NERVOUS SYSTEM

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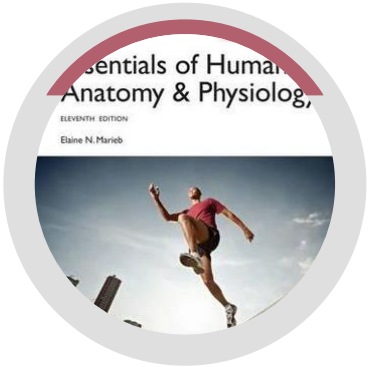
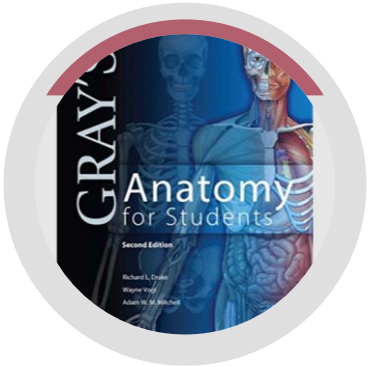
RESOURCES



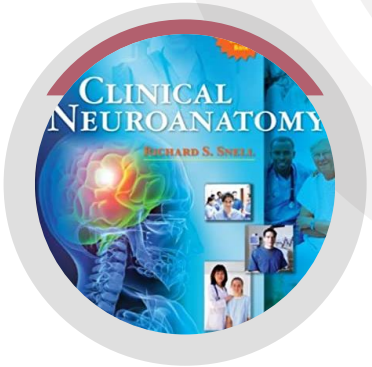
ESSENTIAL OF HUMAN ANATOMY & PHYSIOLOGY

By Elaine Marieb



GRAYS ANATOMY

By Drake, Vogl & Mitchell



CLINICAL NEUROANATOMY

By Richard Snell

TEACH ANATOMY

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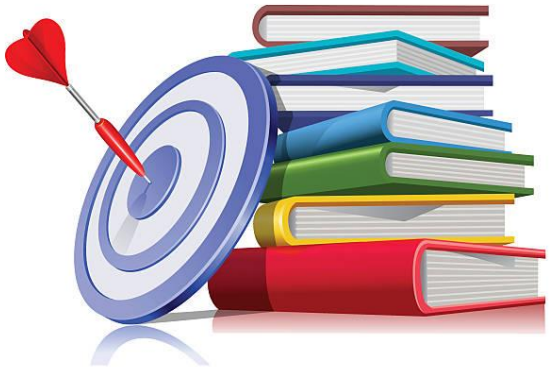
OBJECTIVES

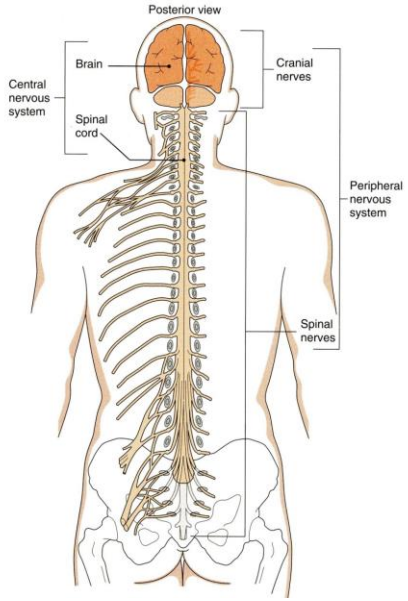
- Define central nervous system and peripheral nervous system and list the major parts of each.
- Describe the structures and functions of neurons and neuroglia.
- Discuss the general structure of a neuron and name its important anatomical regions.
- Describe the composition of gray matter and white matter.
- Identify the major anatomical regions of the cerebral hemispheres, diencephalon, brain stem, and cerebellum.
- Enumerate the three meningeal layers surrounding the brain and spinal cord.
- Identify spinal cord structure.
- Describe the origin and fiber composition of the spinal nerve.
- Identify the cranial nerves by number and by name and list the major functions of each.
- Discuss parts of the autonomic nervous system (sympathetic, parasympathetic).

