CNS
ANATOMY

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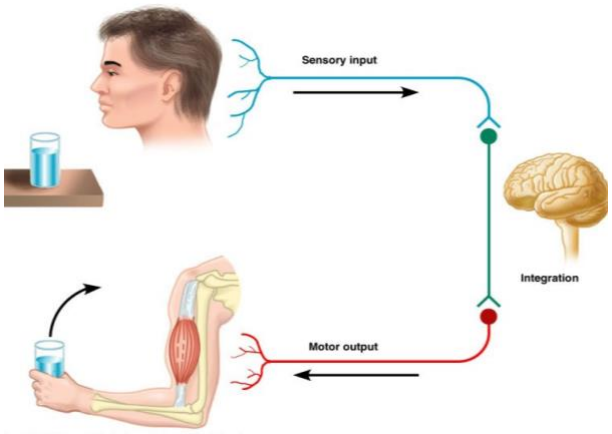
Additional pictures and notes were added for further explanation

❖ The nervous system:

A network of billions of nerve cells linked together in a highly organized fashion to form the rapid control center of the body.



❖ Basic functions of the nervous system:

1- **Sensation (input):** Monitors changes/events occurring in and outside the body. Such changes are known as stimuli (which is mainly physical energy) and the cells that monitor them are receptors.

Examples of changes in the internal environment: blood pressure, concentration of certain gases in the blood. Examples of changes in the external environment: Vision (light) and hearing.

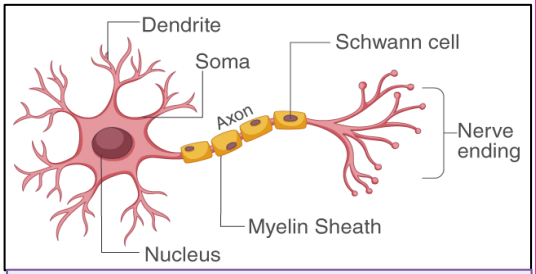
The CNS has receptors that can detect these changes and are capable of transferring certain types of energy into signals.

2- **Integration (CPU):** The parallel processing and interpretation of sensory information to determine the appropriate response. The signals we mentioned earlier move towards the CNS. Then, when the signals reach the CNS, ***integration*** takes place.

3- **Reaction (Motor output):** The signal moves from the CNS to the periphery, activating muscles to contract, and activating glands to secrete (Typically through the release of neurotransmitters (NTs)).

- Motor output: Doesn't solely include the muscles' activity, but the glands' activity as well.

There are 4 basic types of tissue in our body: connective tissue, epithelial tissue, muscle tissue and nervous tissue.



Note: the dendrites carry the signal to the cell body and the axon carries the signal away from the cell body.

❖ Nervous tissue:

- **Highly cellular.**
- **2 cell types.**

1- **Neurons:** they're the <u>functional unit</u> in the CNS and are responsible for signal transduction. They don't divide (specialized cells) and are long lived. They also have high metabolic activity and are electrically excitable (action potential occurs).
-Neurodegenerative diseases occur as a result of the neurons' inability to regenerate.

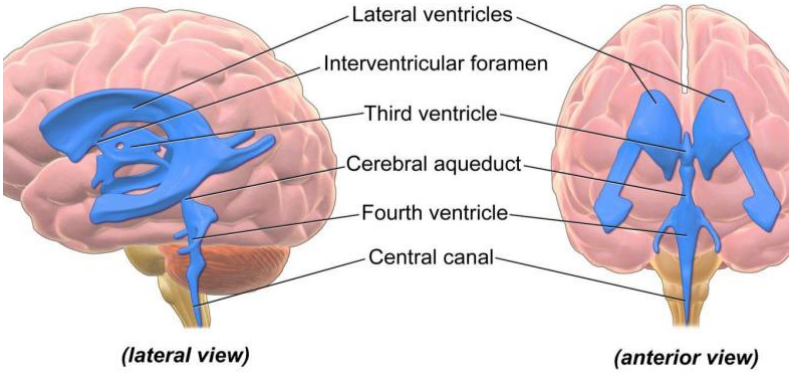
2- **Neuroglia:** They support, nourish and protect neurons, and can divide. They are smaller than neurons but greatly outnumber neurons by about 5 to 50 times. We have 6 types of supporting cells: (4 are found in the CNS, 2 are found in the PNS).

- **The 4 types of cells that are found in the CNS are:**

a) **Oligodendrocytes:** they form myelin in the myelin sheath, which increases the velocity of actions potentials in neurons.

b) **Astrocytes (star-shaped cells):** they aid in the formation of the BBB. They also act as a buffer (they get rid of the excess neurotransmitters).

c) **Ependymal cells:** they line the ventricles (hollow spaces in the brain where the CSF passes through) and the central canal of the spinal cord.



- We have 4 ventricles in the brain: 2 lateral, the 3rd ventricle is in the midline and the 4th ventricle is behind the brain.

d) **Microglial cells:** they're originally monocytes (immune cells of the nervous system) & they have phagocytic activity.

