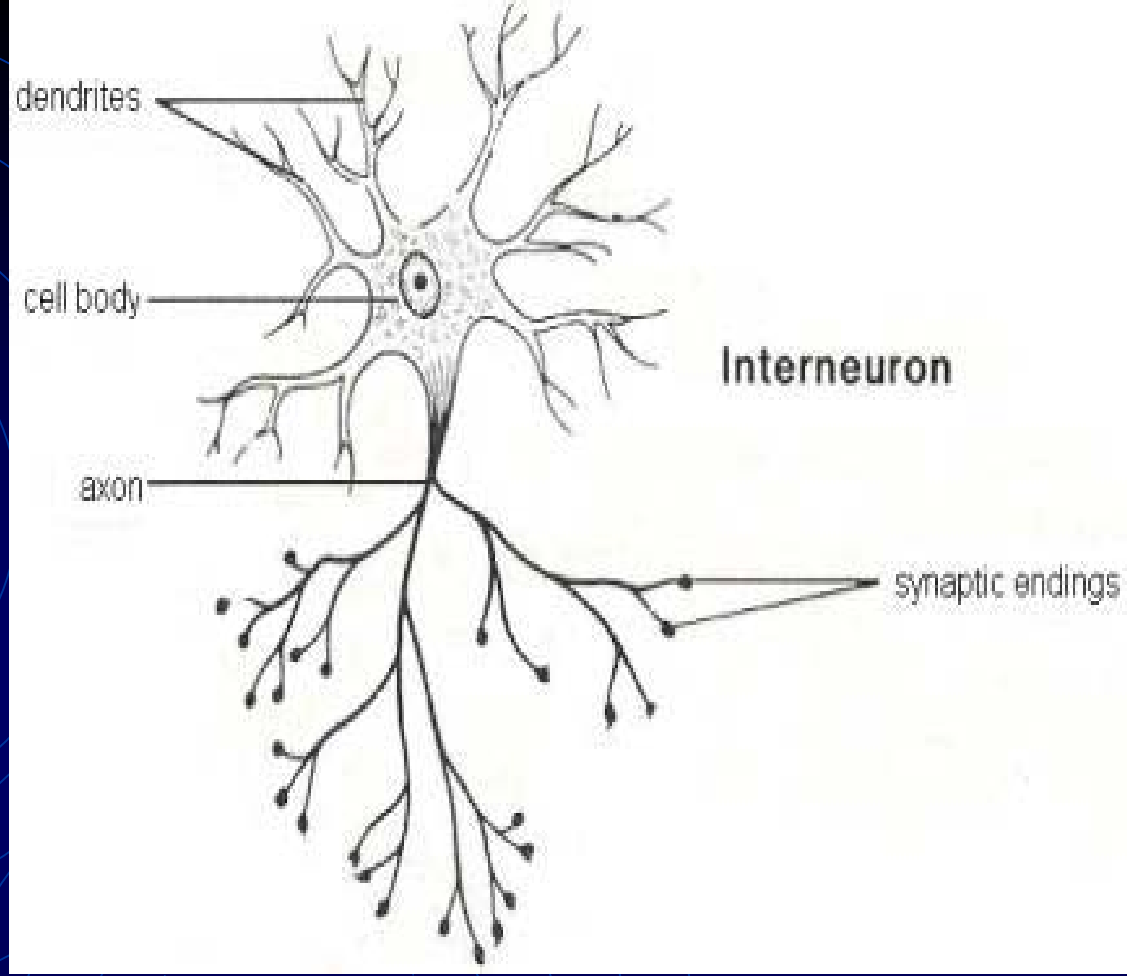
Interneurons

These are found exclusively within the spinal cord and brain.

They are stimulated by signals reaching them from

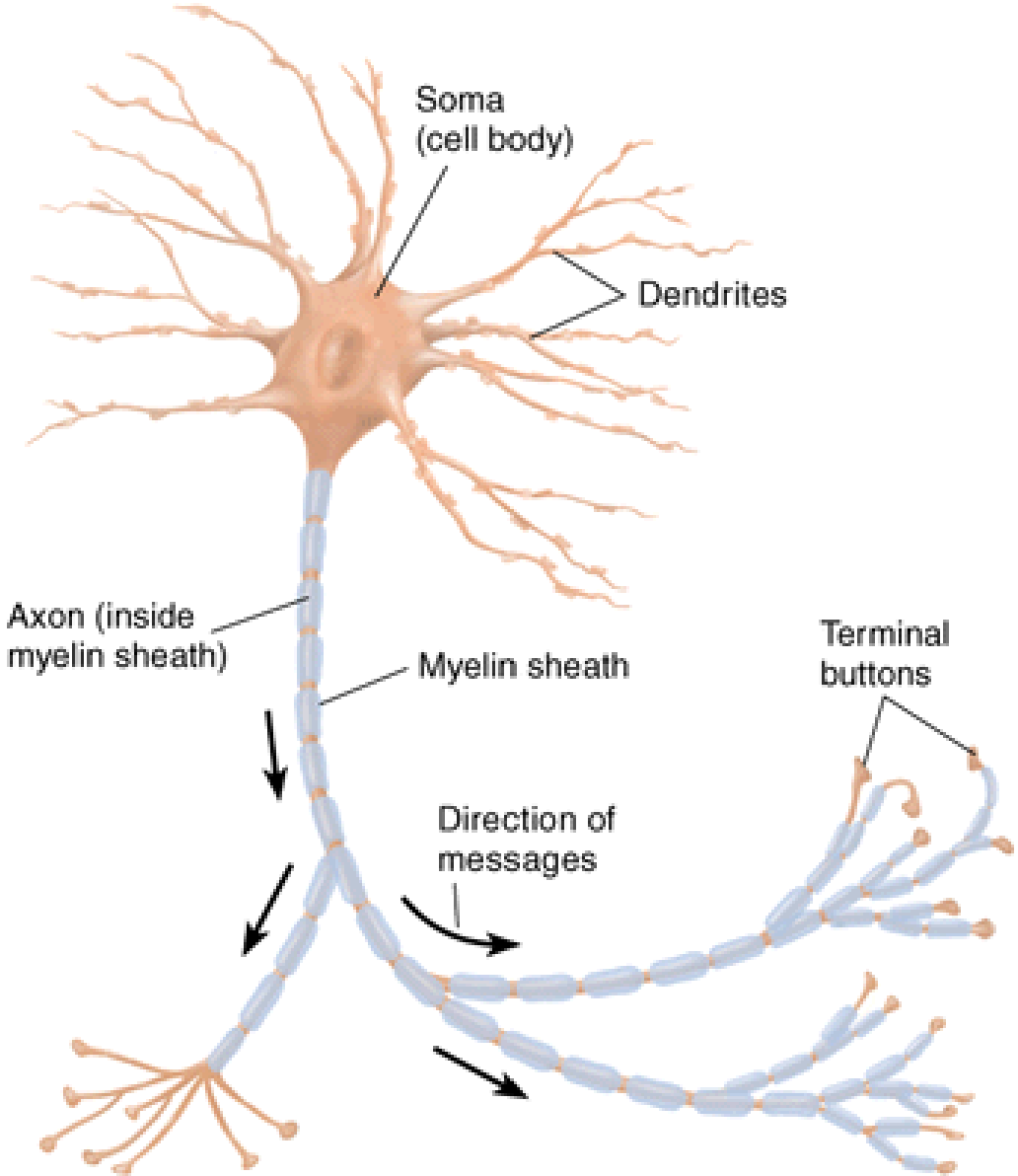
- sensory neurons
- other interneurons or
- both.

Interneurons are also called **association neurons**.



	Sensory neuron	Interneuron	Motor Neuron
Length of Fibers	Long dendrites and short axon	Short dendrites and short or long anxon	Short dendrites and long axons
Location	Cell body and dendrite are outside of the spinal cord; the cell body is located in a dorsal root ganglion	Entirely within the spinal cord or CNS	Dendrites and the cell body are located in the spinal cord; the axon is outside of the spinal cord
Function	Conduct impulse to the spinal cord	Interconnect the sensory neuron with appropriate motor neuron	Conduct impulse to an effector (muscle or gland)

▶ Multipolar Neuron



Motor neurons

These transmit impulses from the central nervous system to the

- muscles and
- glands

that carry out the response.

Most motor neurons are stimulated by interneurons, although some are stimulated directly by sensory neurons.

Structural classification

Most neurons can be anatomically characterized as:

- Unipolar or Pseudounipolar- dendrite and axon emerging from same process.
- Bipolar - single axon and single dendrite on opposite ends of the soma.
- Multipolar - more than two dendrites
  - Golgi I- neurons with long-projecting axonal processes.
  - Golgi II- neurons whose axonal process projects locally.

Some unique neuronal types can be identified according to their location in the nervous system and distinct shape.

Some examples are basket, Betz, medium spiny, Purkinje, pyramidal and Renshaw cells.

Functional classification

- Afferent neurons convey information from tissues and organs into the central nervous system.
- Efferent neurons transmit signals from the central nervous system to the effector cells and are sometimes called motor neurons.
- Interneurons connect neurons within specific regions of the central nervous system.

Afferent and *efferent* can also refer to neurons which convey information from one region of the brain to another.

Classification by action on other neurons

- **Excitatory neurons** evoke excitation of their target neurons. Excitatory neurons in the brain are often glutamatergic. Spinal motoneurons use acetylcholine as their neurotransmitter.

- **Inhibitory neurons** evoke inhibition of their target neurons. Inhibitory neurons are often interneurons. The output of some brain structures (neostriatum, globus pallidus, cerebellum) are inhibitory. The primary inhibitory neurotransmitters are GABA and glycine.

- **Modulatory neurons** evoke more complex effects termed neuromodulation. These neurons use such neurotransmitters as dopamine, acetylcholine, serotonin and others.

