Nervous System

Introduction to Anatomy and Embryology

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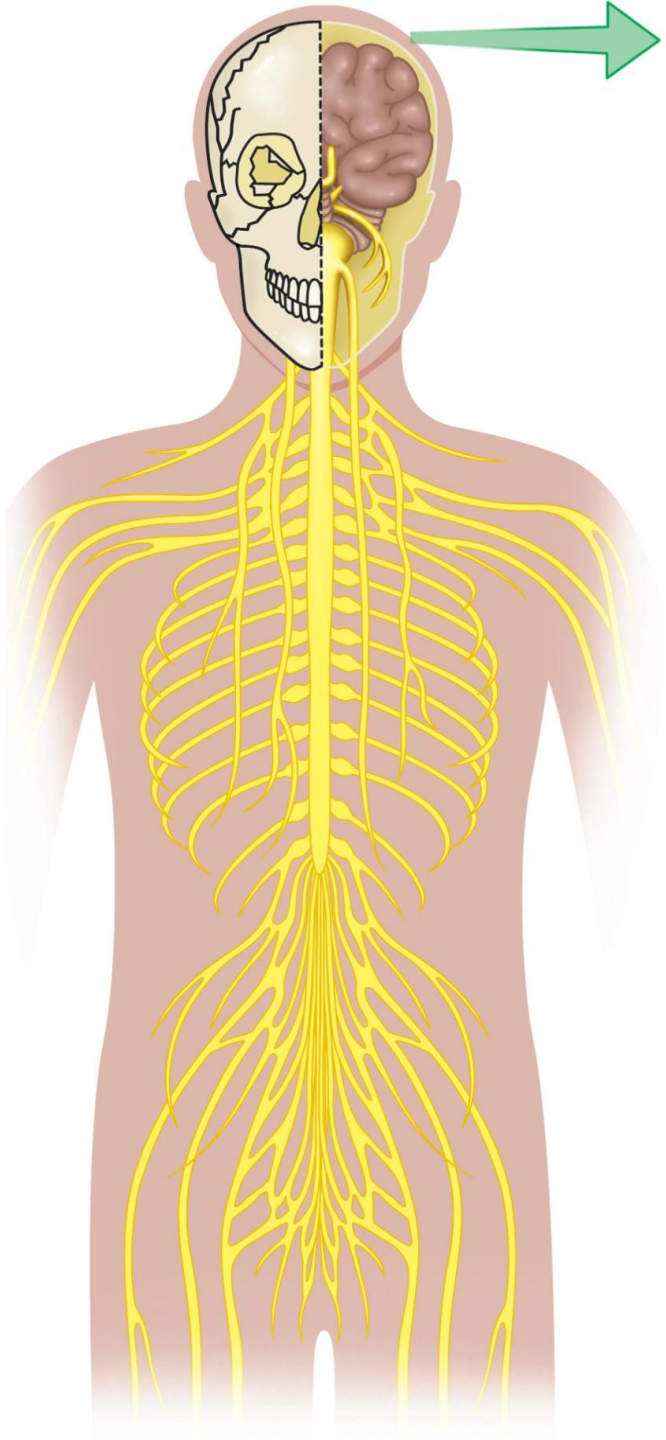
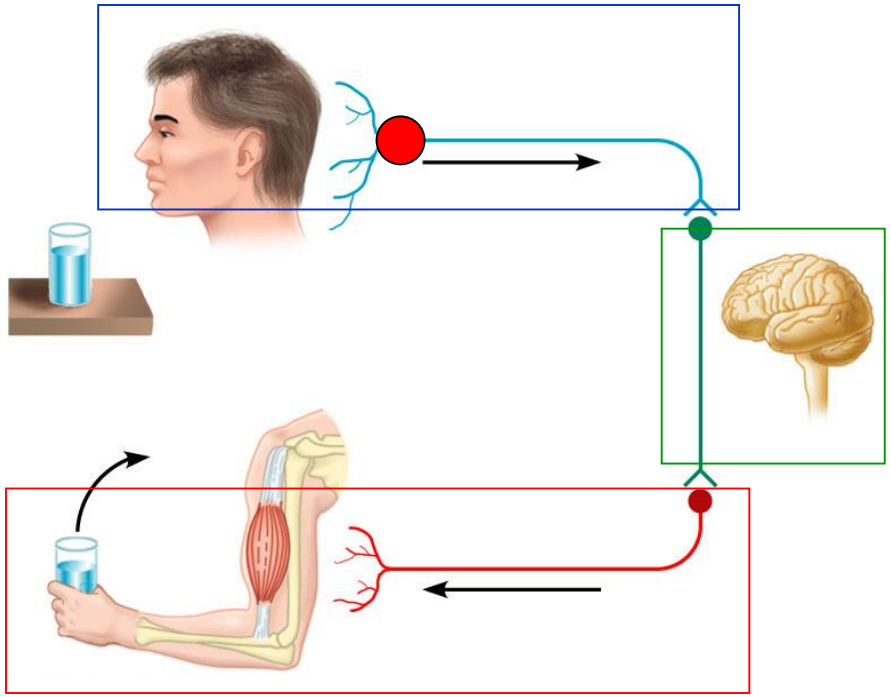
Nervous Tissue





Controls and integrates all body activities within limits that maintain life

Three basic functions

1. sensing changes with sensory receptors
2. interpreting and remembering those changes
3. reacting to those changes with effectors (motor function)

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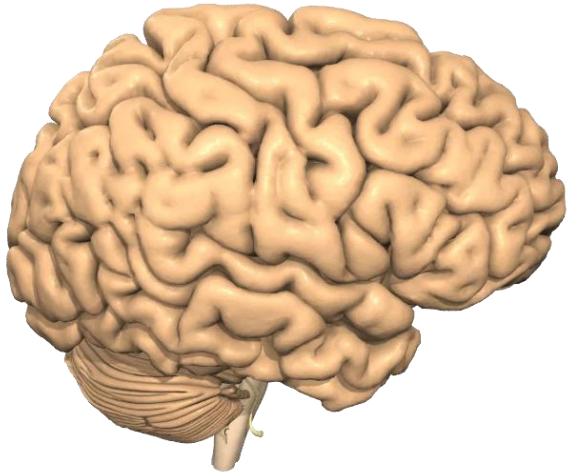
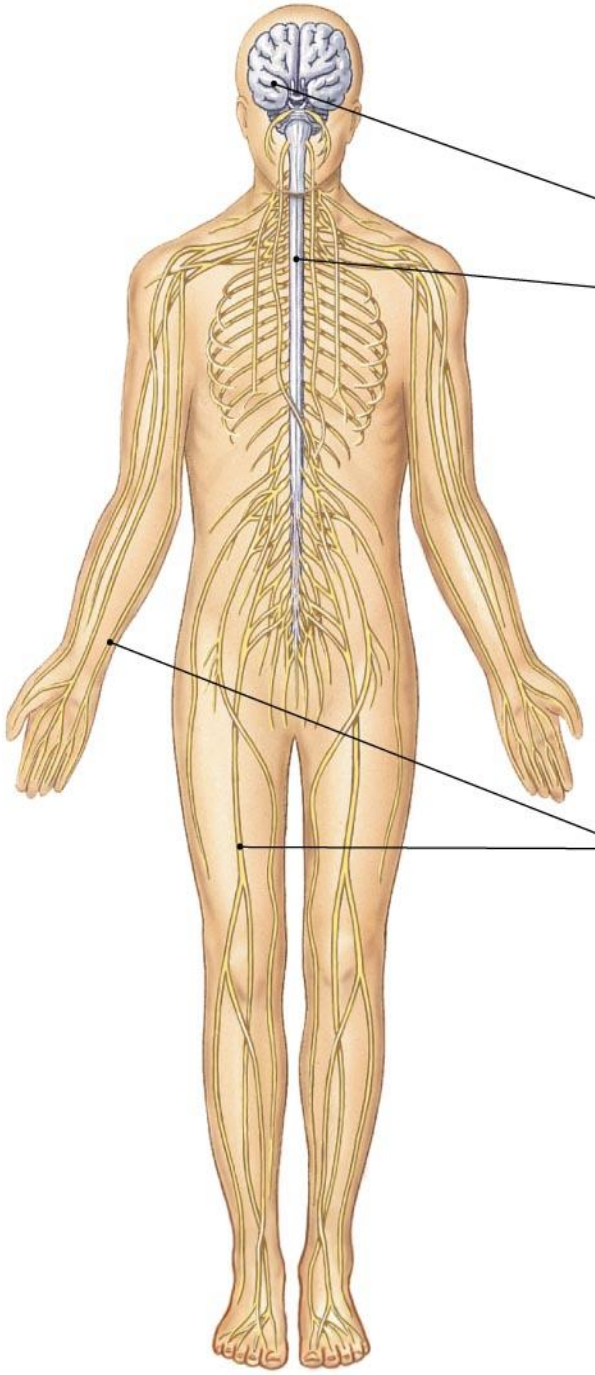


PRIMAL PICTURES

Spinal nerves
31 pairs

Cranial nerves
12 pairs



Central nervous system

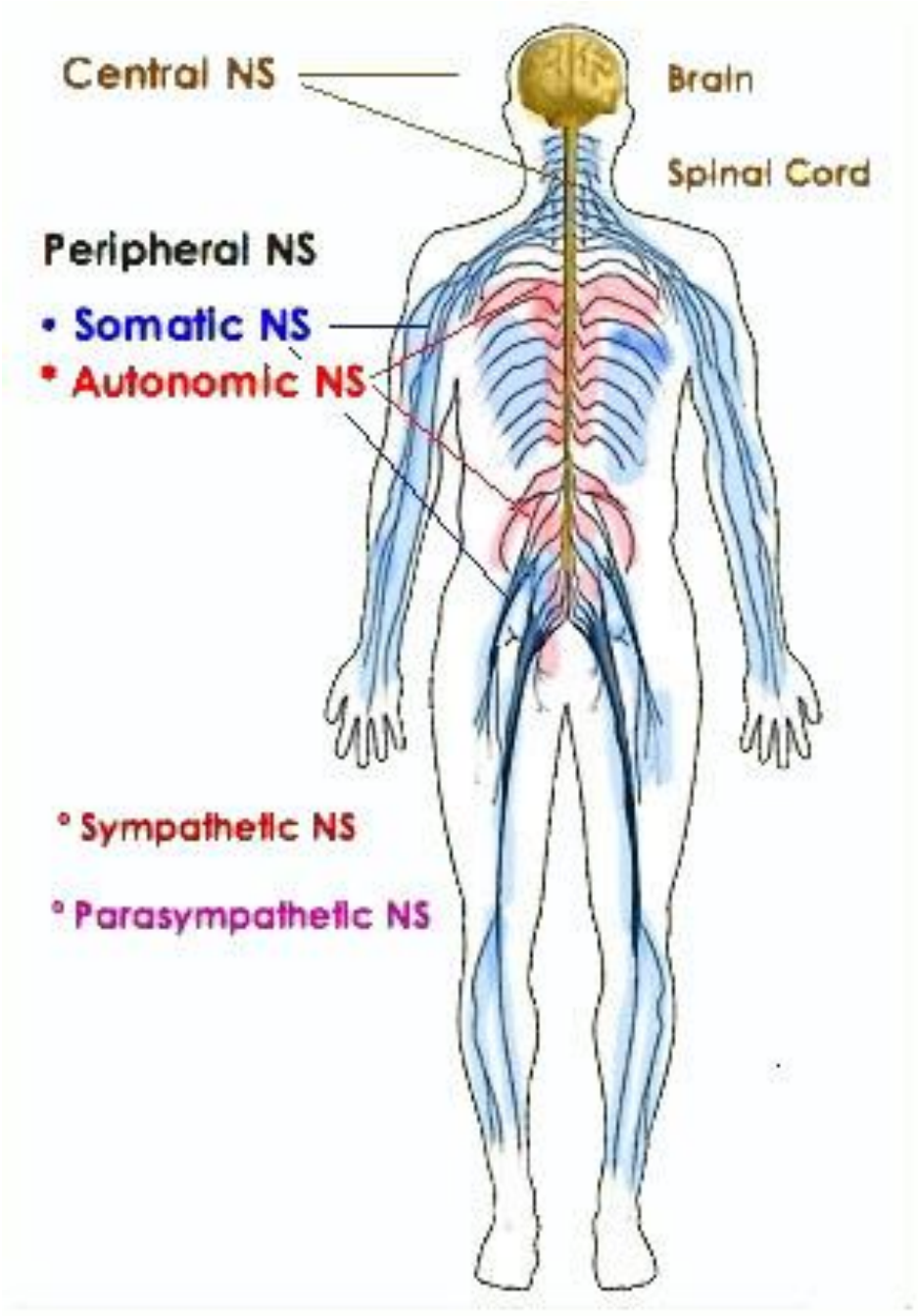
Brain

Spinal cord

Peripheral nervous system

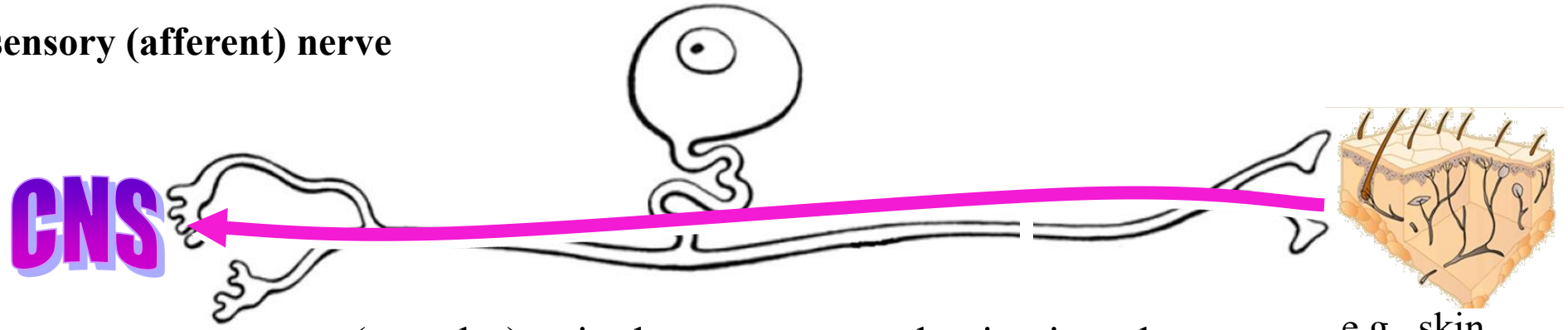
Peripheral nerves

The PNS is divided into:
1- **Somatic nervous system** (SNS)
2- **Autonomic nervous system** (ANS)



Sensory (Afferent) vs. Motor (Efferent)

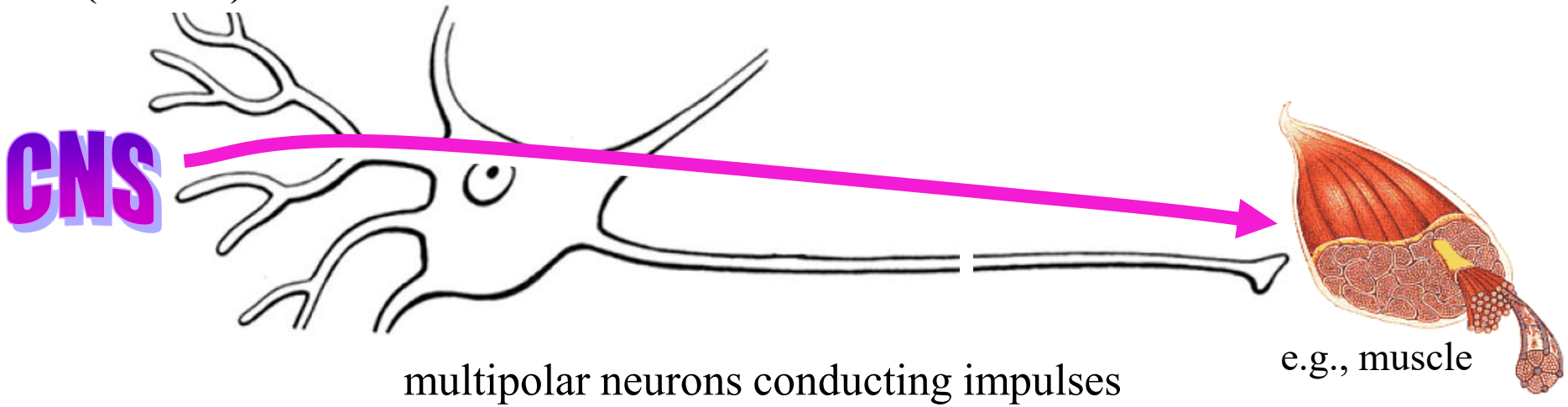
sensory (afferent) nerve



e.g., skin

(pseudo-) unipolar neurons conducting impulses
from sensory organs to the CNS

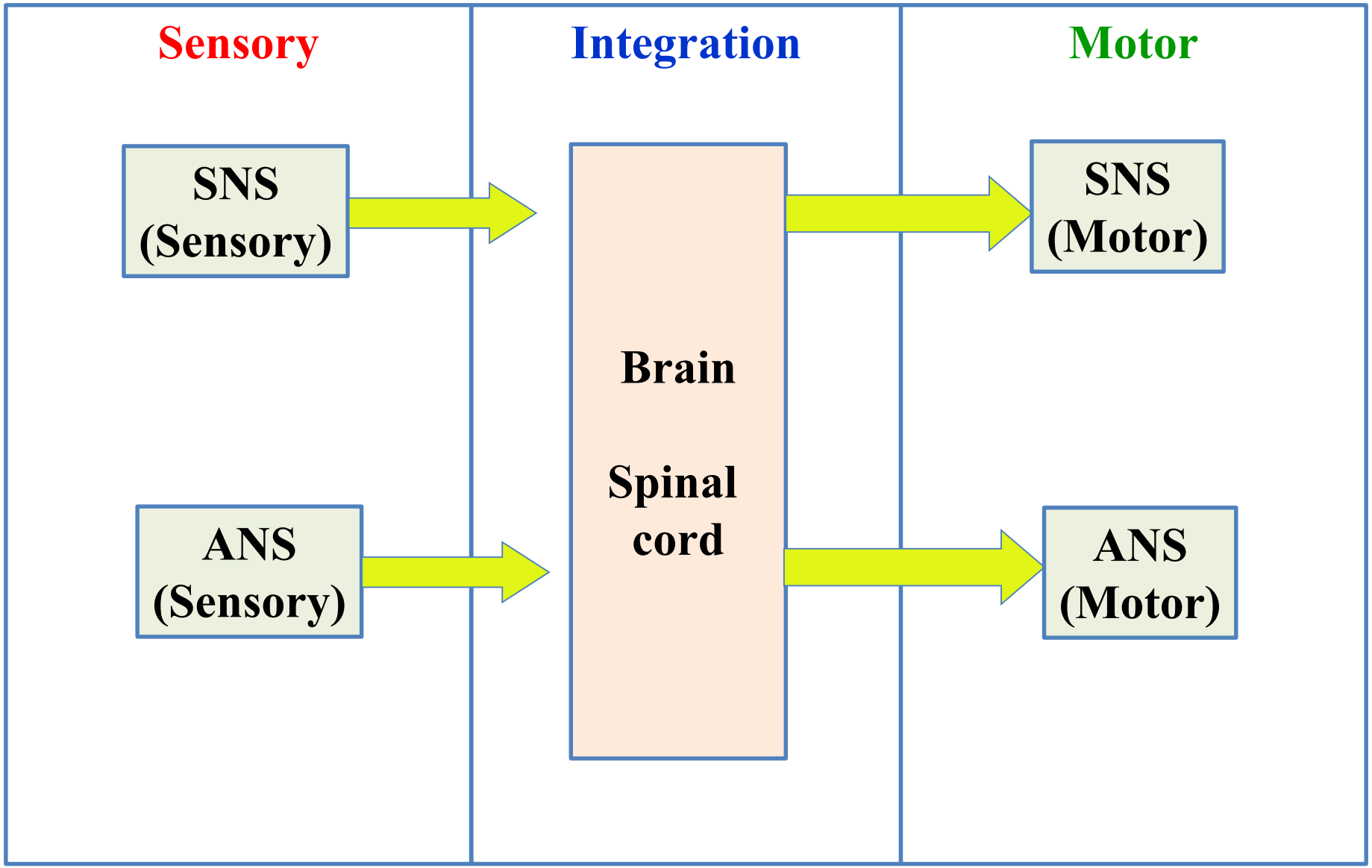
motor (efferent) nerve



e.g., muscle

multipolar neurons conducting impulses
from the CNS to effector organs (muscles & glands)

Organization



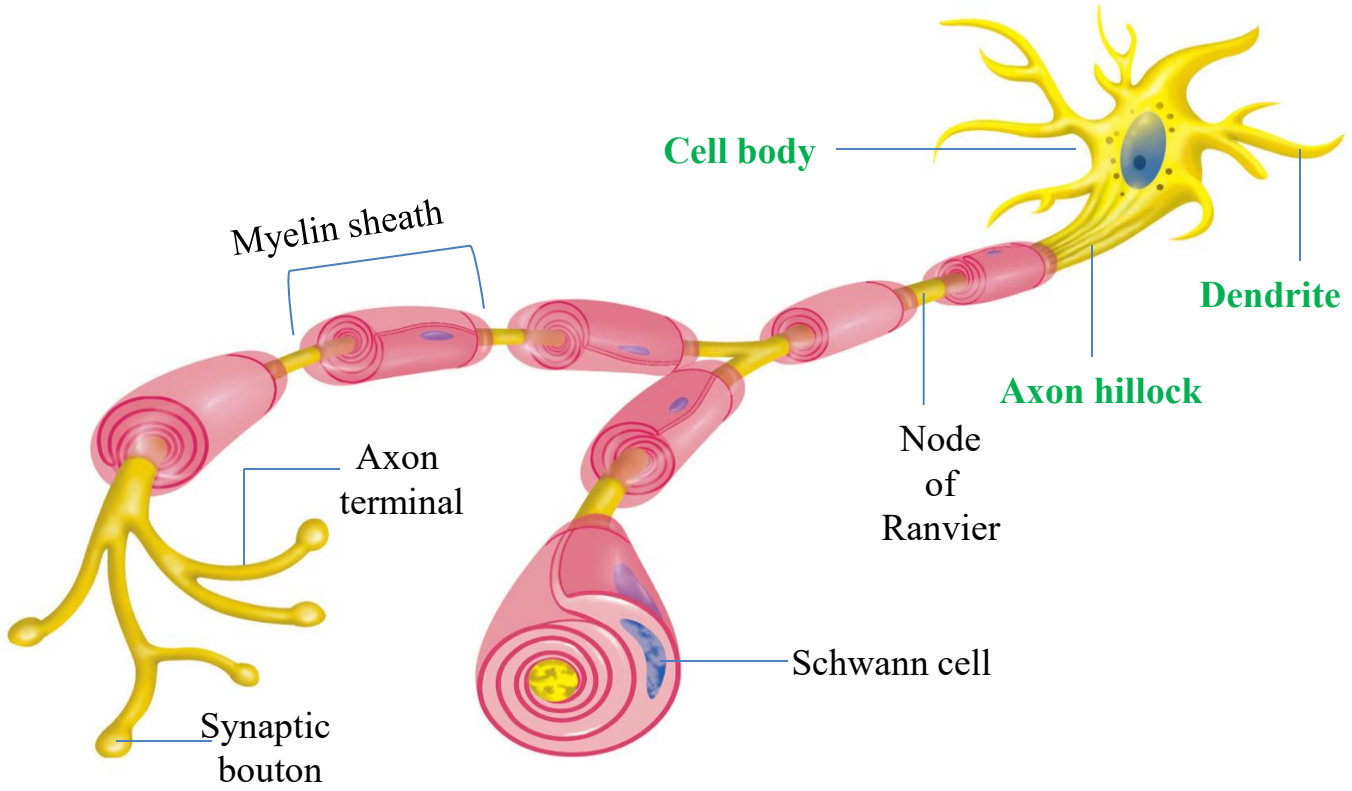
Axoplasm: cytoplasm of axon

Axolemma: cell membrane of axon

Axon hillock: where axon originates from soma

Synaptic boutons: swelling of axon terminal

Synapse: site of transmission of electric nerve impulses between two neurons



Read only ☺

Axon

- Nearly constant diameter
- Much Longer
- Branches less profusely
- Distal end forms terminal arborization and terminal boutons
- Mostly myelinated, could be unmyelinated
- Axoplasm contains mitochondria, microtubules, and neurofilaments but not RER , ribosomes or golgi
- Bidirectional transport along the axon

Axons of the motor neurons that innervate the foot muscles have lengths of nearly a meter

Dendrite

- Becomes much thinner (tapering)
- Short
- Branches profusely
- The cytoplasm of its base is similar to cell body
- Typically unmyelinated

Cells of nervous tissue

Read only ☺

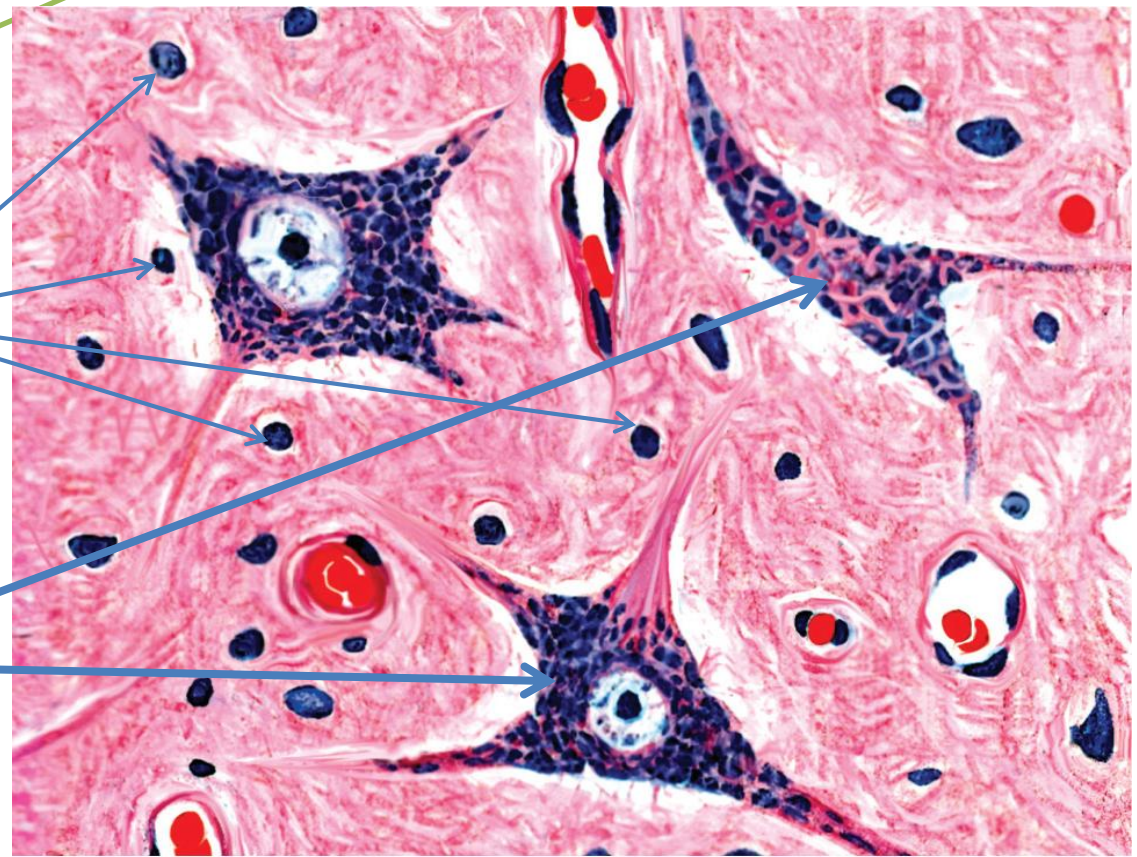
Neurons:

- Sensing, thinking, remembering, controlling muscle activity, and regulating glandular secretions
- Do not divide (no centriols!!!)
- Long lived
- High metabolic activity
- **Electrically excitable**

Neuroglia :

- Support, nourish, and protect neurons
- Divide
- Smaller cells but they greatly outnumber neurons

The most wonderful fact is that, working together, nerve cells can perceive and think and dream. They are us



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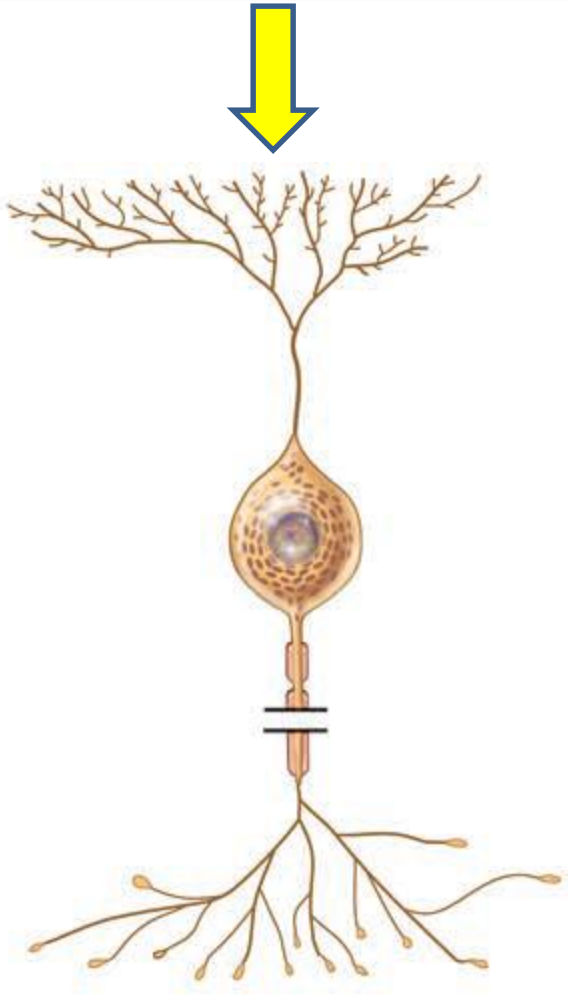
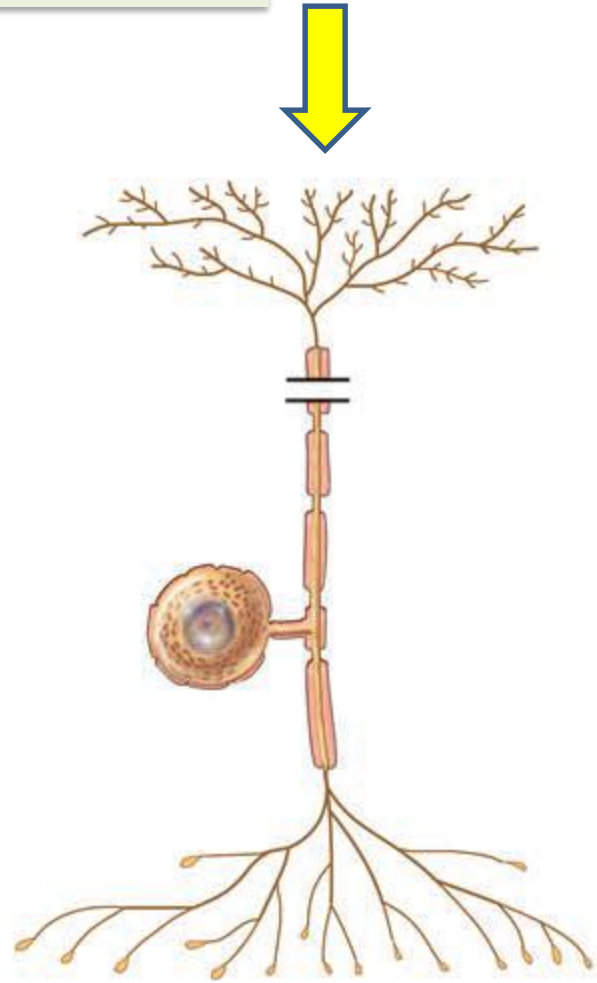
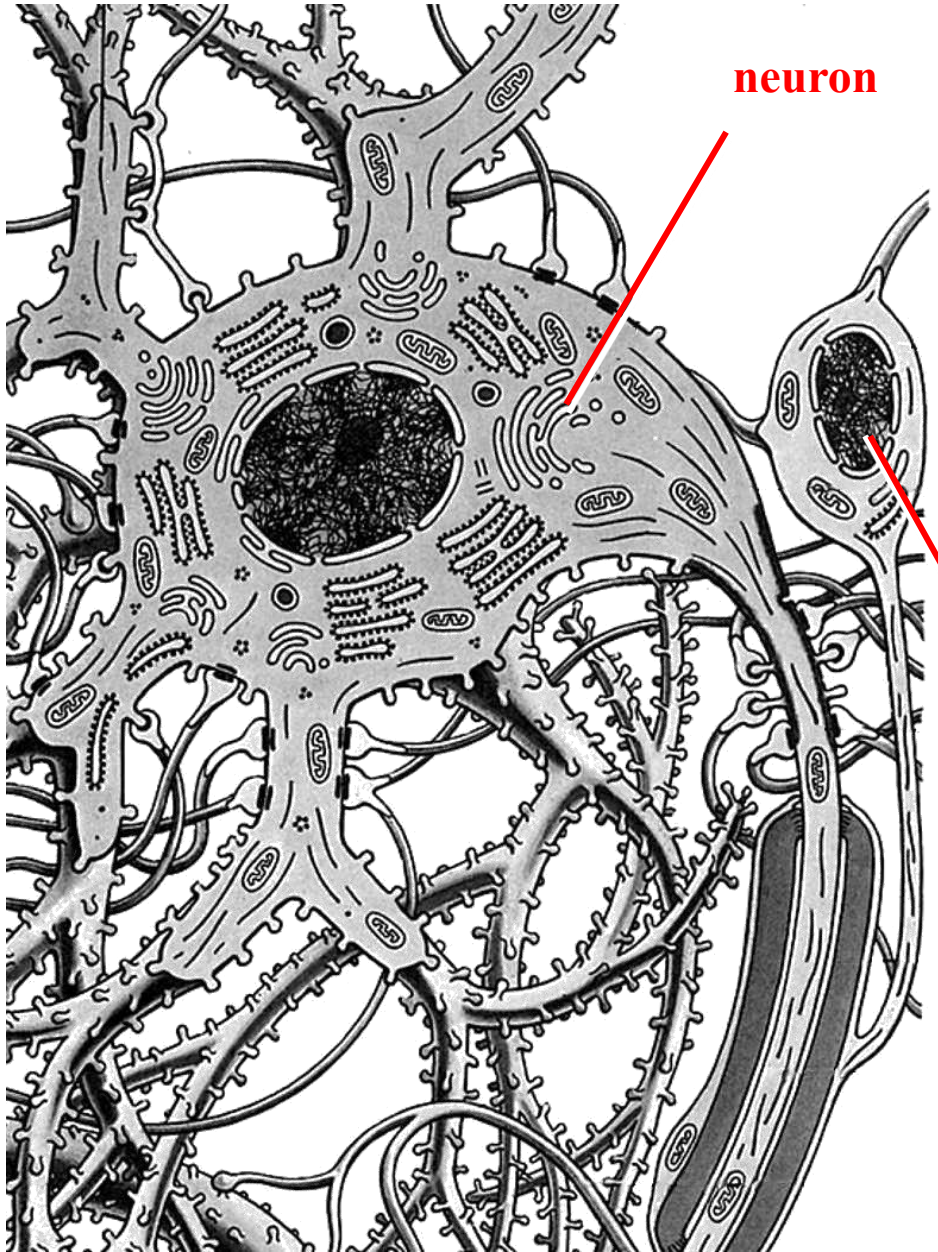
Structural classification of neurons