- **The 2 types of neuroglial cells are found in the PNS are:**

a) **Schwann cells:** they form myelin in the PNS.

b) **Stellate cells:** they support neurons outside the CNS.

❖ **Functional classification of neurons:**

1- **Sensory neurons:** carry the signal towards the CNS from the periphery (posterior/dorsal root).

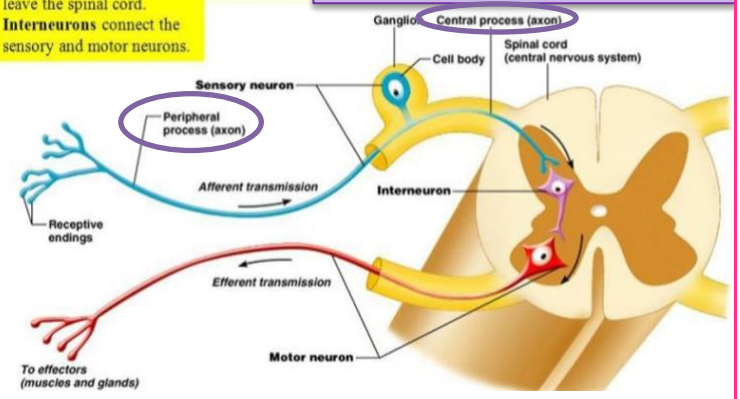
2- **Interneuron (association neuron):** within the CNS.

3- **Motor neuron:** Its cell body is found within the spinal cord itself. It leaves through the ventral root (anterior).

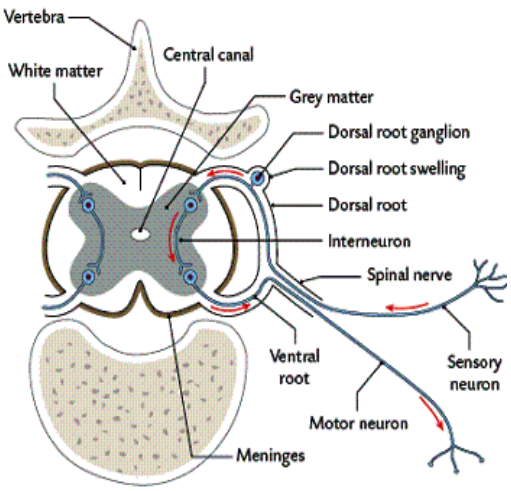
Note: the median nerve is a mixed neuron (sensory & motor).

satellite cells -> support ganglia -> EXTRA: resemble the astrocytes of the CNS and assist in regulating the external chemical environment.

Sensory neurons enter the spinal cord. **Motor** neurons leave the spinal cord. **Interneurons** connect the sensory and motor neurons.



For example: if we were to trace the pathway of a certain stimulus from the periphery (skin), we'll see that the signal gets transferred through the axon of the sensory neuron to the cell body that's found in the dorsal root ganglion. It then enters the CNS, transferred to the interneuron, then to the motor neuron to the effectors (muscles to contract or glands to secrete).



❖ **Basic terminology:**

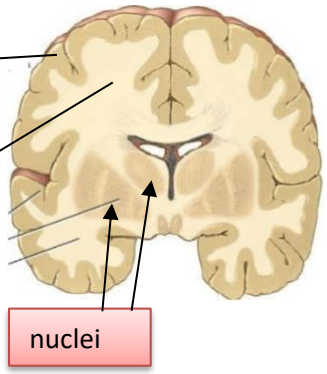
- **White matter:** aggregations of myelinated and unmyelinated axons of many neurons (there's no cell bodies).
- **Gray matter:** contains mainly neuronal cell bodies, dendrites, unmyelinated axons*, axon terminals and neuroglia.

*extra note: the gray matter contains relatively few myelinated axons. The color difference arises mainly from the whiteness of the myelin in the white matter.

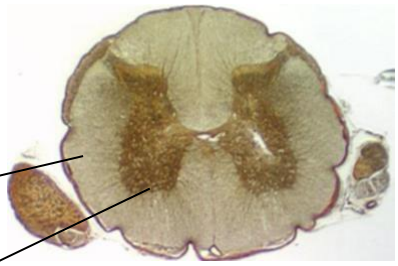
The **neuron** consists of a cell body and processes (axons + dendrites).

- **Nerves:** bundles of processes in the PNS. For example, median nerve which contains only axons (processes). Usually, they're surrounded by CT.
- **Tracts:** bundles of processes in the CNS (no connective tissue). We have ascending (sensory) and descending (motor) tracts. The ascending tract carries the signal from the body within the spinal cord to the brain. However, the descending tract carries the signal from the brain down to the spinal cord to the body.
- **Ganglion:** cluster of nerve cell bodies in PNS, such as: dorsal root ganglia, spinal ganglia, trigeminal ganglia and sympathetic chain.
- They're supported by satellite cells.
- **Nucleus:** cluster of nerve cell bodies in CNS (surrounded by white matter), if not surrounded (Cortex).