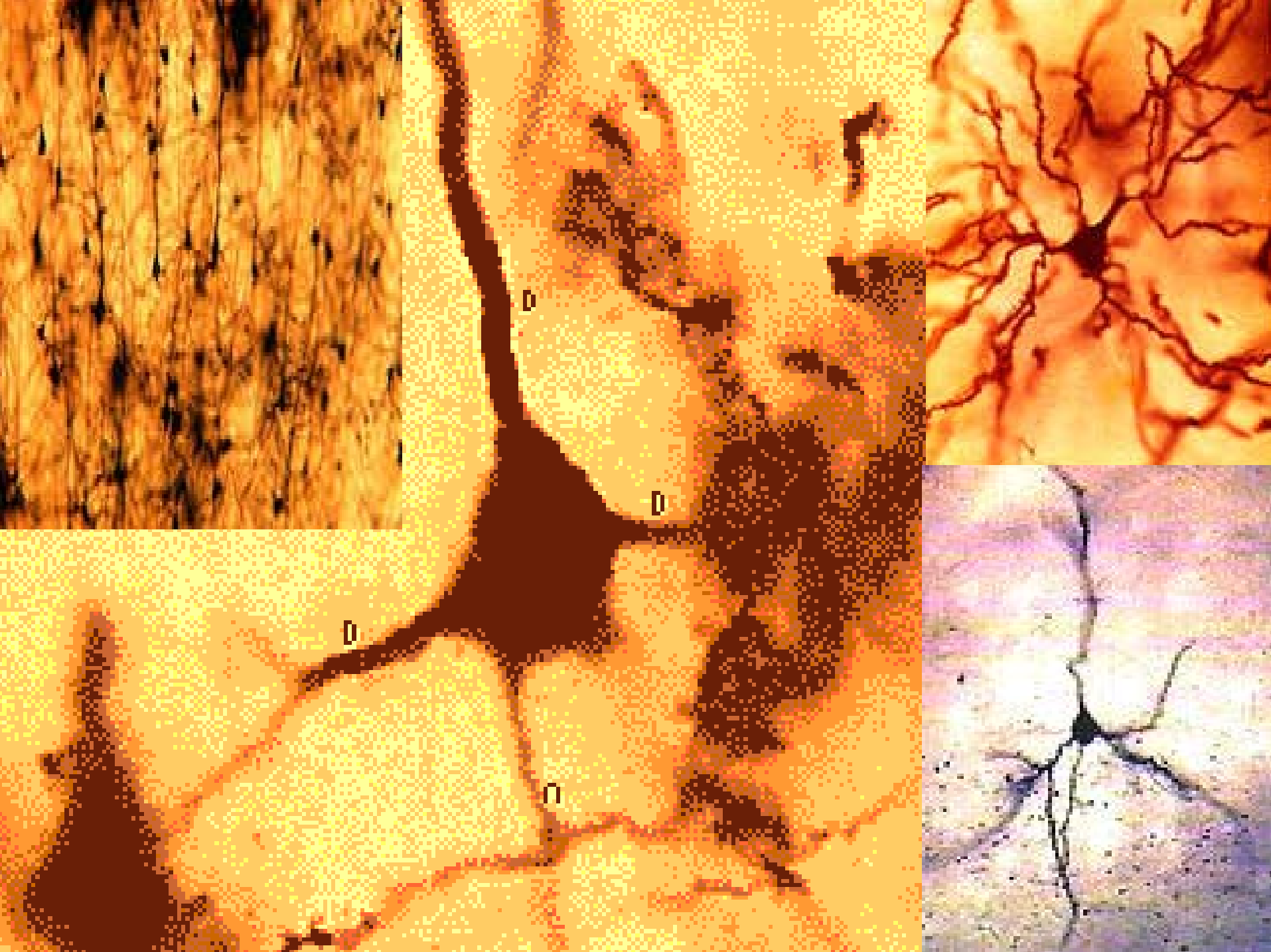
Classification by discharge patterns

Neurons can be classified according to their electrophysiological characteristics:

- **Tonic or regular spiking.** Some neurons are typically constantly (or tonically) active. Example: interneurons in neurostriatum.
- **Phasic or bursting.** Neurons that fire in bursts are called phasic.
- **Fast spiking.** Some neurons are notable for their fast firing rates, for example some types of cortical inhibitory interneurons, cells in globus pallidus.
- **Thin-spike.** Action potentials of some neurons are more narrow compared to the others. For example, interneurons in prefrontal cortex are thin-spike neurons.

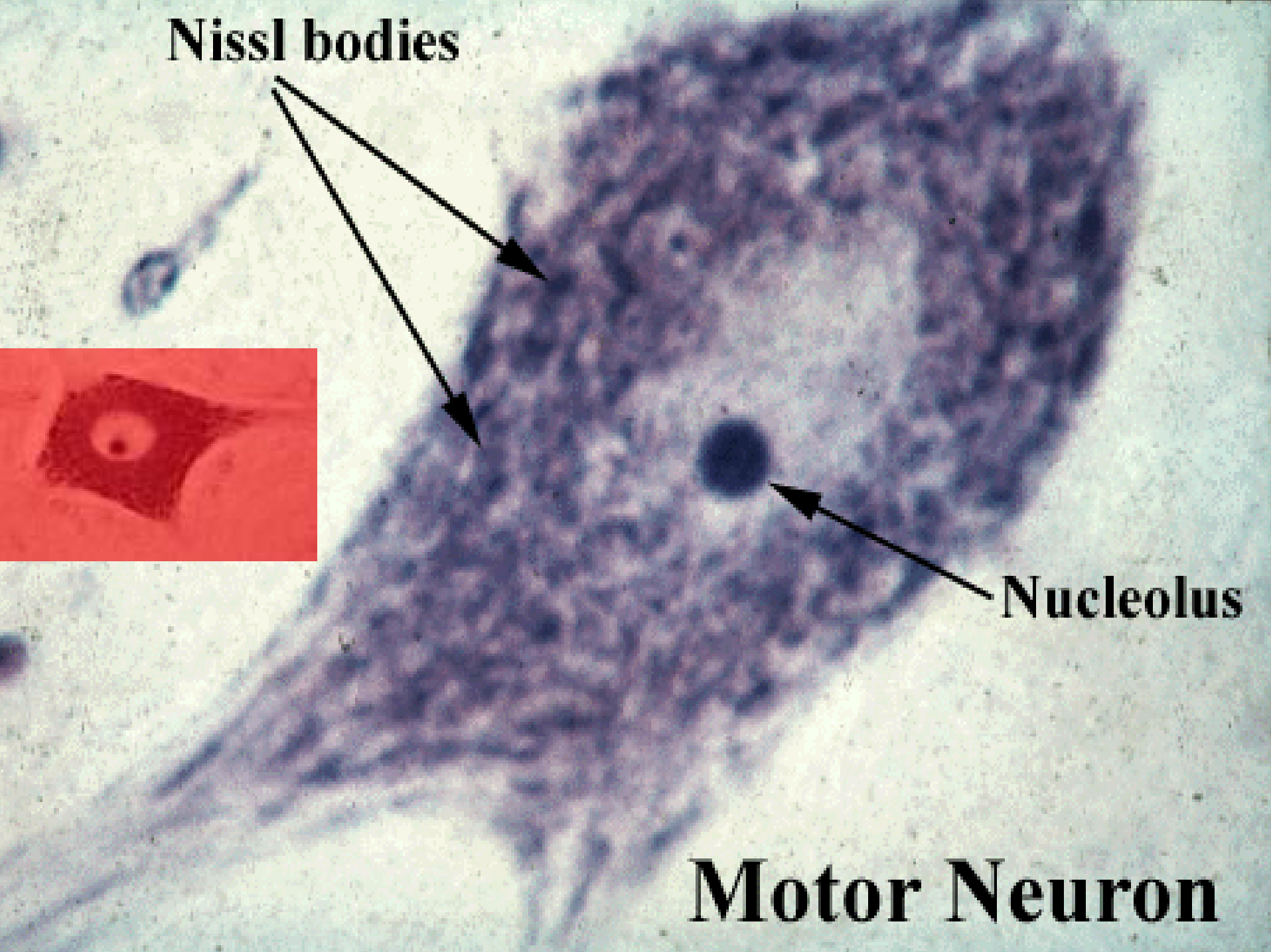
Classification by neurotransmitter released

Some examples are cholinergic, GABA-ergic, glutamatergic and dopaminergic neurons.



A **Nissl body** (or **Nissl granule** or **tigroid body**) is a large granular body found in nerve cells.

These granules are rough endoplasmic reticulum (with ribosomes) and are the site of protein synthesis.
Nissl bodies show changes under various physiological conditions and in pathological conditions they may dissolve and disappear (karyolysis).


Nissl bodies
Nucleolus
Motor Neuron

The **axolemma** is the membrane of a neuron's axon.

It is responsible for maintaining the cell's membrane potential, and it contains channels through which ions can flow.