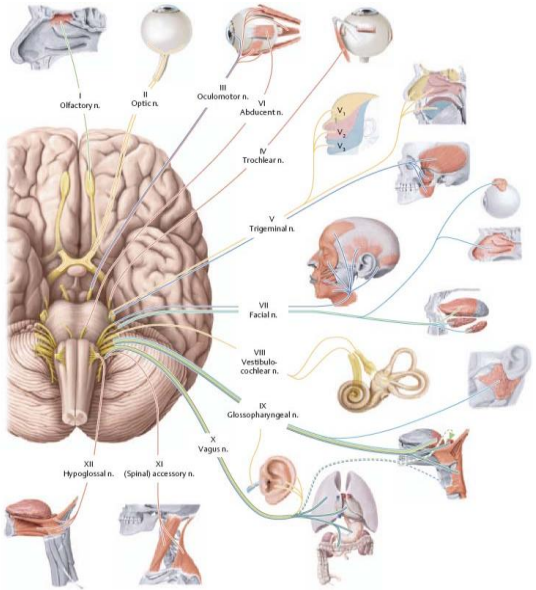


ANATOMY

STRUCTURAL CLASSIFICATION

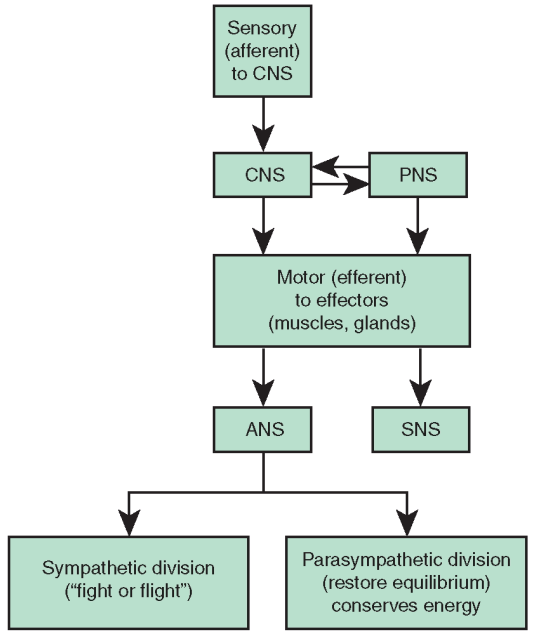
- **Central nervous system** (CNS): it includes the brain and spinal cord that are not capable of regeneration, occupy the dorsal body cavity, are protected by.
    - Bones (skull and vertebral column).
    - Three meninges (pia mater, arachnoid mater and dura mater).
    - Cerebrospinal fluid (CSF) in the subarachnoid space.
- **Peripheral nervous system** (PNS): it includes all parts of the nervous system outside the CNS.
    - 12 pairs of cranial nerves, carry impulses to and from the brain.
    - 31 pairs of spinal nerves, carry impulses to and from the spinal cord.





FUNCTIONAL CLASSIFICATION

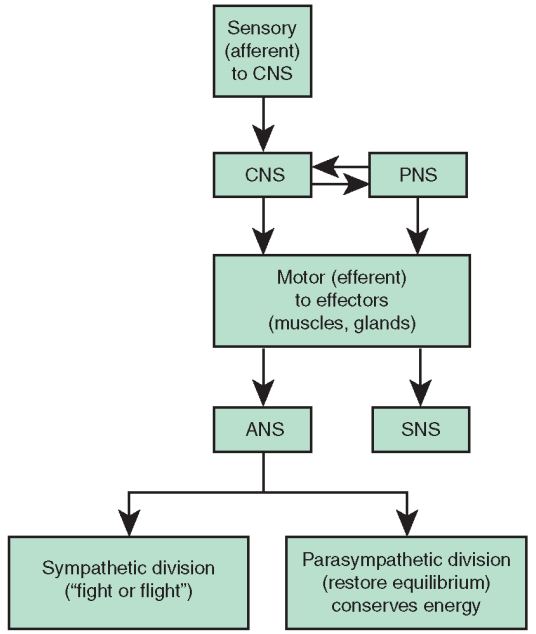
- It divides only the PNS structures into two principal subdivisions:
- **The sensory division** (afferent): which convey impulses to the central nervous system from sensory receptors located in various parts of the body. It subdivided into:
    - **Somatic** (soma = body) sensory (afferent) fibers, delivering impulses from the skin, skeletal, muscles, and joints.
    - **Visceral** sensory (afferent) fibers, transmitting impulses from the visceral organs.



CNS = Central nervous system
PNS = Peripheral nervous system
ANS = Autonomic nervous system
SNS = Somatic nervous system

FUNCTIONAL CLASSIFICATION

- The **motor division** (efferent): which carries impulses from the CNS to effector organs, the muscles and glands.
    - The somatic nervous system or voluntary nervous system, allows us to consciously, or voluntarily, control our skeletal muscles.
    - The autonomic nervous system (ANS) or involuntary nervous system, regulates events that are automatic, or involuntary, such as the activity of smooth muscle, cardiac muscle, and glands, it has two parts, the sympathetic and parasympathetic.



CNS = Central nervous system
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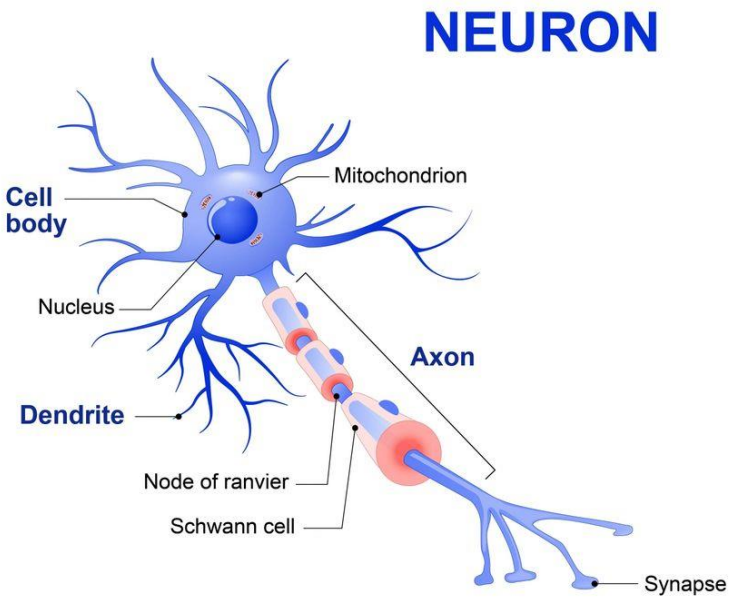
NEURONS