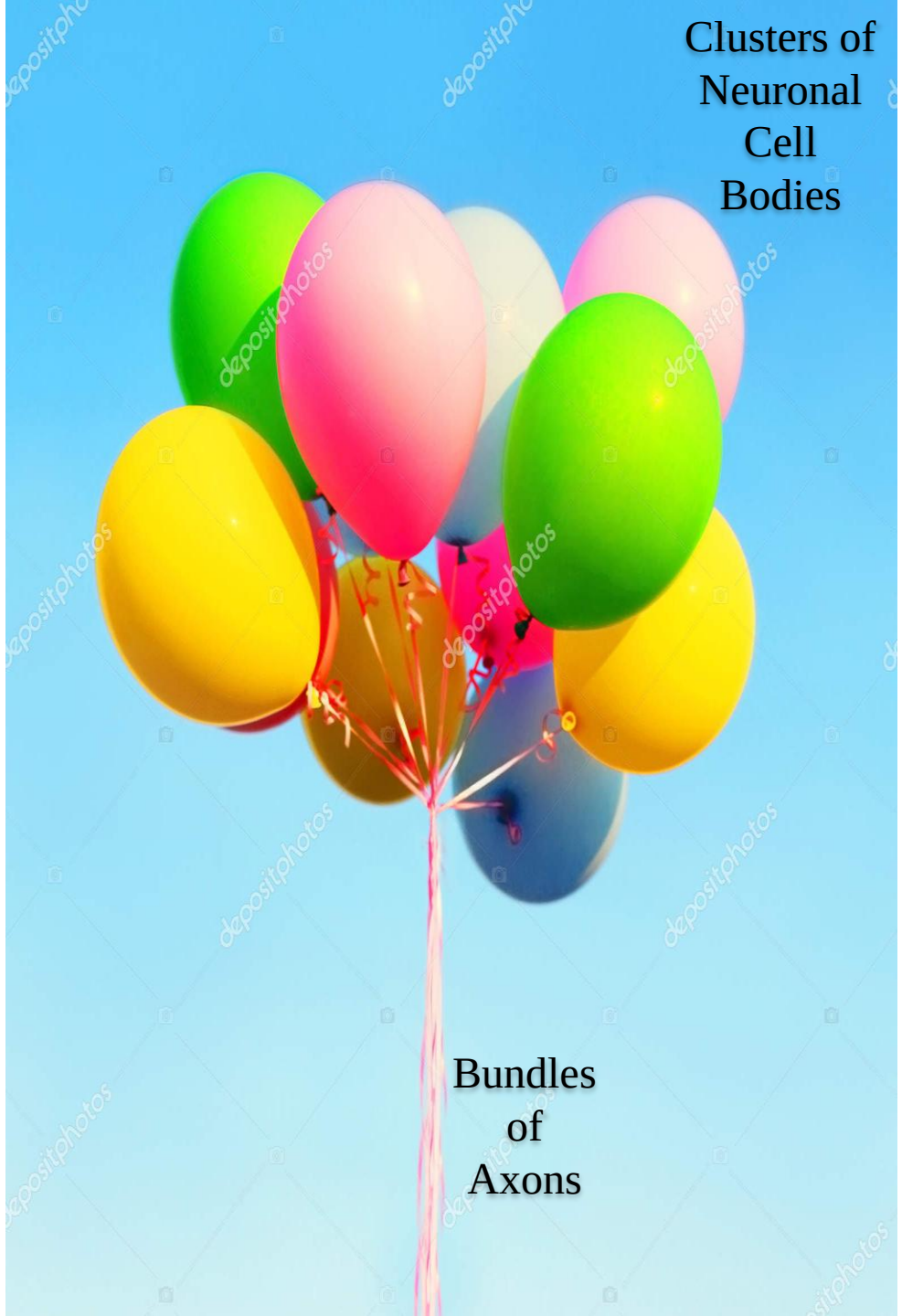
1. **Multipolar neurons**
   - Usually have several dendrites and one axon
   - Motor neurons
2. **Bipolar neurons**
   - Have one main dendrite and one axon
   - The retina of the eye
3. **Unipolar neurons (pseudounipolar neurons)**
   - Sensory neurons







1. Tissues: neurons vs. glia
2. Position: CNS vs. PNS
3. Function 1: sensory vs. motor
4. Function 2: somatic vs. visceral



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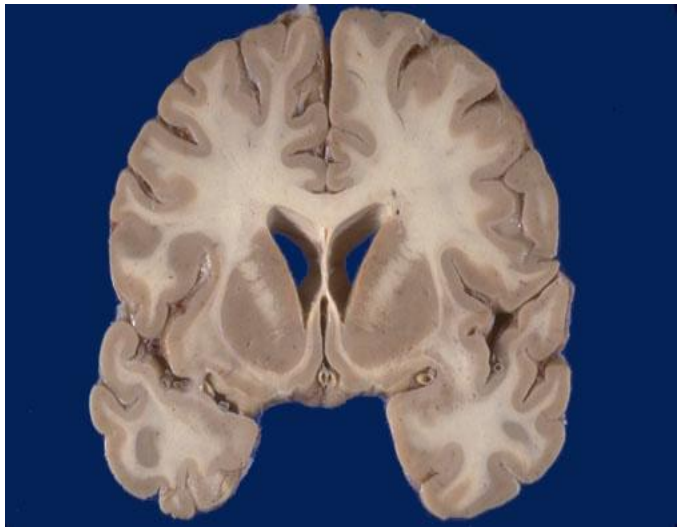
Transverse section of spinal cord

Clusters of Neuronal Cell Bodies

1. **Ganglion** (plural is ganglia): a cluster of neuronal cell bodies located in the PNS.
2. **Grey matter (Cortex/Nucleus)**: a cluster of neuronal cell bodies located in the CNS.



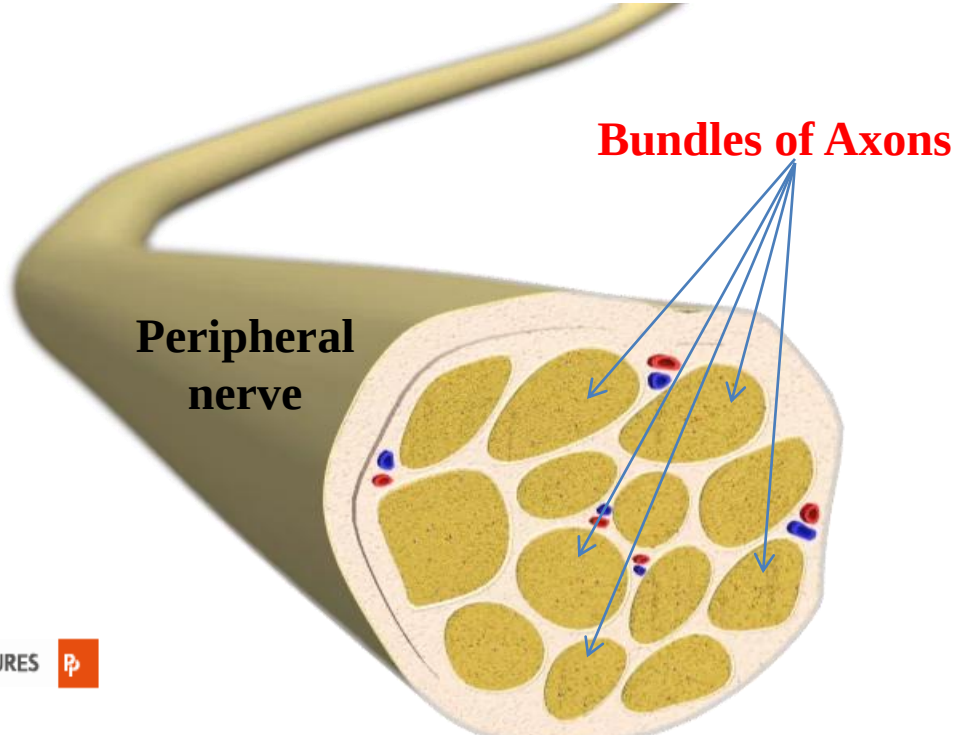
Coronal section of brain

Bundles of Axons

A **nerve:** is a bundle of axons that is located in the PNS.

- Cranial nerves connect the brain to the periphery
- Spinal nerves connect the spinal cord to the periphery

White matter/ tract: is a bundle of axons located in the CNS.



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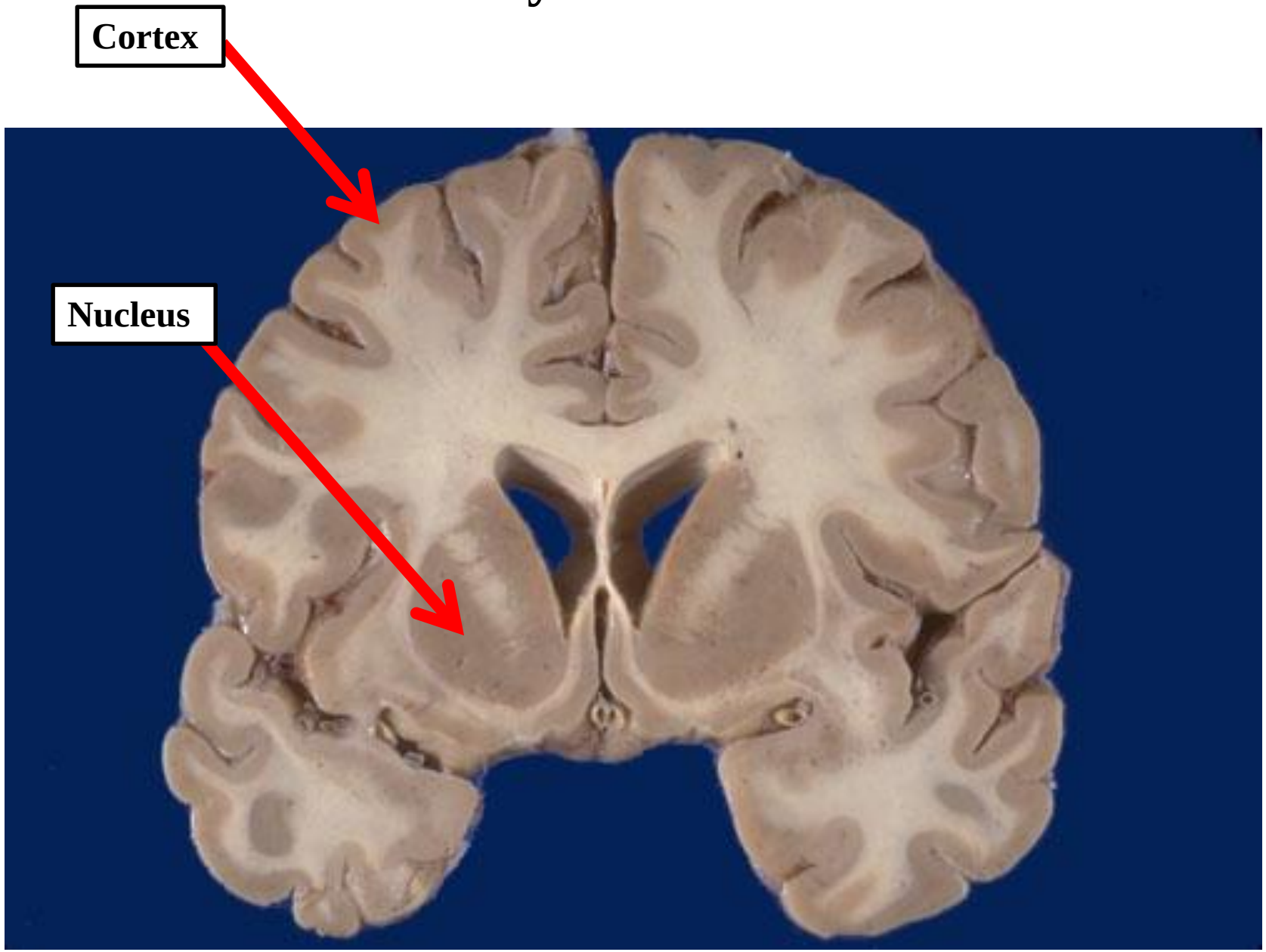
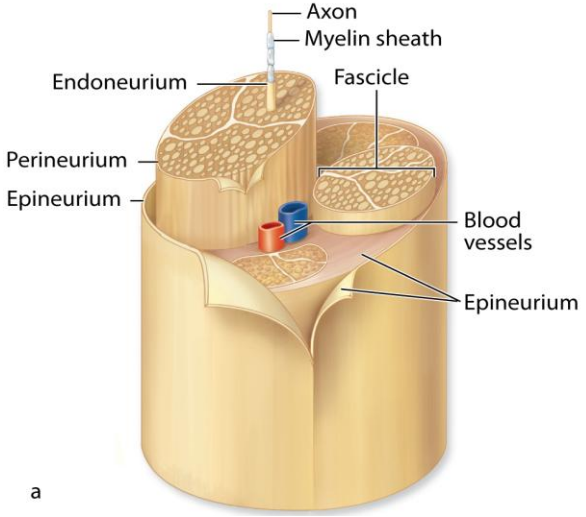
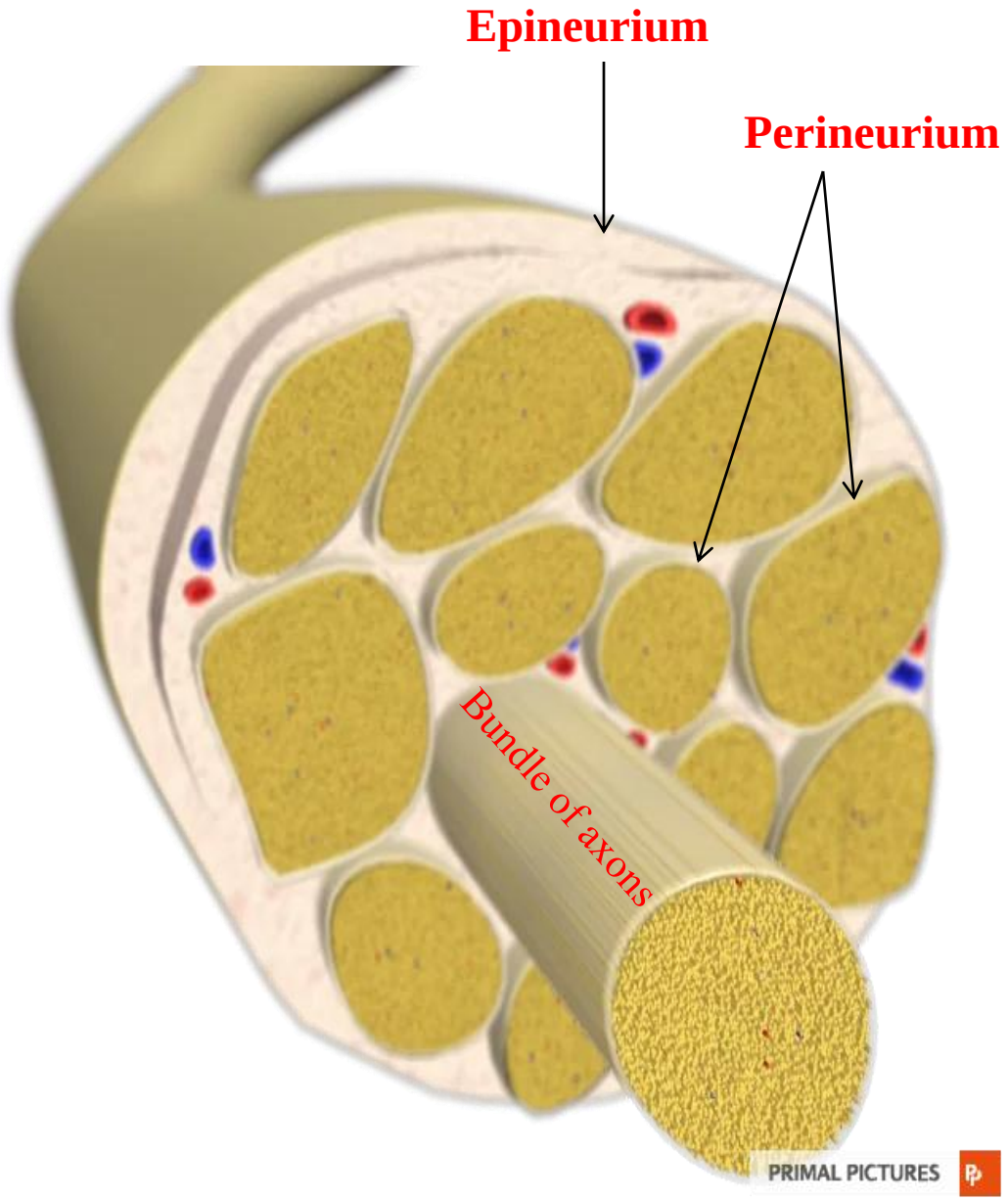
Gray matter



Peripheral nerves

- Consist of **Cranial** and **Spinal** nerves connecting brain and spinal cord to peripheral tissues.
- Peripheral nerves consist of parallel bundles of nerve axons, **Myelinated** or **Unmyelinated**, surrounded by connective tissue sheaths.
- Spaces between bundles usually contains fat.
- Nerve fiber = axon + myelin

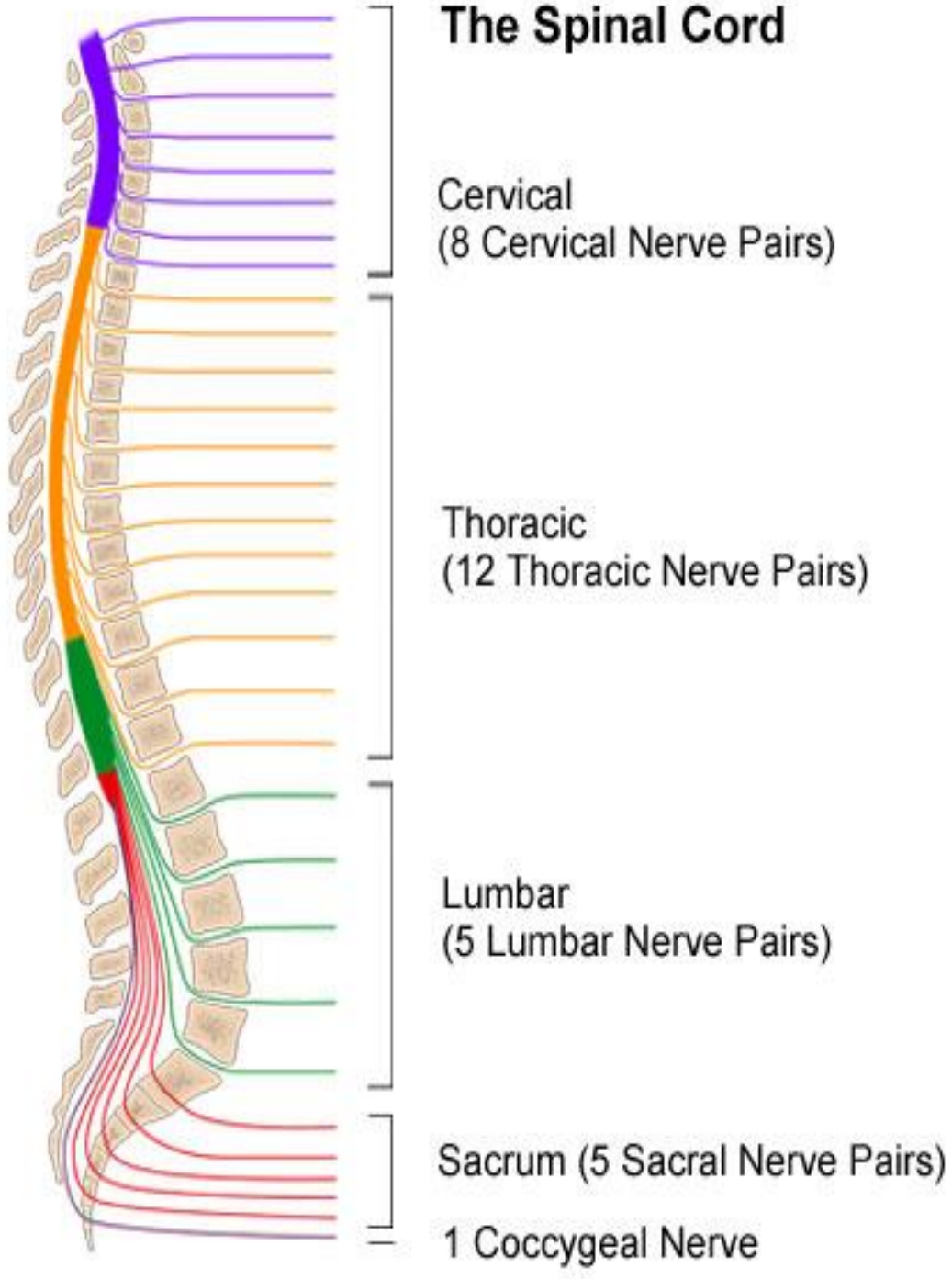




The spinal cord is divided into 31 segments where pairs of spinal nerves (mixed; sensory and motor) are attached

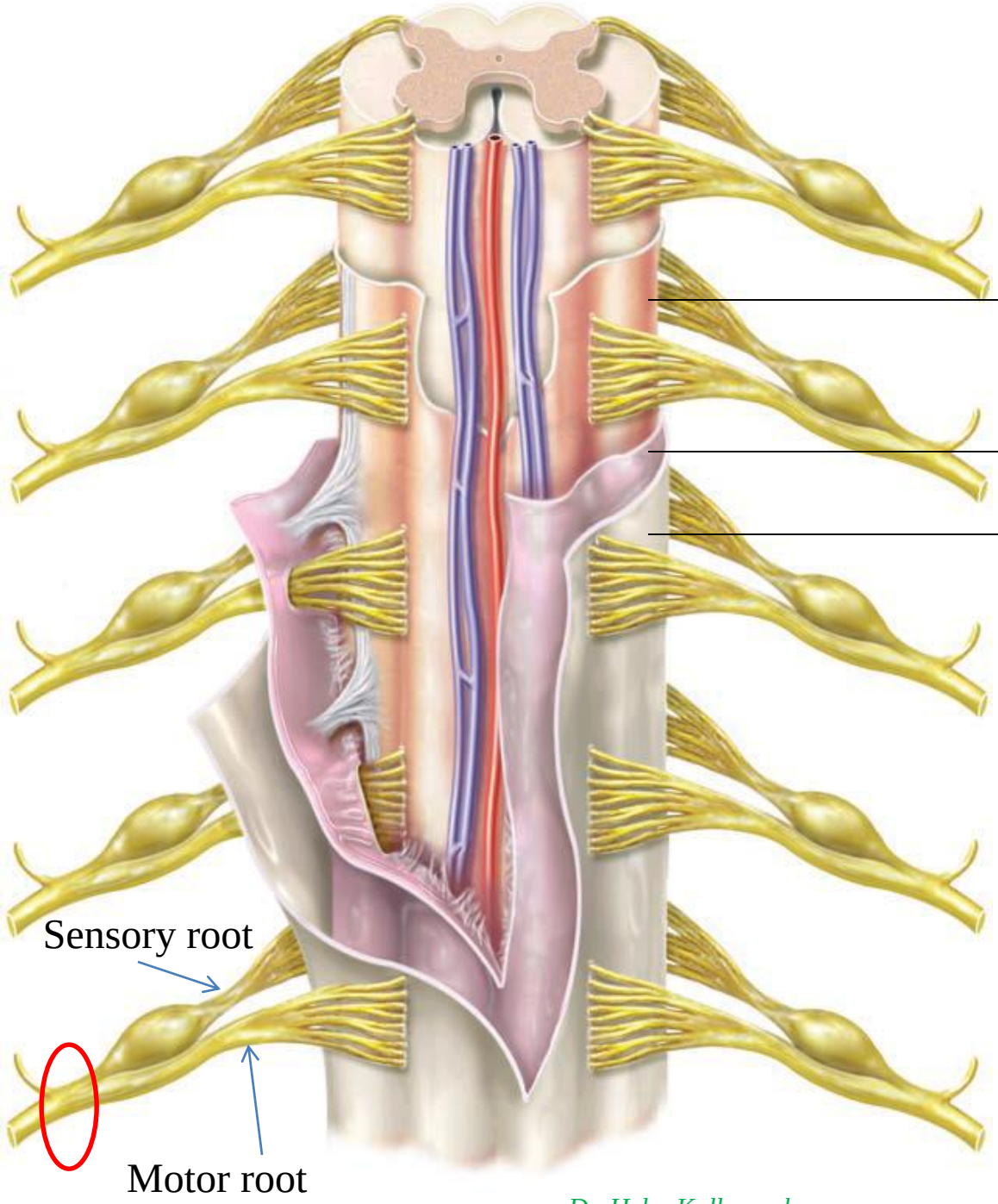
8 cervical segments forming 8 pairs of cervical nerves
12 thoracic segments forming 12 pairs of thoracic nerves
5 lumbar segments forming 5 pairs of lumbar nerves
5 sacral segments forming 5 pairs of sacral nerves
1 coccygeal segment forming one pair of coccygeal nerves

31 pairs of spinal nerves supply all of the body **except head**



Spinal Nerves

- Each spinal nerve is formed from two roots
  - Dorsal root – sensory root and ganglion
  - Ventral root – motor root



Each root is formed from a set of rootlets that attach to the spinal cord

Meninges: Connective tissue membranes

- **Pia mater**
- **Arachnoid mater**
- **Dura mater**

Enveloping the brain and the spinal cord are three membranous layers known as the meninges. From superficial to deep, these layers are the dura mater, arachnoid mater, and pia mater. The meninges function to protect the brain and the spinal cord from mechanical trauma, support the cranial vasculature and form a continuous cavity through which the cerebrospinal fluid (CSF) circulates.

These membranes collectively define three clinically important potential spaces: the epidural, subdural, and subarachnoid spaces.

Spinal Nerves

- Branches

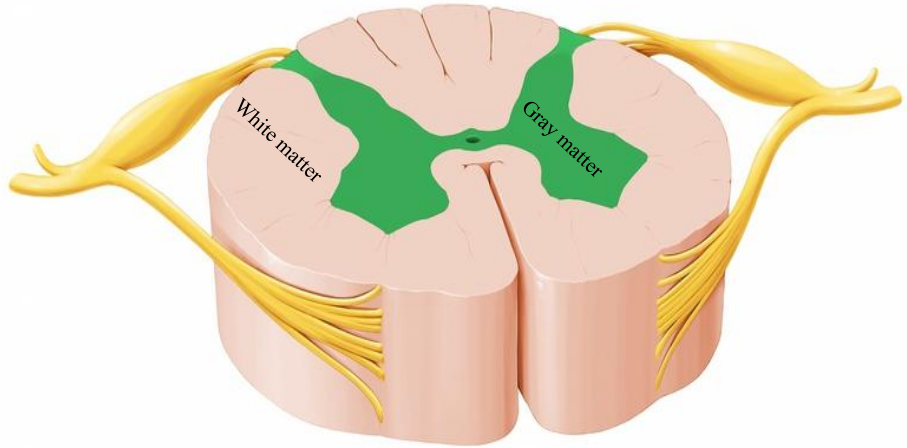
1) Posterior (dorsal) ramus

serves muscles and skin of the posterior surface of the trunk

2) Anterior (ventral) ramus

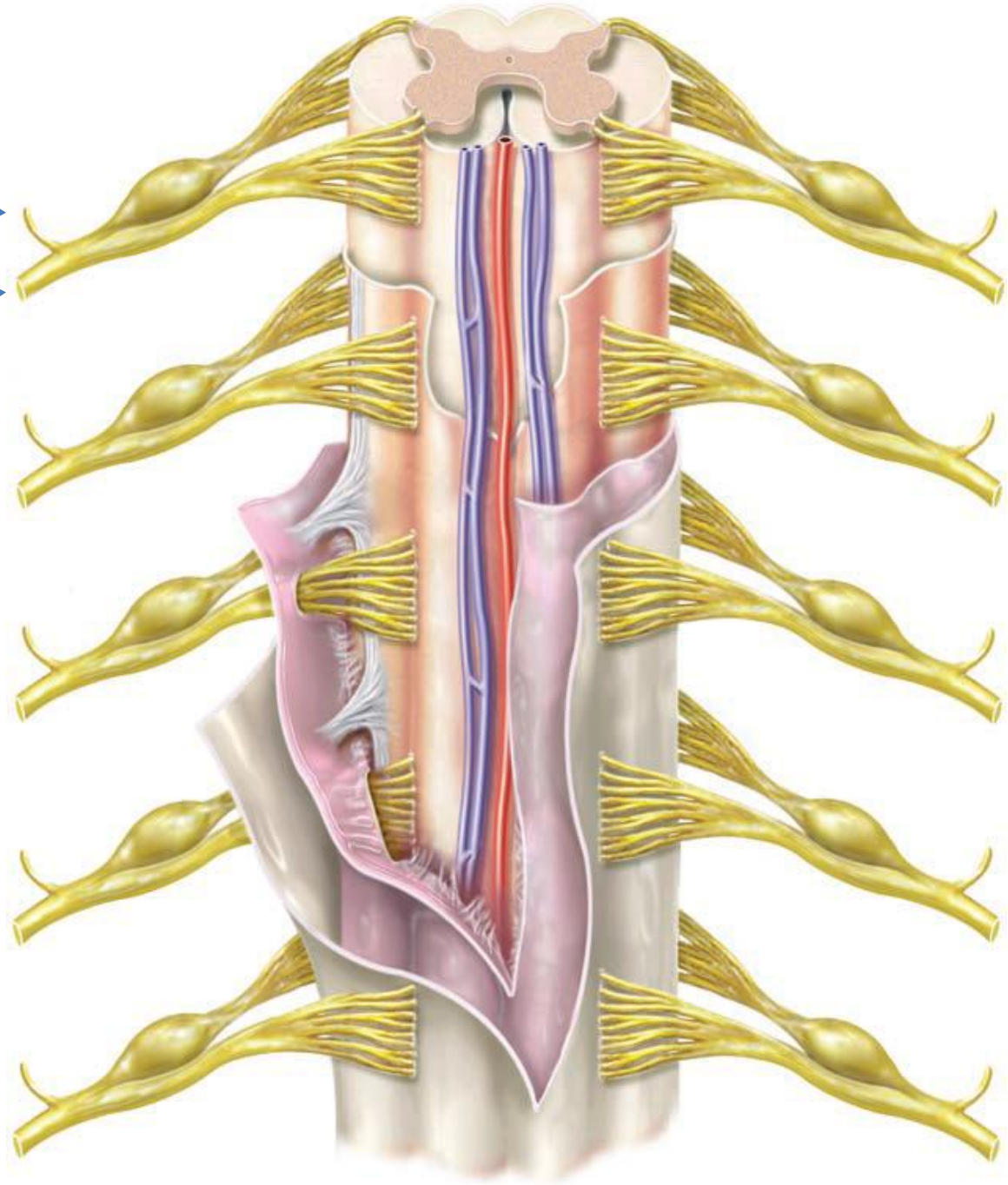
serves the muscles and structures of the upper and lower limbs and the skin of the lateral and anterior surfaces of the trunk

Forms plexus



Cross Section of Spinal Cord

The spinal cord is composed of inner core of gray matter which is surrounded by an outer covering of white matter