In the brain, we have on the **outside** gray matter which is called the cortex and, on the **inside**, we have the white matter.

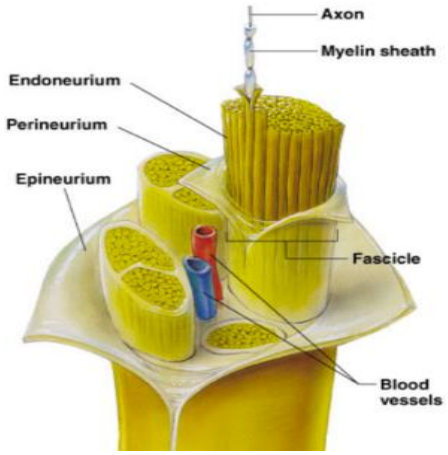


On the other hand, in the spinal cord we have in the **outside** white matter and in the **inside** gray matter.



❖ **The connective tissue of the nervous system:**

-Within each nerve, each axon is surrounded by an **endoneurium.**
-Groups of fibers are bound together into bundles (fascicles) by a **perineurium**.
-All the fascicles of a nerve are enclosed by an **epineurium.**



❖ **Organization of the nervous system:**
❖ **Anatomical divisions: 1- CNS 2- PNS.**

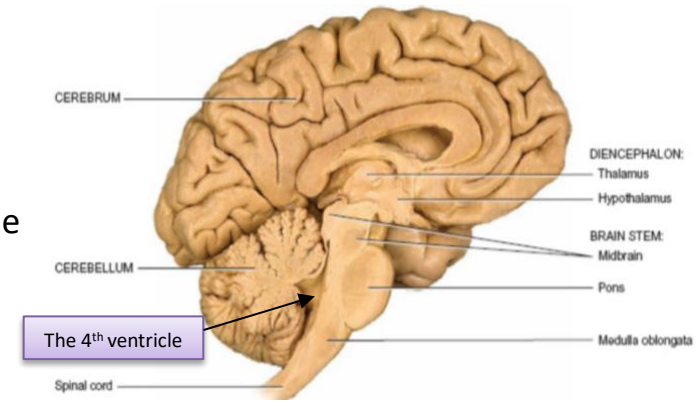
1-The central nervous system: Consists of the brain (found inside the cranial cavity) and the spinal cord (found inside the vertebral canal). It's the center of integration and control.

2-The peripheral nervous system: the nervous system outside of the brain and the spinal cord. It consists of:

-31 spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal), they carry information to and from the spinal cord. **(Occasionally form plexuses).**
-12 cranial nerves (Olfactory, Optic, Oculomotor, Trochlear, Trigeminal, Abducent, Facial, Vestibulocochlear, Glossopharyngeal, Vagus, Accessory and Hypoglossal), they carry information to and from the brain.

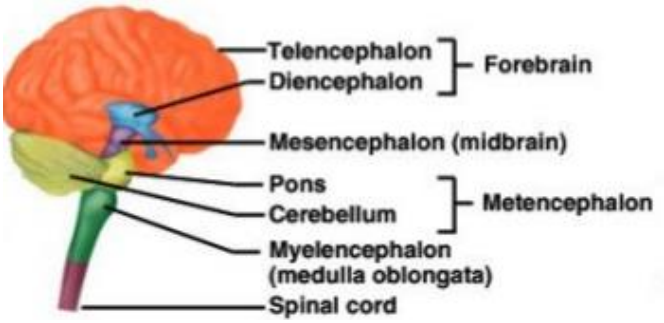
A mnemonic for the cranial nerves: **O**h, **O**h, **O**h **T**o **T**ake **A** **F**amily **V**acation! **G**o **V**egas **A**nd **H**awaii

❖ **The brain divisions at the embryonic level:** it was a tube at the very beginning.



1- **Forebrain (prosencephalon):**
a) cerebrum (telencephalon) -the outer part- includes the cortex and the subcortical white matter.
b) diencephalon: which includes the thalamus, hypothalamus, epithalamus and subthalamus.
2- **Midbrain (mesencephalon).**
3- **Hindbrain (Rhombencephalon):** which includes pons, medulla oblongata and cerebellum. **Between the cerebellum and the brain stem, we have the 4th ventricle of the brain (it's the cavity of the hindbrain).**

The brain can also be divided into: cerebrum, cerebellum and the brain stem (midbrain, pons and medulla oblongata).



❖ **Peripheral nervous system:**

- Responsible for communication between the CNS and the rest of the body. Can be divided into:
  1- Sensory division (afferent): it conducts impulses from receptors to the CNS and informs the CNS of the state that the body is In, both interiorly and exteriorly. The sensory nerve fibers can be **somatic** (from skin, skeletal muscles or joints)- You can feel it at a conscious level- or **visceral** (from within organs or body cavities).
  2- Motor division (efferent): it conducts impulses from CNS to effectors (muscles to contract or glands to secrete). It has motor nerve fibers.