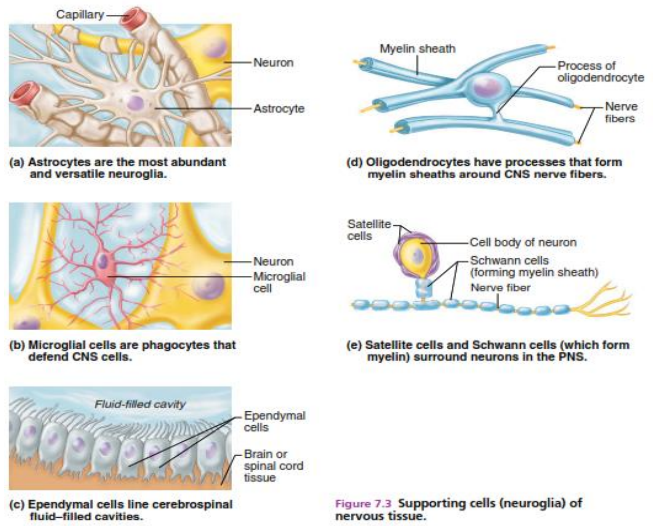
- They are specialized cells to transmit messages (nerve impulses).
- Regions of neurons:
  - **Cell body:** nucleus and metabolic center of the cell.
  - **Processes:** fibers that extend from the cell body.
- Processes (fibers)
  - **Dendrites:** conduct impulses toward the cell body.
    - Neurons may have hundreds of dendrites.
  - **Axons:** conduct impulses away from the cell body.
    - Neurons have only one axon arising from the cell body at the axon hillock.
    - End in axon terminals, which contain vesicles with neurotransmitters.
    - Axon terminals are separated from the next neuron by a gap.
    - The axons are generally called nerve fibers, typically conduct (electrical signals) away from the cell body.
- Synaptic cleft: gap between axon terminals and the next neuron.
- Synapse: functional junction between nerves where a nerve impulse is transmitted.

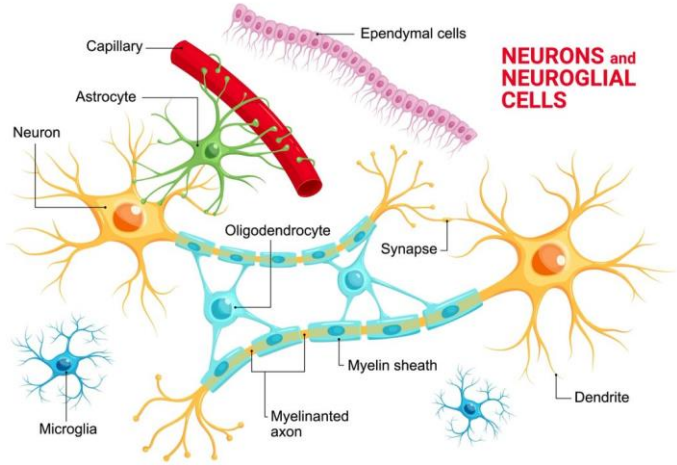


SUPPORTING CELLS

- They are named neuroglia, glial cells or glia, and include cells that support, insulate, and protect the delicate neurons:

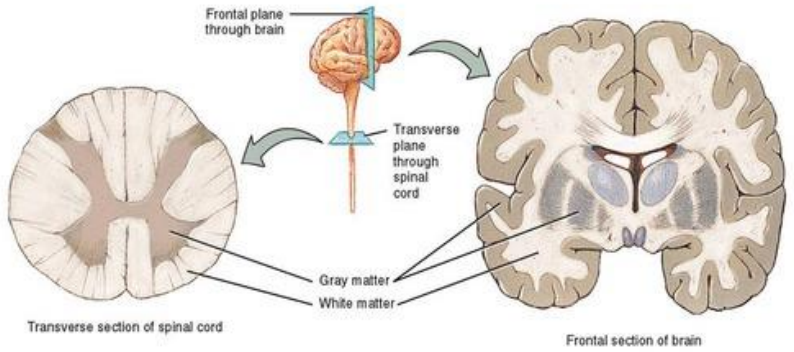
    1. **Astrocytes:** most abundant, ½ neural tissue, and it form a living barrier between capillaries and neurons (blood brain barrier), protect the neurons from harmful substances in the blood.
    2. **Microglia**: spiderlike phagocytes engulf dead brain cells and bacteria.
    3. **Ependymal cells**: line the central cavities of the brain and the spinal cord, forms a protective watery cushion around the CNS called cerebrospinal fluid (CSF).
    4. **Oligodendrocytes**: wrap around the nerve fibers, producing fatty insulating coverings called Myelin sheaths.
    5. **Schwann cells:** form the myelin sheath around nerve fibers in the PNS.

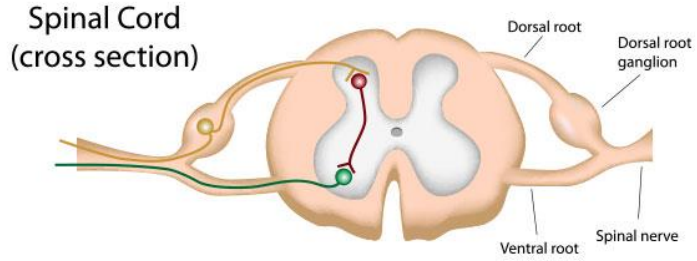




NERVOUS TISSUE

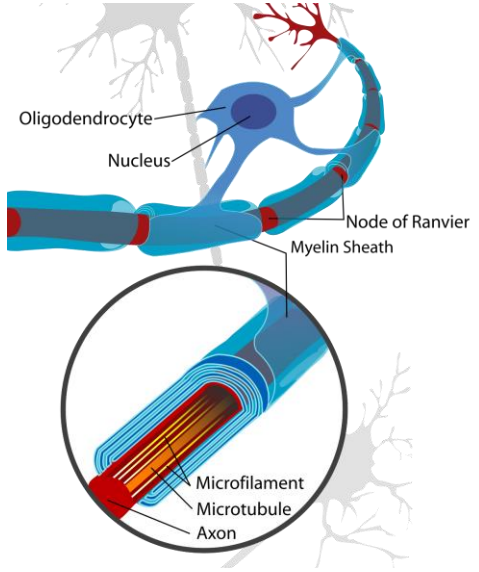
- **White matter** consists of dense collections of myelinated fibers, bundles of nerve fibers (neuron processes) running through the CNS are called tracts, whereas in the PNS they are called nerves.
- **Gray matter** refers to unmyelinated regions of the CNS (unmyelinated fibers and cell bodies).
- **Ganglia**, small collections of cell bodies are found in a few sites outside the CNS in the PNS.