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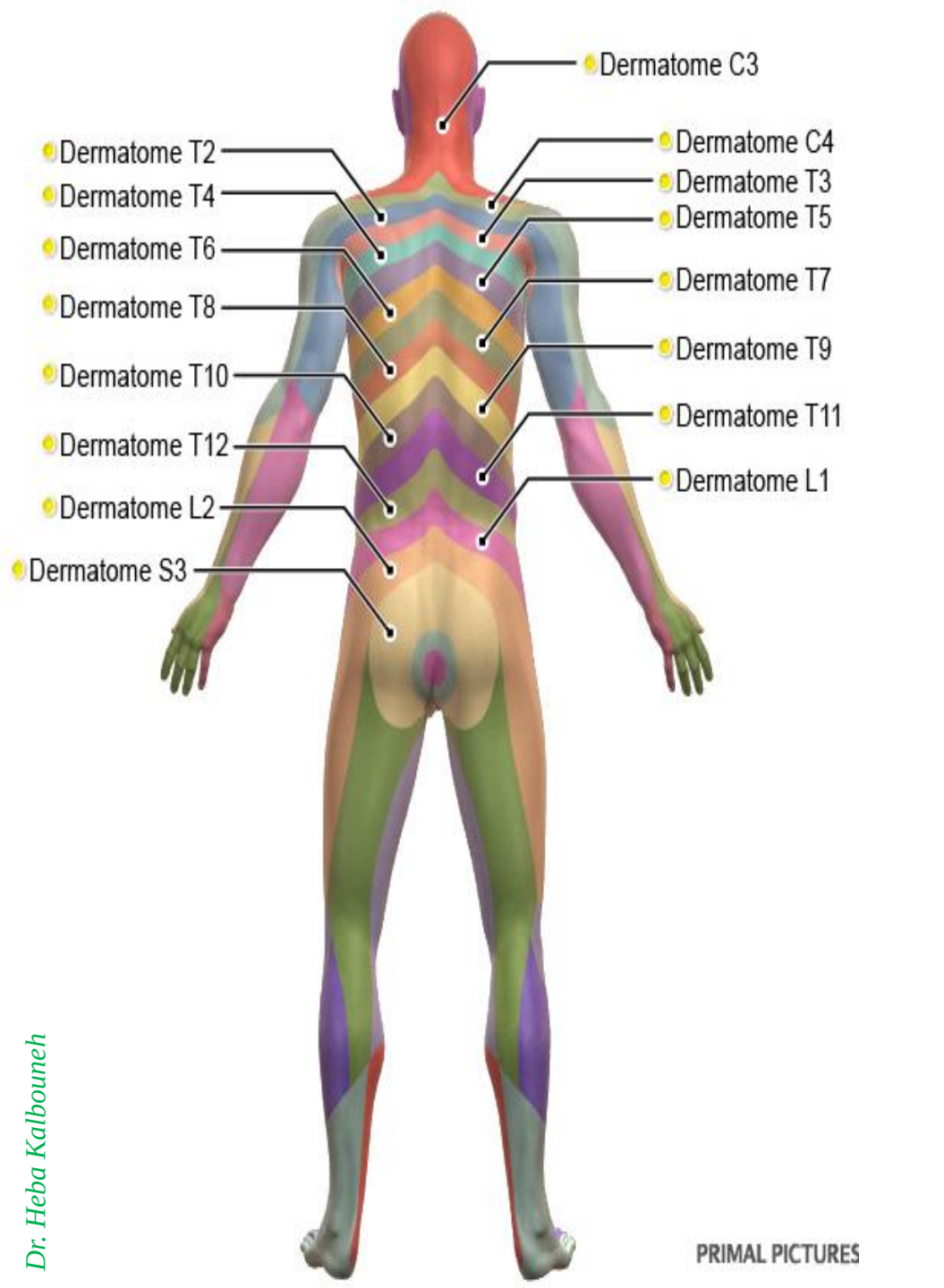
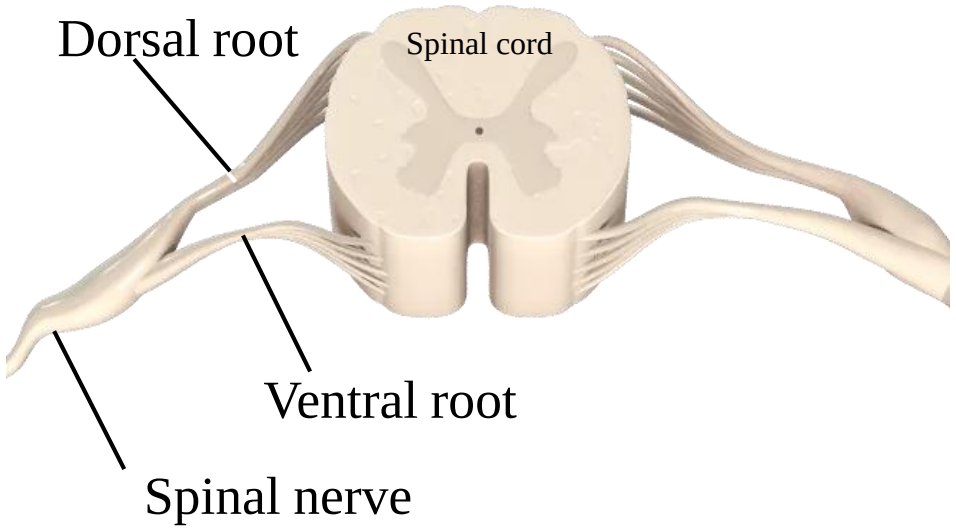
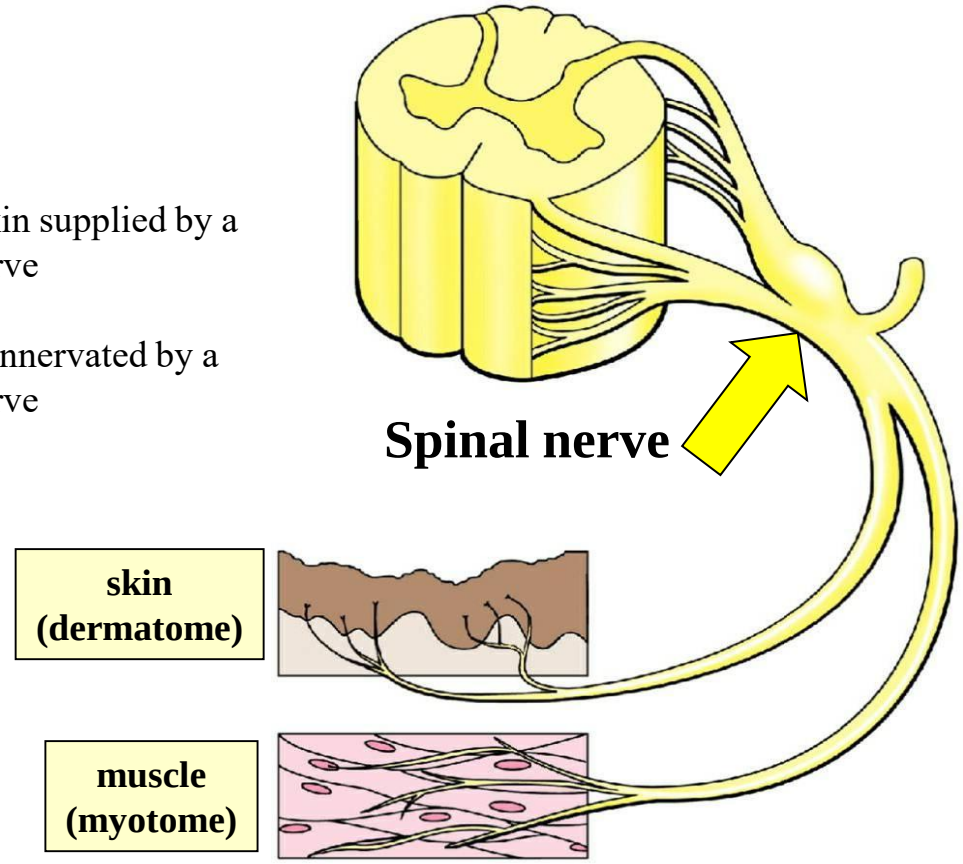


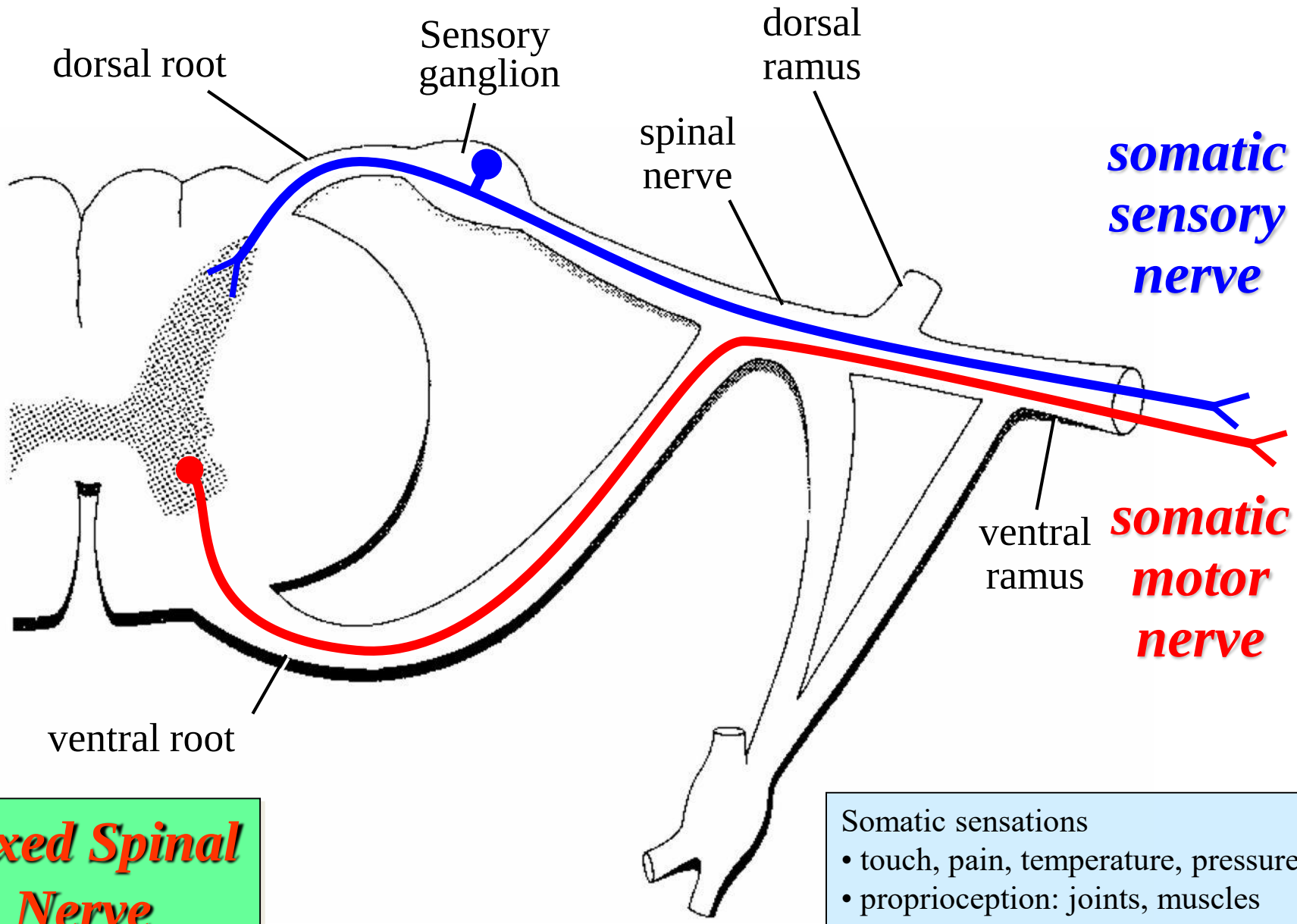


Dermatome: is the area of skin supplied by a single spinal nerve

Myotome: mass of muscle innervated by a single spinal nerve



Structure of Spinal Nerves: Somatic Pathways

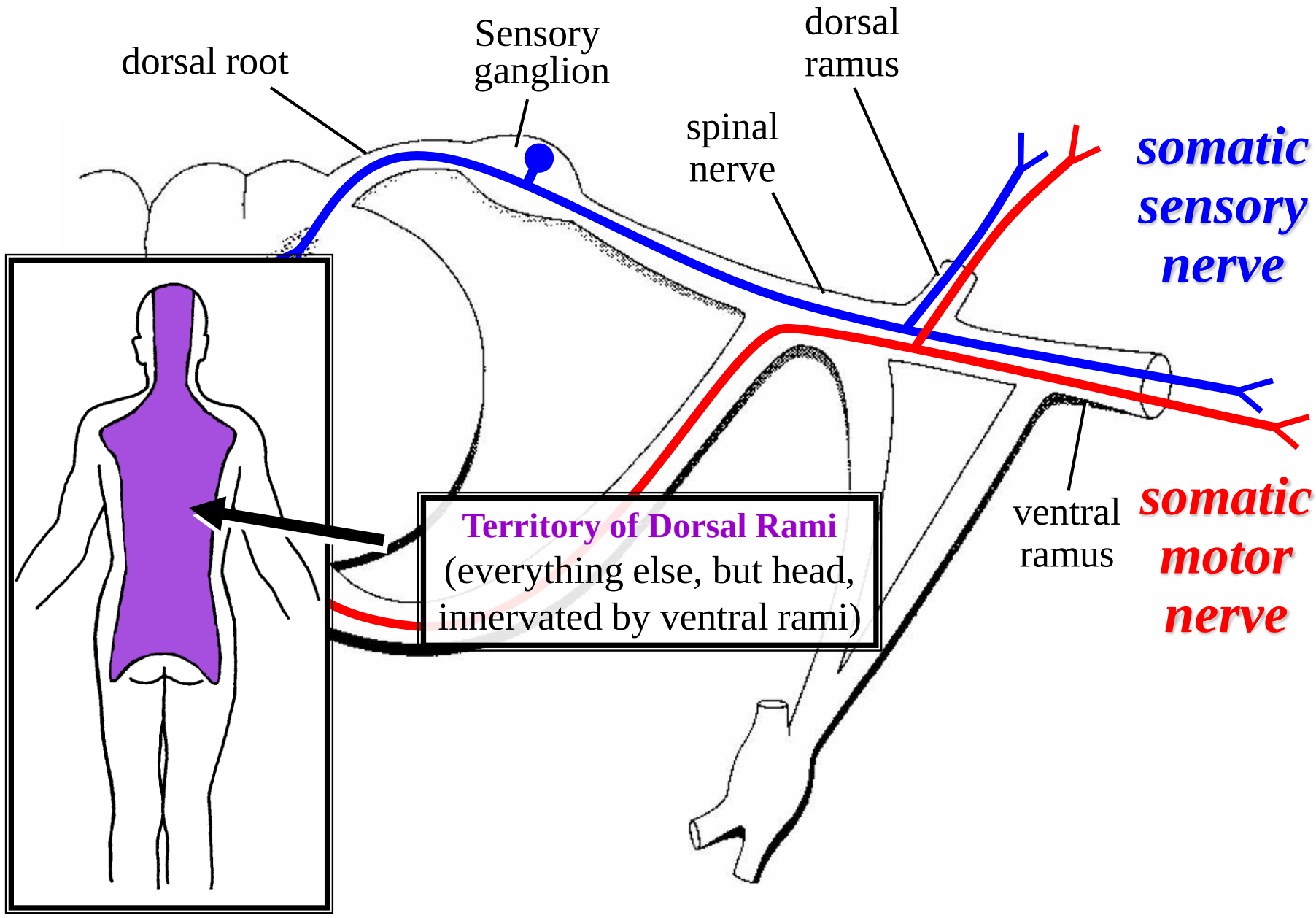


Mixed Spinal Nerve

Somatic sensations
- touch, pain, temperature, pressure
- proprioception: joints, muscles

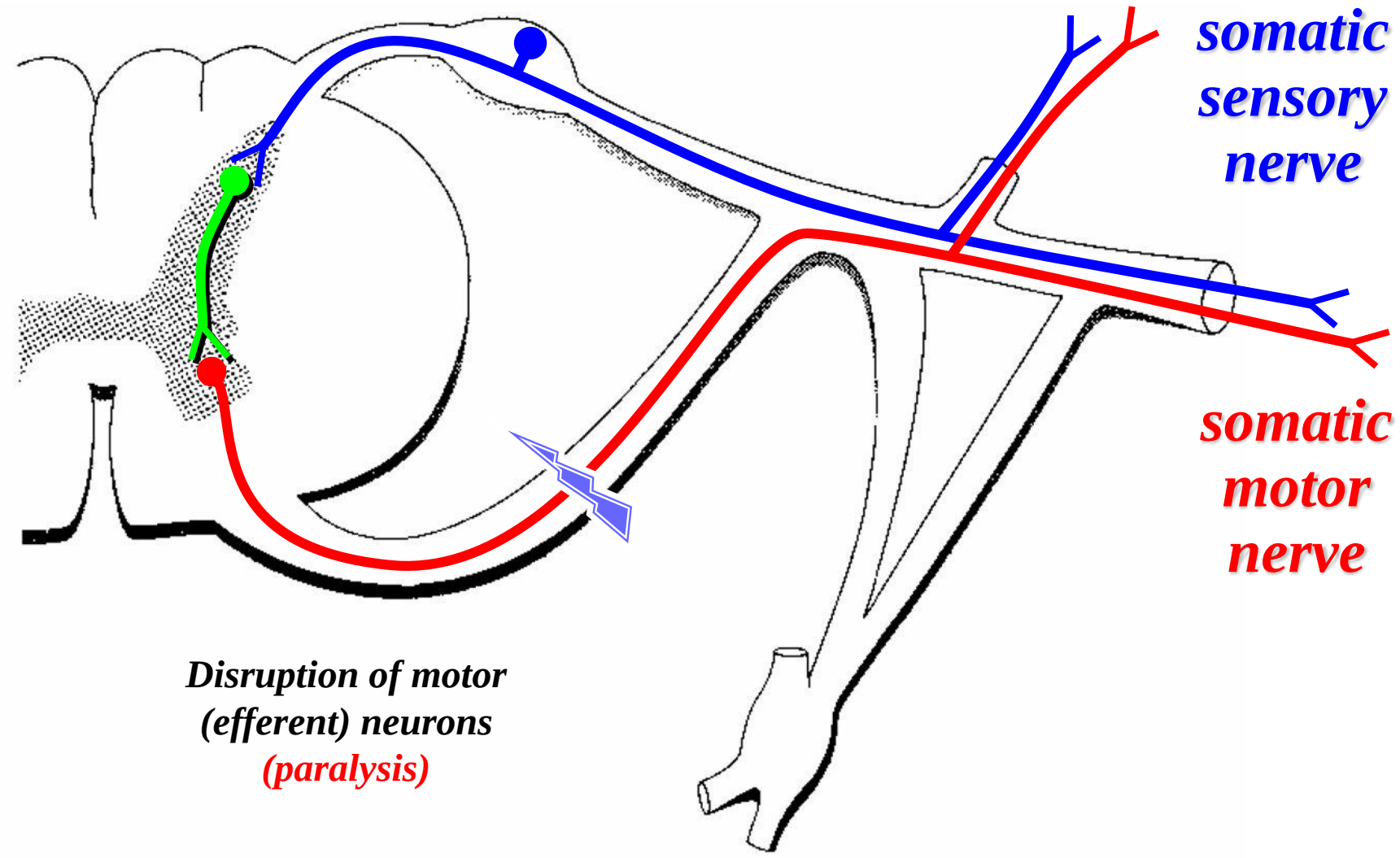
Somatic motor activity: innervate skeletal muscles

Structure of Spinal Nerves: Dorsal & Ventral Rami



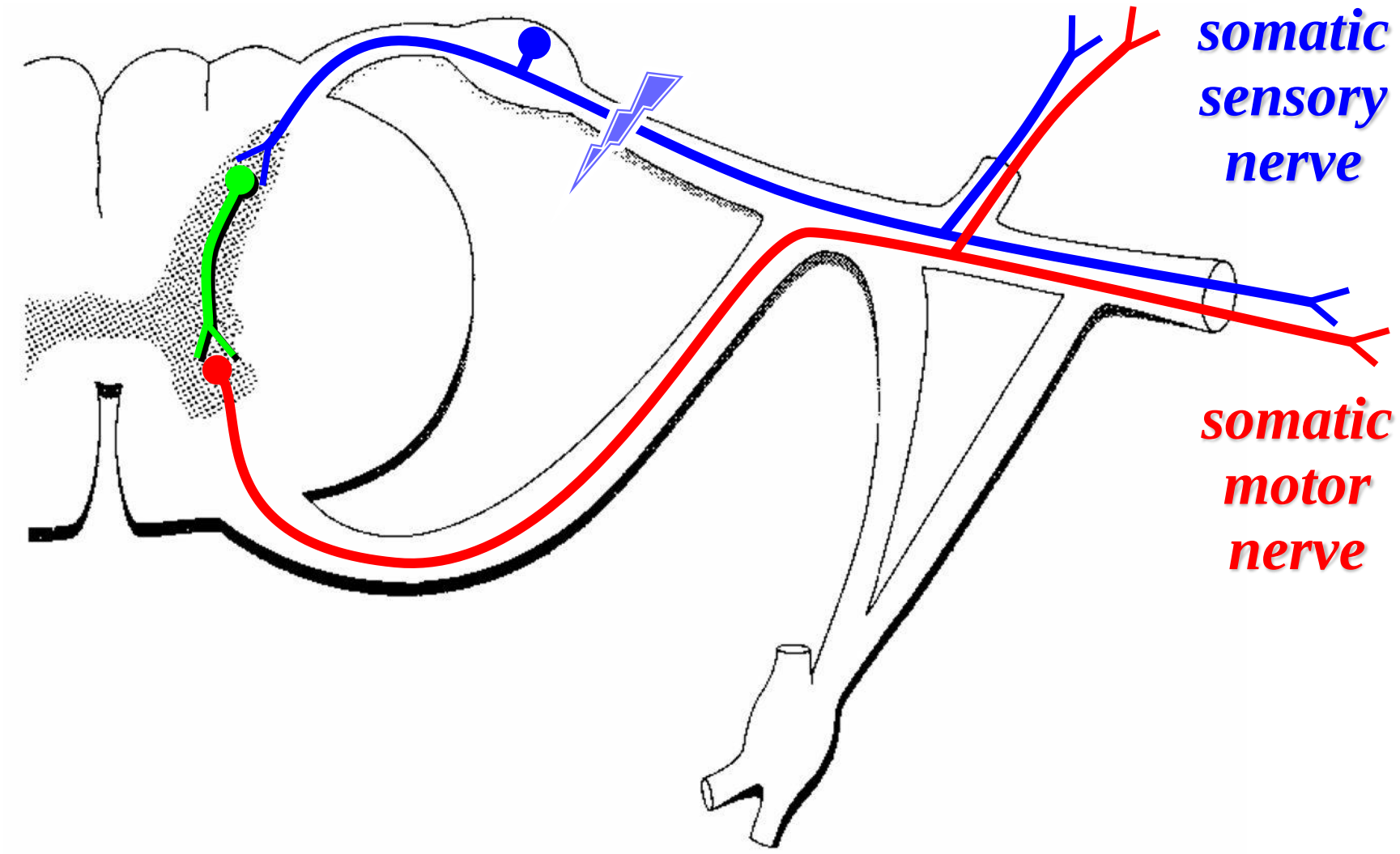
Stern *Essentials of Gross Anatomy*

Impact of Lesions



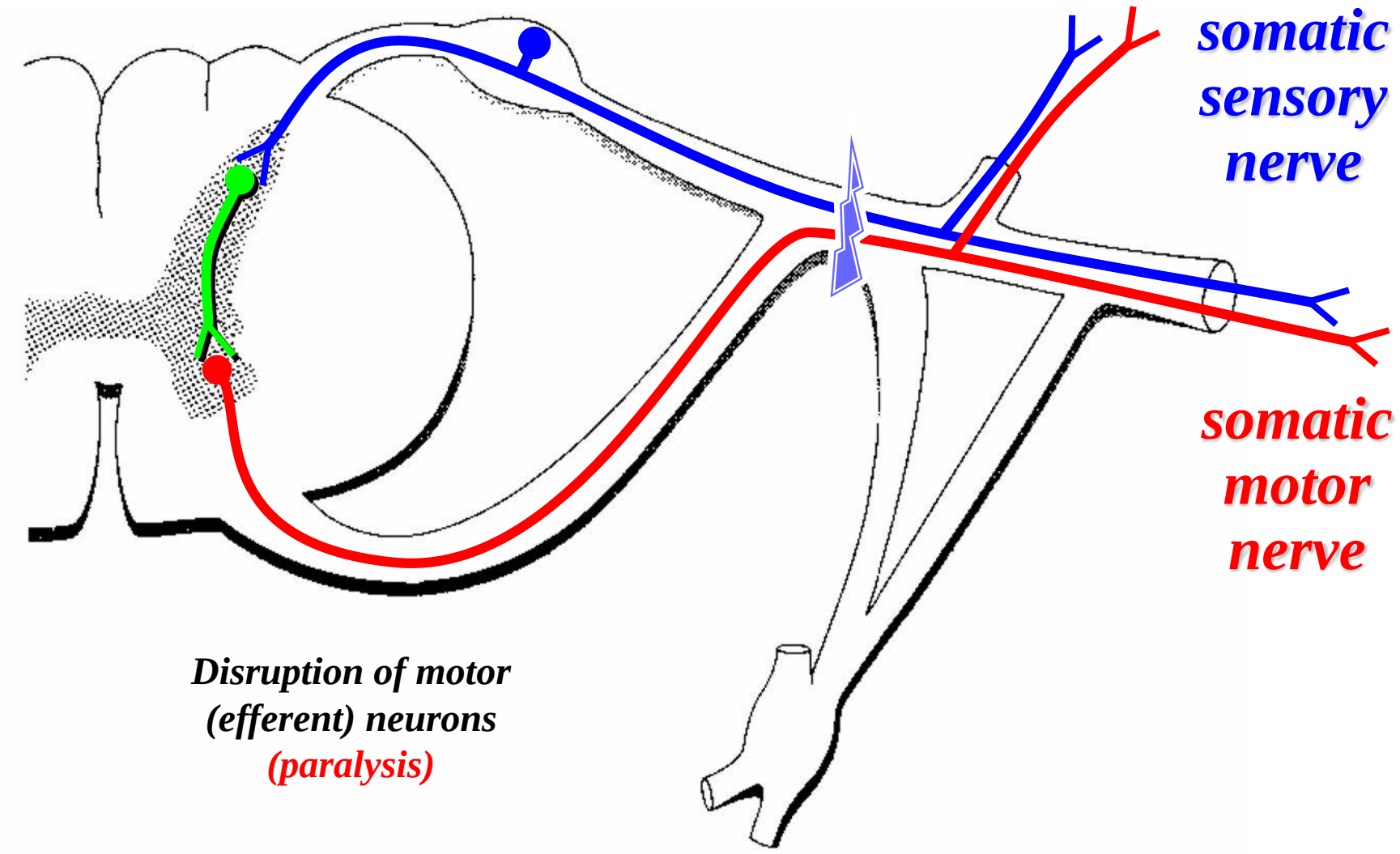
Impact of Lesions

Disruption of sensory (afferent) neurons (paresthesia)



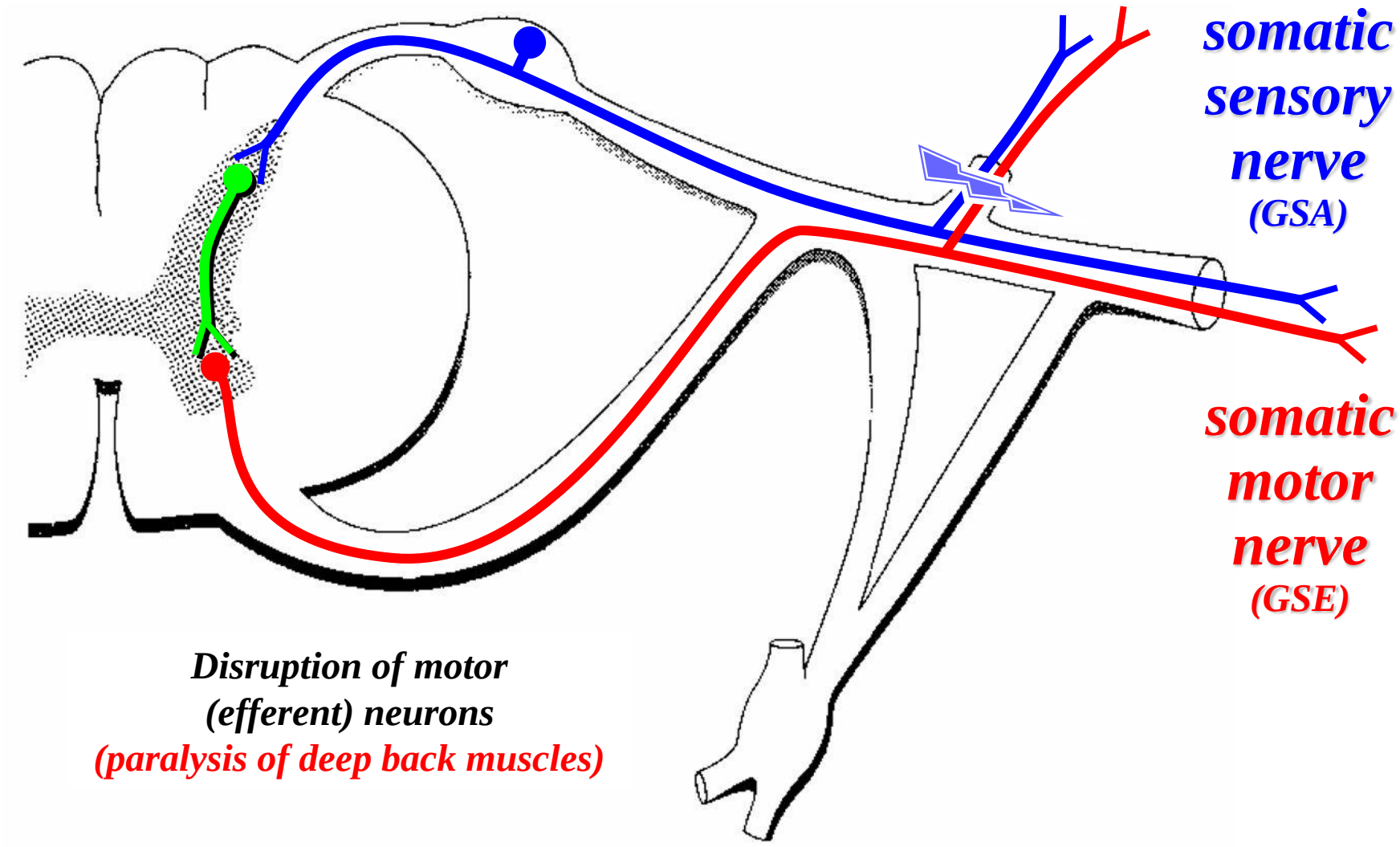
Impact of Lesions

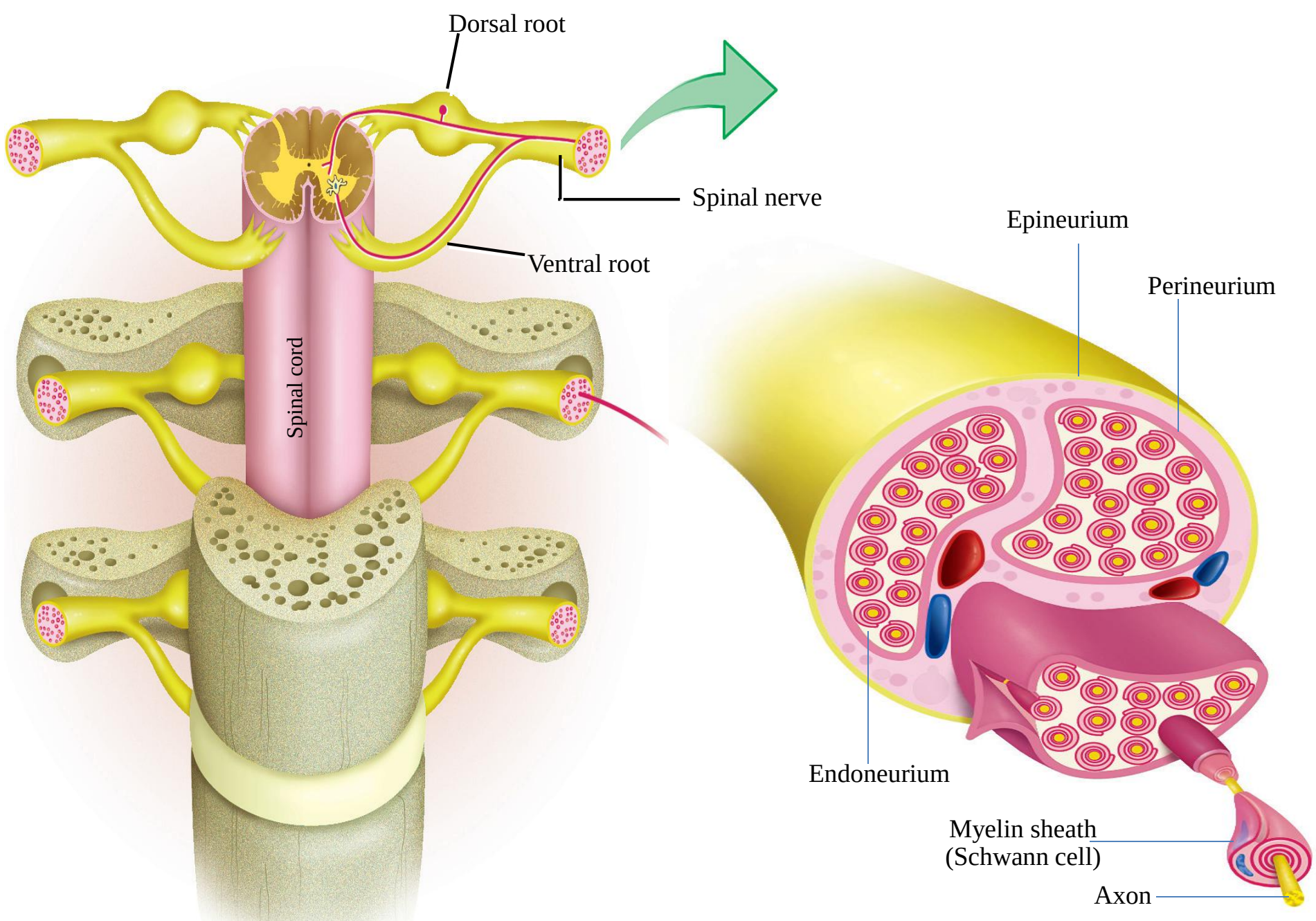
Disruption of sensory (afferent) neurons (paresthesia)



Impact of Lesions

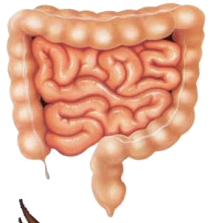
Disruption of sensory (afferent) neurons ***(back paresthesia)***





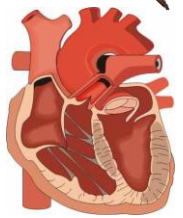
Autonomic nervous system

- ANS is the subdivision of the peripheral nervous system that regulates body activities that are generally **not under conscious control**
- **Visceral motor** innervates **non-skeletal (non-somatic) muscles**
- Composed of a special group of neurons serving:
  - Cardiac muscle (the heart)
  - Smooth muscle (walls of viscera and blood vessels)
  - Glands



glands

smooth muscle

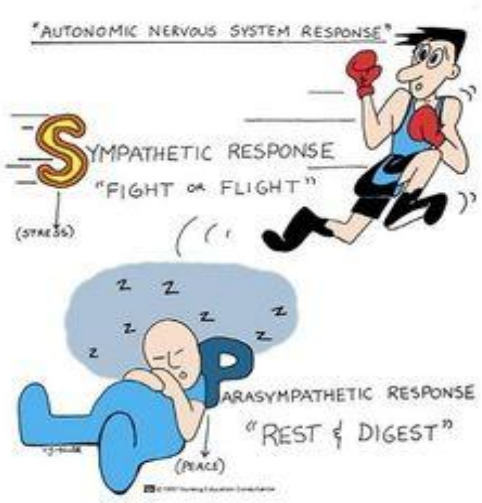


cardiac muscle

Divisions of Autonomic nervous system

- Parasympathetic division
- Sympathetic division

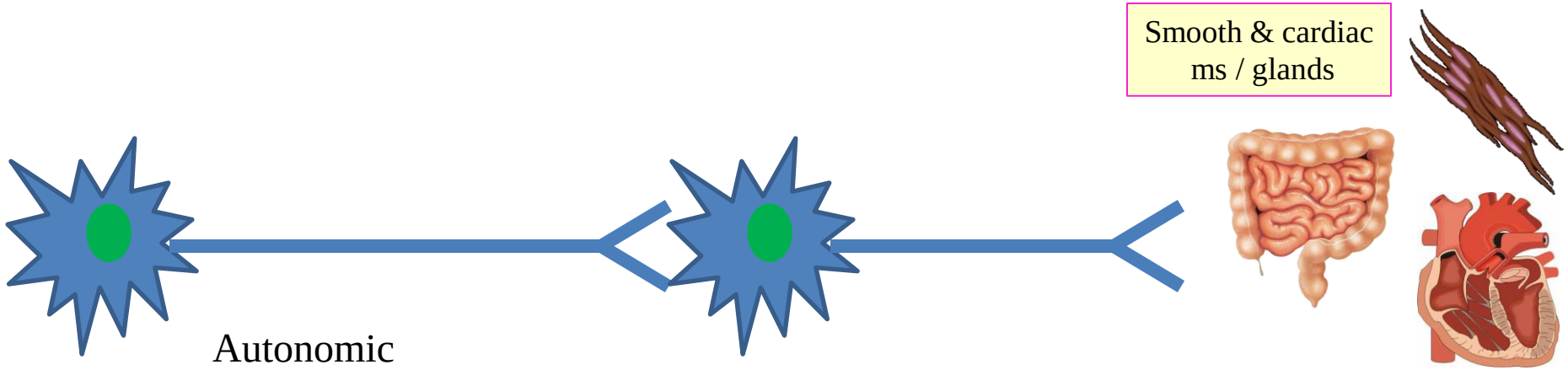
Serve almost the same organs but cause opposing or antagonistic effects