Peripheral nervous system	
Somatic nervous system	Autonomic nervous system
1- Sensory neurons: (somatic sensory neurons) • Convey information to the CNS from sensory receptors in the skin, skeletal muscles and joints and from the receptors for the special senses. * **2- Motor neurons: (somatic motor neurons)** • Voluntary. • Conduct impulses from the CNS to skeletal muscles.	**1- Sensory neurons: (autonomic visceral sensory neurons)** • Convey information to the CNS from autonomic sensory receptors, located primarily in the visceral organs (smooth muscle organs in the thorax, abdomen and pelvis). **2- Motor neurons: (autonomic motor neurons)** • Involuntary (generally). • Conducts impulses from the CNS to smooth muscle, cardiac muscle and glands.

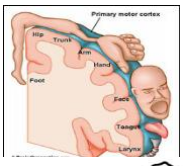
Example: Sensory autonomic neurons are responsible for detection of blood pressure (baroceptors).

***special senses: (the 5 senses) the doctor said they're all somatic sensations except for taste (some sources consider both taste and smell as visceral).**

- ❖ Now, we're going to trace the different pathways of neuronal signals through both PNS and CNS:
- First, the **sensory** pathway: **(spinothalamic tract)**

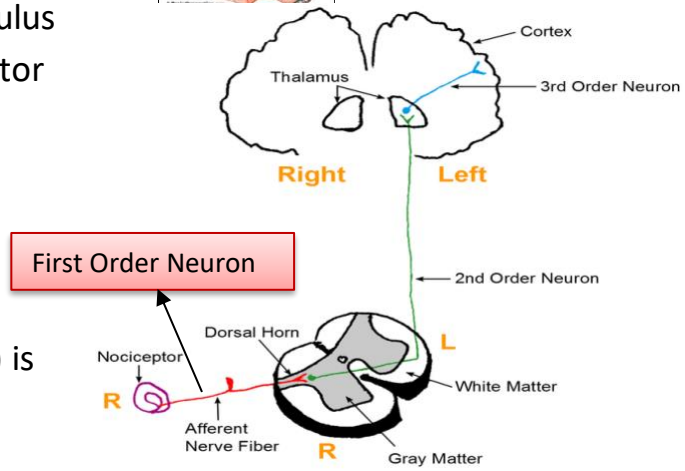
-Signals aren't transmitted through a single neuron, we need several neurons to move it from the periphery to the cerebral cortex.

-every area in the cerebral cortex represents an area in your body.



If someone is stung by a bee, the pain stimulus will be conducted to the spinal cord: Receptor → cell body (in the dorsal root ganglia) → axon → ***synapse*** in the spinal cord **(dorsal horn).**

The neuron that transmits the signal from the periphery to the spinal cord (CNS) is called the **First Order Neuron.**



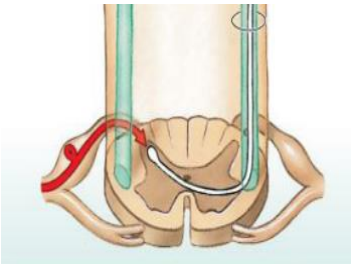
The first order neuron synapses with another neuron. This second neuron ascends up through the spinal cord in a tract (white matter), moving through the brainstem, reaching the forebrain/diencephalon → specifically **the thalamus** where another ***synapse*** occurs.
we call that ascending neuron a **Second Order Neuron.**

- **The cerebral cortex is our final destination; the place where interpretation/integration takes place. However, this information/signal cannot be transmitted to the cortex unless it passes through the thalamus -as if it were the cortex's secretary-.**

Finally, the second order neuron synapses with another neuron in the thalamus, which moves the signal from the thalamus to the cortex, it's called the Third Order Neuron.

The cell bodies of the three neurons are found in:
1st order → dorsal root ganglia, 2nd order → dorsal horn of spinal cord, 3rd order → thalamus

Notice how the signal came from one side and along its course, it went to the opposite side. This is called **decussation** ***axons crossing the midline to the opposite side of the spinal cord or brain stem) in each somatosensory pathway***



Sensation from the right goes to the left hemisphere.

-Why did we need more than one neuron?

This provides a chance for **neuromodulation**; regulation of these pathways.