Neurons (gray matter): soma, axon (axon hillock, axoplasm, **axolemma**, neurofibril/neurofilament), dendrite (Nissl body, dendritic spine)
types (bipolar, pseudounipolar, multipolar, pyramidal, Purkinje, Renshaw, granule)

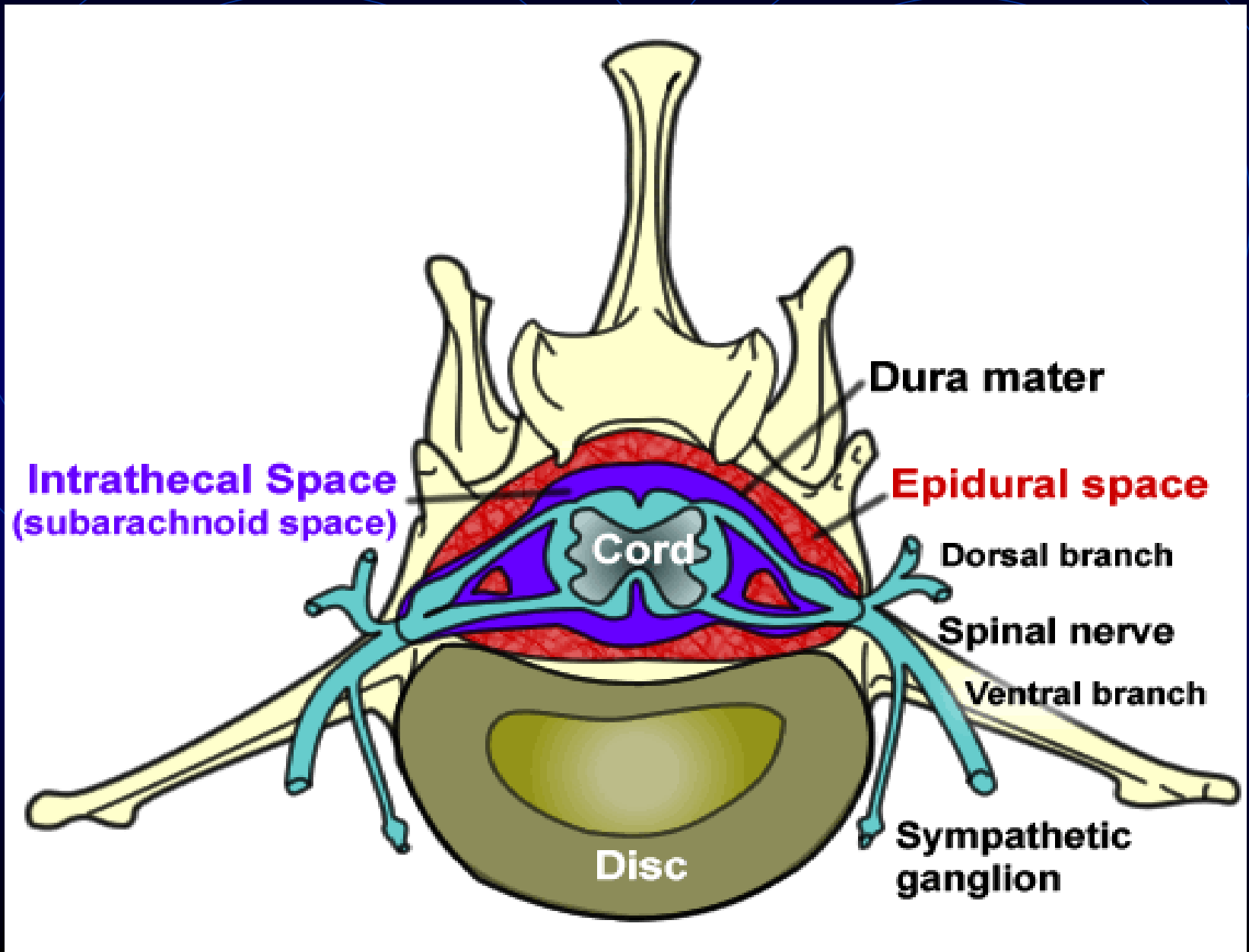
Synapses: neuropil, boutons, synaptic vesicle, neuromuscular junction, electrical synapse

Sensory receptors: Free nerve ending, Meissner's corpuscle, Merkel nerve ending, Muscle spindle, Pacinian corpuscle, Ruffini ending, Olfactory receptor neuron, Photoreceptor, Hair cell, Taste bud

Glial cells: astrocyte, ependymal cells, microglia, radial glia

Myelination (white matter): Schwann cell, oligodendrocyte, nodes of Ranvier, internode, Schmidt-Lanterman incisures, neurolemma

SPINAL CORD ANATOMY