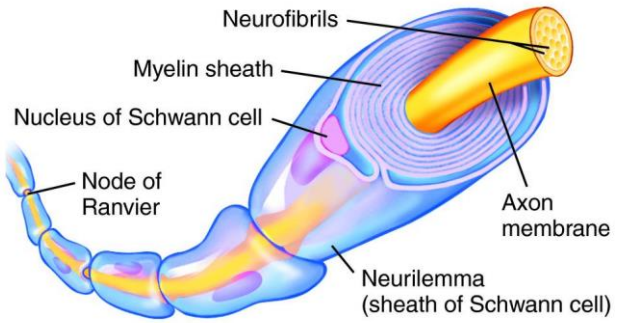


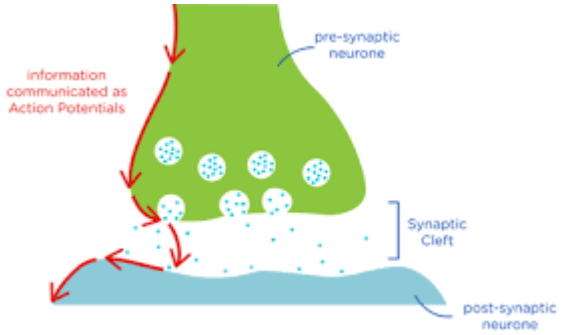


MYELIN SHEATH

- The nerve fibers are covered with whitish, fatty material called myelin which insulates the fibers and increases the transmission rate of nerve impulses.
- The **Schwann cell**, external to the myelin sheath, is called the neurilemma because the myelin sheath is formed by many individual Schwann cells, it has gaps, or indentations, called **nodes of Ranvier**
- Axons at their terminal end, forming hundreds to thousands of axon terminals.
- These terminals contain hundreds of tiny vesicles, or membranous sacs, that contain chemicals called **neurotransmitters**.
- Each axon terminal is separated from the next neuron by a tiny gap called the **synaptic cleft.**

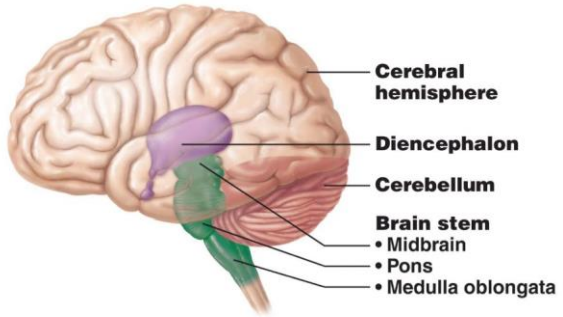






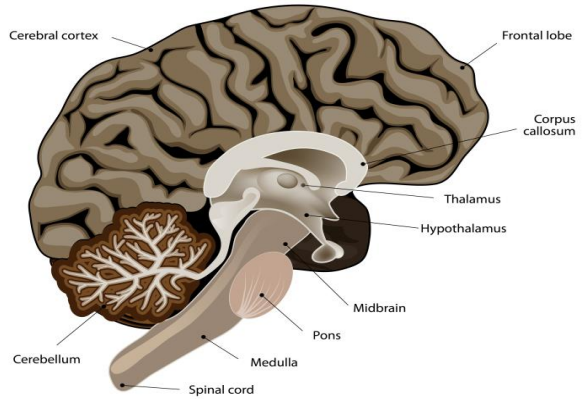
THE BRAIN

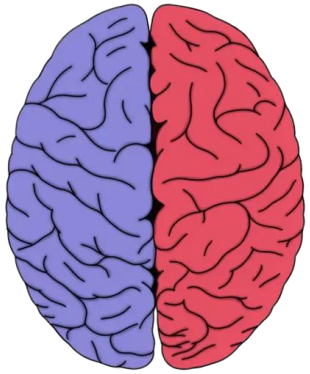
1. Cerebrum (Cerebral Hemisphere)
2. Diencephalon (Thalamus and Hypothalamus)
3. Brain stem (Midbrain, Pons, and Medulla Oblongata)
4. Cerebellum



CEREBRUM

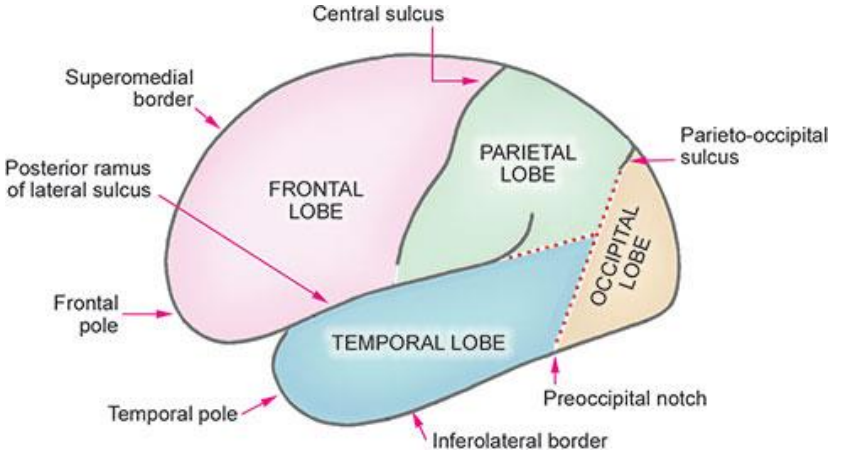
- It is the largest part of the brain.
- It is divided by a deep longitudinal fissure into two parts (right and left cerebral hemispheres).
- These two hemispheres connected by a mass of white matter known as **corpus callosum**.
- Each hemisphere has a cavity named lateral ventricle.
- The superficial part is composed of grey matter forming the cerebral cortex.
- The deeper layers consist of white matter or nerve fibers.
- The cerebral cortex shows many gyri (elevated ridges), sulci (shallow grooves), and fissures (deeper grooves).