- Second, the **motor** pathways: (CNS → Periphery/effectors)

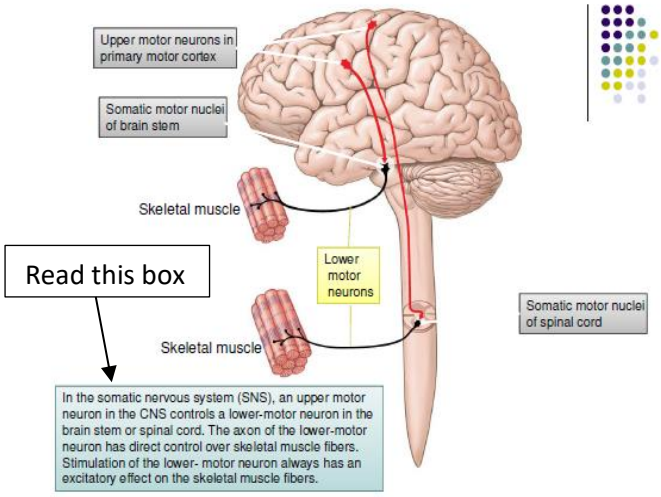
- Nerves that originate from the spinal cord: spinal nerves. Nerves that originate from the brain: cranial nerves
- Each spinal nerve has 2 roots: Dorsal (always sensory), Ventral (always motor)
- Motor neurons could be somatic or visceral (autonomic).

-after the signal has been interpreted, a response is generated from the CNS to the periphery:

a) motor **somatic**:

-if the skeletal muscle is not in the head/neck region: (spinal nerves)

A neuron descends through a tract (white matter) from the cortex to a specific segment in the spinal cord and ***synapses*** with another neuron in the **ventral horn** of the cord. This descending neuron is called an **Upper Motor Neuron**.



The synapse happens between:

An upper motor neuron & an **Interneuron** → then another ***synapse*** between the interneuron and a **Lower Motor Neuron;** which transmits the signal to the periphery. (Skeletal muscles)

- In some cases: an upper motor neuron can synapse directly with a lower motor neuron without the need of an interneuron.
- Upper motor neurons regulate and control the activity of the lower motor neurons.

The cell bodies of the neurons are located in:
Upper motor → cortex, lower motor → ventral horn, ***interneuron→ gray matter of the spinal cord**

-If the muscle is in the head/neck region: (Cranial nerves)

- All the cranial nerves originate from the brainstem except for: the olfactory (1) & the optic (2) nerves.
- Cranial nerves are either sensory, motor, or both (mixed).
- Some cranial nerves have autonomic (parasympathetic) motor fibers, like the vagus nerve.

The pathway is similar to the somatic motor spinal nerve pathway, but the upper motor neuron descends from the cortex to the brainstem instead of the spinal cord.

-In the brainstem, there are no dorsal and ventral horns. Instead, cell bodies of the lower motor neurons form what we call a **nucleus**.
- Upper motor neuron (cortex) → lower motor neuron (brainstem nuclei) → skeletal muscle, E.g. the facial nerve supplying motor innervation to the buccinator muscle & orbicularis oris.

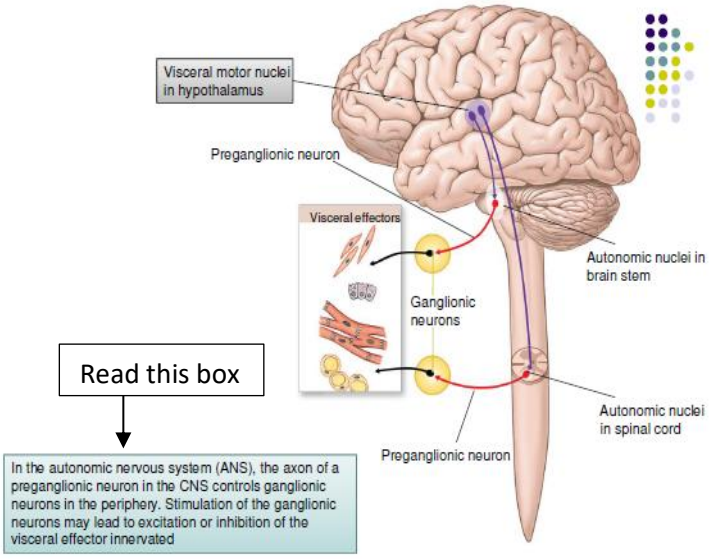
b) motor **visceral** (autonomic):

- A response signal is conducted from the high centers of the brain to lower compartments of the CNS.

High centers**: The Hypothalamus.**

-The BIG BOSS of the ANS; all the autonomic activities in the body are controlled by the hypothalamus.

-Low compartments: spinal cord segments & brainstem (cranial nerves)

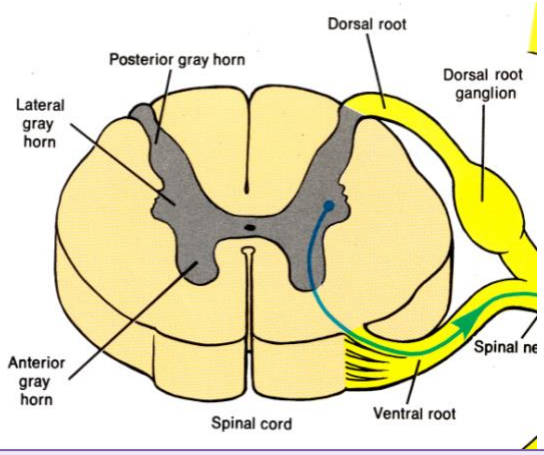


- Remember: in ANS, we already know 2 neurons involved in the pathway: **Preganglionic** and **Postganglionic** neurons.
- So, higher neurons carry the autonomic signals from the **hypothalamus** and descend to lower compartments to ***synapse*** with a **Preganglionic neuron**.
- The preganglionic neuron ***synapses*** with a **Postganglionic neuron** in a sympathetic or parasympathetic ganglion.
- The postganglionic neuron innervates the effectors; smooth, cardiac muscles and glands.