There are 31 spinal cord segments:

- 8 cervical segments
- 12 thoracic segments
- 5 lumbar segments
- 5 sacral segments
- 1 coccygeal segment

There are two regions where the spinal cord enlarges:

- **Cervical enlargement** - corresponds roughly to the brachial plexus nerves, which innervate the upper limb. It includes spinal cord segments from about C4 to T1. The vertebral levels of the enlargement are roughly the same (C4 to T1).

- **Lumbosacral enlargement** - corresponds to the lumbosacral plexus nerves, which innervate the lower limb. It comprises the spinal cord segments from L2 to S3, and is found about the vertebral levels of T9 to T12.

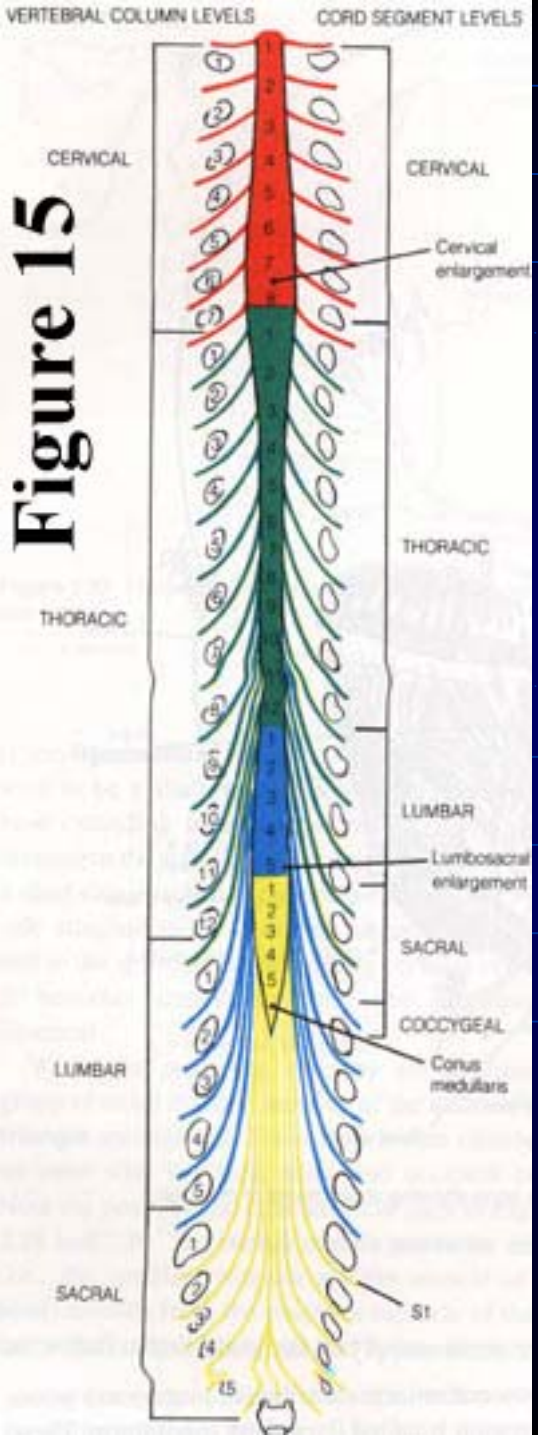
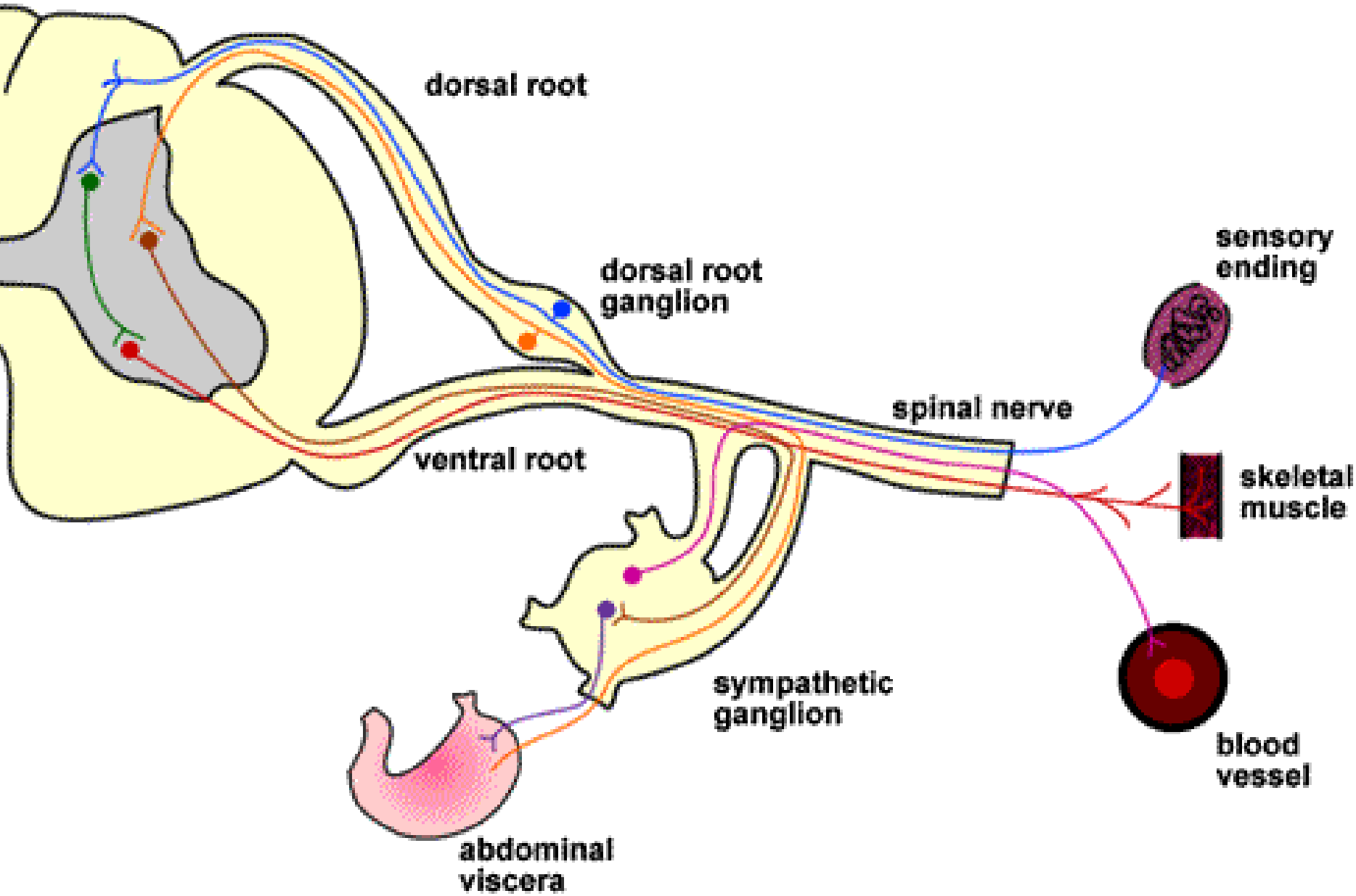
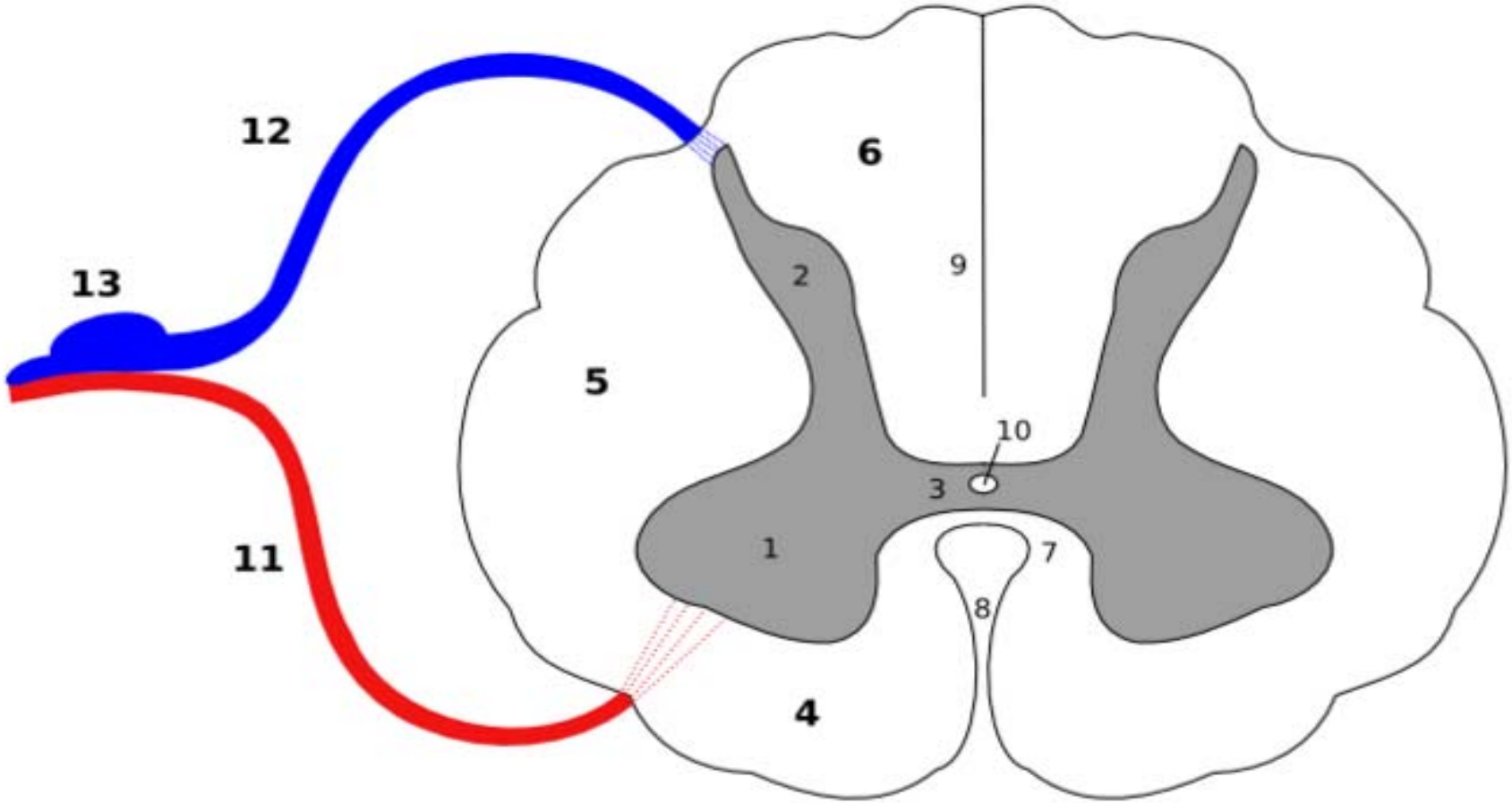