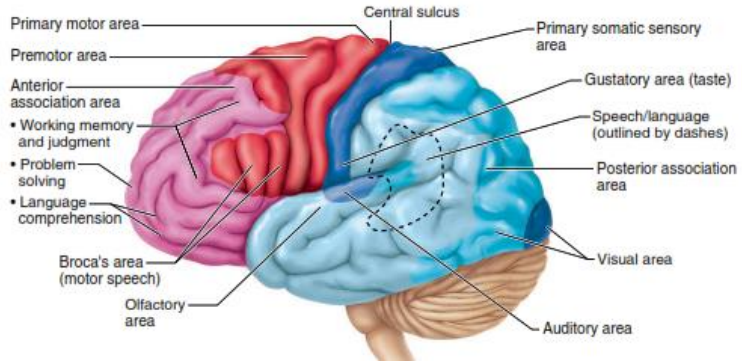
ANATOMICAL IDENTIFICATION OF CEREBRAL HEMISPHERES

- **Three poles:** frontal, temporal and occipital.
- **Three surfaces:** supero-lateral, medial and inferior.
- **Three borders:** supero-medial, infero-lateral and infero-medial
- Fissures or sulci divide each cerebral hemisphere into a number of lobes, named for the cranial bones that lie over them.
- Five lobes: frontal, parietal, temporal , occipital and limbic lobe.
- There are many sulci are found but only 3 sulci will be mentioned that determine the main 4 lobes:
    1. The **central sulcus**: a vertical sulcus separates the frontal lobe anteriorly from the parietal lobe posteriorly.
    2. The **lateral sulcus:** a horizontal sulcus separates the temporal lobe inferiorly from both frontal &parietal lobes superiorly.
    3. The **parieto-occipital sulcus:** it limits the occipital lobe posteriorly from the parietal lobe anteriorly.



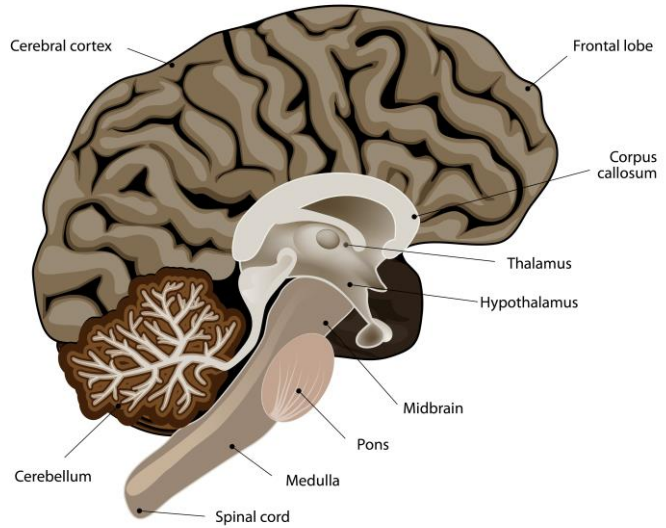
IMPORTANT CEREBRAL CORTICAL AREAS

- The primary somatic sensory area
  - located in the parietal lobe posterior to the central sulcus, allows to recognize pain, differences in temperature, or a light touch.
- The primary motor area
  - located in the frontal lobe anterior to the central sulcus, consciously move our skeletal muscles.
- The motor speech area (Broca's area)
  - found at the base of the precentral gyrus (the gyrus anterior to the central sulcus).
- Sensory speech area
  - located at the junction of the temporal, parietal, and occipital lobes, allows you to sound out words.



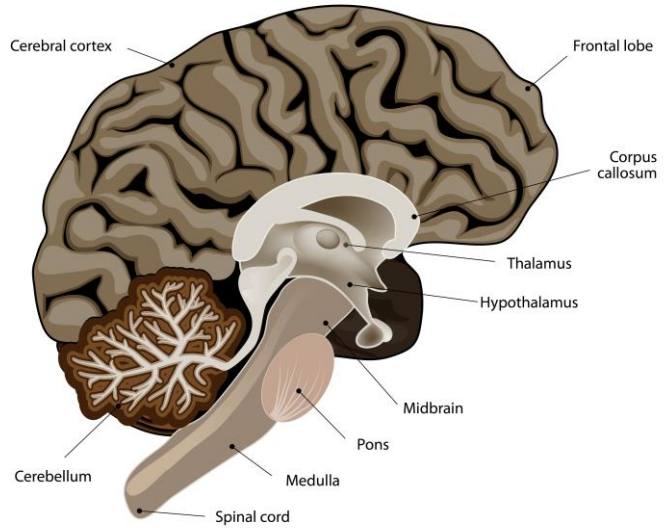
DIENCEPHALON

- It is part of the cerebrum on the medial aspect of each hemisphere. It includes:
- **The Thalamus:**
  - Large ovoid grey mass of specific nuclei and acts as a gateway for the cerebral cortex.
  - Relays sensory impulses to cerebral cortex.
  - Relays impulses between cerebral motor cortex and lower motor centers.
  - Involved in memory.