Where does the first synapse take place?

a) Brainstem: some cranial nerves carry autonomic fibers (**parasympathetic only)**
e.g.: the Vagus nerve innervating the viscera.
b) Spinal cord segments: specifically, in the
Lateral horn of the gray matter.

The structure of the gray matter:



A cross-section of the spinal cord showing butterfly-shaped gray matter with surrounding white matter.

1- **Dorsal** (posterior) horn**: sensory** function
- the 1st and 2nd order neurons of the sensory pathway synapse here.

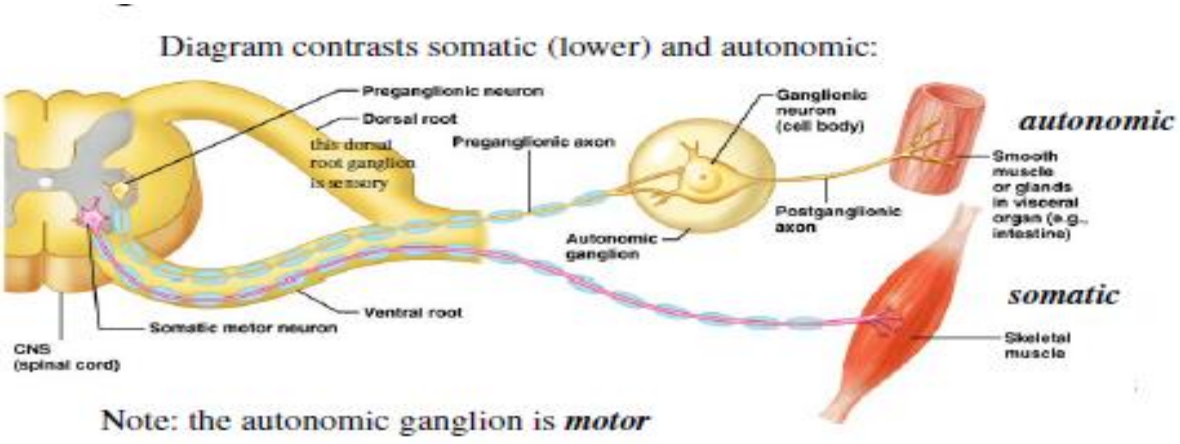
2- **Ventral** (anterior) horn: **motor** function
- the upper somatic motor neurons synapse with the lower somatic motor neurons here.

3- Lateral horn: found only in ANS spinal segments.
- The higher hypothalamic neurons synapse with the preganglionic neurons here.

- **Spinal segments that have lateral horns/ ANS spinal segments:**
- Sympathetic: Thoracolumbar → all the thoracic segments (T1-T12) + L1-L2
- Parasympathetic: Craniosacral → sacral segments (S1-S5)

- The cranial part of the parasympathetic nervous system are the brainstem nuclei as we've mentioned previously.

Recap: Higher neuron (hypothalamus) → Preganglionic neuron (lateral horn/brainstem) → ANS ganglia → Postganglionic neuron → Effector organs.



- Remember: Each spinal nerve has 2 roots → ventral & dorsal. The motor neurons (visceral and somatic) pass through the VENTRAL root (always motor)

- Axon of 1st (preganglionic) neuron leaves CNS to synapse with the 2nd (ganglionic) neuron

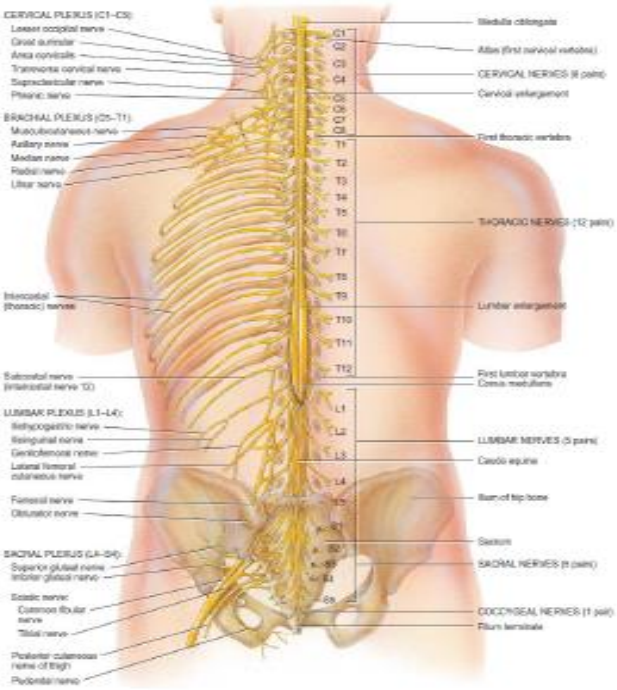
- Axon of 2nd (postganglionic) neuron extends to the organ it serves

-What's the difference between the ANS ganglia and the dorsal root ganglia?