Parasysmpathetic: routine maintenance
"rest &digest"
Sympathetic: mobilization & increased metabolism
"fight, flight or fright"

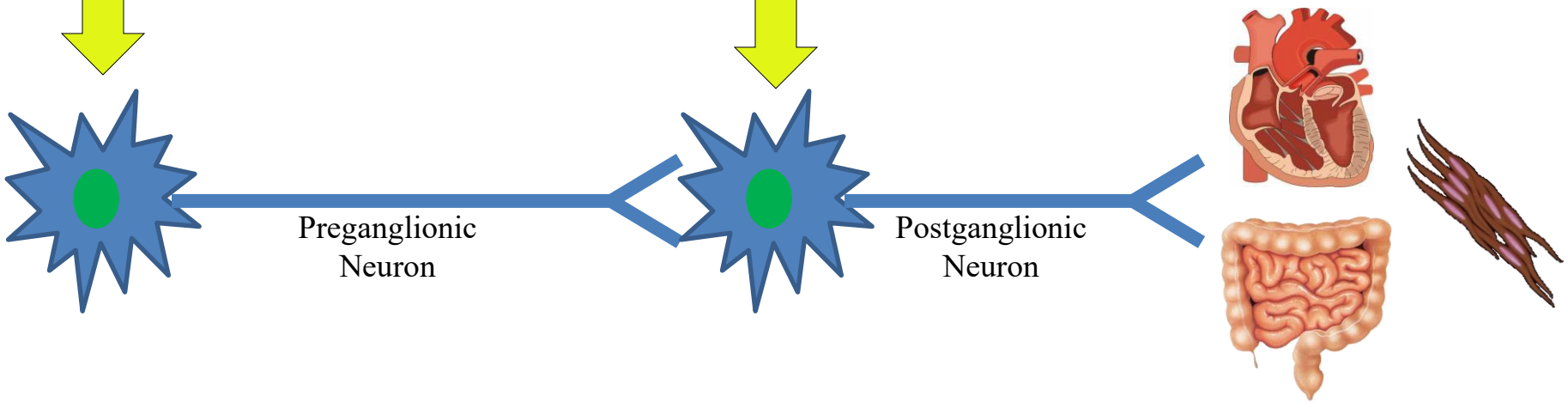
Basic anatomical difference between the motor pathways of the voluntary somatic nervous system (to skeletal muscles) and those of the autonomic nervous system

- Somatic division:
  - Cell bodies of motor neurons reside in CNS (brain or spinal cord)
  - Their axons (sheathed in nerves) extend all the way to their skeletal muscles
- Autonomic system: chains of two motor neurons
  - 1st = preganglionic neuron (cell body in brain or cord)
  - 2nd = postgangionic neuron (cell body in ganglion outside CNS)
  - Slower because lightly or unmyelinated



The cell body of preganglionic neuron is in CNS
Nucleus

The cell body of postganglionic neuron is outside CNS
Ganglion



- Axon of 1st (preganglionic) neuron leaves CNS to synapse with the 2nd (ganglionic) neuron
- Axon of 2nd (postganglionic) neuron extends to the organ it serves

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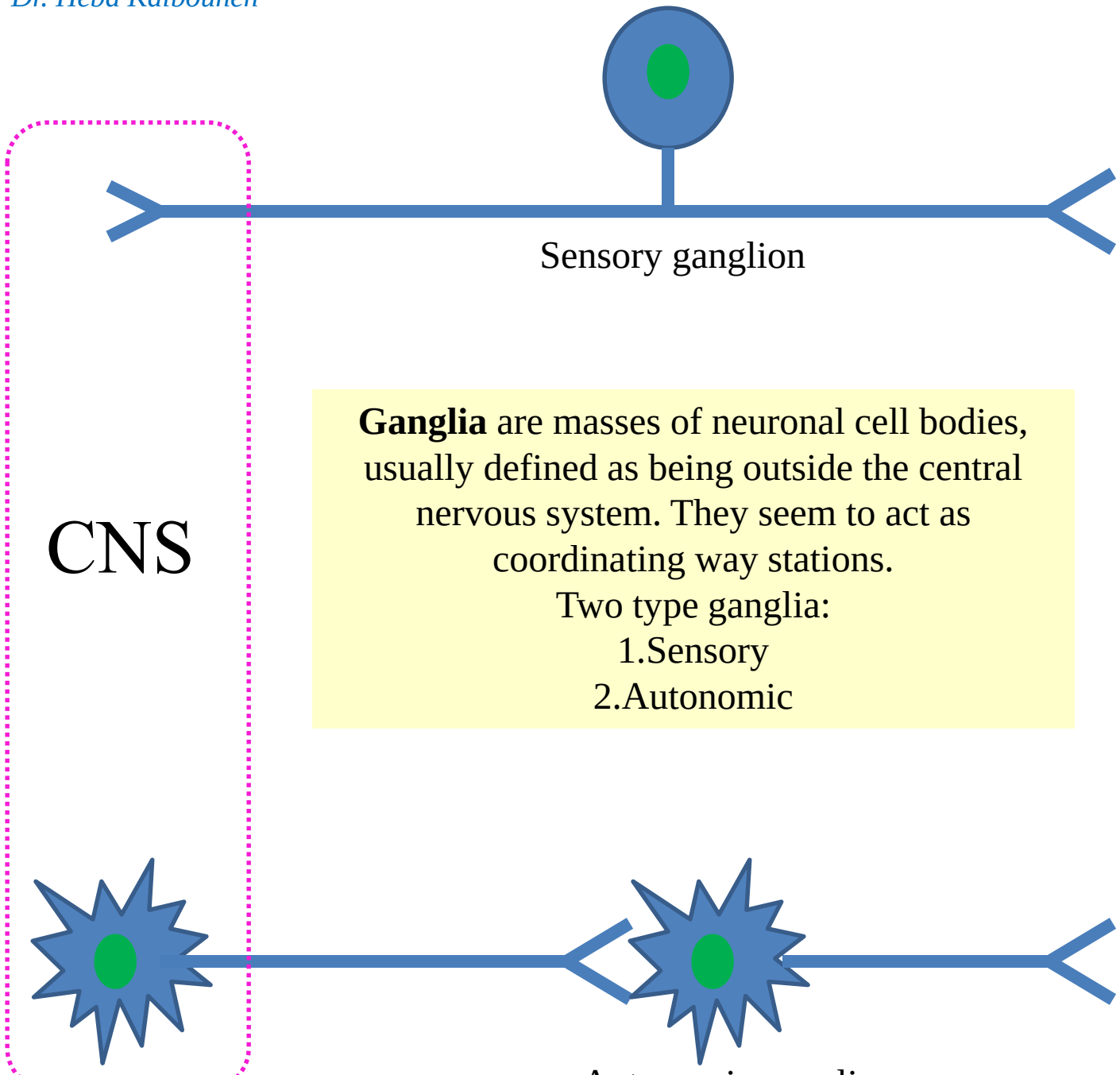
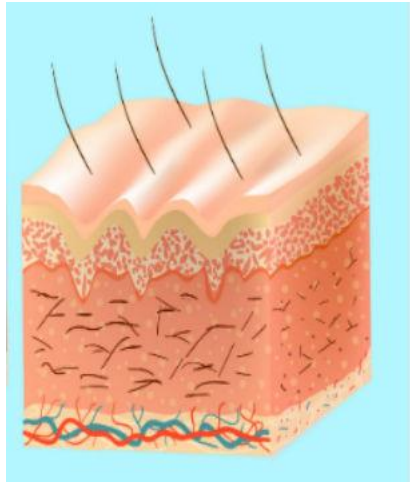




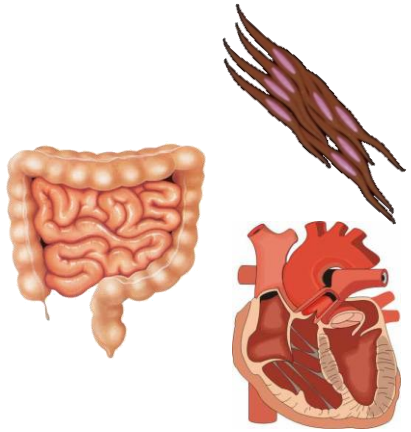
Ganglia are masses of neuronal cell bodies, usually defined as being outside the central nervous system. They seem to act as coordinating way stations.

Two type ganglia:

1.Sensory

2.Autonomic

Note: Sensory ganglia do not receive synapses While Autonomic ganglia do contain synapses



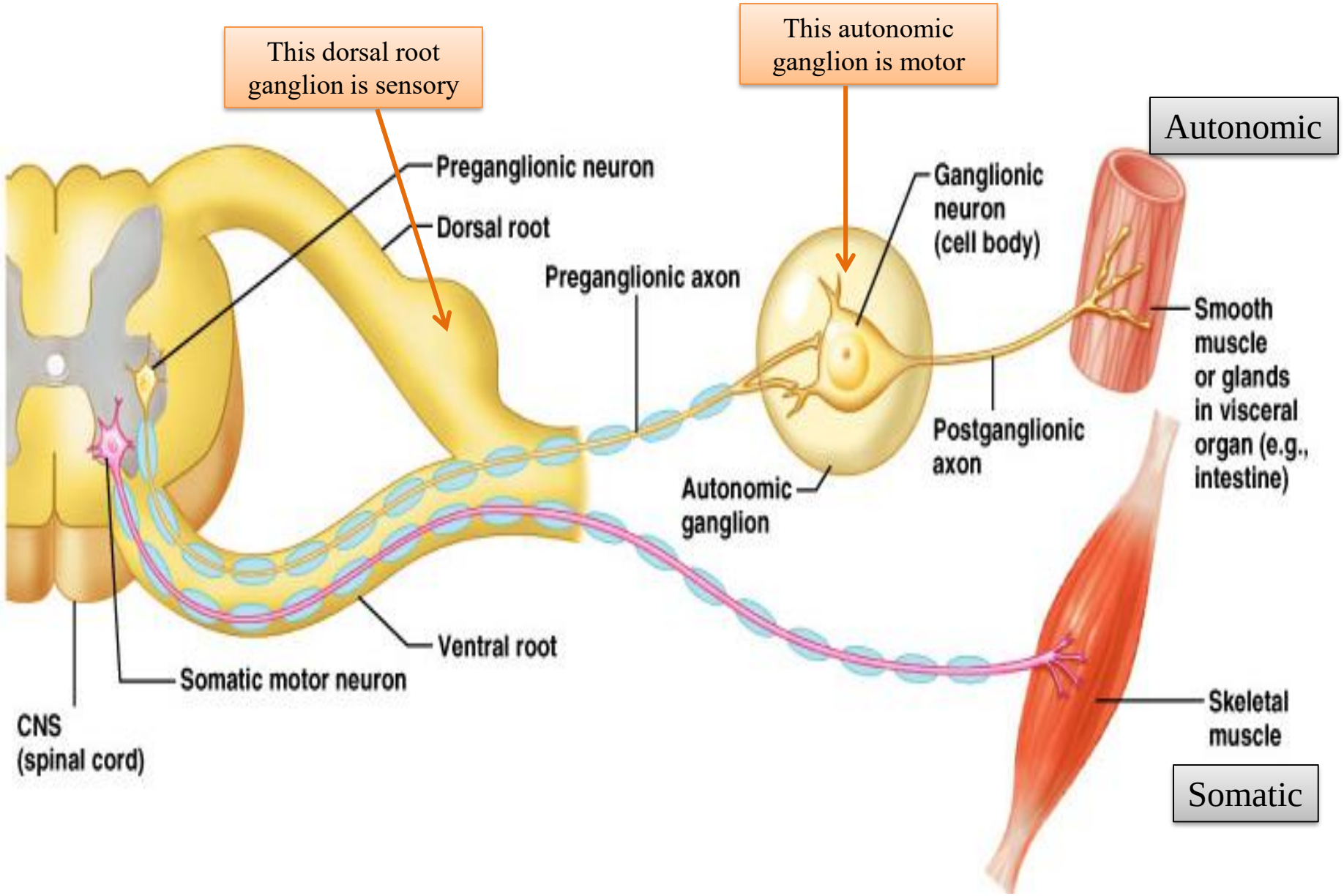
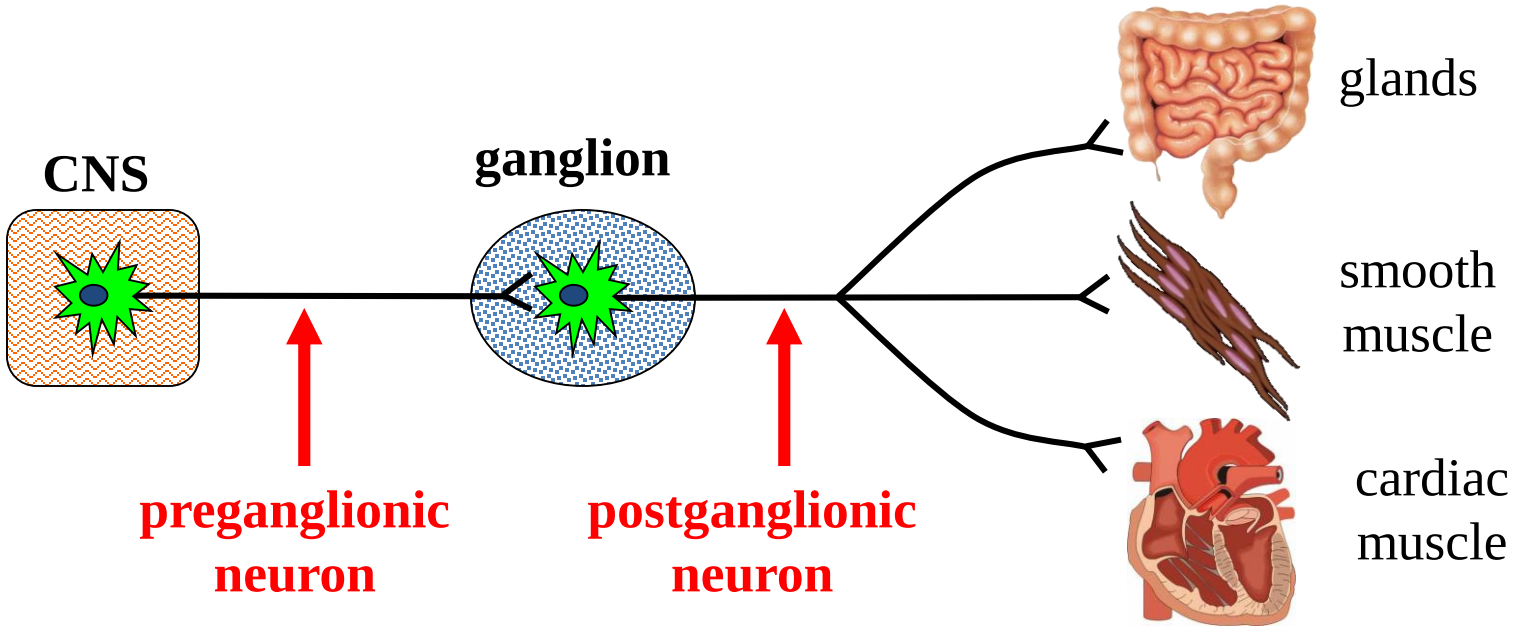


Diagram contrasts somatic and autonomic

Autonomic Nervous System

Similarities between Sympathetic & Parasympathetic

- Both are efferent (motor) systems: “visceromotor”
- Both involve regulation of the “internal” environment generally outside of our conscious control: “autonomous”
- Both involve 2 neurons that synapse in a peripheral ganglion
- Innervate glands, smooth muscle, cardiac muscle

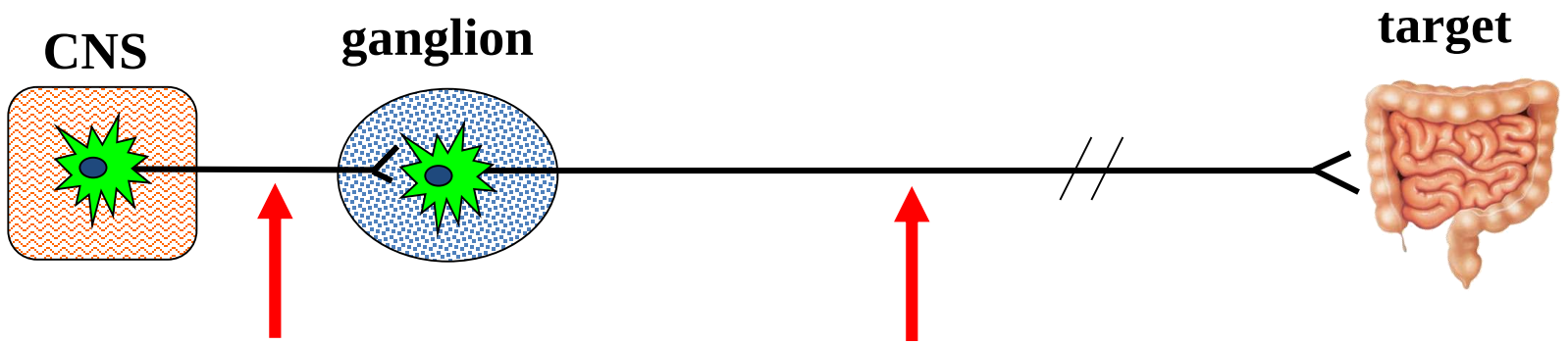


Autonomic Nervous System

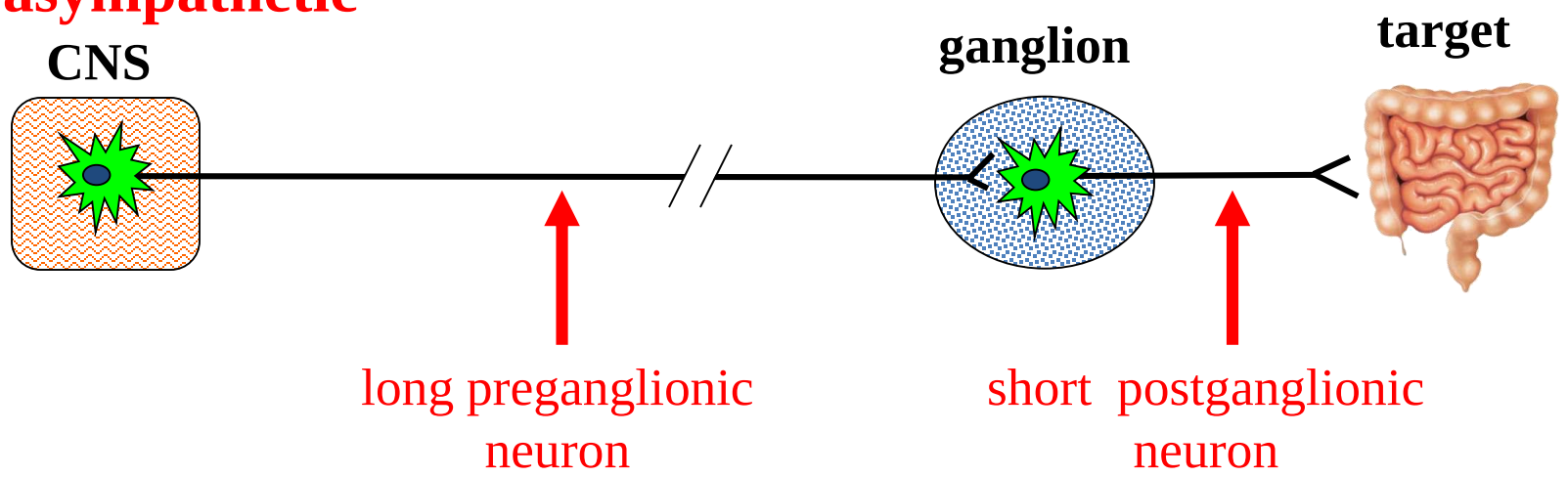
Differences between Sympathetic & Parasympathetic

Relative Lengths of Neurons

Sympathetic



Parasympathetic



Overview of the Autonomic Nervous System

Differences between Sympathetic & Parasympathetic

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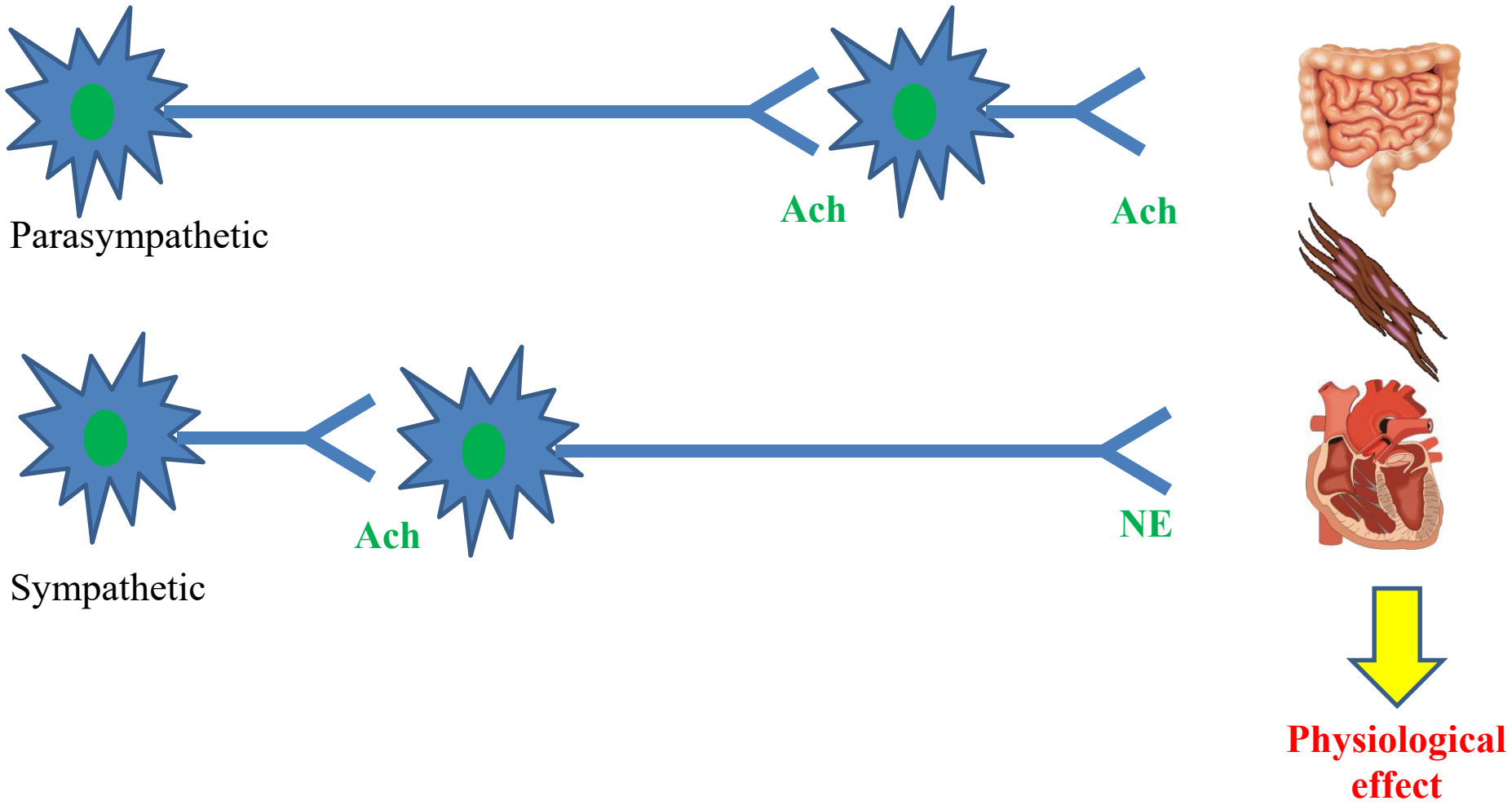
Types of neurotransmitters



Autonomic Nervous System

Differences between Sympathetic & Parasympathetic

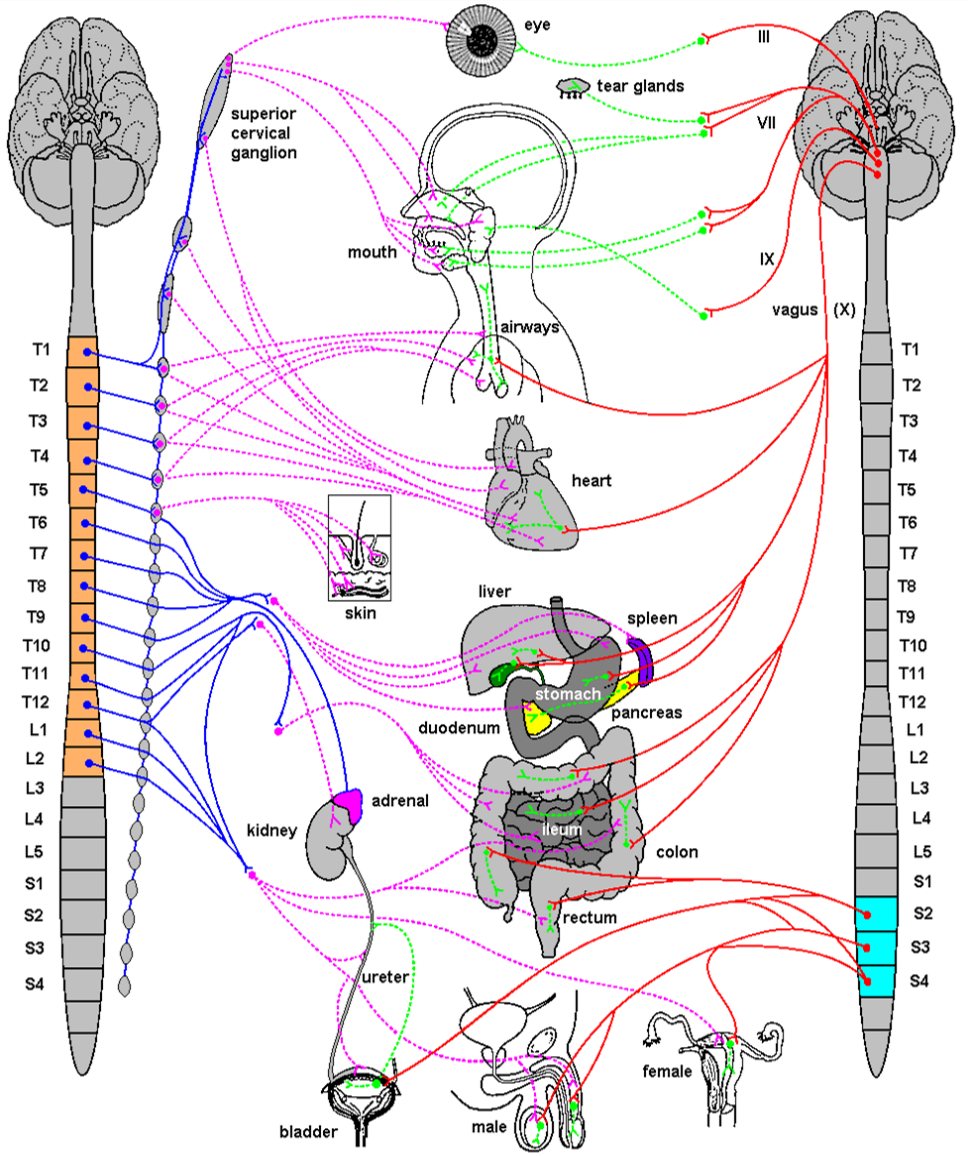
Location of Preganglionic Cell Bodies

Sympathetic

Thoracolumbar

T1 – L2 levels of the spinal cord

vasomotor



Parasympathetic

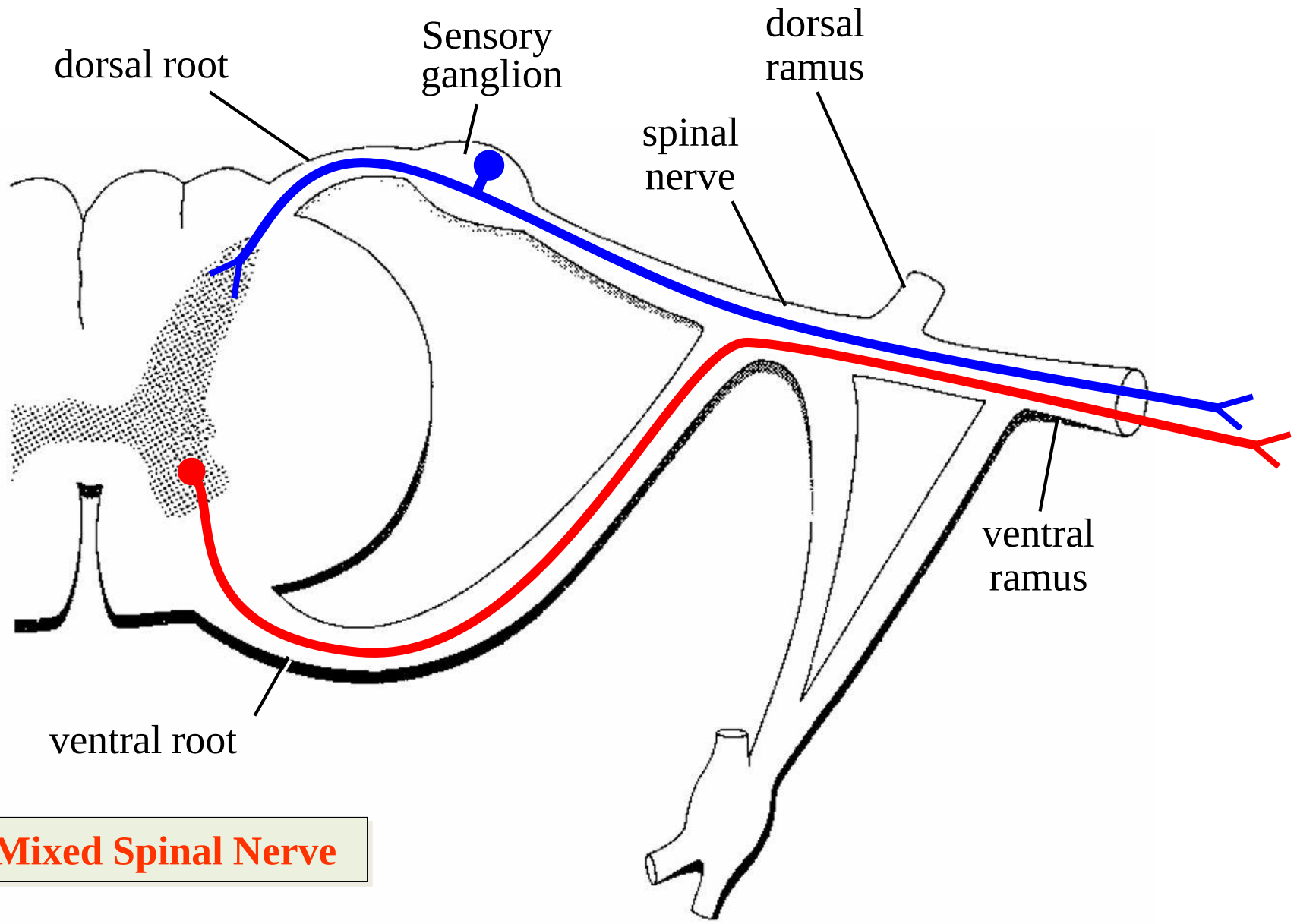
Craniosacral

Brain: CN III, VII, IX, X

Spinal cord: S2 – S4

secretomotor

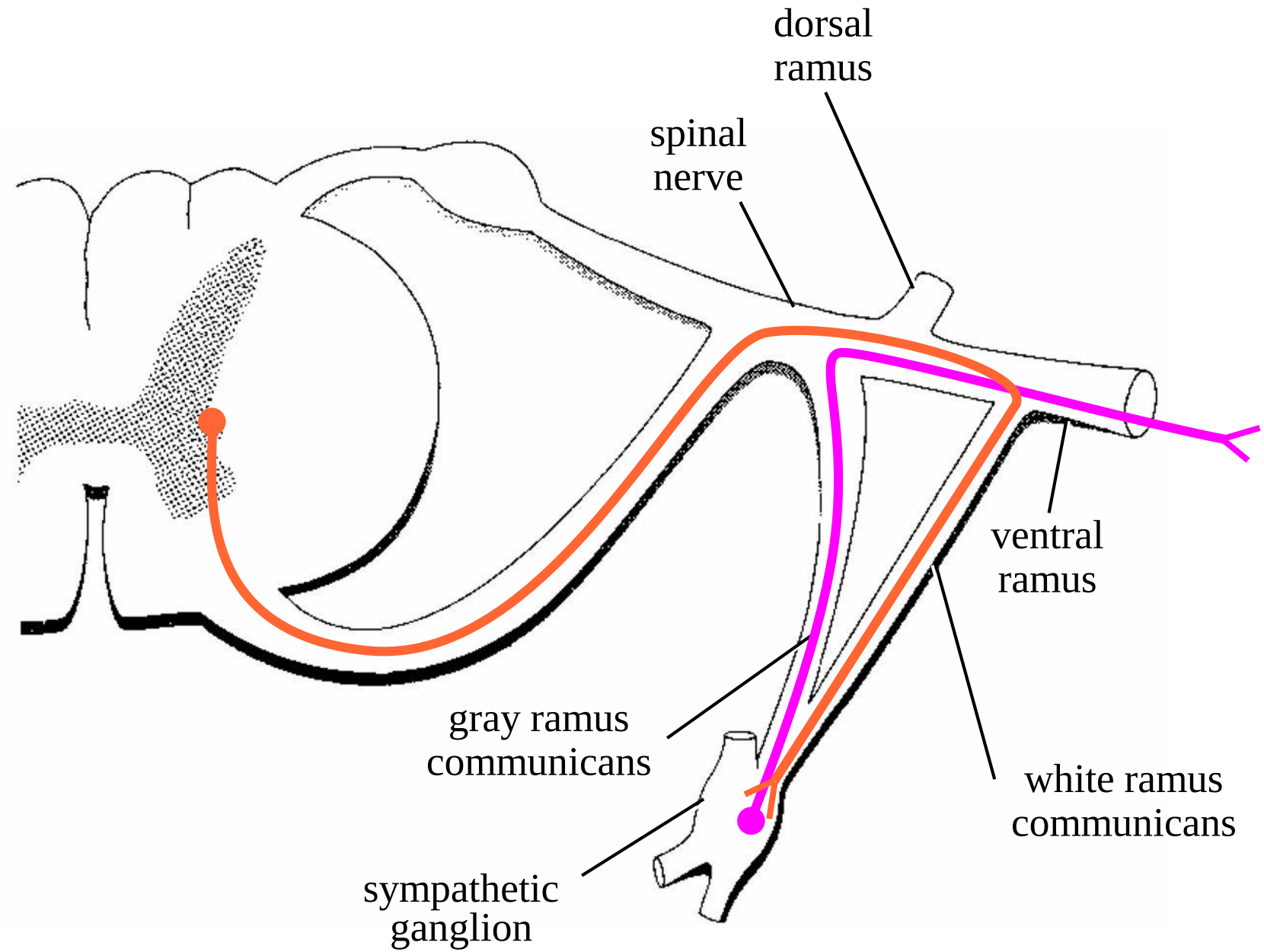
Structure of Spinal Nerves: Somatic Pathways