Figure 15

The spinal cord proper begins at the level of the foramen magnum of the skull and ends at the level of the L1ÐL2 intervertebral joint


dorsal root
dorsal root ganglion
sensory ending
spinal nerve
ventral root
skeletal muscle
sympathetic ganglion
blood vessel
abdominal viscera

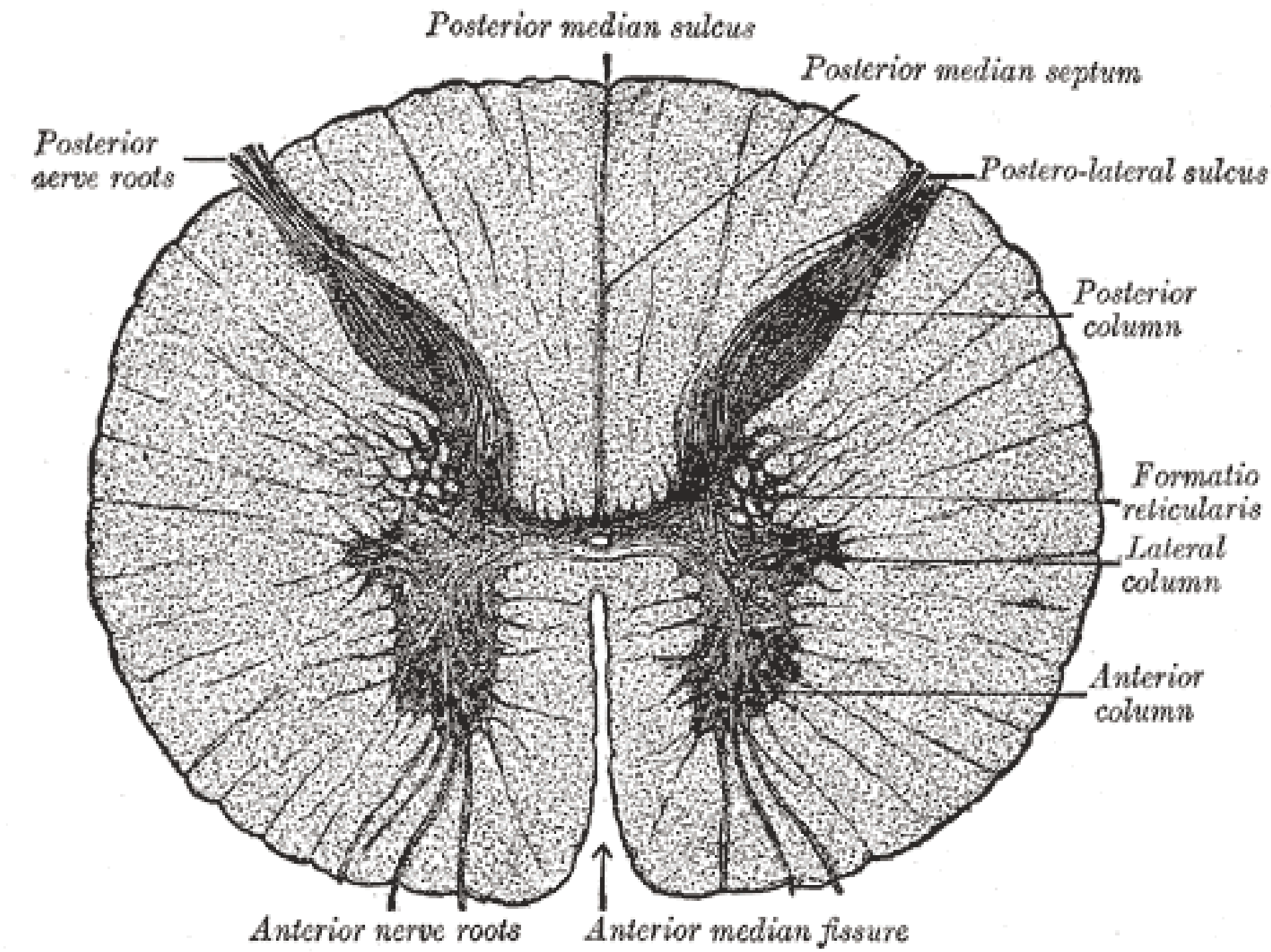


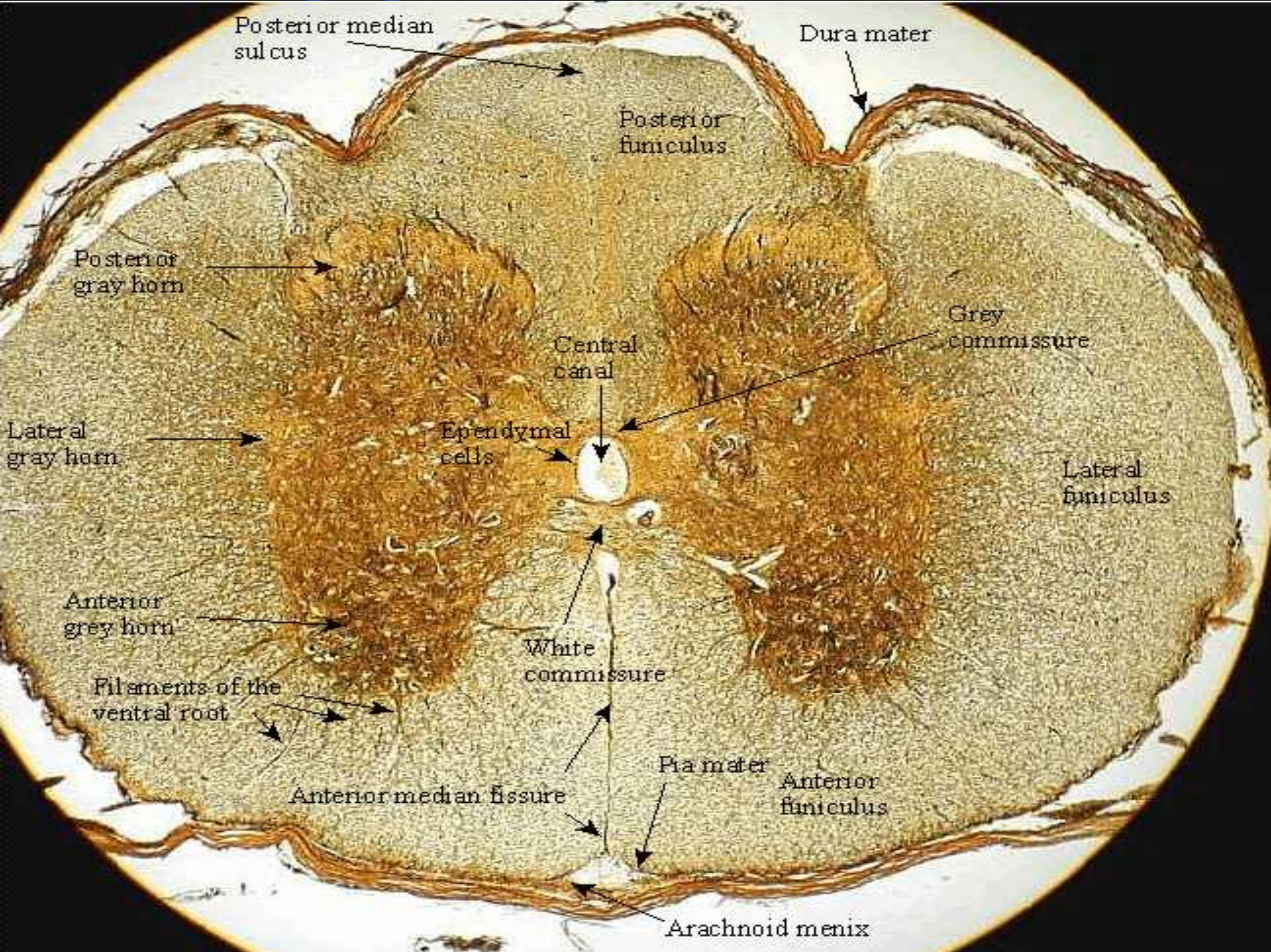
Substantia grisea

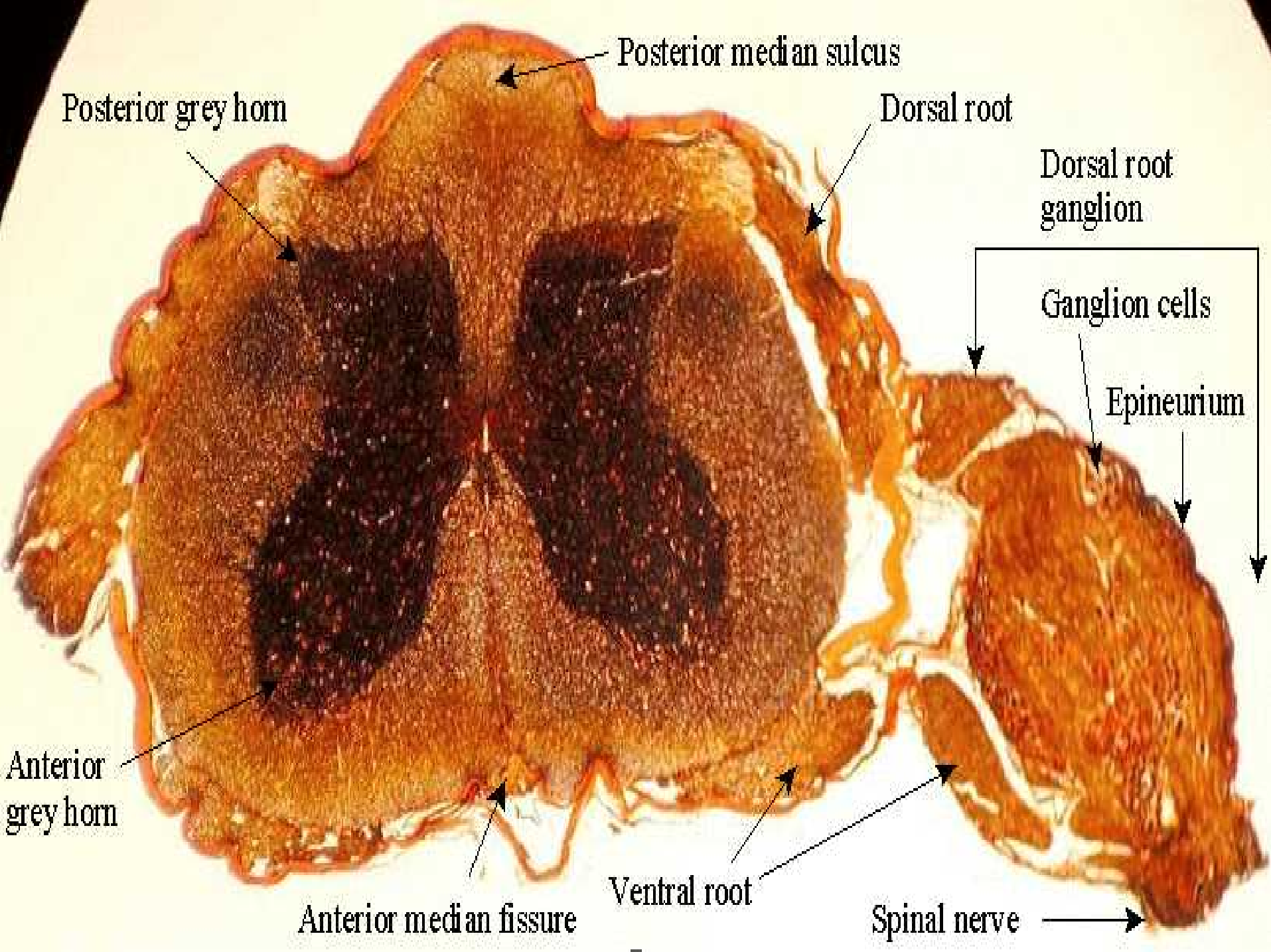
1. Cornu anterius
2. Cornu posterius
3. Commisura grisea