The ANS ganglia **contain the synapses** between the nerve terminals of the preganglionic neurons and the postganglionic neurons' cell bodies.

The dorsal root ganglia have <u>no synapses</u> (Ganglion cells in dorsal root ganglia do not receive synapses). They're composed of the cell bodies of the **sensory** neurons. (pseudounipolar neurons)

❖ **External anatomy of Spinal Cord:**



- It runs through the vertebral canal.
- Extends from foramen magnum (opening in the occipital bone of the skull) to L1/L2.
- Slightly flattened anteriorly and posteriorly.
- Length of the adult spinal cord ranges from 42 to 45 cm.

- <u>Not</u> uniform in diameter: we have 2 enlargements that give rise to plexuses to supply the upper and lower limbs.

1- Cervical enlargement: supplies upper limbs **-The brachial plexus (C5-C8 & T1).**
2- Lumbar enlargement: supplies lower limbs **-The lumbosacral plexus.**

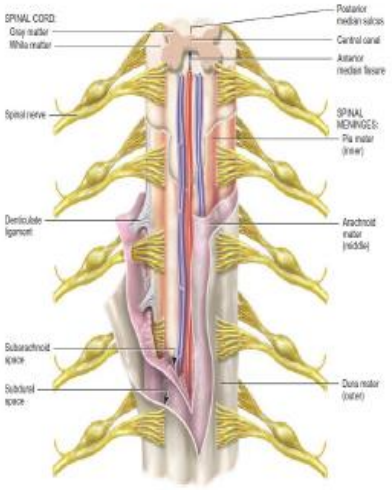
- Regions/segments: Cervical (8), Thoracic (12), Lumbar (5), Sacral (5), Coccygeal (1)

→ Give rise to (31) pairs of spinal nerves **(All are mixed nerves)**

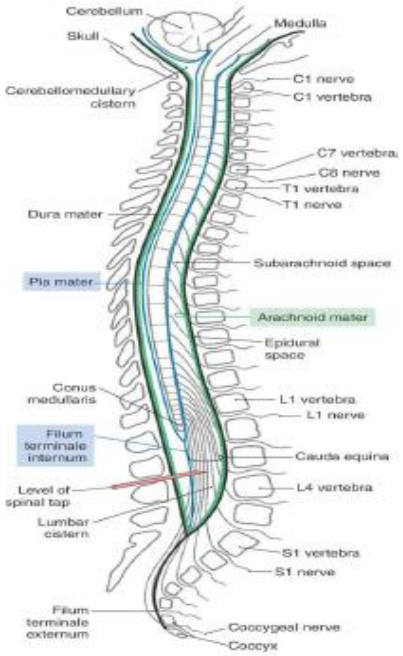
Note: The number of segments = the number of nerves **BUT not the vertebrae**; we have 8 cervical spinal segments but 7 cervical vertebrae.

*** The average person is born with 33 individual bones (the vertebrae). By the time a person becomes an adult most have only 24 vertebrae because some vertebrae at the bottom end of the spine fuse together during normal growth and development.**

- The spinal cord ends between L1-L2 forming a tapered inferior end (conical structure) called **Conus Medullaris**
- 2/3 of the vertebral canal are occupied by the spinal cord.
- The lower third contains the lower spinal nerves → horsetail appearance.
  -This structure is called **Cauda Equina** (origin of spinal nerves extending inferiorly from conus medullaris).



❖ The connective tissue of the spinal cord**:**
Meninges (السحايا)



We have 3 CT membranes: Dura, Arachnoid & Pia mater.

1) **Dura** mater: (الجافية)

- Outermost layer -lines the bony canal/closest to the bone-; continuous with epineurium of the spinal nerves
- **Dense irregular** connective tissue
- Extends from the level of the foramen magnum to S2 Forming the **Filum Terminale Externum** (the closed end of the Dura mater caudally; so, it is a connective tissue that anchors the Dura mater to the coccyx bone).

2) **Arachnoid** mater: (العنكبوتية)

- Thin web-like arrangement of **delicate collagen** and **some elastic fibers**.
- Adheres to the inner surface of the dura mater, ending at the level of S2.

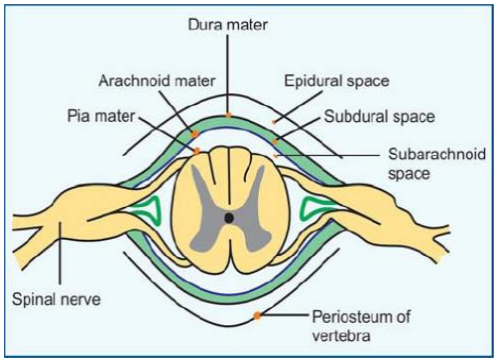
3) **Pia** mater: The innermost layer

- Thin transparent connective tissue layer that adheres (Bound tightly) to the surface of the spinal cord **and brain**.