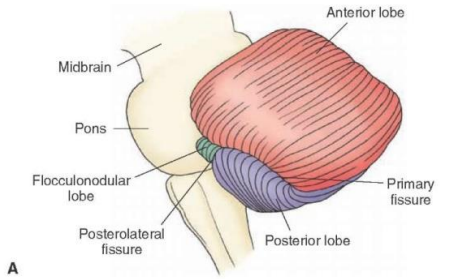
DIENCEPHALON

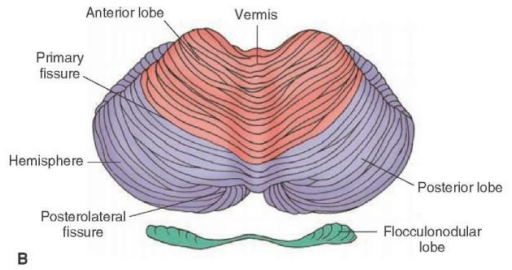
- **The Hypothalamus**
  - It is the part that lies below the thalamus.
  - It is the chief integration center of autonomic (involuntary) nervous system.
  - Regulates body temperature, food intake, water balance, and thirst.
  - Regulates hormonal output of anterior pituitary gland and acts as an endocrine organ (producing ADH and oxytocin).
  - The third ventricle lies between the two thalami.

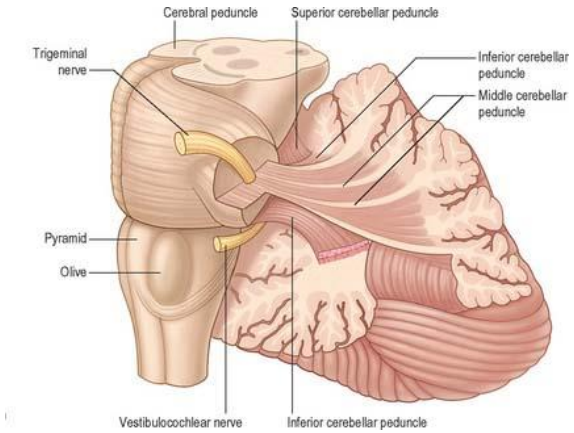


CEREBELLUM

- Formed of two cerebellar hemispheres, connected by median **vermis**.
- Control balance.
- Provides precise timing for skeletal muscle activity and coordination of body movements.
- It has an apparent connections with the brain stem elements via three peduncles:
  - **Superior peduncle:** connects the mid brain with cerebellum.
  - **Middle peduncle:** connects the pons with cerebellum.
  - **Inferior peduncle:** connects the medulla with cerebellum.

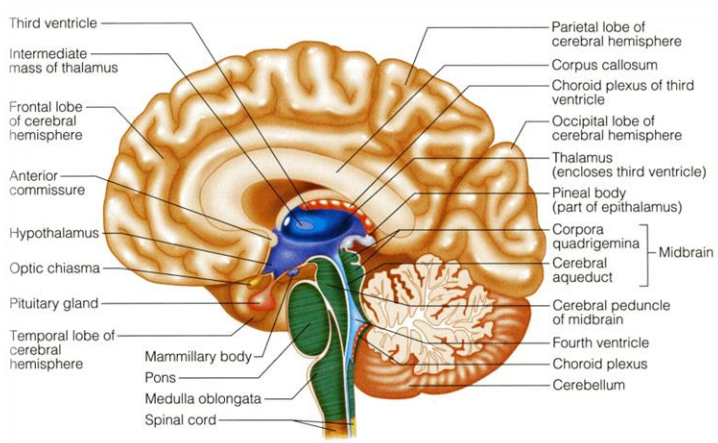


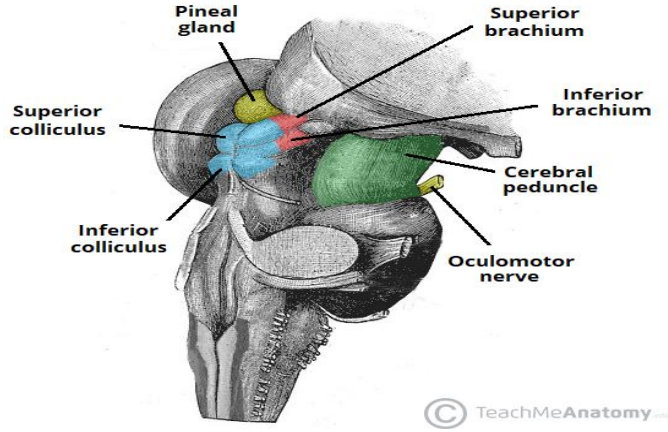




BRAINSTEM

- It is the junctional part between the cerebrum superiorly, cerebellum posteriorly and spinal cord inferiorly.
- It is 3 inches (approximately 7.5 cm).
- Its main parts are the mid brain, the pons and medulla.
- The fourth ventricle lies posterior to the pons and medulla and anterior to the cerebellum.
- The midbrain is composed primarily of two bulging fiber tracts (the cerebral peduncles).
- Dorsally located four rounded protrusions called the corpora quadrigemina and has a tiny canal (cerebral aqueduct) which give passage to CSF.

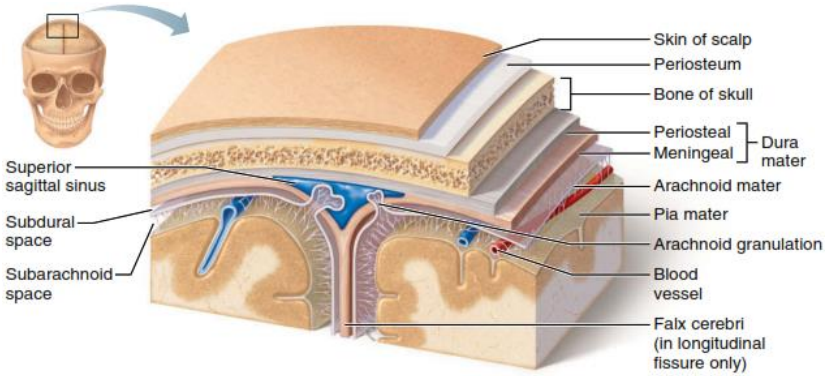


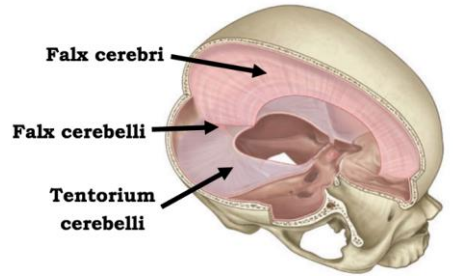


MENINGES

- They are 3 connective tissue membranes covering and protecting the CNS structures meninges.