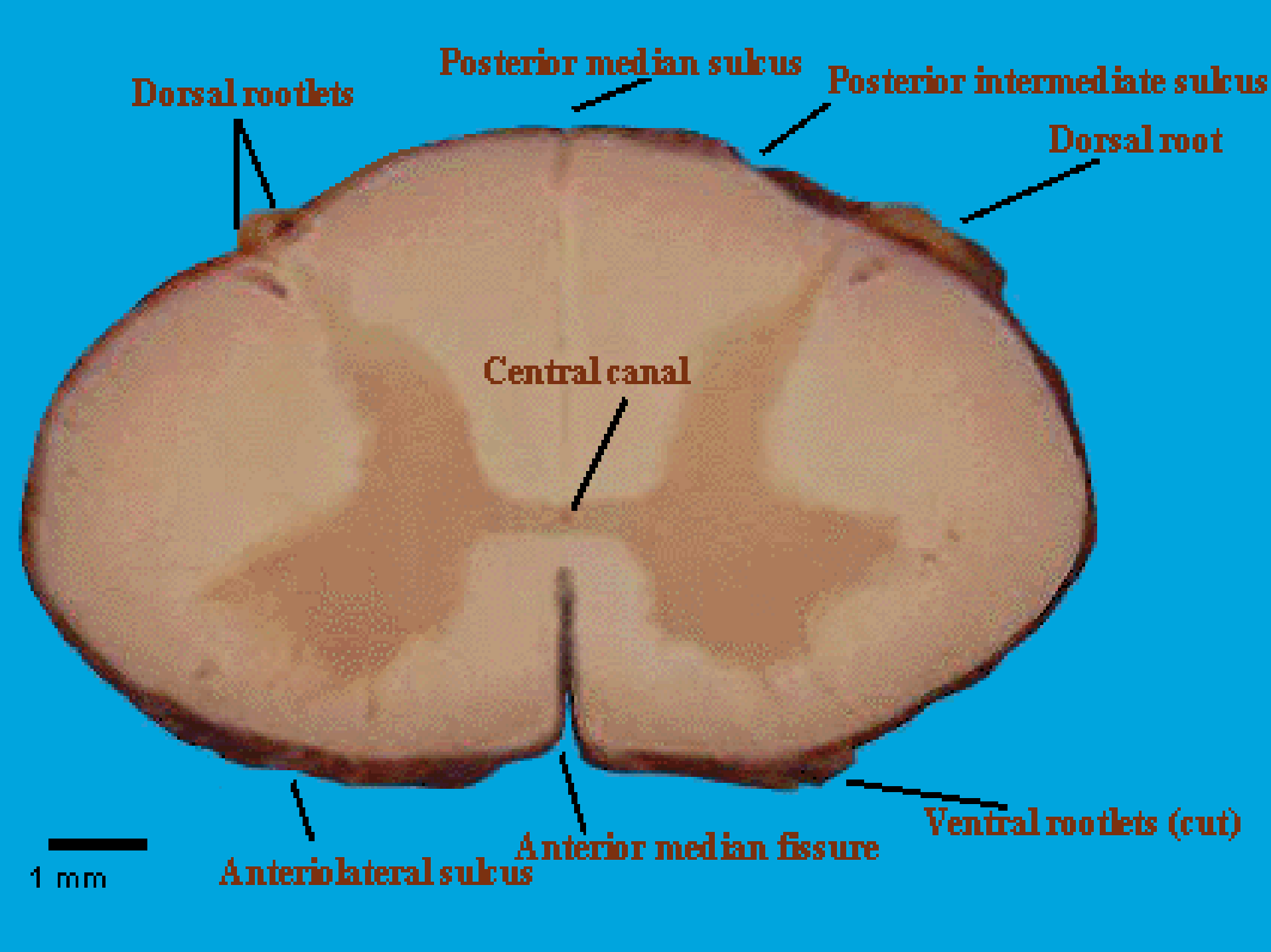
Substantia alba

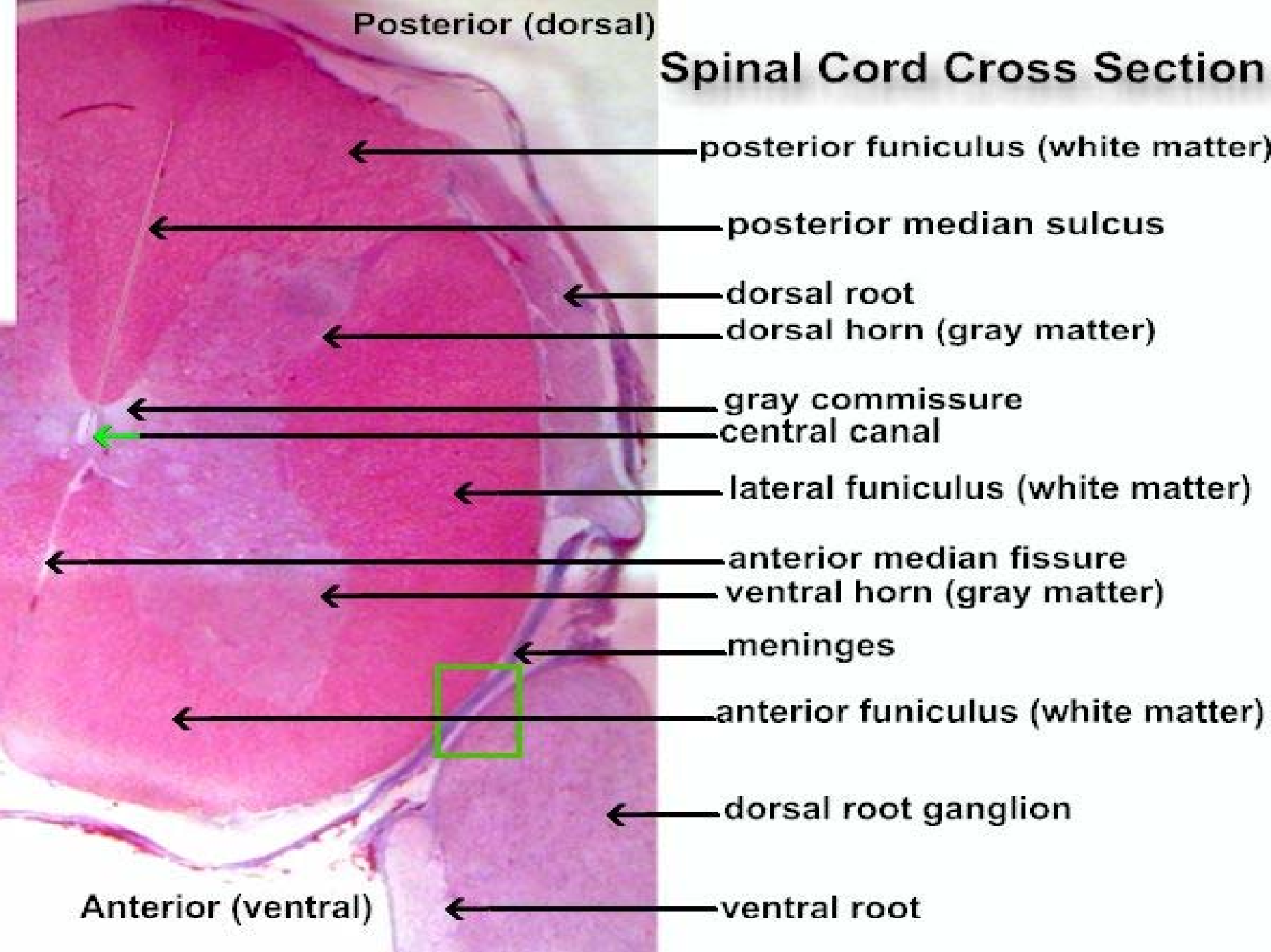
4. Funiculus anterior
5. Funiculus lateralis
6. Funiculus posterior
7. Commisura alba anterior
8. Fissura mediana anterior
9. Sulcus medianus posterior
10. Canalis centralis
11. Radix anterior
12. Radix posterior
13. Ganglion sensorium nervi spinalis

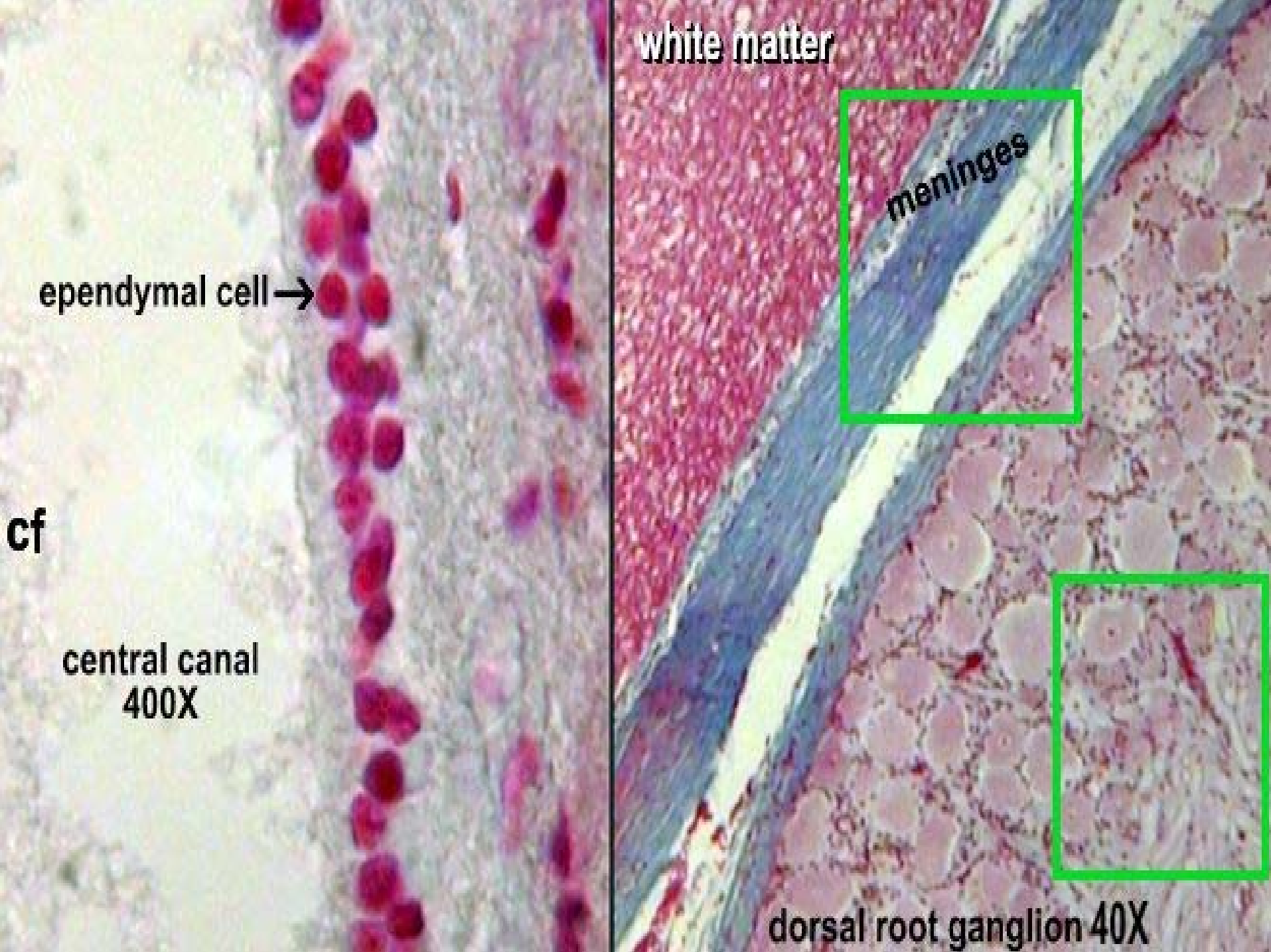

Posterior median sulcus
Posterior median septum
Posterior nerve roots
Postero-lateral sulcus
Posterior column
Formatio reticularis
Lateral column
Anterior column
Anterior nerve roots
Anterior median fissure