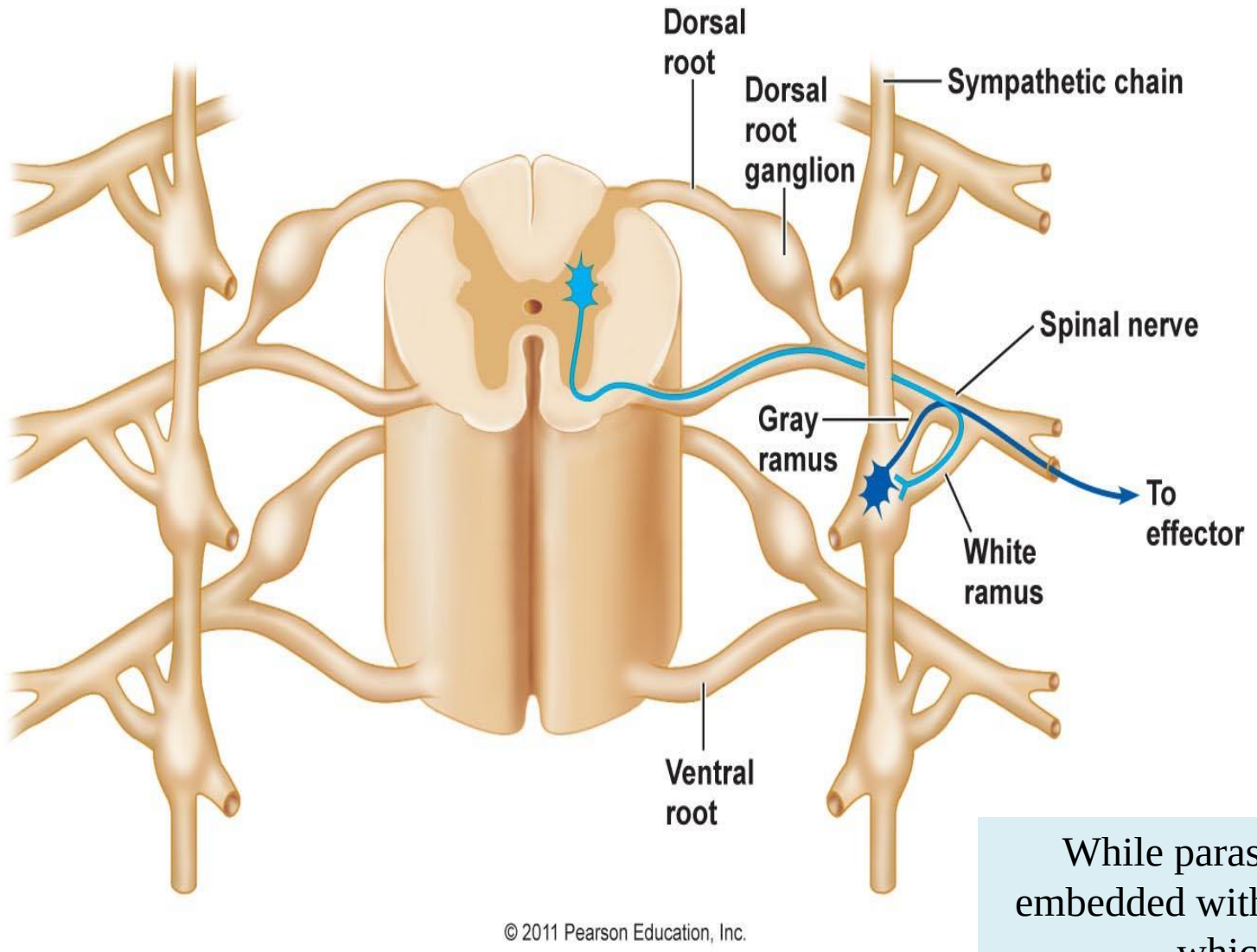
Mixed Spinal Nerve

Stern *Essentials of Gross Anatomy*

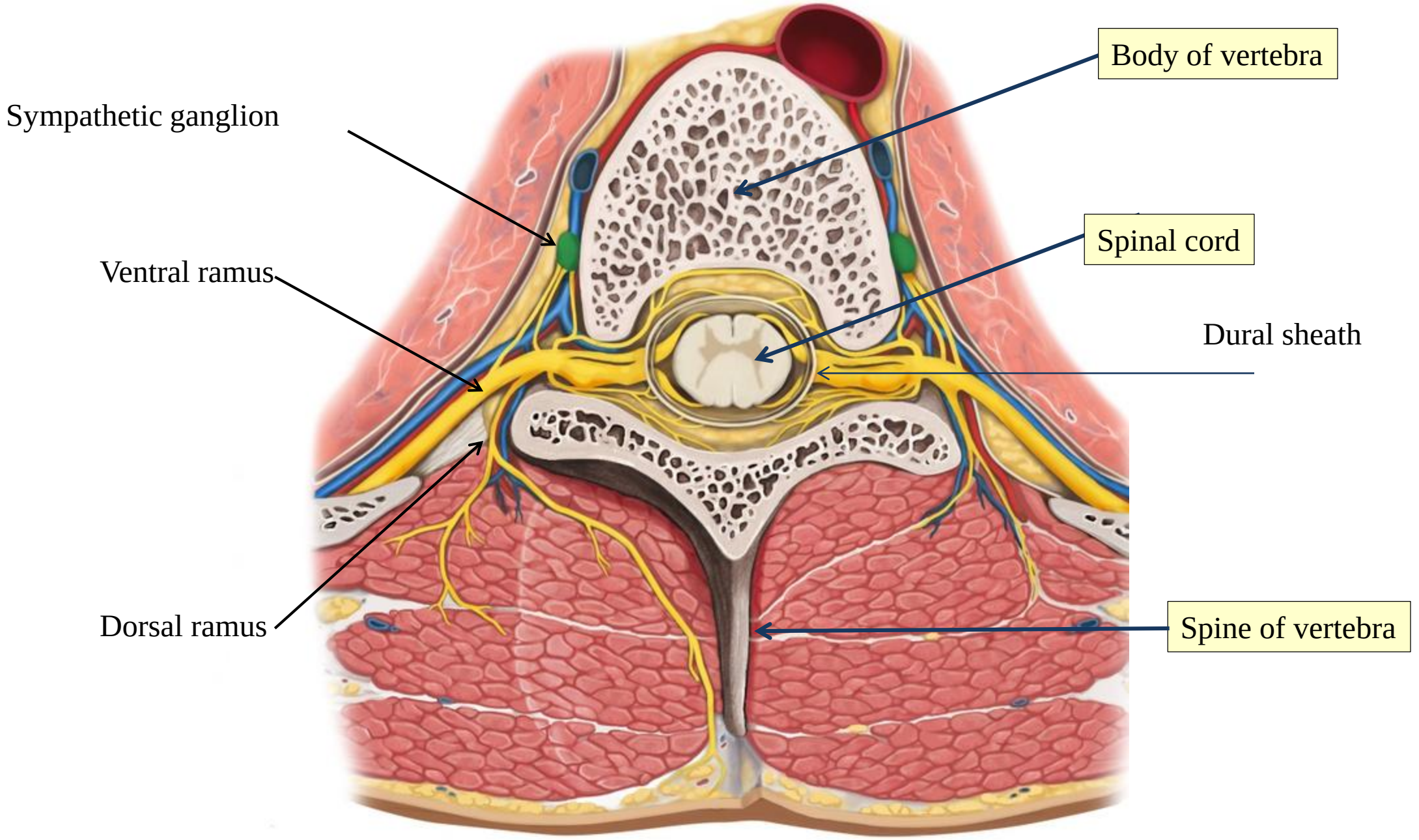
Structure of spinal nerves: Sympathetic pathways



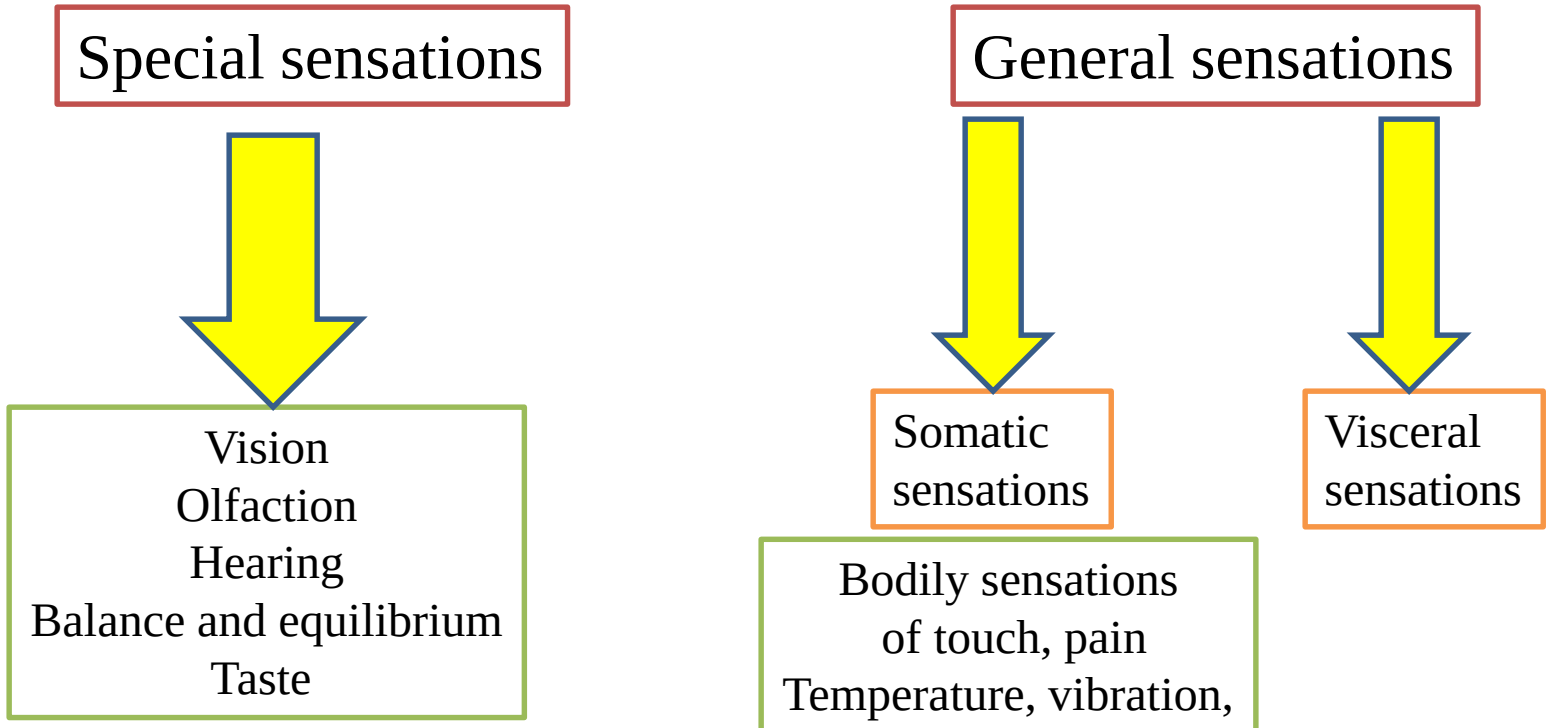
Sympathetic ganglia are the ganglia of the sympathetic nervous system
They are located close to and on either side of the spinal cord in long chains



While parasympathetic ganglia are embedded within the walls of the organs which they innervate


Body of vertebra
Sympathetic ganglion
Spinal cord
Ventral ramus
Dural sheath
Dorsal ramus
Spine of vertebra

Types of sensations



Proprioception: perception of the position and movement of the body

keep us aware of the position of our body parts

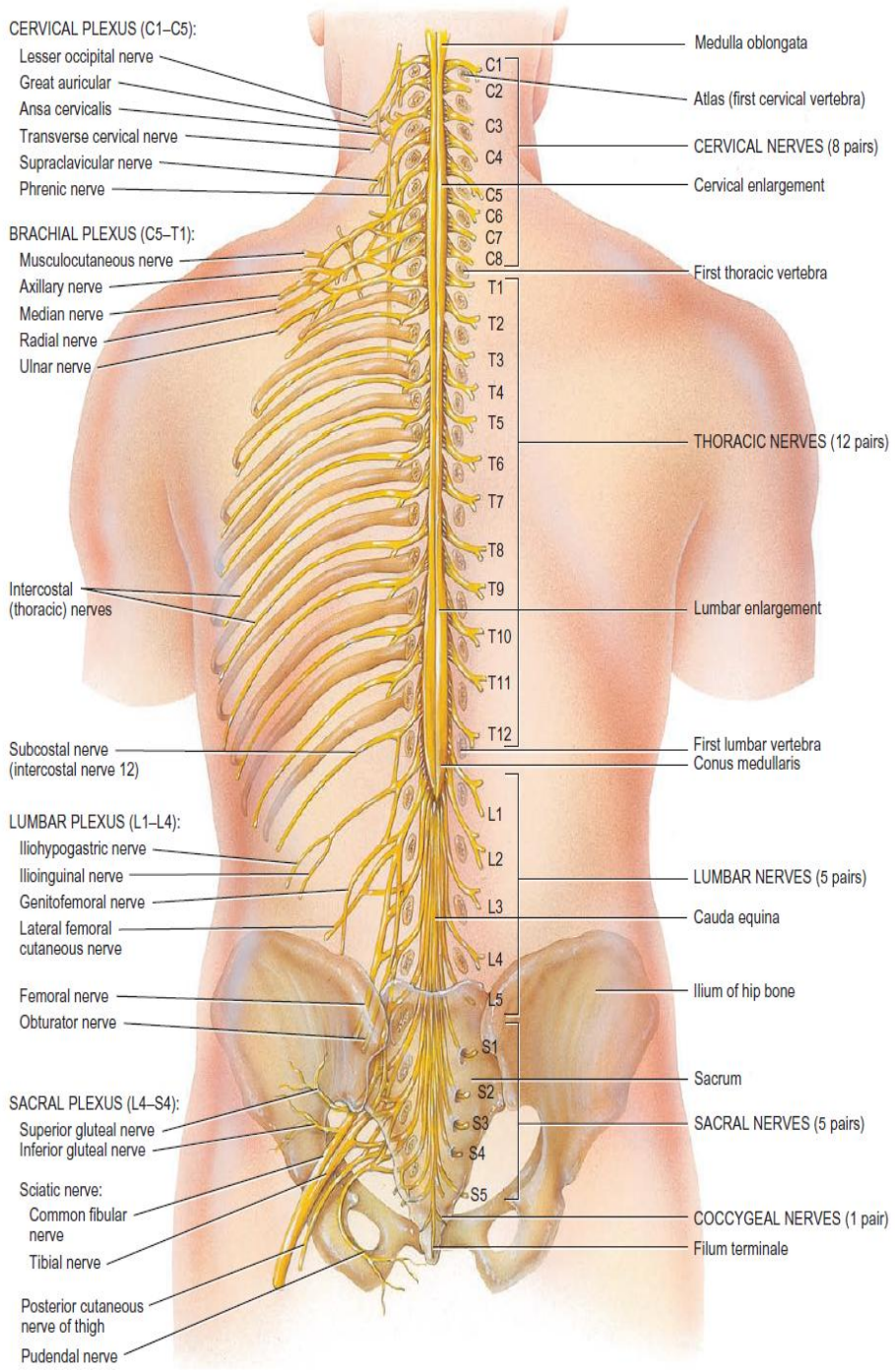
External anatomy of Spinal Cord

- Runs through the vertebral canal
- Extends from foramen magnum to the level between first and second lumbar vertebra
- Regions
  - Cervical
  - Thoracic
  - Lumbar
  - Sacral
  - Coccygeal
- Gives rise to 31 pairs of spinal nerves
  - All are *mixed* nerves

Functions:

1-Transmission of impulses to and from brain

2-Execution of simple reflexes

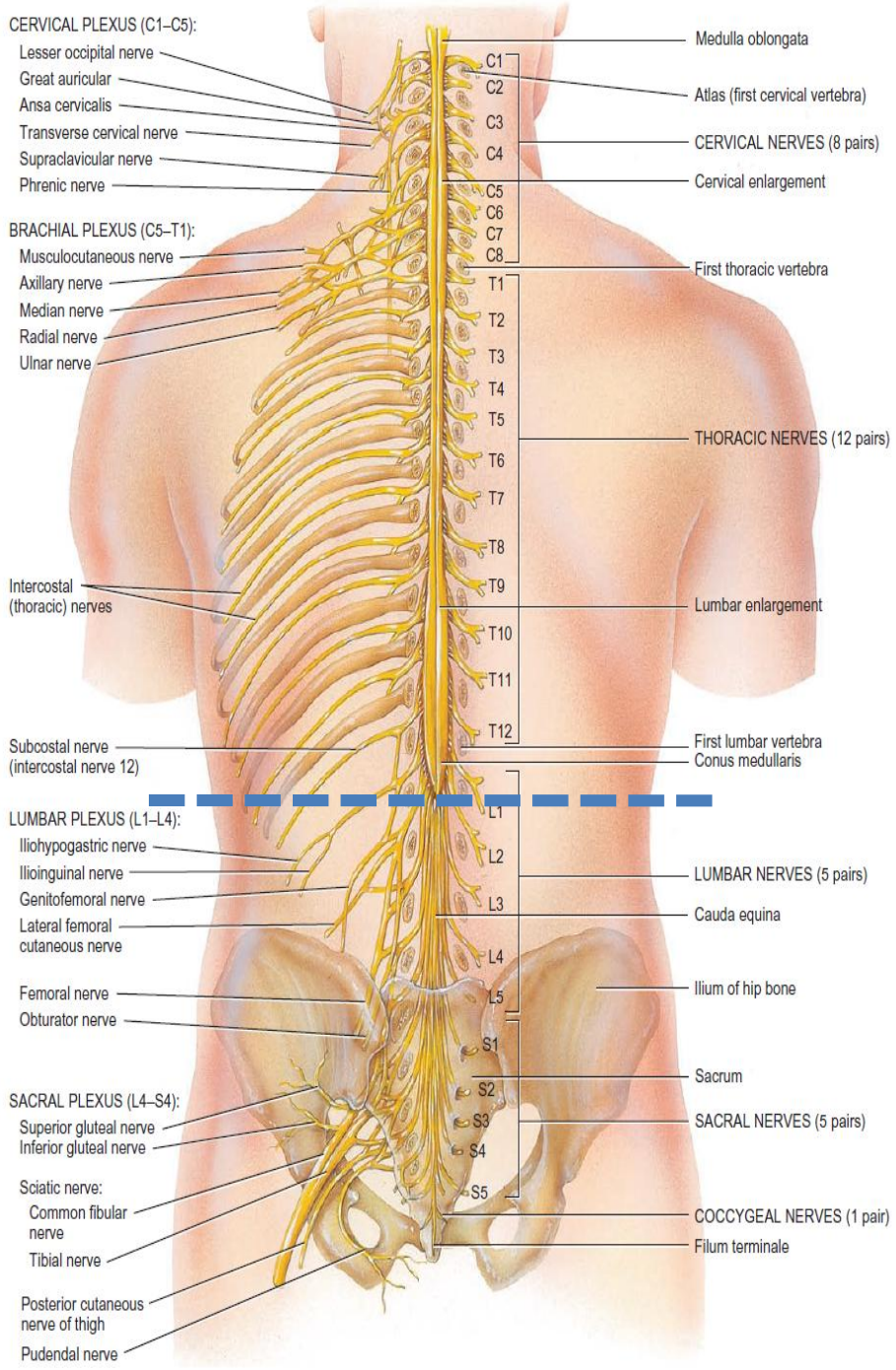


There are two regions where the spinal cord enlarges:

Cervical enlargement – corresponds to the brachial plexus nerves, which innervate the upper limb

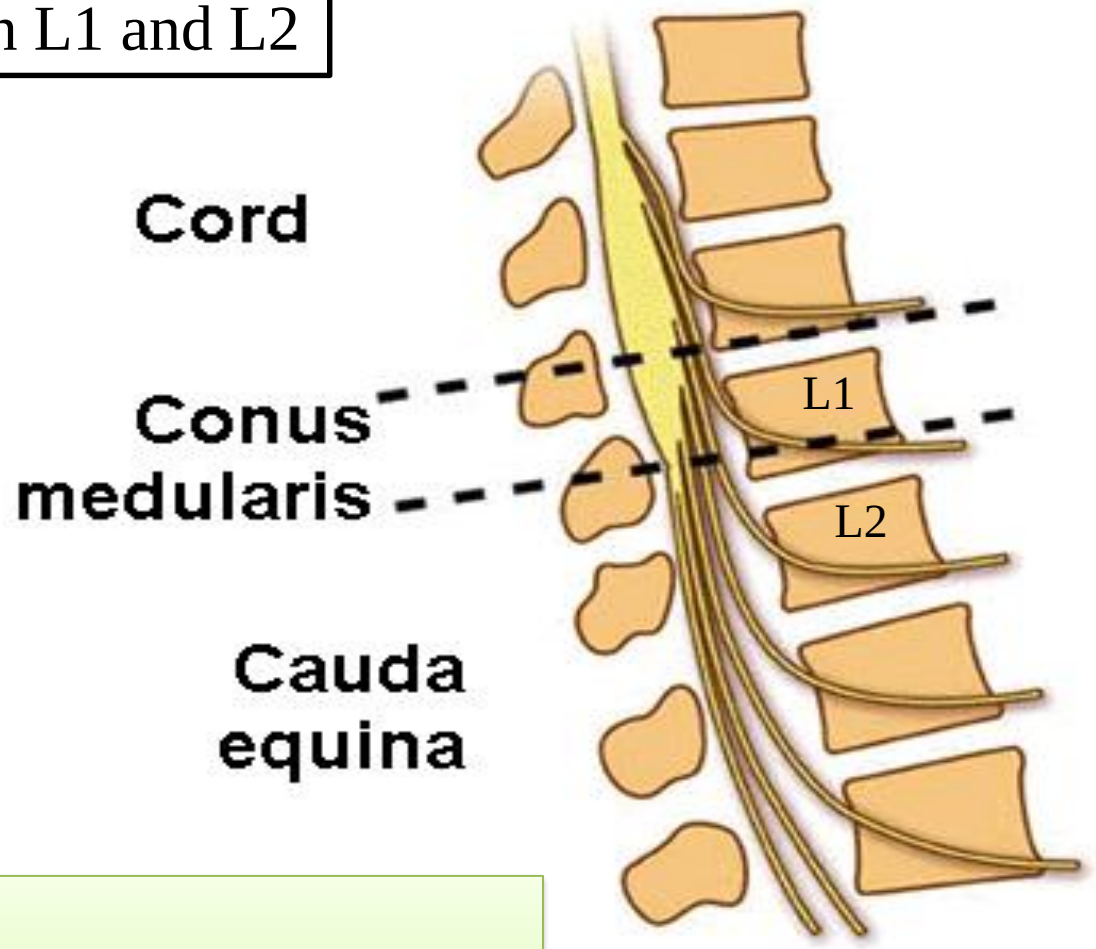
Lumbar enlargement – corresponds to the lumbosacral plexus nerves, which innervate the lower limb.

- Length of the adult spinal cord ranges from 42 to 45 cm
- Conus medullaris- tapered inferior end (conical structure)
  - Ends between L1 and L2
- Cauda equina - origin of spinal nerves extending inferiorly from conus medullaris.

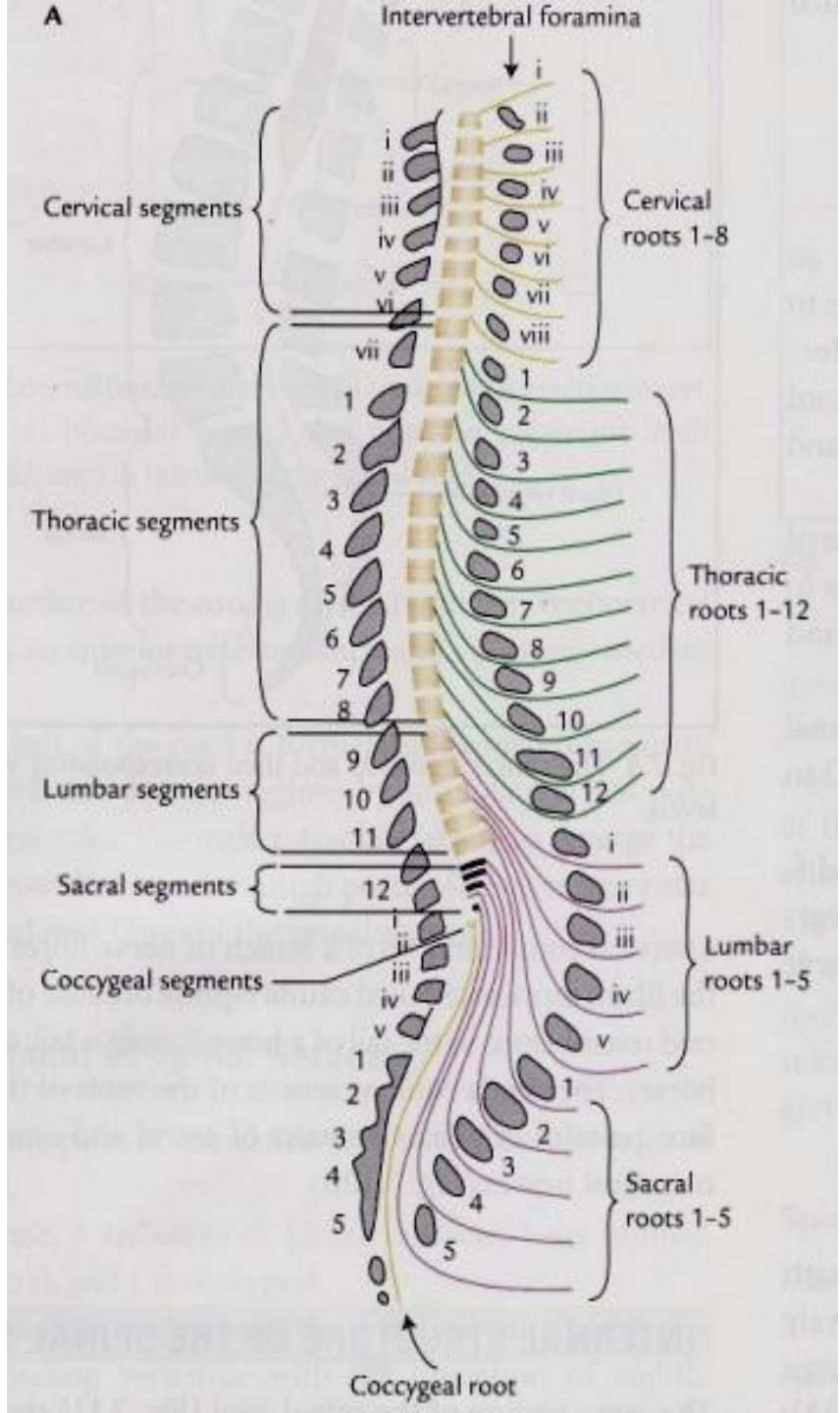


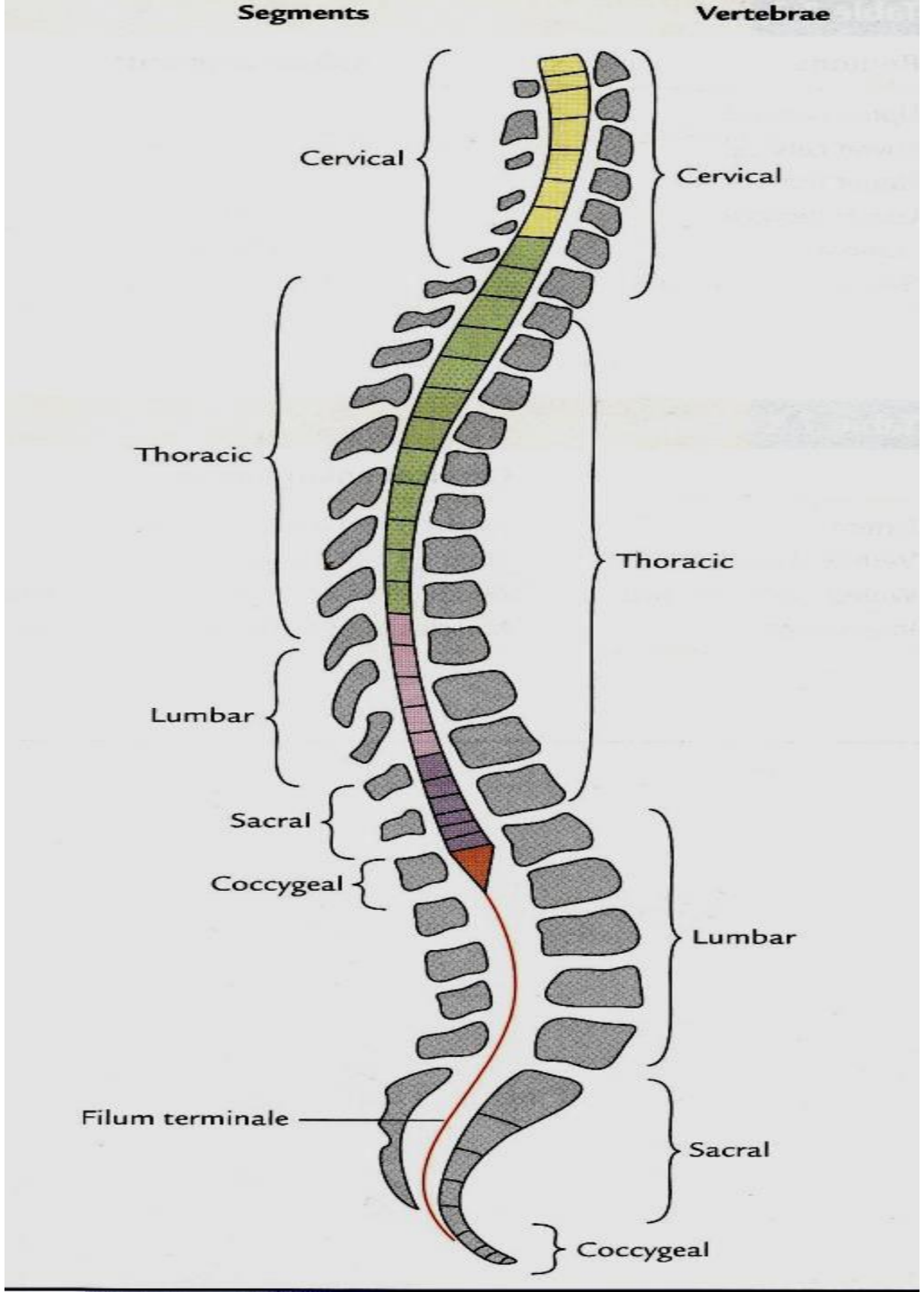
Spinal cord ends between L1 and L2

The spinal cord is shorter than the spinal column



In fetus
occupies the whole Vertebral column till 3rd month IUL
Adult
occupies the upper 2/3 of vertebral column

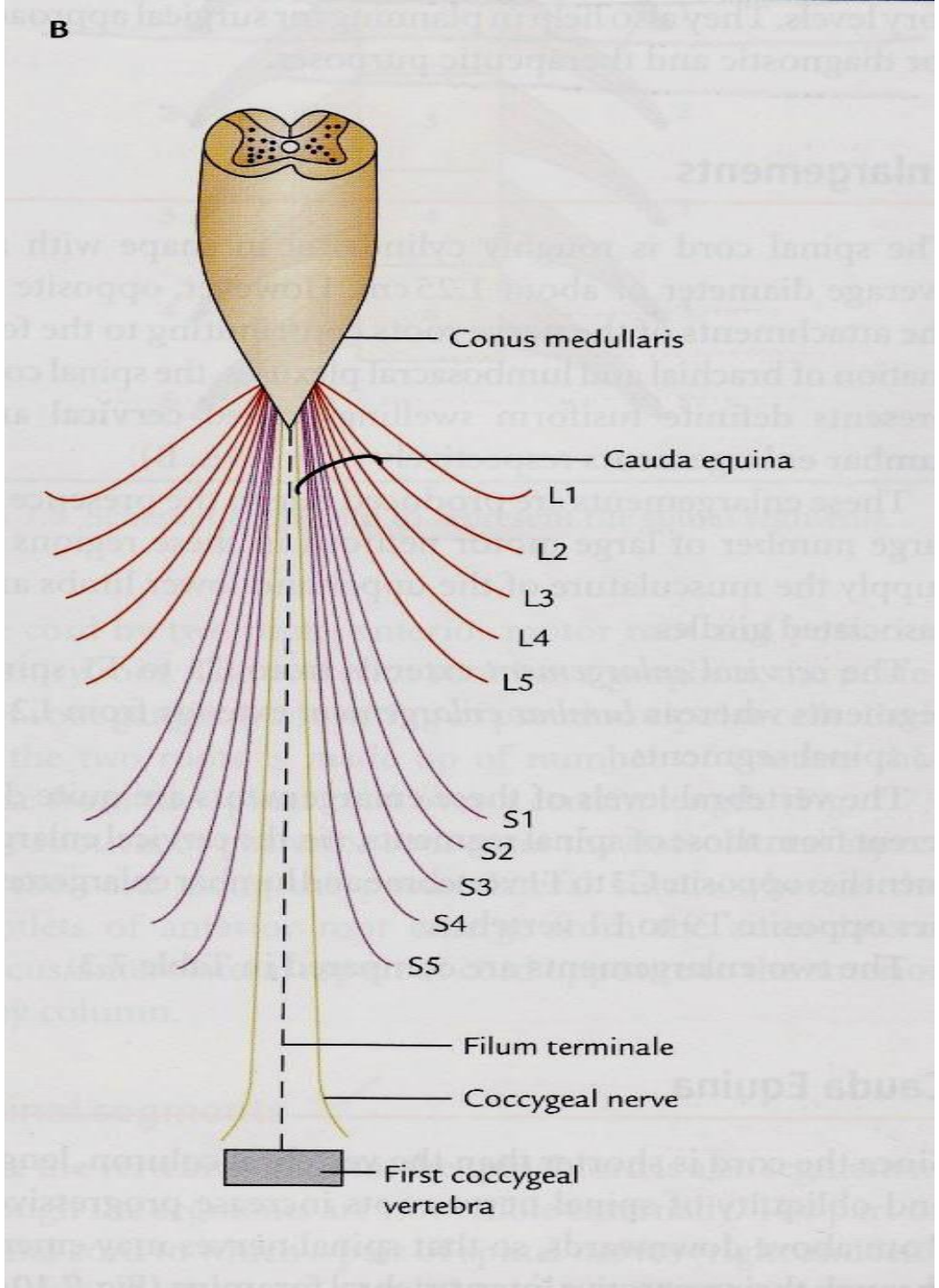

A
Intervertebral foramina
Cervical segments
Thoracic segments
Lumbar segments
Sacral segments
Coccygeal segments
Cervical roots 1–8
Thoracic roots 1–12
Lumbar roots 1–5
Sacral roots 1–5
Coccygeal root


Segments
Vertebrae
Cervical
Cervical
Thoracic
Thoracic
Lumbar
Sacral
Coccygeal
Lumbar
Filum terminale
Sacral
Coccygeal

Cauda equina

The nerve roots of the lower 4 lumbar, 5 sacral and 1 coccygeal nerves take a vertical course to form a bunch of nerve fibers around the filum terminale.