1. Dura mater
    - The outermost tough layer.
    - One of its layers is attached to the inner surface of the skull (periosteal layer).
    - The other, called the meningeal layer which forms the outermost covering of the brain and continues as the dura mater of the spinal cord.
    - It encloses Dural venous sinuses that collect venous blood, such as the superior sagittal sinus.
    - It forms folds that attaches the brain to the cranial cavity; falx cerebri and the tentorium cerebelli, separate the cerebellum from the cerebrum.

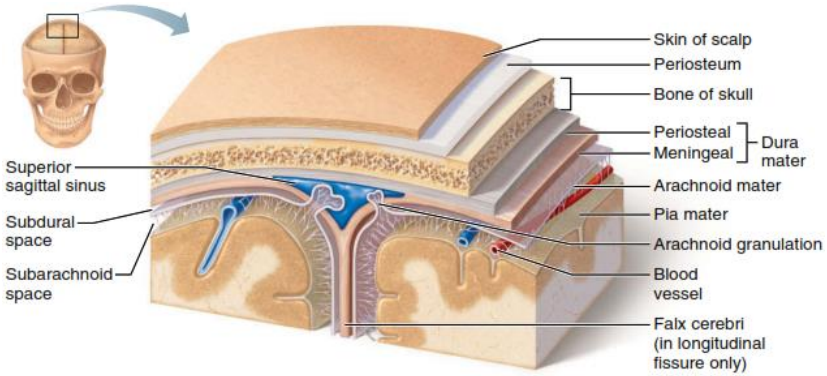