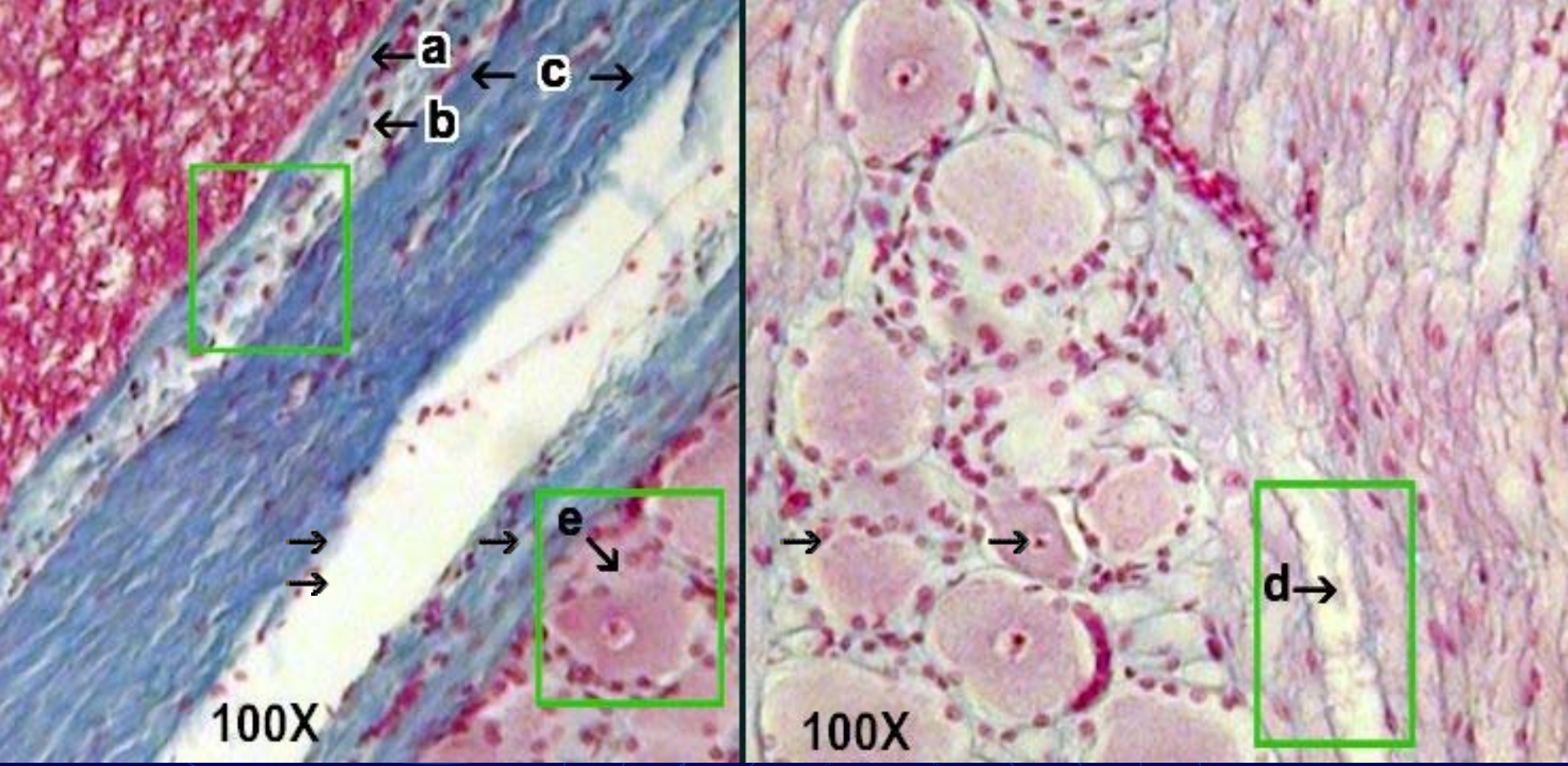

Posterior median sulcus
Dura mater
Posterior funiculus
Posterior gray horn
Grey commissure
Central canal
Lateral gray horn
Ependymal cells
Lateral funiculus
Anterior grey horn
White commissure
Filaments of the ventral root
Pia mater
Anterior funiculus
Anterior median fissure
Arachnoid menix


Posterior median sulcus
Posterior grey horn
Dorsal root
Dorsal root ganglion
Ganglion cells
Epineurium
Anterior grey horn
Anterior median fissure
Ventral root
Spinal nerve

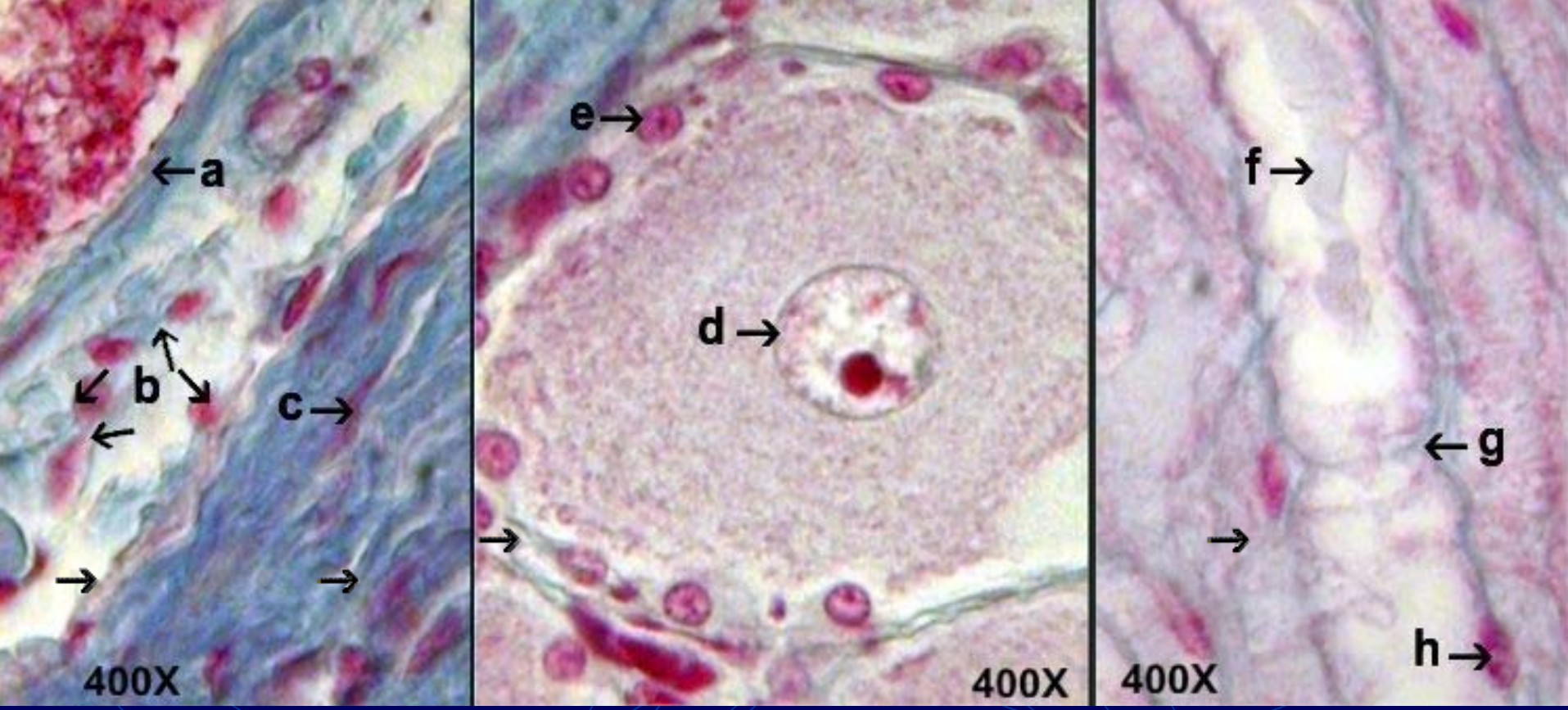

Dorsal rootlets
Posterior median sulcus
Posterior intermediate sulcus
Dorsal root
Central canal
Ventral rootlets (cut)
Anterior median fissure
Anteriolateral sulcus
1 mm


Posterior (dorsal)
Spinal Cord Cross Section
posterior funiculus (white matter)
posterior median sulcus
dorsal root
dorsal horn (gray matter)
gray commissure
central canal
lateral funiculus (white matter)
anterior median fissure
ventral horn (gray matter)
meninges
anterior funiculus (white matter)
dorsal root ganglion
Anterior (ventral)
ventral root