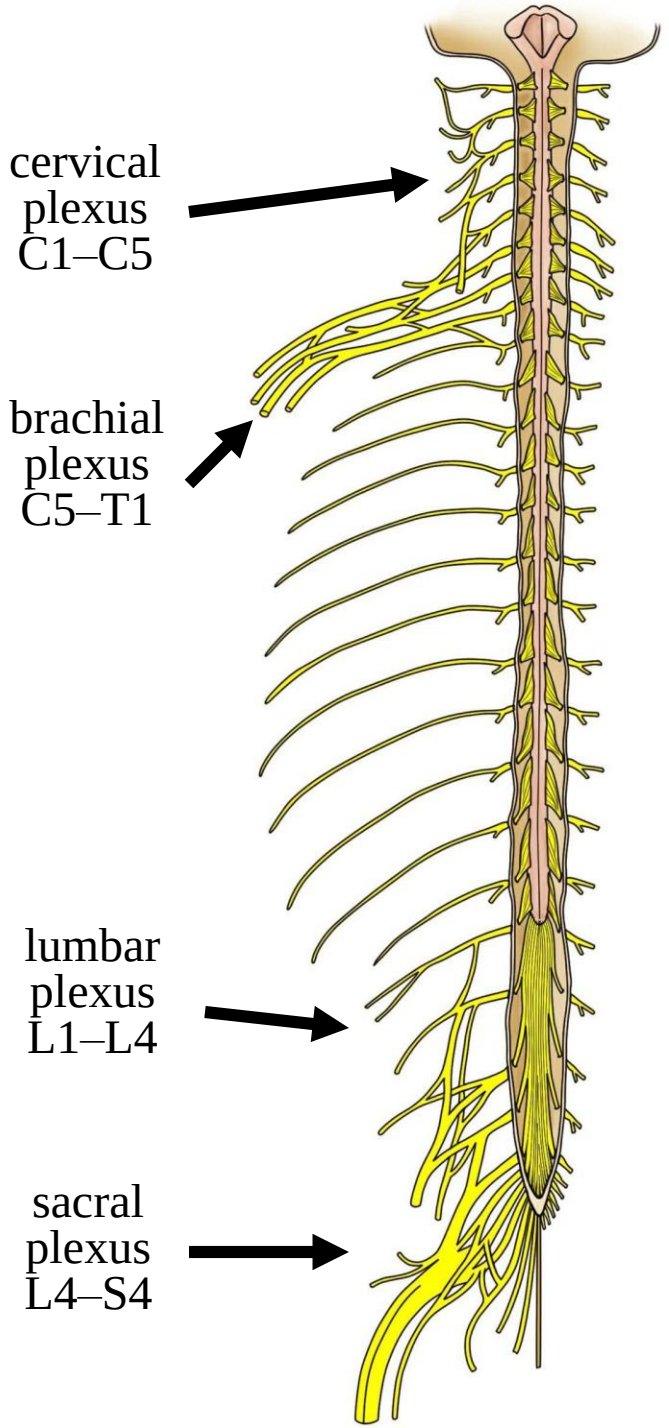
- Resemblance :
cauda - tail
equina - horse



PNS Plexus Formation

Plexus formation: mixing of nerves from different cord levels by union and division of bundles

Each spinal nerve contributes to more than one peripheral nerve

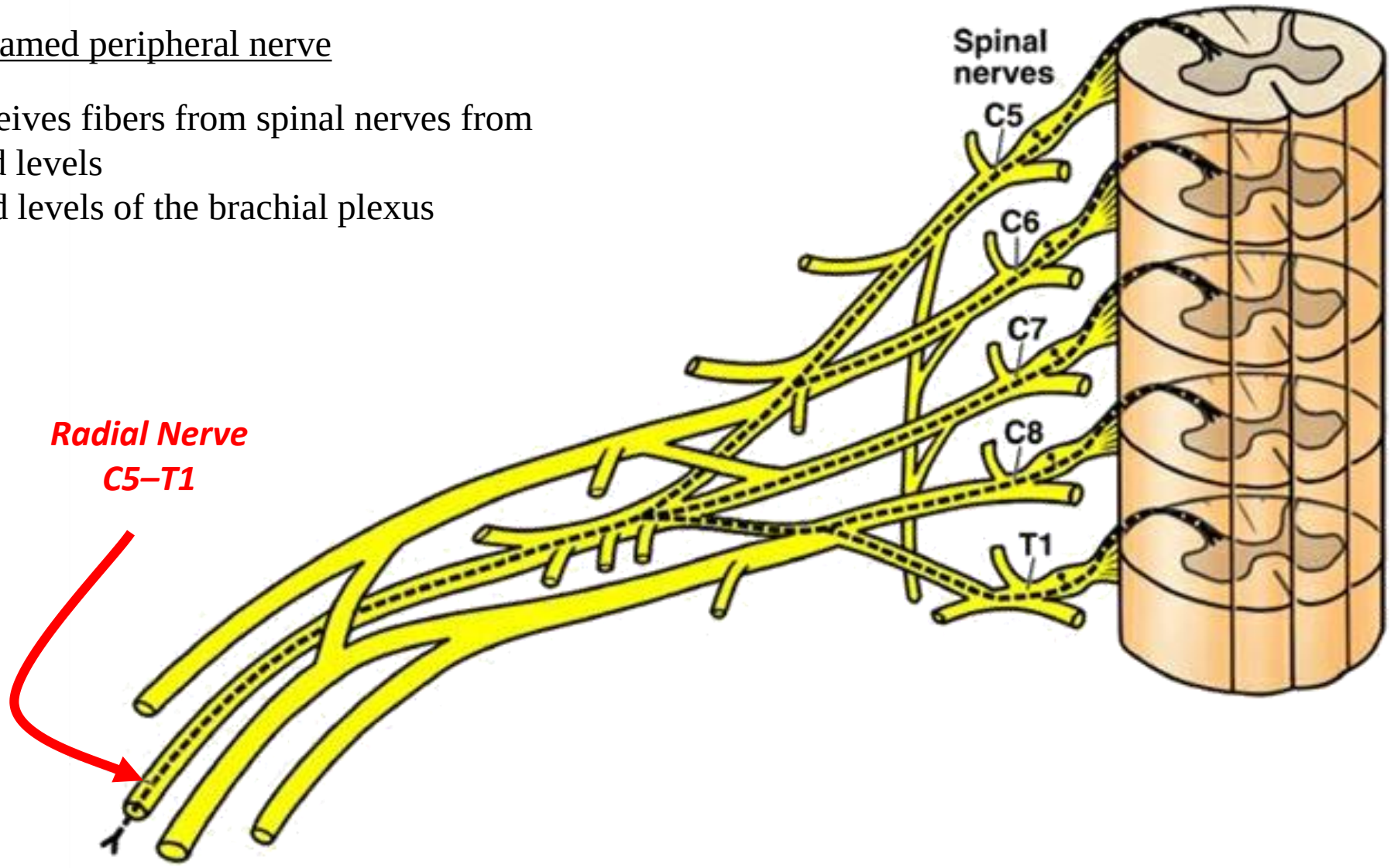


PNS Plexus Formation

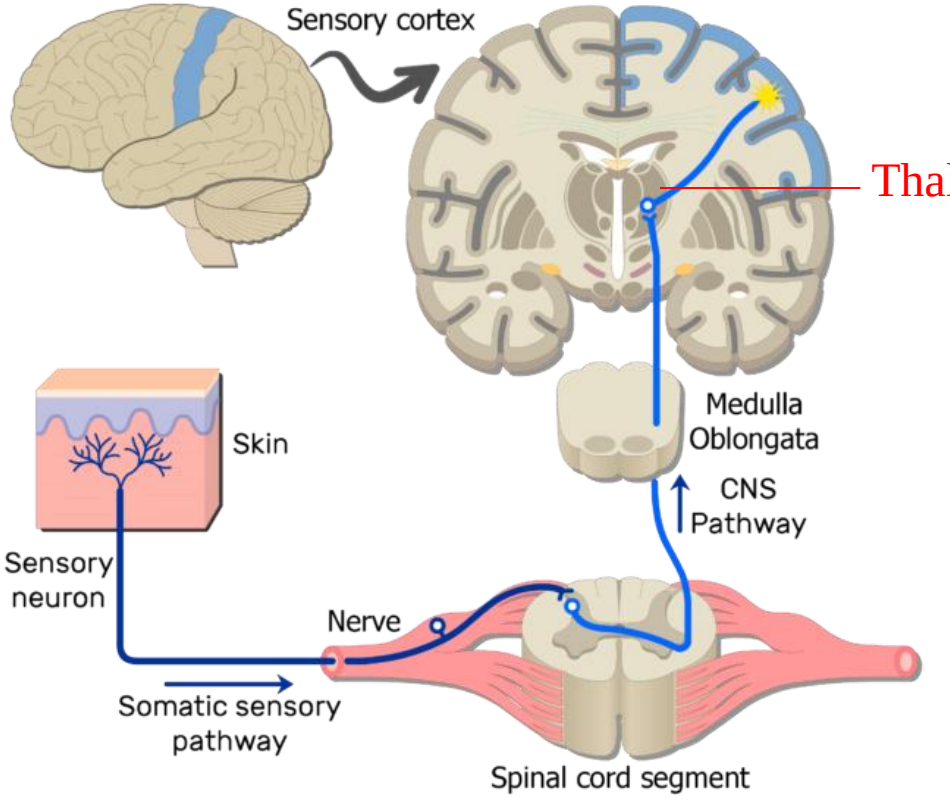
Brachial Plexus (C5–T1)

Example of named peripheral nerve

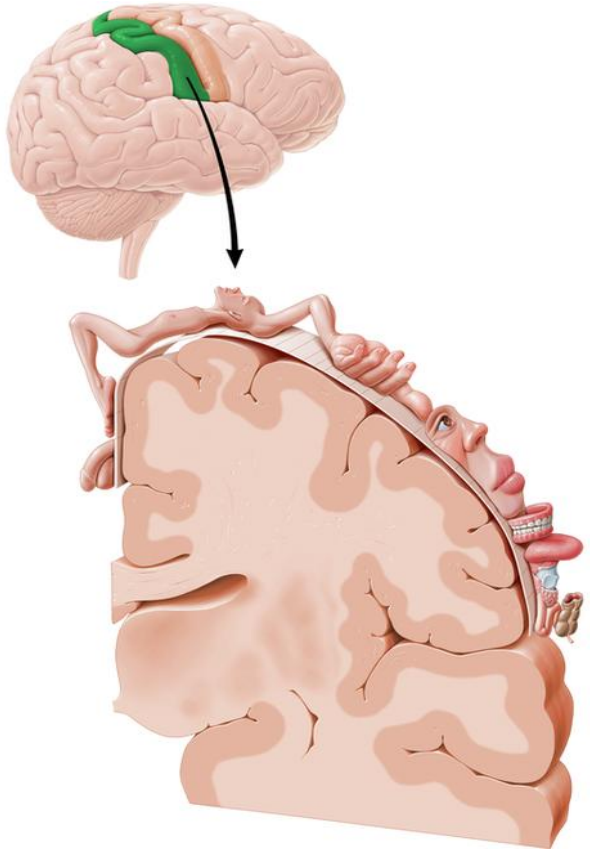
Radial nerve receives fibers from spinal nerves from **five** different cord levels
— in fact, all cord levels of the brachial plexus

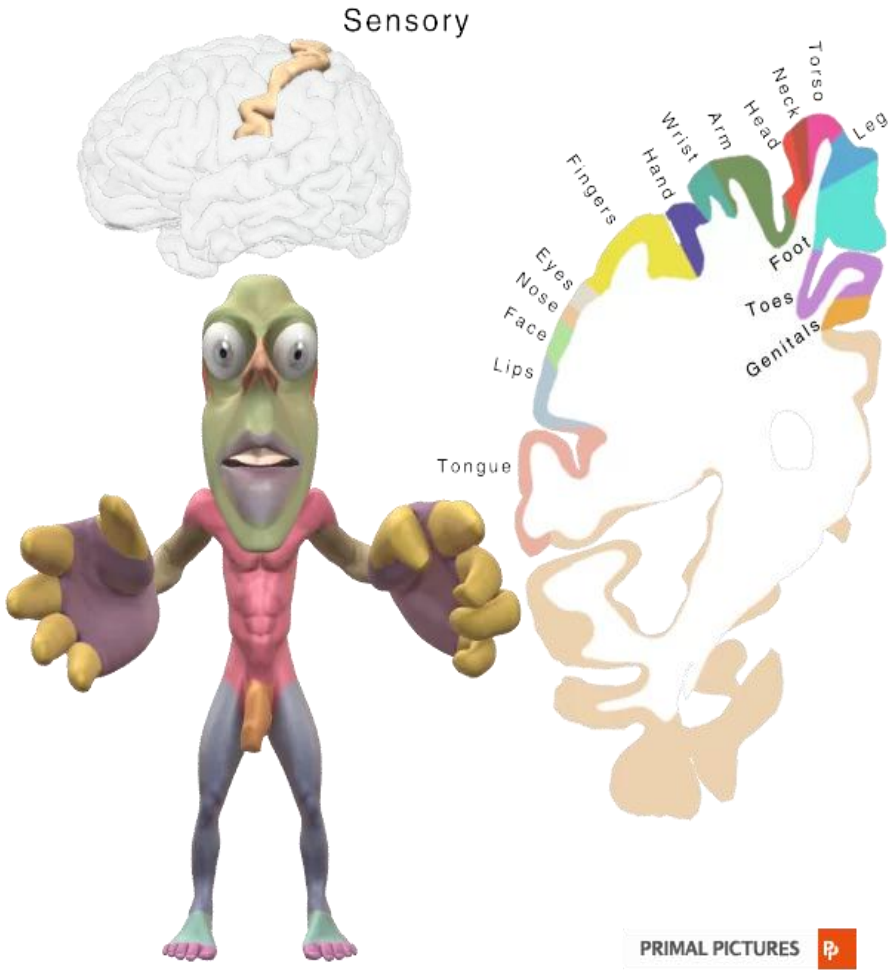


Sensory area (Postcentral gyrus)



When the sensory information reaches the sensory area we now feel that we have pain in a particular region in our body





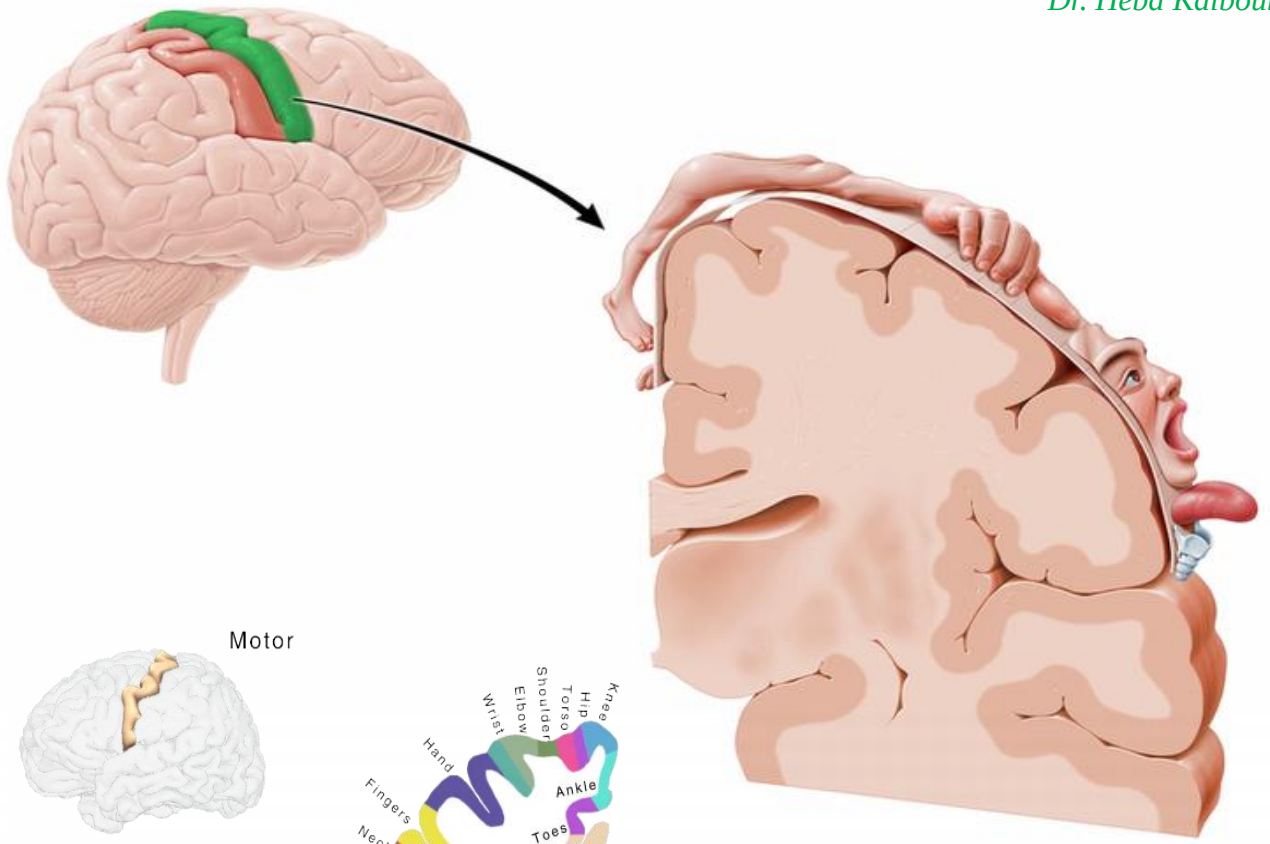
The sensory information from the right side of your body goes to the left side of your brain

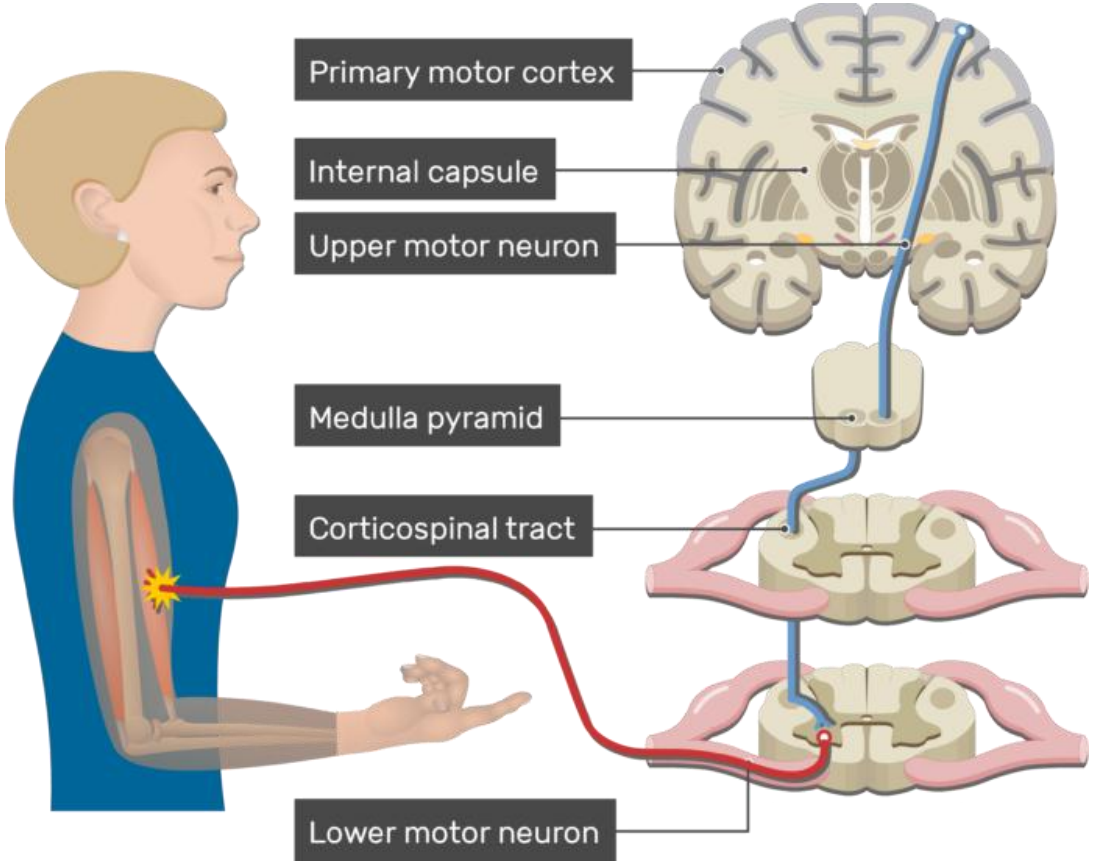
Motor area (Precentral gyrus)

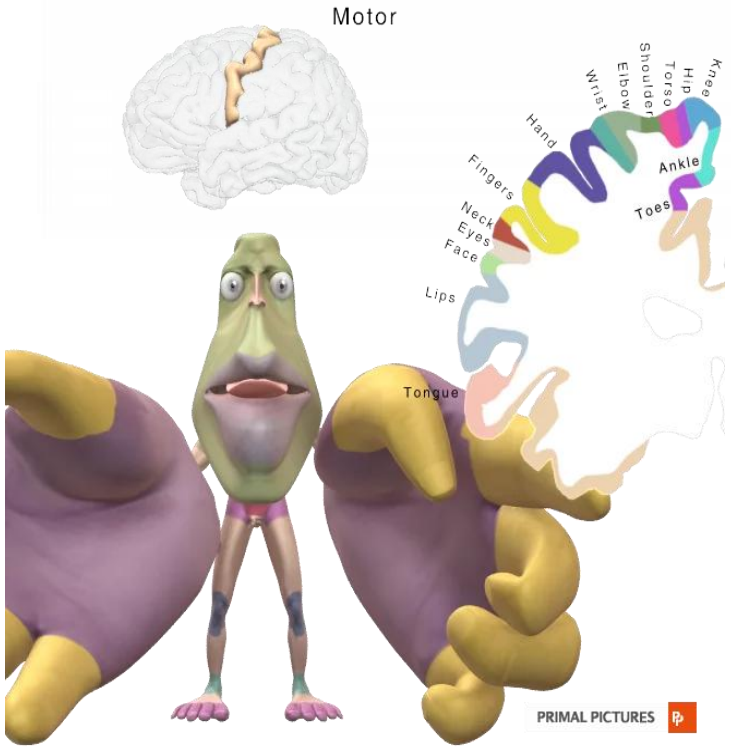
Dr. Heba Kalbouneh

is the region of the cerebral cortex involved in the planning, control, and execution of voluntary movements

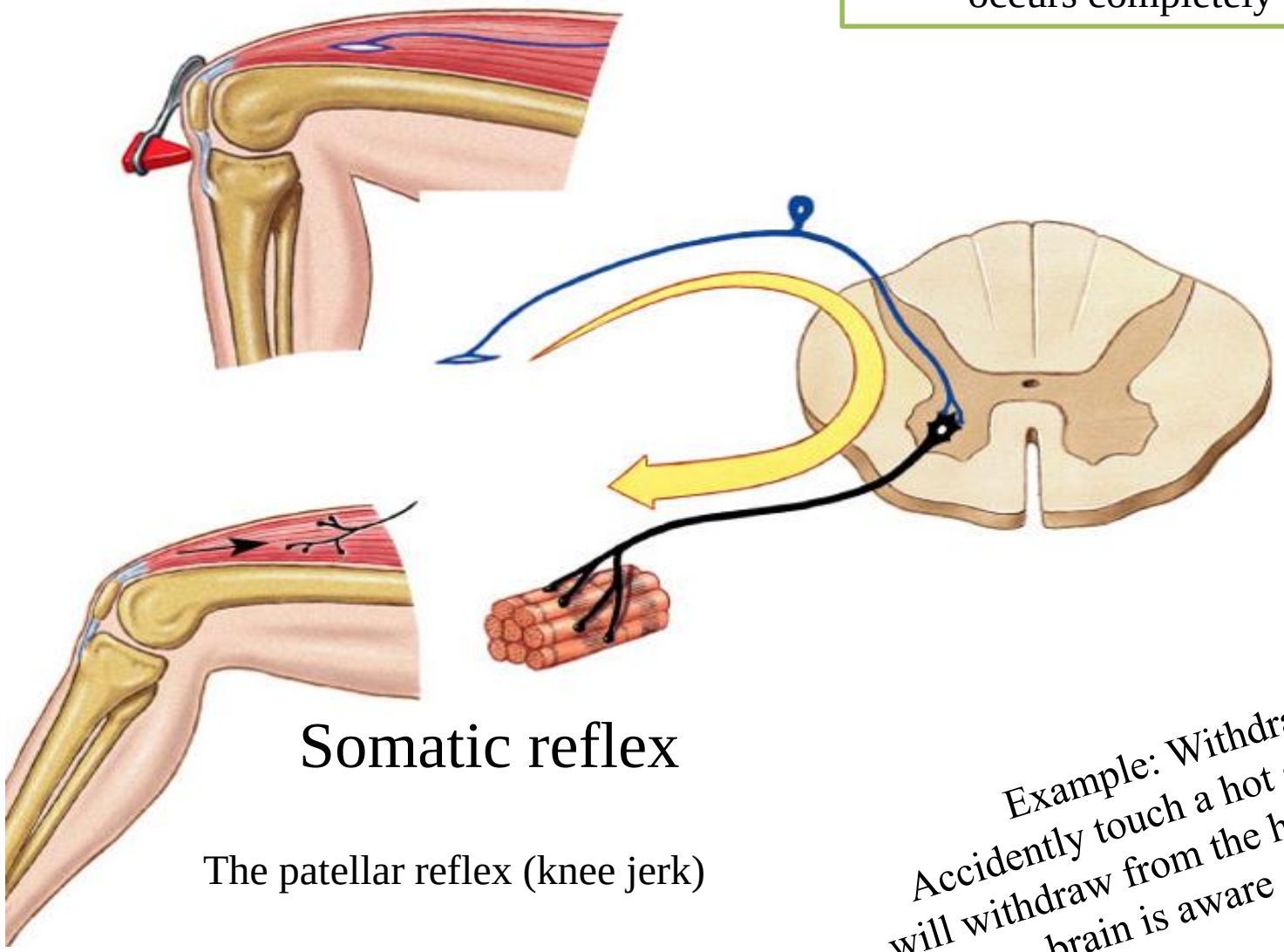
Note: The motor cortex on the left side of the brain controls movement of the right side of the body,







A spinal reflex is a sensory-motor nerve pathway that occurs completely independent of the brain

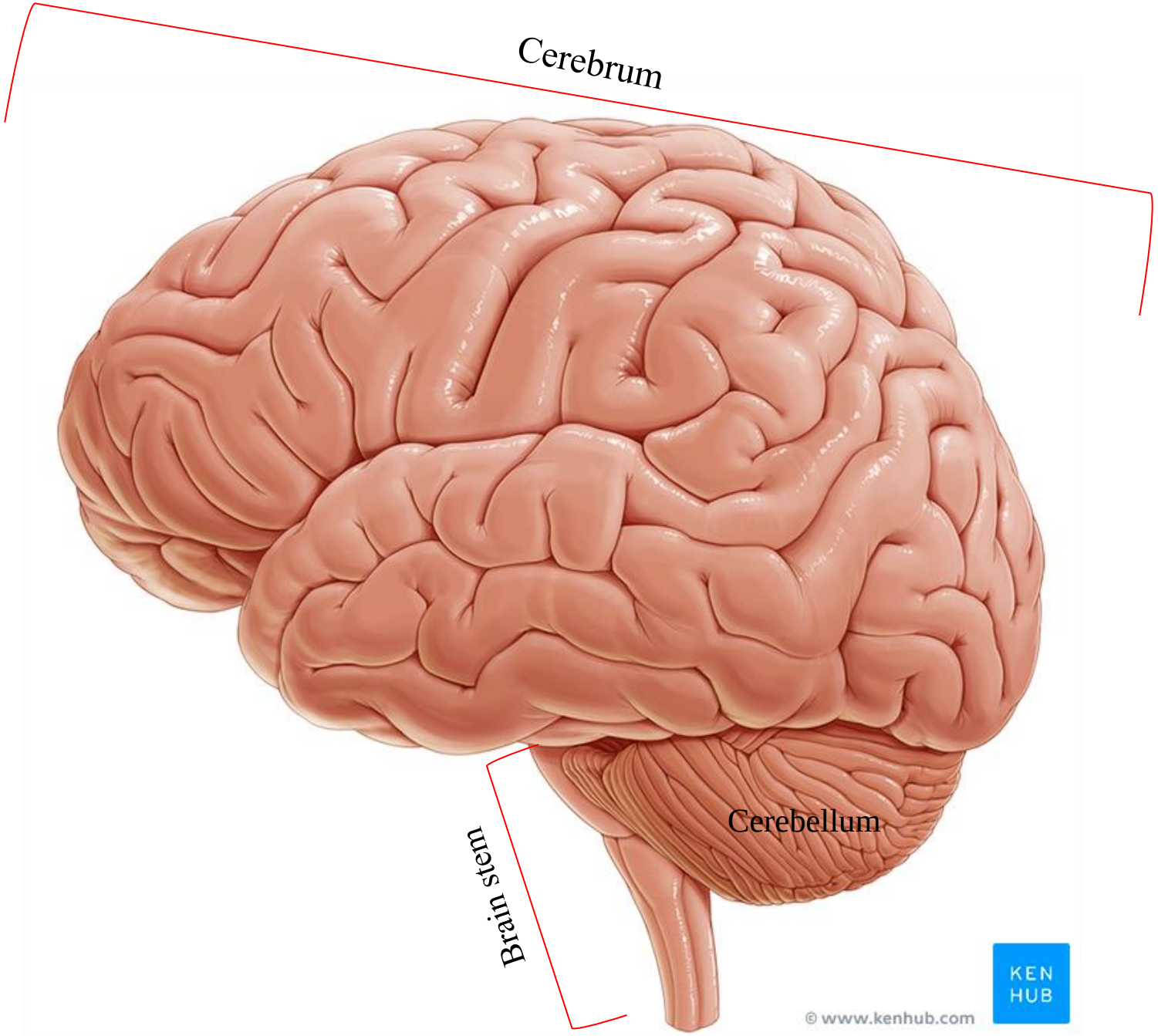


Somatic reflex

The patellar reflex (knee jerk)

Example: Withdrawal Reflex
Accidently touch a hot stove and your hand will withdraw from the heat source before your brain is aware of the problem

Brain lies in the cranial cavity
1- Cerebrum
2- Diencephalon (thalamus)
3- Brain stem:
Midbrain
Pons
Medulla
4- Cerebellum

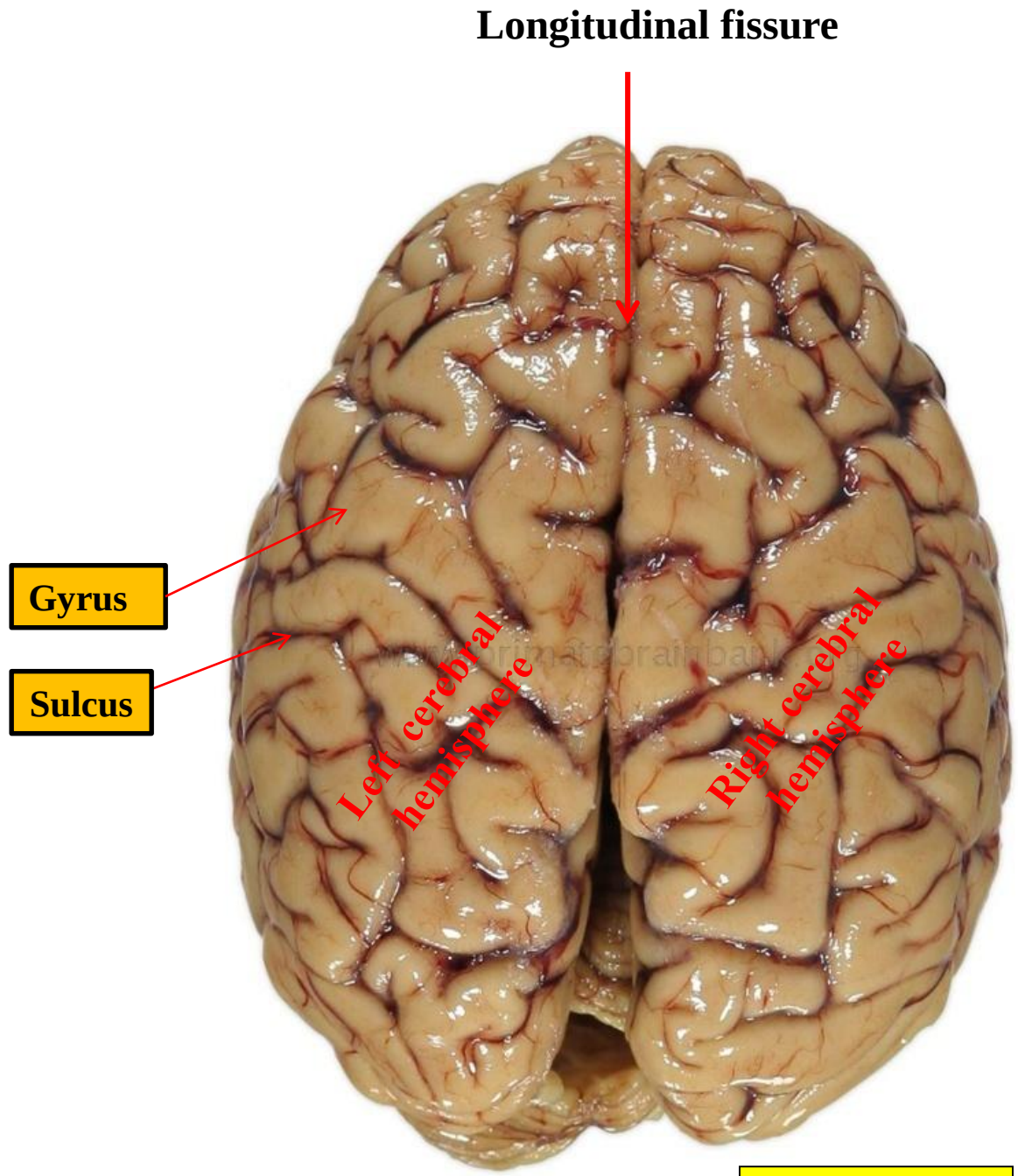


The **cerebrum** is organized into two hemispheres that are connected by a large bundle of white matter tissue called the **corpus callosum**.