*** the 3 meninges also surround the brain. This will be discussed in upcoming lectures. ***

- Since it is firmly attached to the spinal cord, thus, both end at the level of L1-L2. It forms the **Filum Terminale Internum;** a connective tissue at the caudal (inferior) end of the pia mater that is attached to the filum terminale externum of the dura mater which is attached to the coccyx bone.

→ So, both Filum Terminale Externum (directly) & Internum (indirectly) anchor the spinal cord to the coccyx providing stability and protection within the canal.



- Forms the **denticulate ligaments** that attach the spinal cord to the arachnoid mater and inner surface of the dura mater.

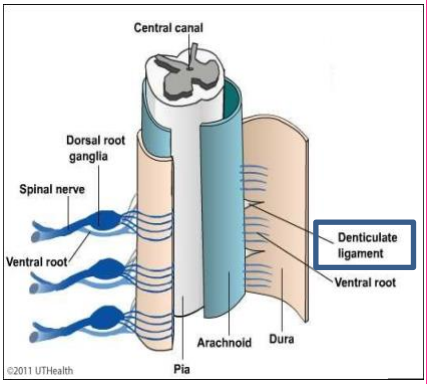
❖ **Spaces:** epidural/ subarachnoid/ subdural

1) Epidural space: extradural (outside the dura)

-space between the dura mater and the wall of the vertebral canal.

- Fat-filled

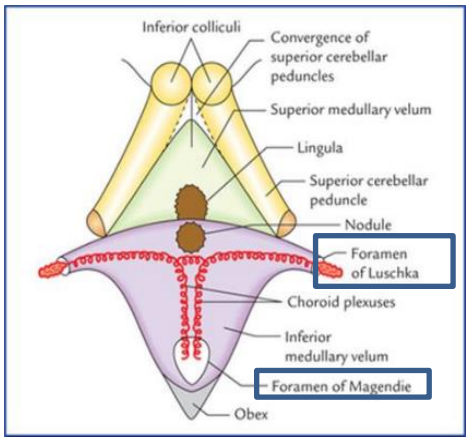
- **Epidural anesthesia** → commonly used for labor pain. (آلام المخاض)



2) Subdural space: contains serous fluid (between the dura and arachnoid)

3) Subarachnoid space: between pia and arachnoid

- A true space and **the most important one**.
- Major blood vessels supplying the CNS pass through this space.
- **It also has physiologic functions related to temperature, protection…etc.**



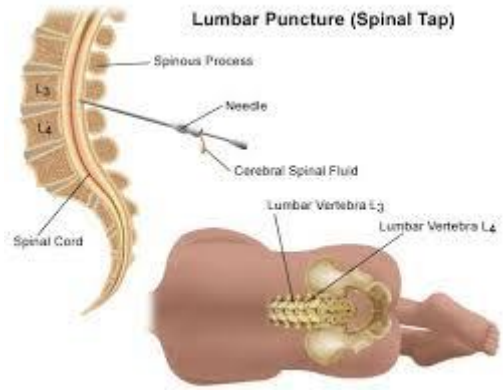
-filled with CSF.

-The CSF circulates through the brain ventricles, central canal of the spinal cord, subarachnoid space.

- From the **4th** ventricle, the CSF passes into the subarachnoid space through 4 openings: the central canal of the spinal cord, **two lateral** apertures (**foramina of Luschka**) and a **single median** aperture (**foramen of Magendie**).

- A sample of the CSF can be taken using a lumbar puncture (spinal tap). It is diagnostic (indicates infection, changes in CSF pressure).

A lumbar puncture is safer anywhere between L2→S2 (no spinal cord) **but the needle is usually inserted between L3-L4** at the level of the anatomical plane → supracristal line.



❖ A short quiz:

1- Which of the following accurately describes the direction of an impulse moving through a neuron that carries information to the CNS from the PNS?

a) An afferent neuron, impulse moving distally
b) An efferent neuron, impulse moving proximally
c) An efferent neuron, impulse moving distally
d) An afferent neuron, impulse moving proximally

2- Which of the following structures is a part of the rhombencephalon?

a) Temporal lobe
b) Thalamus
c) Medulla
d) Substantia nigara

3- What kind of nerve cells are thought to be helpers for neurons?

a) Prison cells
b) Stem cells
c) Glial cells.
d) Muscle cells

4- If an individual were to sustain a significant injury to their right cerebral hemisphere, where might somatosensory loss of functioning occur?

a) Right side of the body
b) Left side of the body
c) There's no evidence that loss of functioning would occur
d) Both sides of the body

❖ **Answers: 1- D 2- C 3- C 4- B**