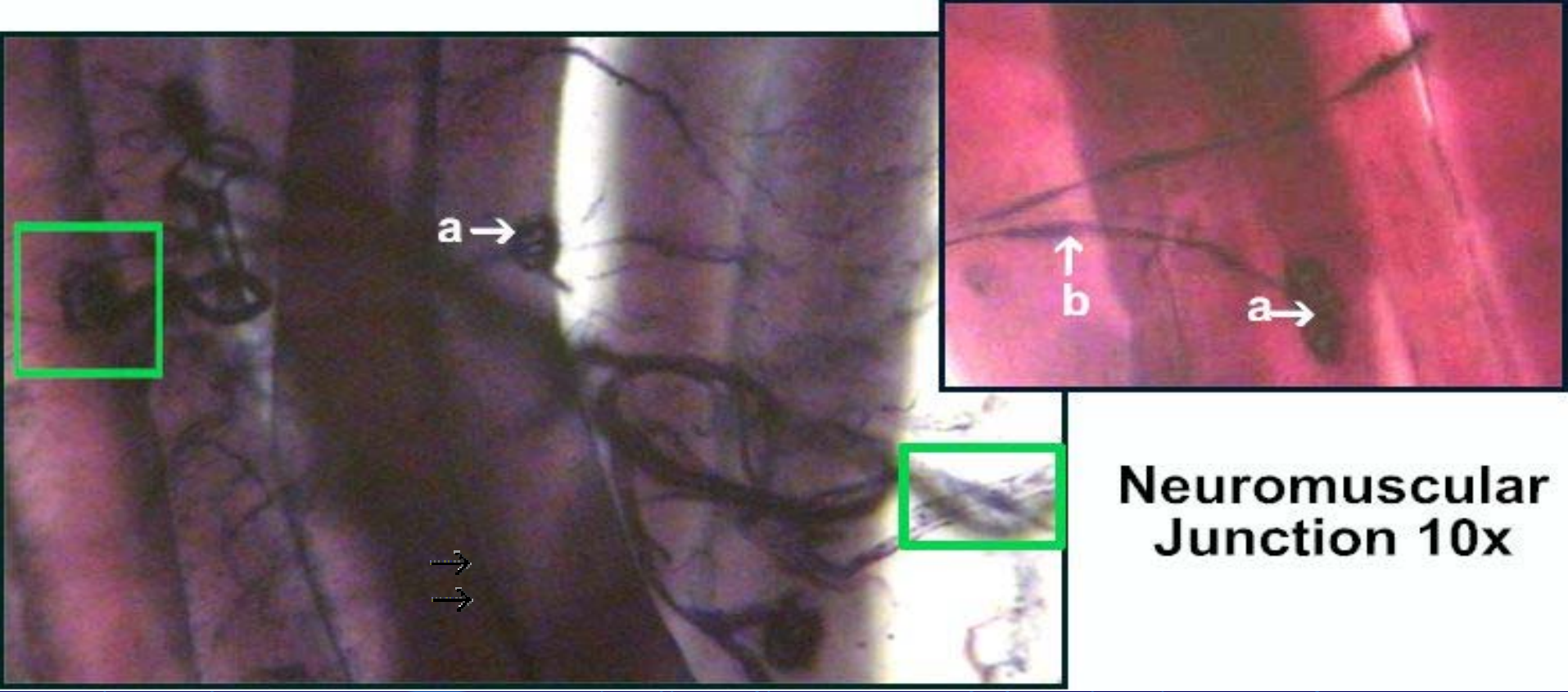

ependymal cell
cf
central canal
400X
white matter
meninges
dorsal root ganglion 40X



a pia mater b subarachnoid space c dura mater d myelinated axon e unipolar neuron of the dorsal root ganglion surrounded by satellite cells (neuroglia).

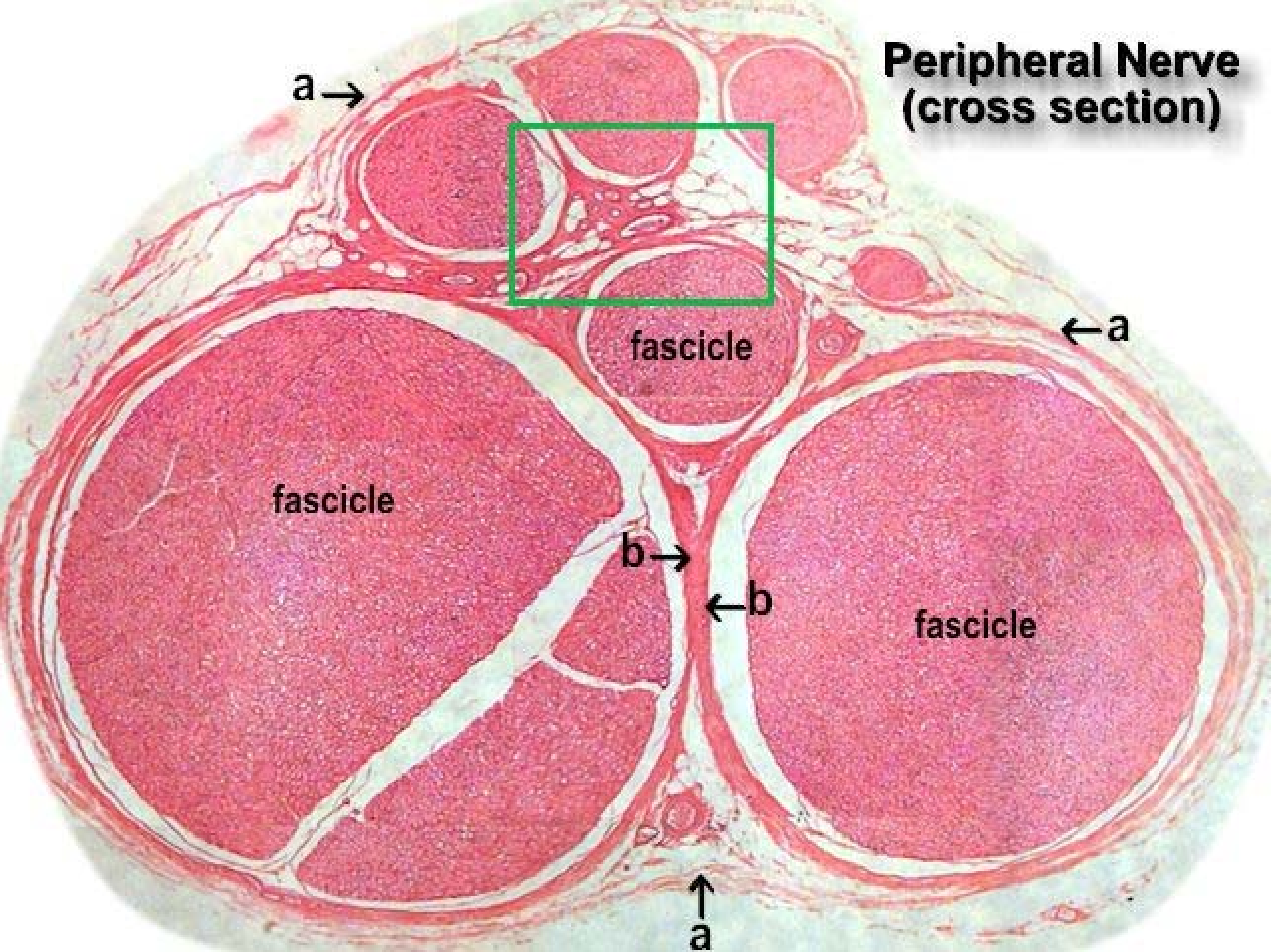


a ⟶ Pia mater b ⟶ Subarachnoid space filled with cerebral spinal fluid, wastes and various cells. c ⟶ Fibrocyte mixed in the blue collagen fibers of the dura mater. d ⟶ Nucleus & nucleolus of unipolar neuron e ⟶ Nucleus of one of many tiny satellite cells
surrounding the large unipolar neuron. f ⟶ Myelinated axon g ⟶ Node of Ranvier h ⟶ Nucleus of white Schwann cell



a Synaptic bulbs over the motor end plate - neuromuscular junction

b Neuron axon terminal - black fibers


Peripheral Nerve
(cross section)
a
a
a
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b
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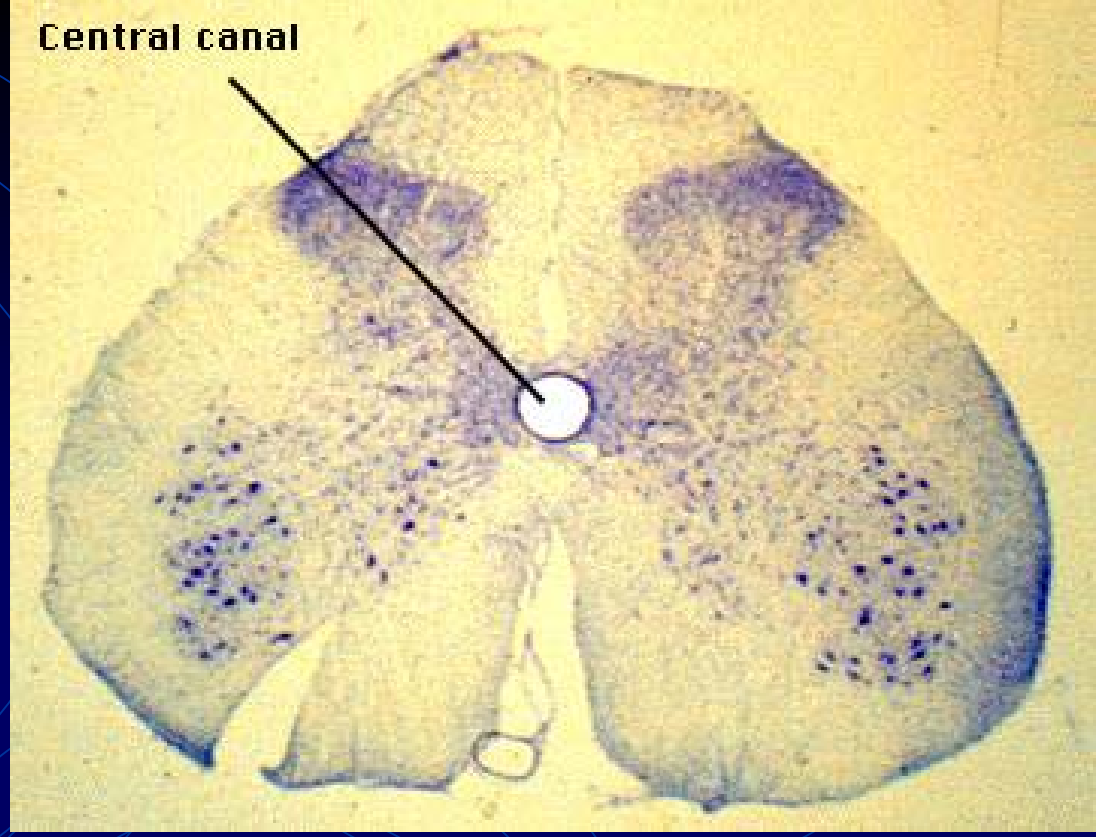

The **central canal** is the cerebrospinal fluid-filled space that runs longitudinally through the length of the entire spinal cord. The central canal is contiguous with the ventricular system of the brain.