The outer surface of the cerebrum exhibits many elevated ridges of tissue called **gyri**, that are separated by grooves called **sulci**.

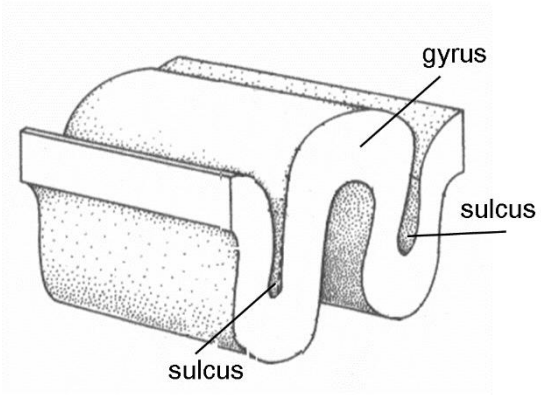
The gyri and sulci increase the surface area of the cerebrum, providing it with its characteristic convoluted appearance.

The most prominent sagittal fissure, the **longitudinal fissure,** separates the cerebrum into right and left halves called **cerebral hemispheres**



Superior view

Gyrus (ridge)



Sulcus
(shallow groove)

Fissure
(deep groove)

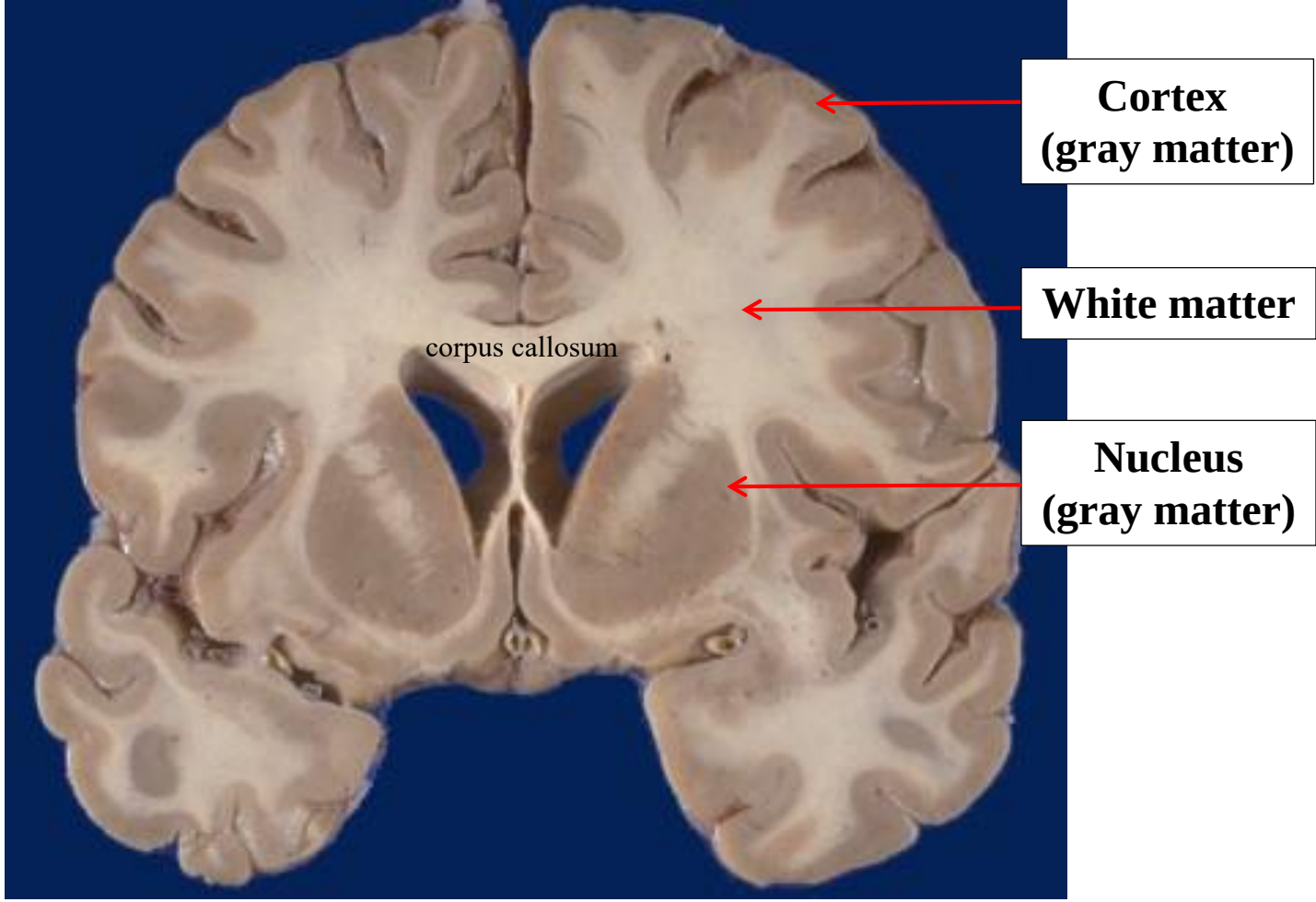
The deepest grooves between folds are known as **fissures;** the shallower grooves between folds are termed **sulci**

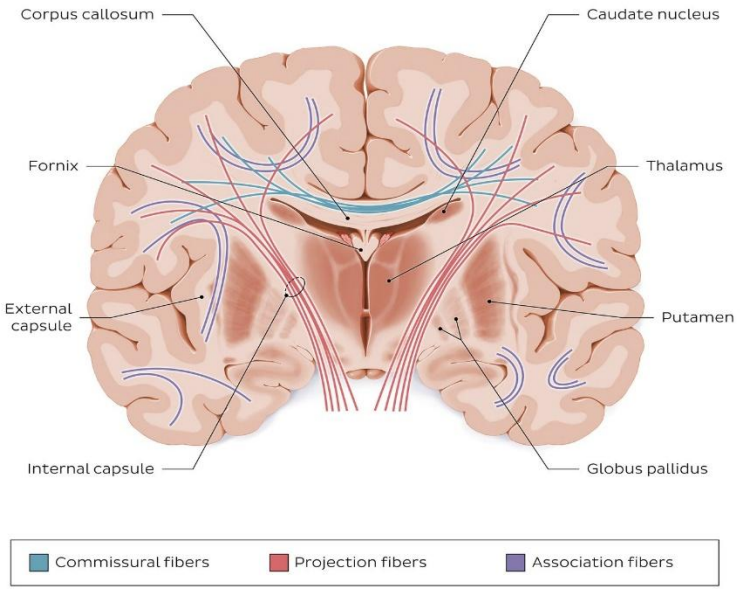
The cerebral cortex forms the surface of each hemisphere; it is composed of gray matter and is the most complex part of the cerebrum. Functionally, it can be divided into three general areas:

Primary motor area, which is involved in the planning and execution of movement;

Primary sensory areas, which receive and process sensory input;

Association areas, which serve to integrate information from several structures/areas.





Deep to the cerebral cortex (i.e. gray matter containing neuronal cell bodies) is the cerebral white matter which is composed of axons of neurons reaching between different areas of the brain. Most of these nerve fibers are myelinated which gives the white matter its color. While the gray matter facilitates information processing, the white matter serves the important role of function of enabling information transfer.

Note: a nucleus (pl.: nuclei) is a cluster of neuronal cell bodies in the central nervous system, located deep within the cerebral hemispheres and brainstem (surrounded by white matter)

Surfaces of Cerebral Hemisphere

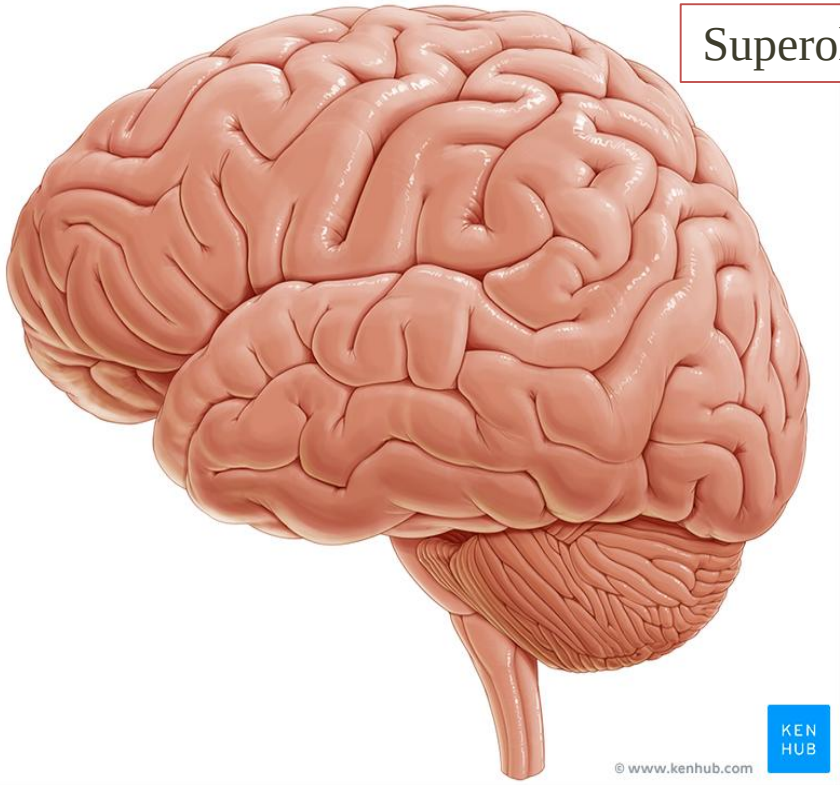
Three surfaces:

Superolateral surface

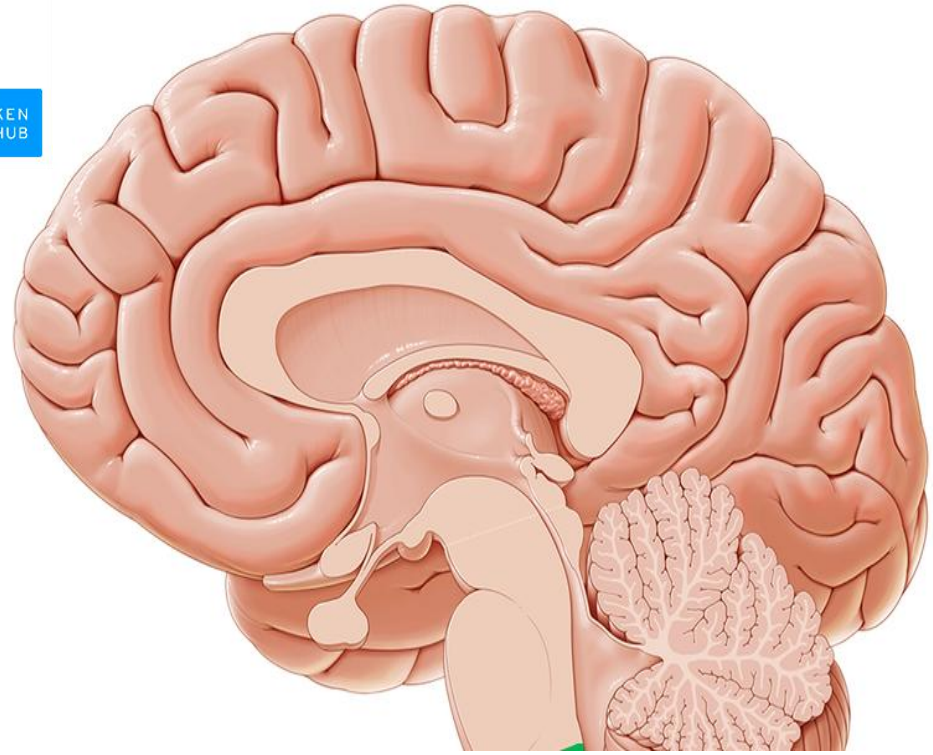
Inferior surface

Medial surface

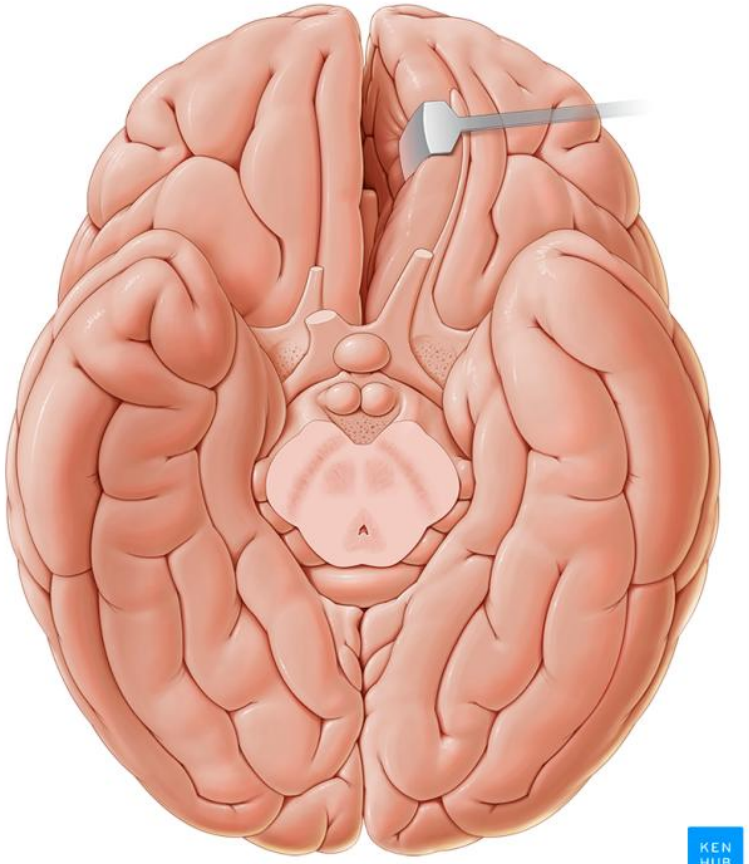
Superolateral surface



Medial surface



Inferior surface



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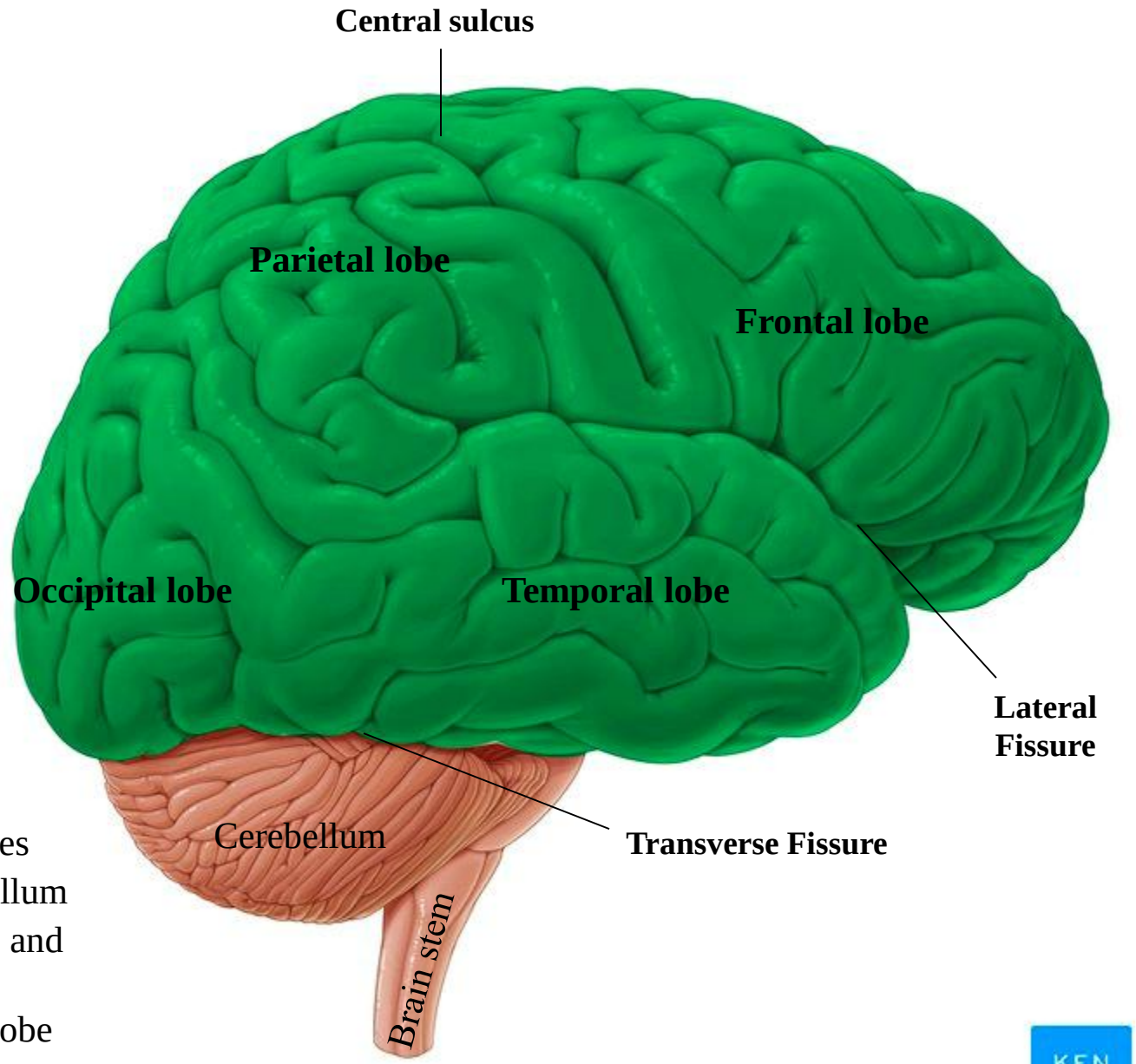
Cerebral hemispheres are divided into lobes

Lobes are named according to the cranial bones under which they lie. Lobes are:

- Frontal
- Parietal
- Temporal
- Occipital



Longitudinal Fissure: Divides the two Cerebral Hemispheres

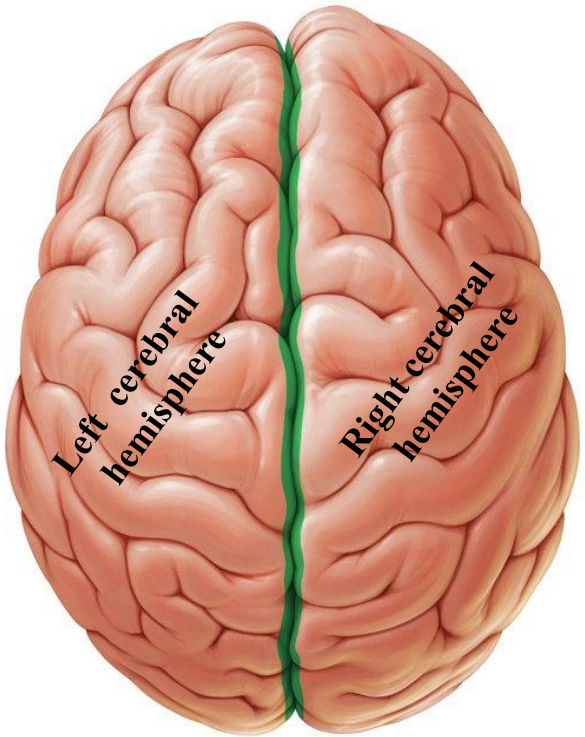
Transverse Fissure : Separates the Cerebrum from the Cerebellum

Lateral Fissure : Divides the Temporal Lobe from the Frontal and Parietal Lobes

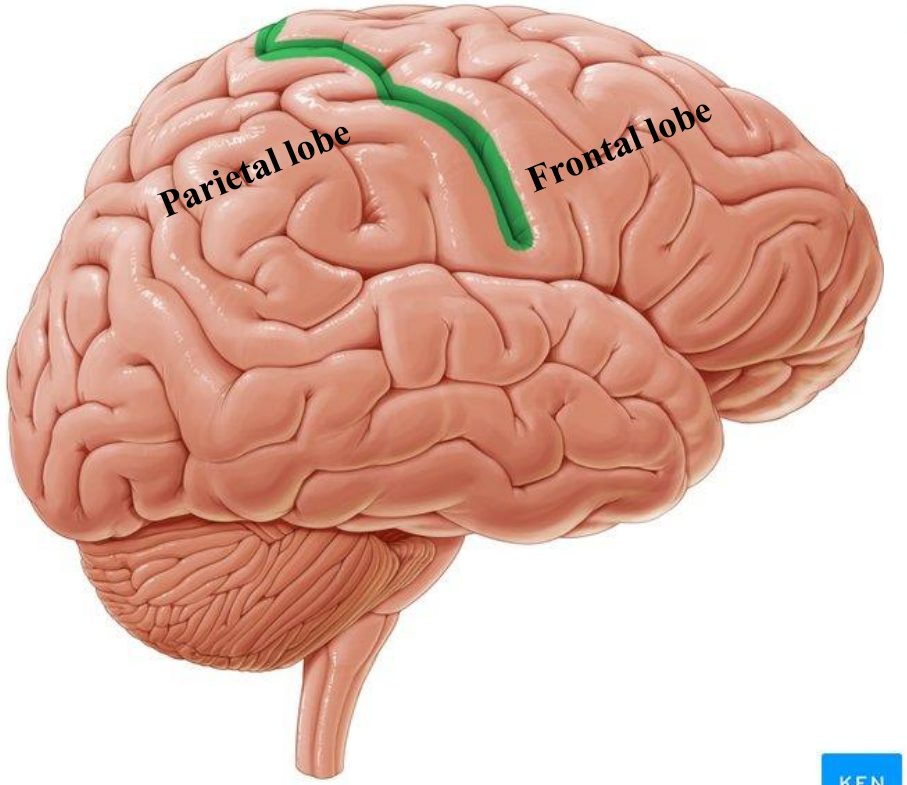
Central Sulcus: Divides the Frontal Lobe from the Parietal Lobe

Parieto-occipital sulcus: Marks the boundary between the Parietal and Occipital lobes

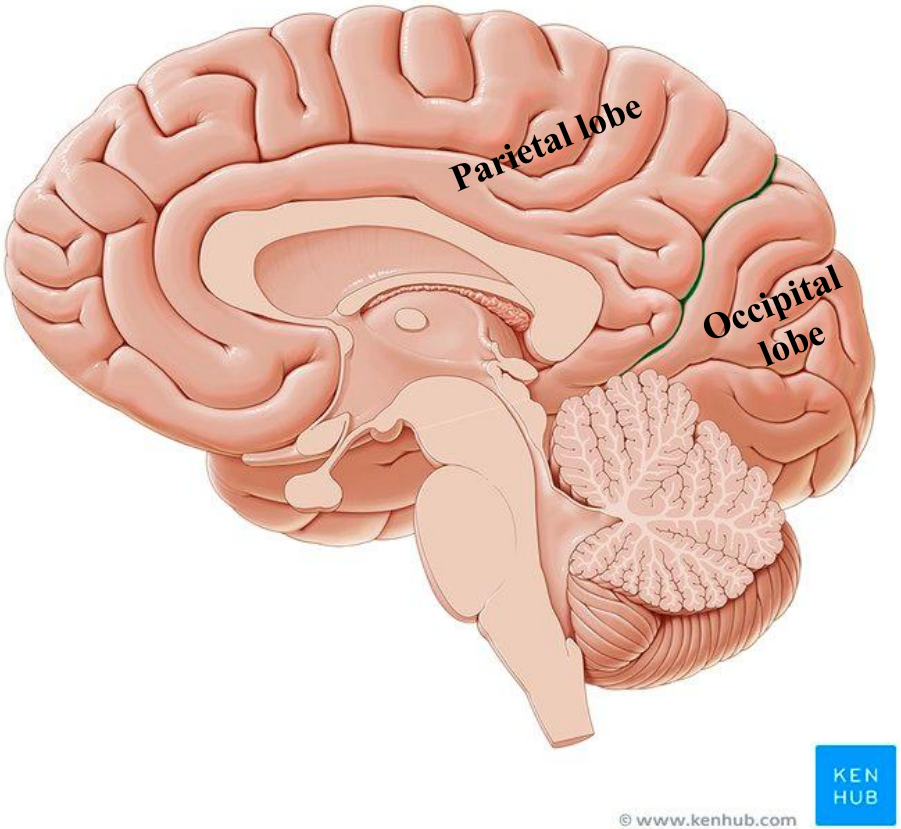
Longitudinal Fissure



Central Sulcus



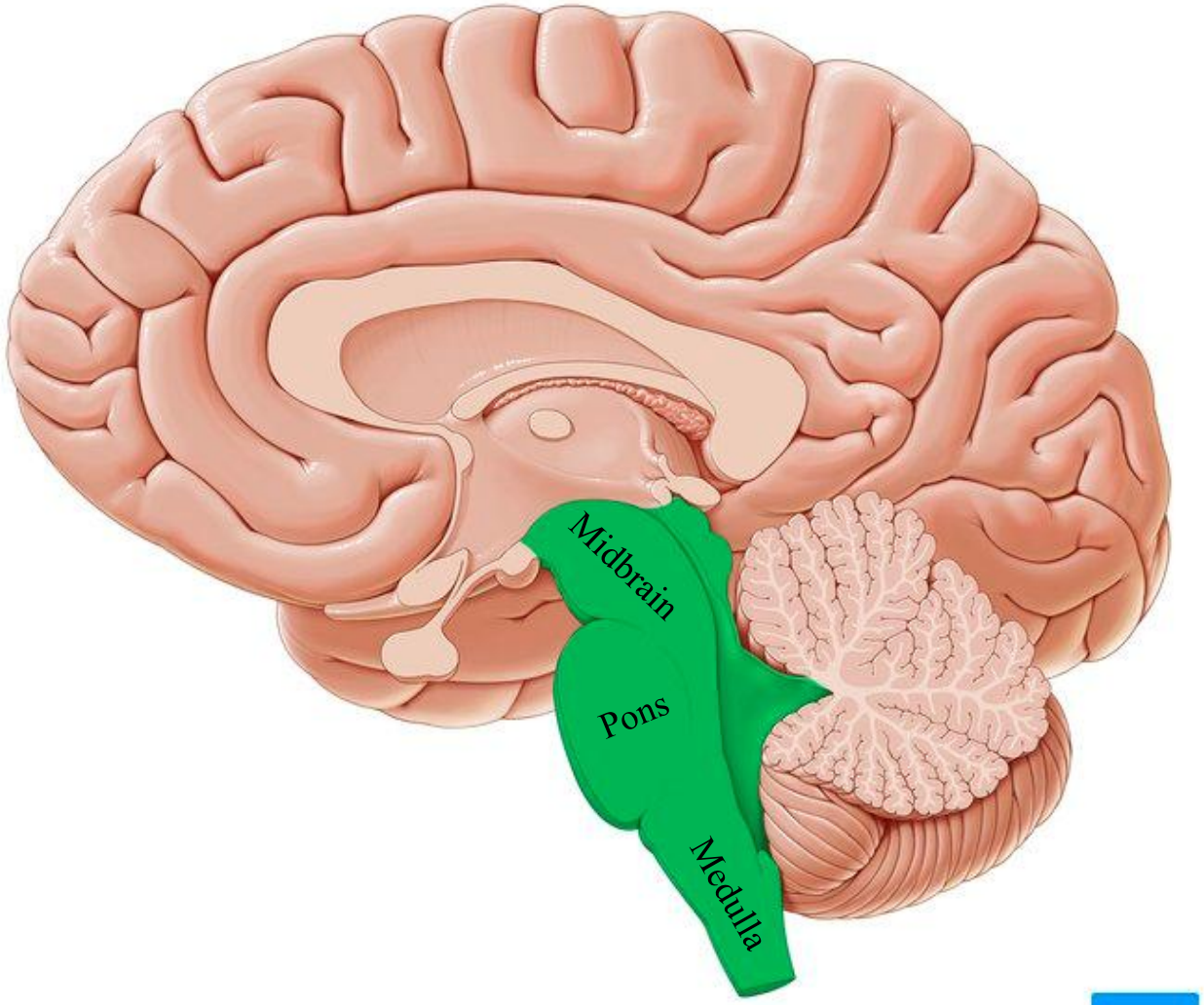
Parieto-occipital sulcus



The **brainstem** is the region of the brain located inferior to the thalamus, superior to the spinal cord and anterior to the cerebellum.

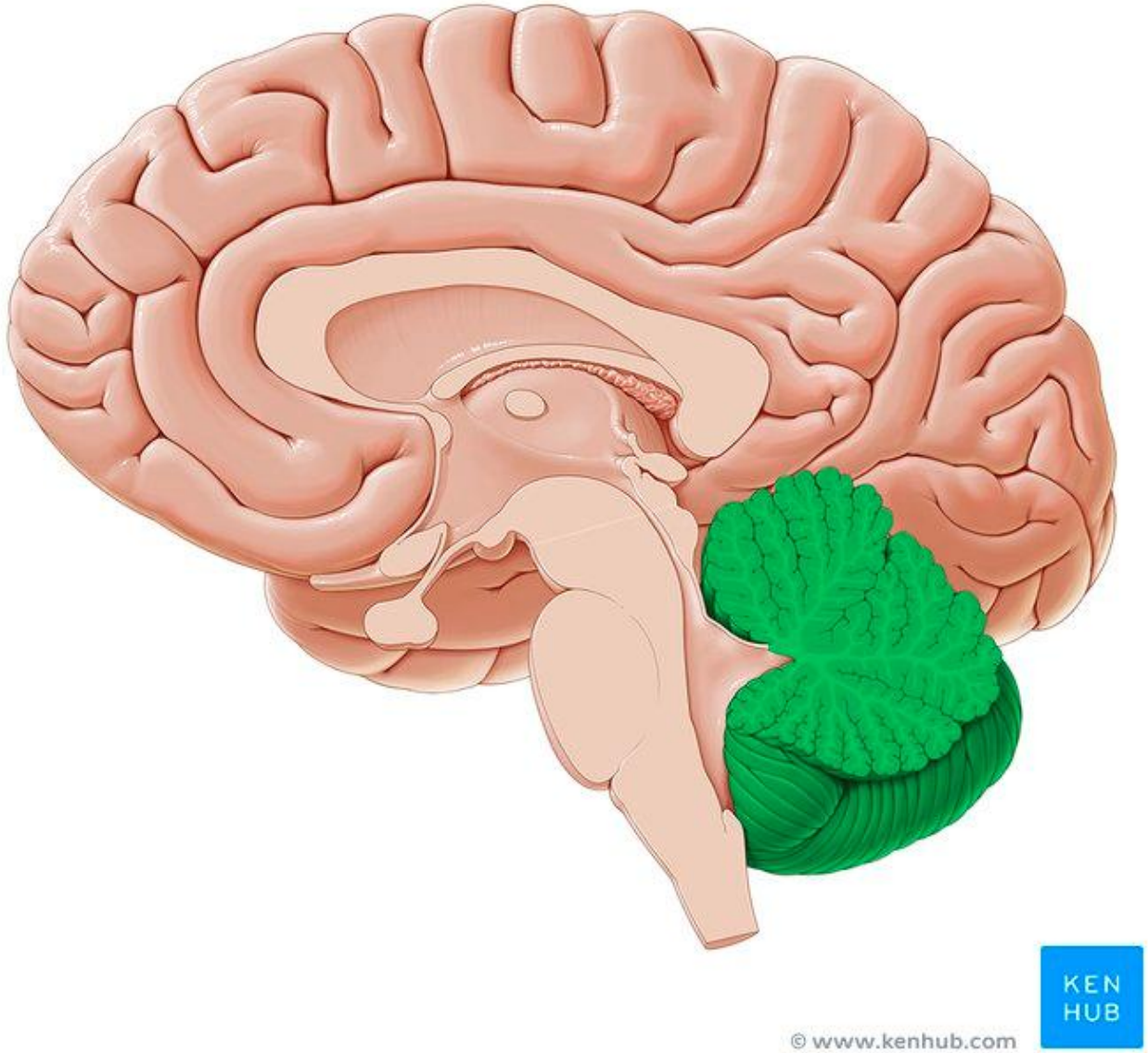
It is made up of three parts: midbrain, pons and medulla oblongata, each with its unique structure and function.

The main functions of the brainstem include the regulation of breathing, heart rate, blood pressure, and several other lower order processes fundamental for survival. The brainstem also houses most cranial nerve nuclei and is a passageway for ascending and descending neural pathways.



Cerebellum: A part of the central nervous system found posteriorly to the brainstem that is in charge for motor learning, coordination and precision of motor functions.

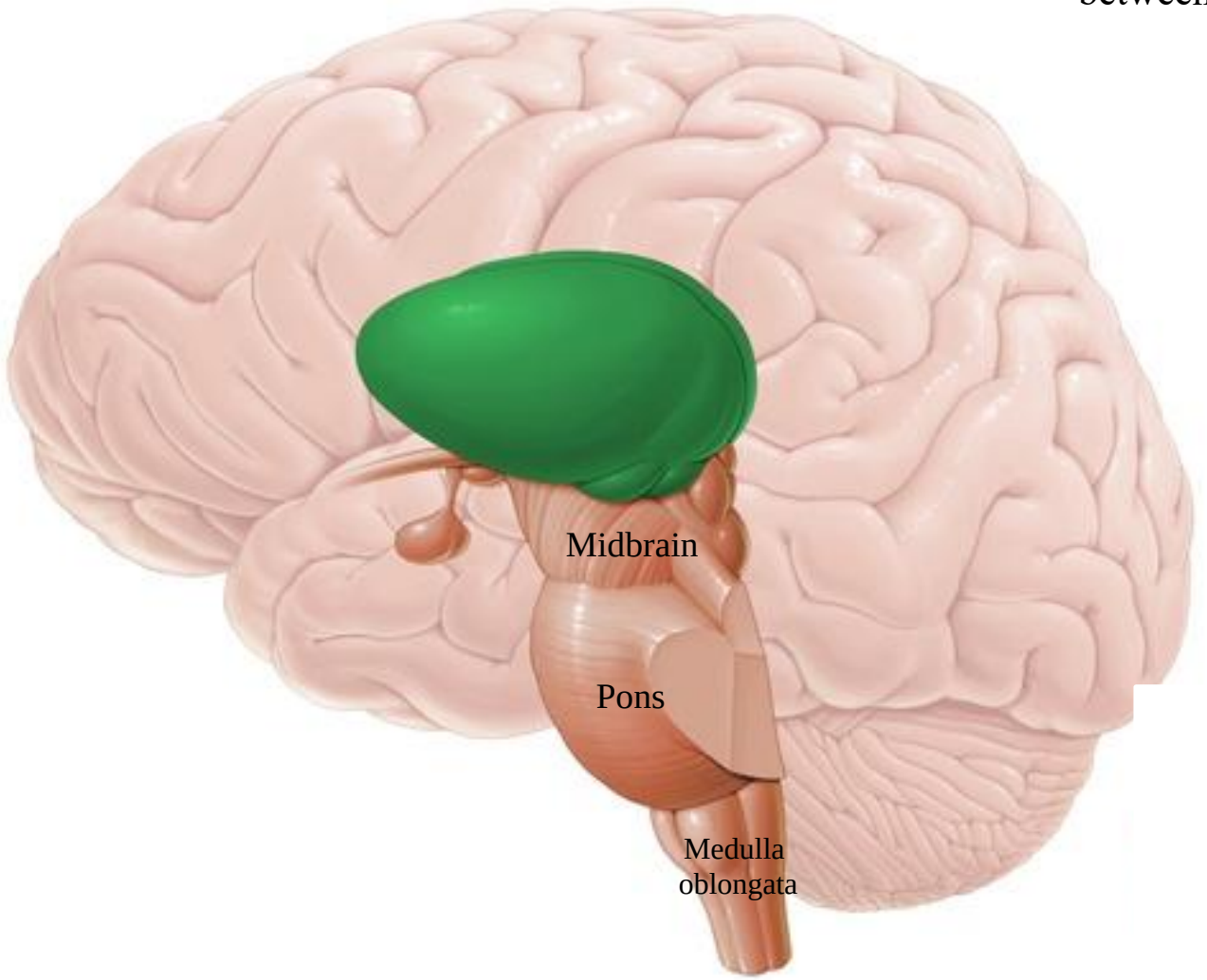
The cerebellum and brainstem are a testament to the fact that good things do come in small packages. Occupying only a fraction of the volume of the cerebrum, these structures are responsible for simplifying every second of your life and keeping you alive. Thanks to them, you can subconsciously and automatically walk, perform smooth actions, maintain your balance, breathe, regulate your blood pressure, together with many other functions. Also, do you know the main hero keeping a patient alive during a 'vegetative state' or a coma? It's solely the brainstem, as the cerebrum is dysfunctional.

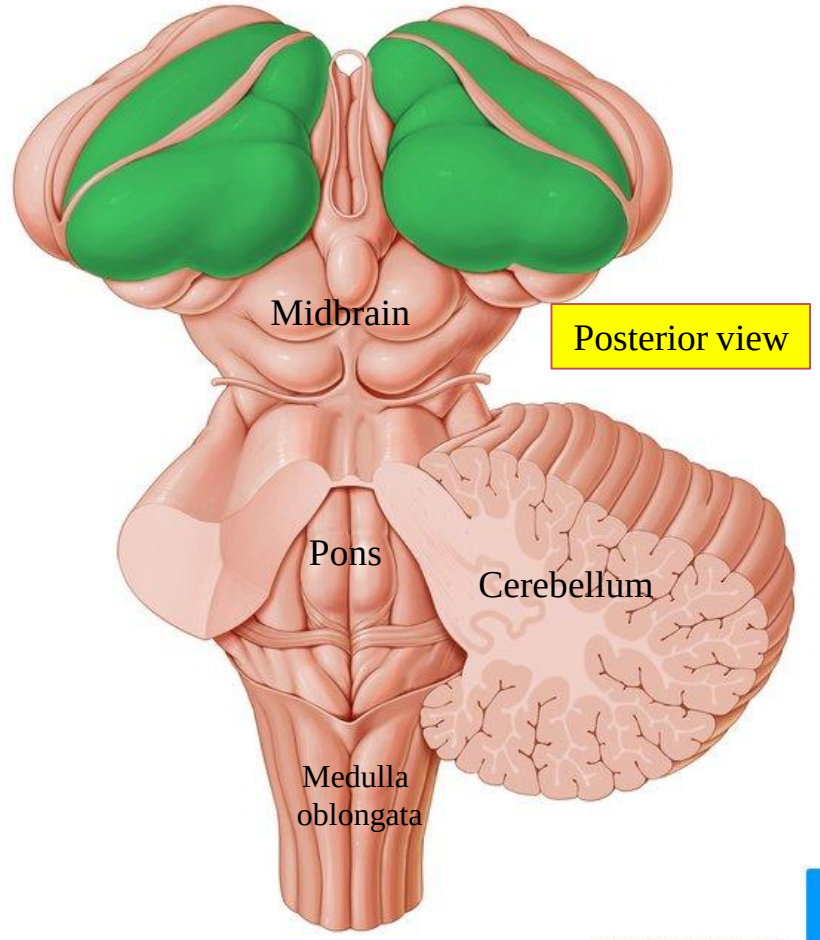


Diencephalon
(Thalamus)
is located deep in the brain
underneath the cerebrum

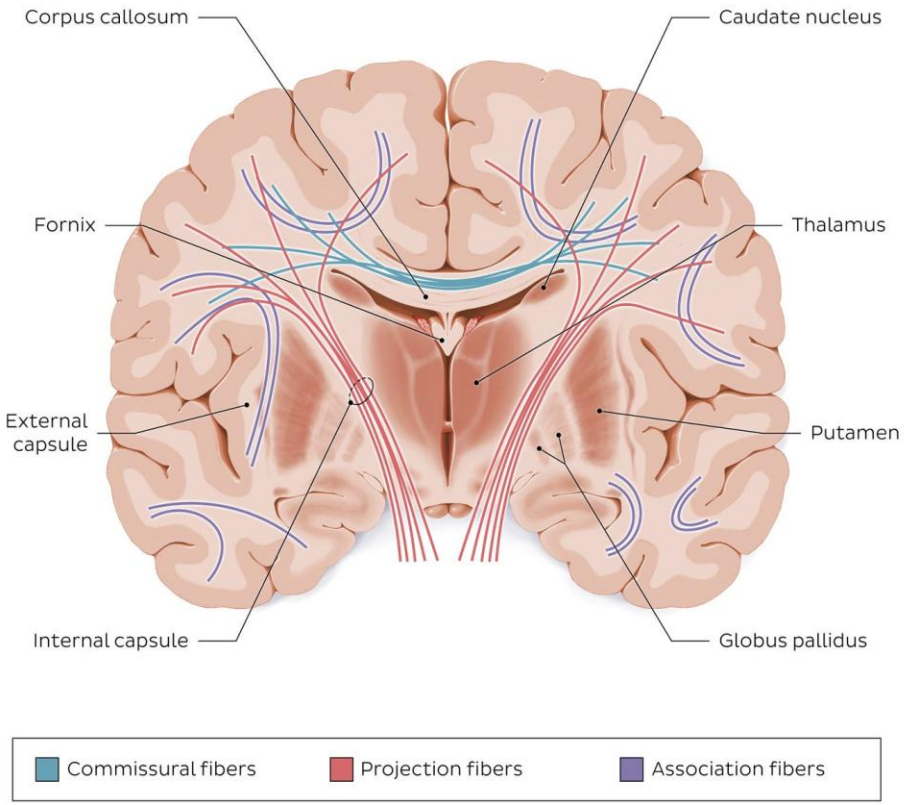
Every major city has a central hub through which its citizens can access public transportation to get to their desired destination. In the case of the human body, the nervous system can be divided into the major road ways (white matter/ nerves) that carry individuals (impulses) to and from the big city (the brain).

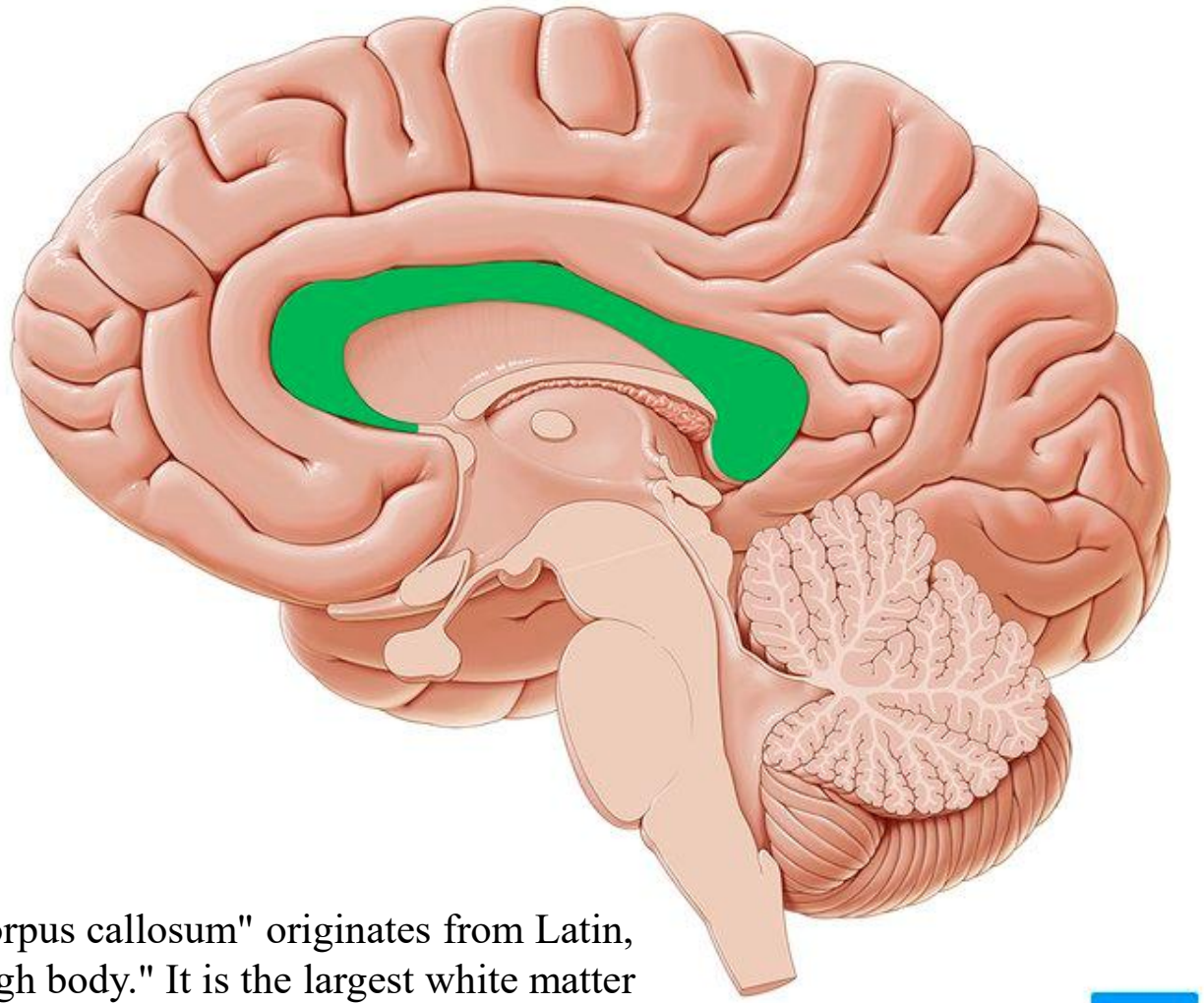
The thalamus is ideally situated deep to the cerebral cortices and conveniently acts as the central hub. The thalamus relays and integrates a myriad of motor and sensory impulses between the higher centers of the brain and the peripheries.





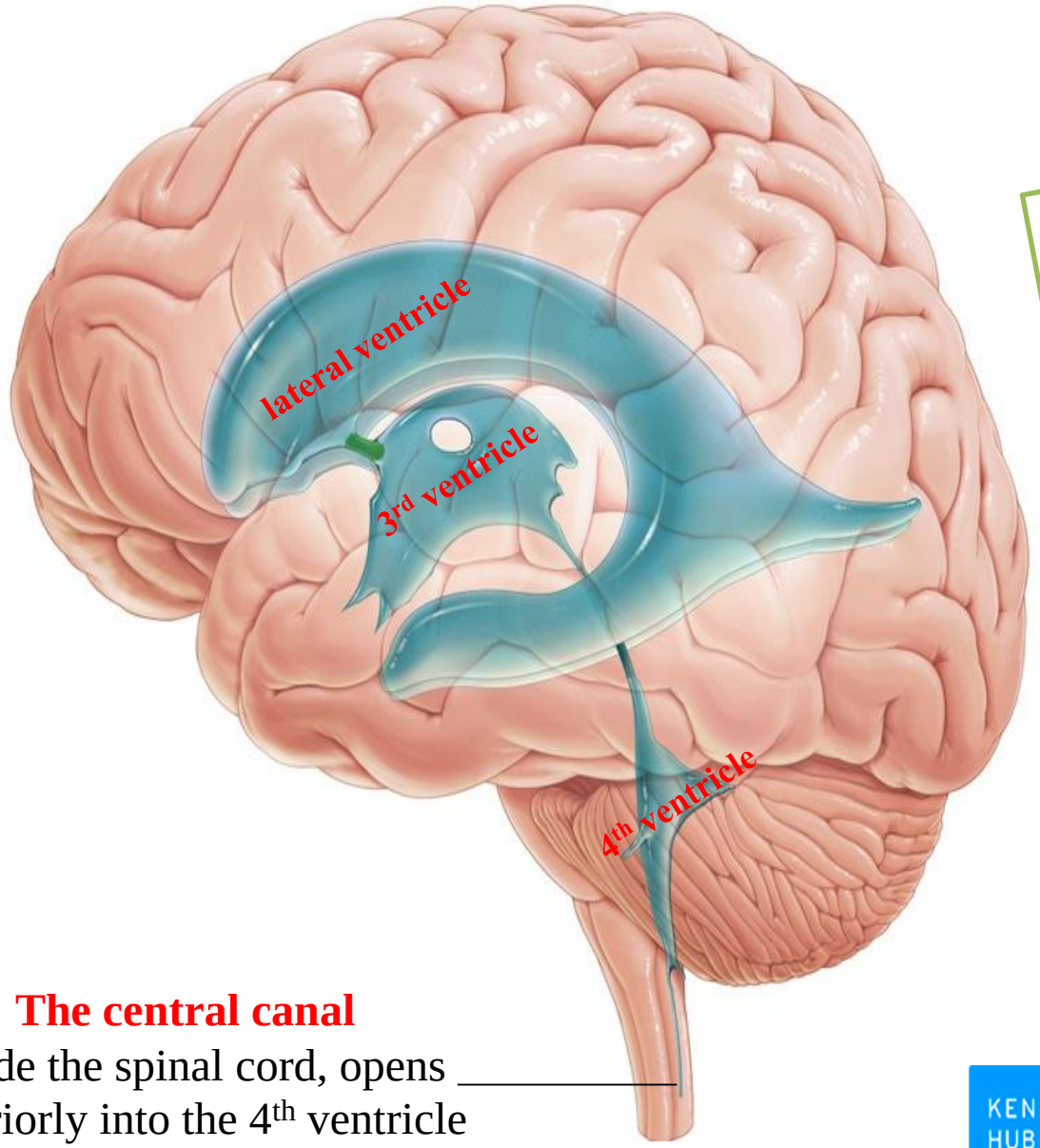
The **corpus callosum** is a large white matter tract that connects the two hemispheres of the brain. This bundle of nerve fibers, facilitates the interhemispheric communication between the left and right cerebral hemispheres and it plays a critical role in integrating motor, sensory and cognitive functions of the brain.





The name "corpus callosum" originates from Latin, meaning "tough body." It is the largest white matter structure in the brain both in terms of size (around 700 square millimeters for the midsagittal cross-section) and number of axonal projections (around 200 million axons) between the two hemispheres.

Ventricles are CSF-filled cavities within the brain



Think of them as ventricles 1st and 2nd

Two lateral ventricles

one in each hemisphere of the cerebrum

The third ventricle

between the right and left thalamus

The fourth ventricle

between the pons, medulla and the cerebellum

The central canal

Inside the spinal cord, opens _____ superiorly into the 4th ventricle

KEN HUB

Cerebrospinal fluid (CSF) is a clear, colorless liquid composed primarily of water that protects the brain and spinal cord from chemical and physical injuries.

The total volume of CSF is 80 to 150 ml in an adult

CSF continuously circulates through cavities in the brain and spinal cord and around the brain and spinal cord in the subarachnoid space (the space between the arachnoid mater and pia mater).

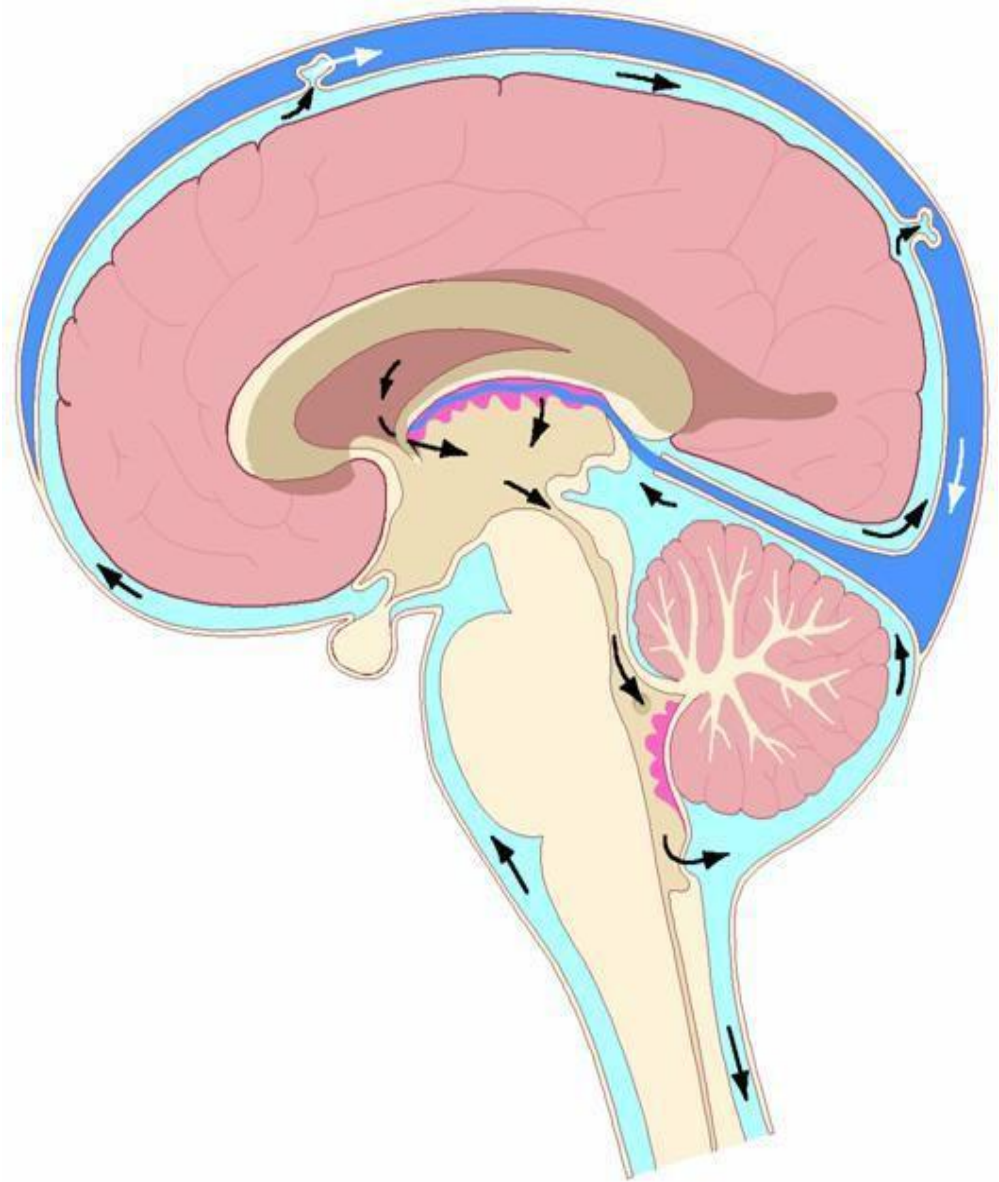
The CSF has three basic functions:

1. **Mechanical protection.**

CSF serves as a shock-absorbing medium

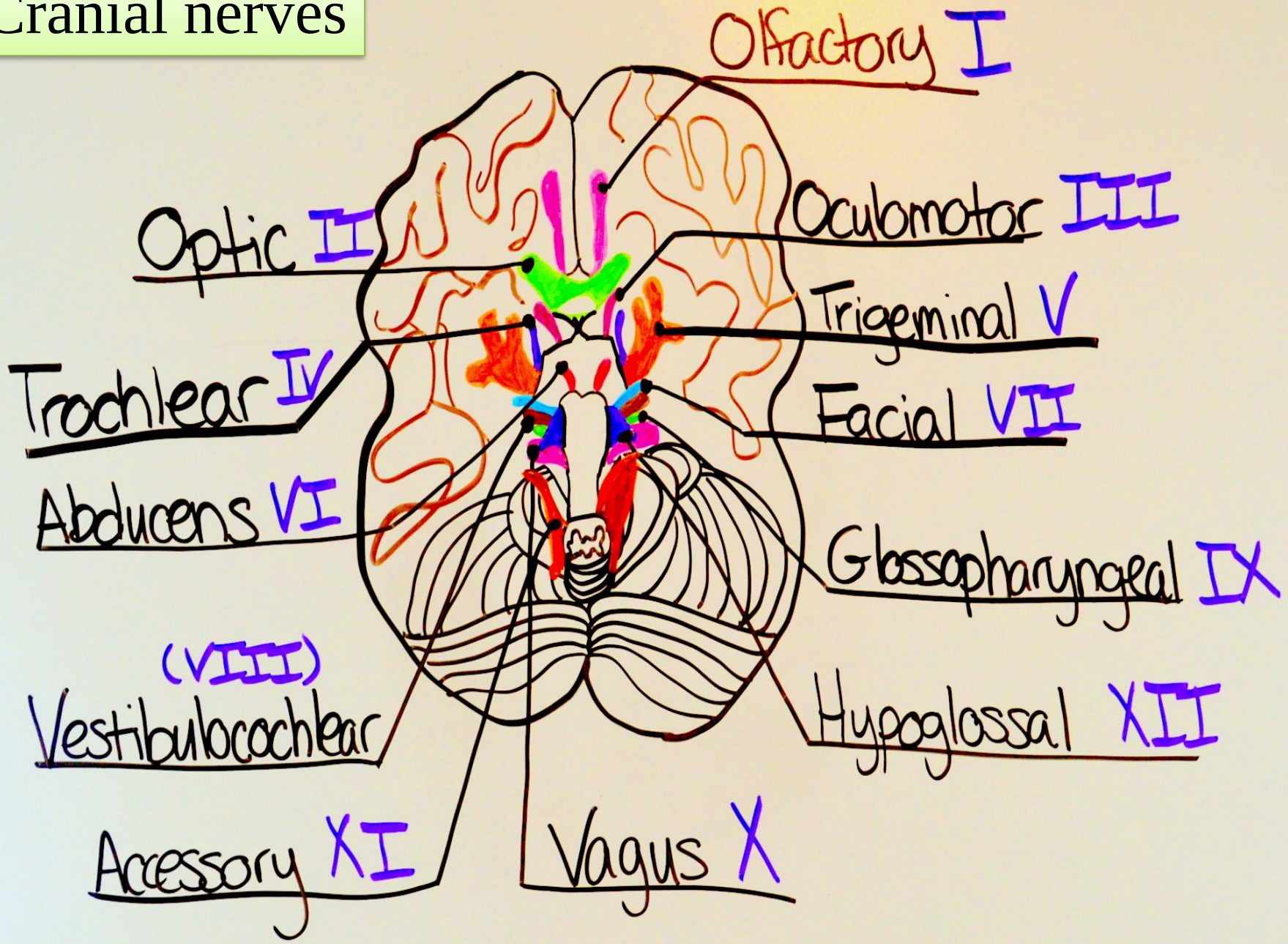
2. Circulation.

CSF is a medium for minor exchange of nutrients and waste products between the blood and adjacent nervous tissue.



The spinal subarachnoid space extends down as far as the second sacral vertebra

Cranial nerves

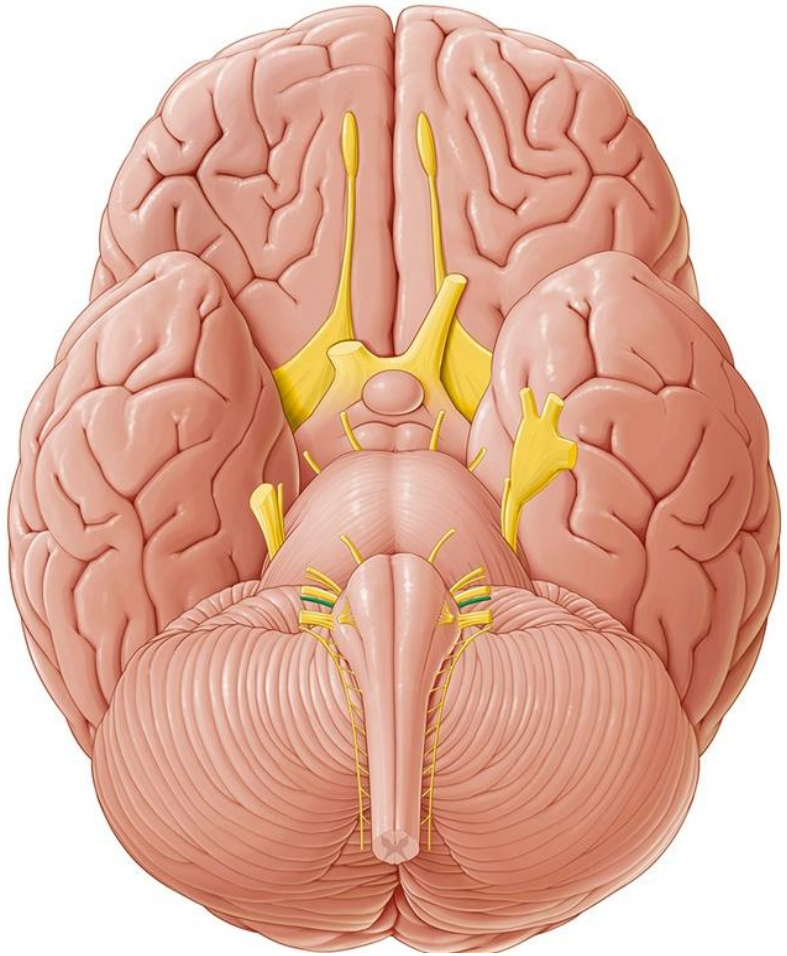


The numbering of the cranial nerves is based on the order in which they emerge from the brain, front to back

I	Olfactory
II	Optic
III	Oculomotor
IV	Trochlear
V	Trigeminal
VI	Abducens
VII	Facial
VIII	Vestibulocochlear
IX	Glossopharyngeal
X	Vagus
XI	Accessory
XII	Hypoglossal

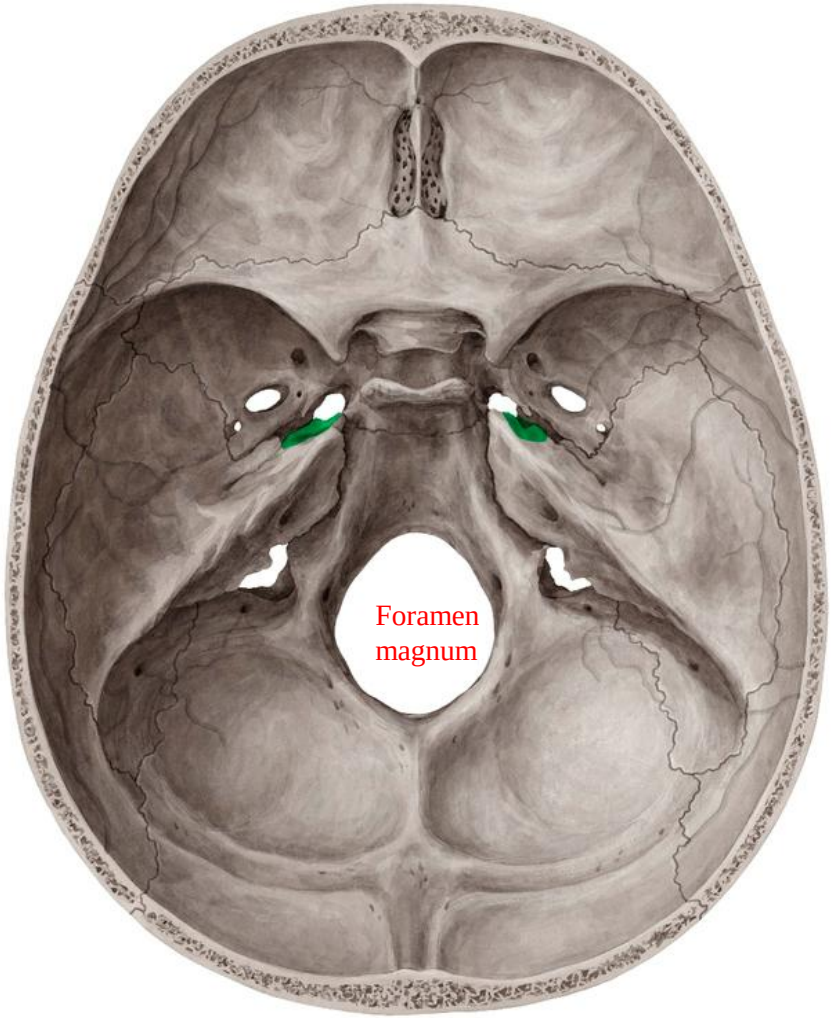
1st

Anterior



12th

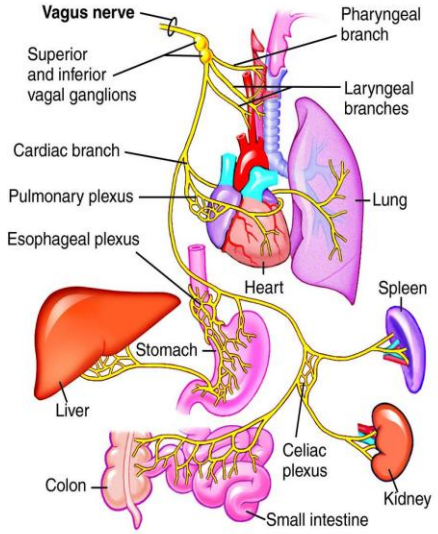
Posterior

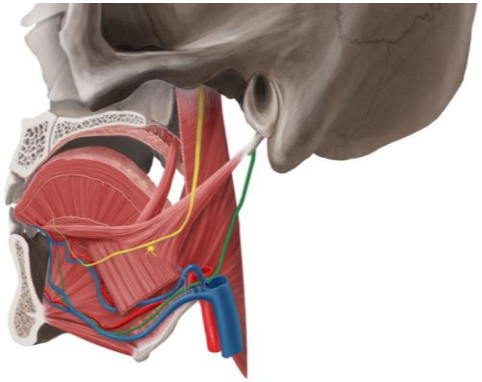


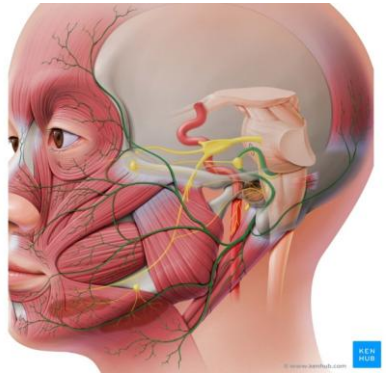
Base of the skull

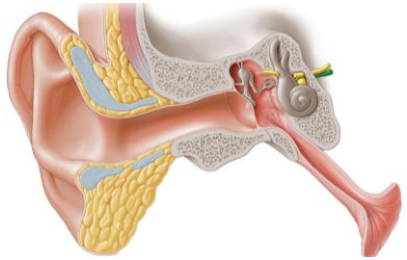
Cranial nerves

- **Olfactory** (I) nerve; sensory for smell
- **Optic** (II) nerve; sensory for vision
- **Oculomotor** (III) nerve; motor for eye muscles
- **Trochlear** (IV) nerve; motor for an eye muscle
- **Trigeminal** (V) nerve; mixed (sensory for the skin of the face and motor for muscles of mastication)
- **Abducens** (VI) nerve; motor for an eye muscle
- **Facial** (VII) nerve; mixed sensory and motor (for muscles of facial expression)
- **Vestibulocochlear** (VIII) nerve; sensory for hearing and equilibrium.
- **Glossopharyngeal** (IX) nerve; mixed sensory and motor (Elevates the pharynx during swallowing)
- **Vagus** (X) nerve; mixed
- **Accessory** (XI) nerve; motor (movement of head and pectoral girdle)
- **Hypoglossal** (XII) nerve; motor for tongue muscles









The cranial nerves emerge from the brain and are transmitted through foramina and fissures in the base of the skull.

All the nerves are distributed in the head and neck except the vagus, which also supplies structures in the thorax and abdomen.

The olfactory, optic, and vestibulocochlear nerves are entirely sensory; the oculomotor, trochlear, abducent, accessory, and hypoglossal nerves are entirely motor; and the remaining nerves are mixed