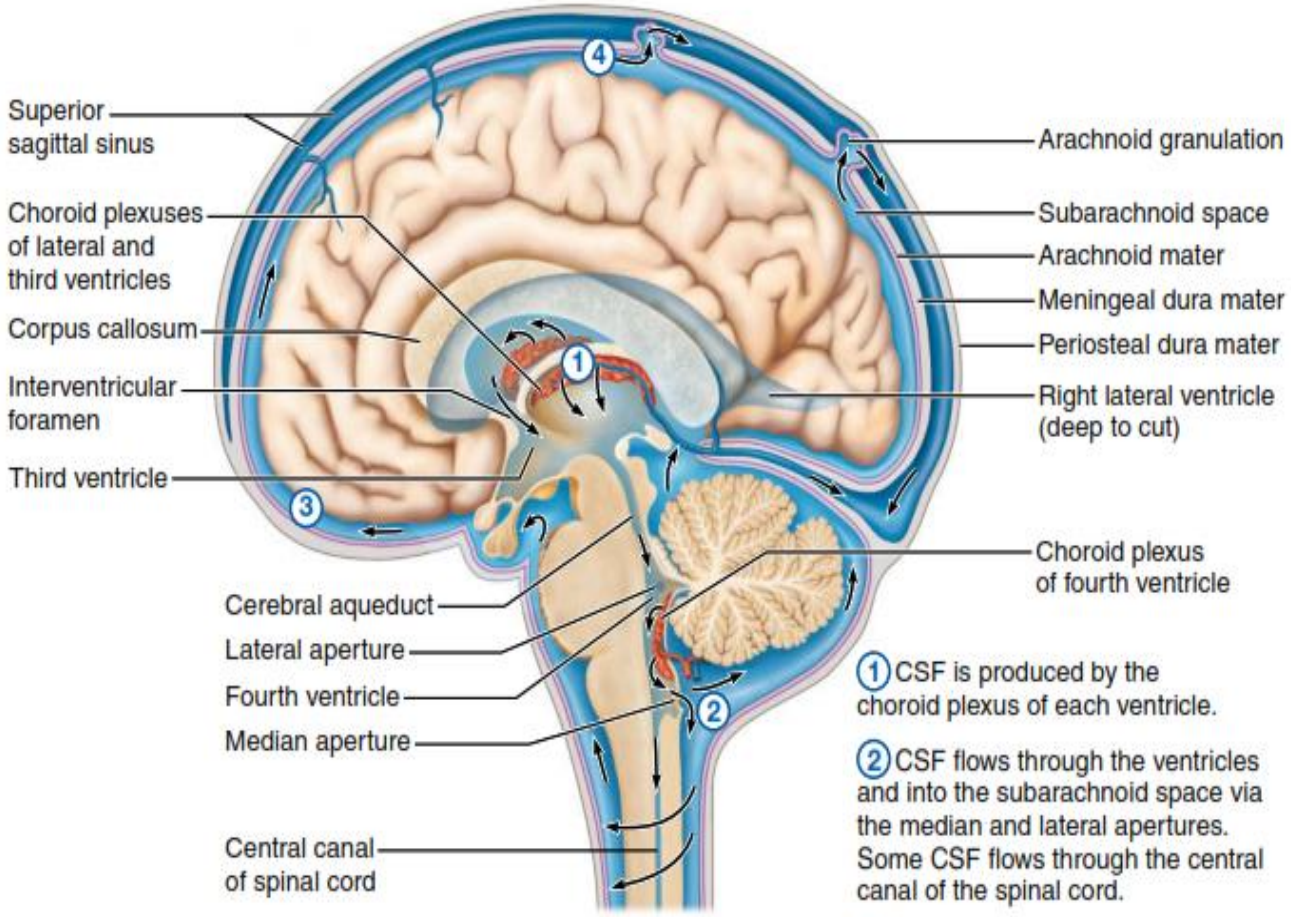


MENINGES

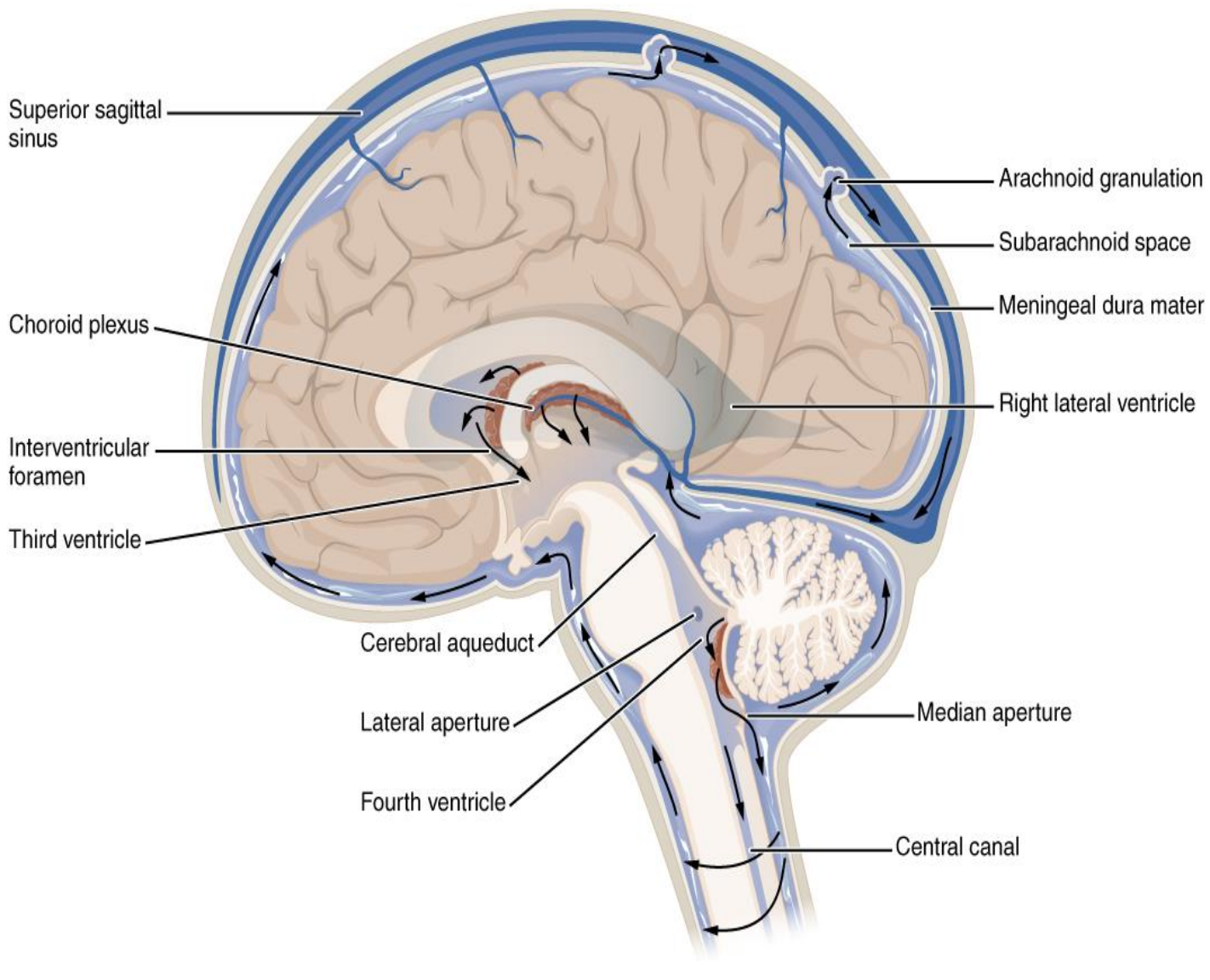
1. **Arachnoid mater:** The middle meningeal layer
2. **Pia mater:** the delicate inner layer that clings tightly to the surface of the brain and spinal cord.

- The **subarachnoid space** (between arachnoid and pia) is filled with cerebrospinal fluid, which absorbed into the venous blood in the dural sinuses through the arachnoid granulations that protrude through the dura mater.



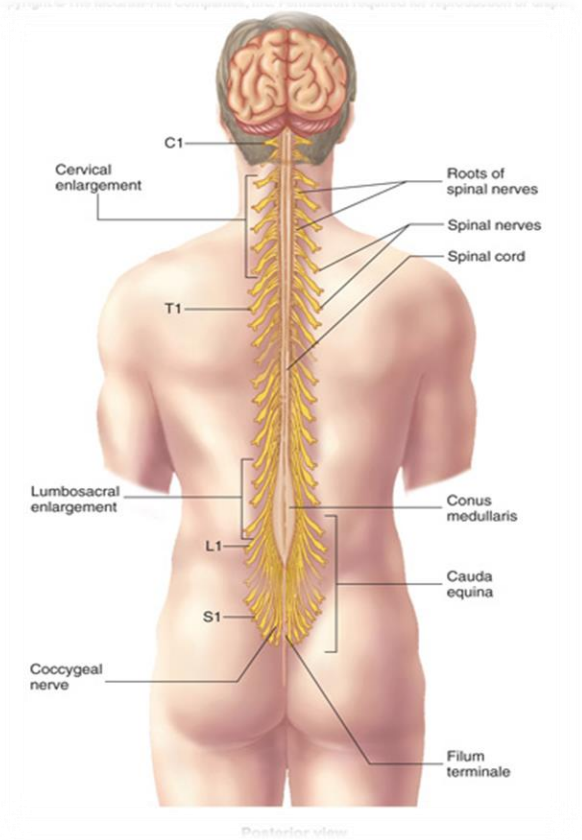


(c) CSF circulation



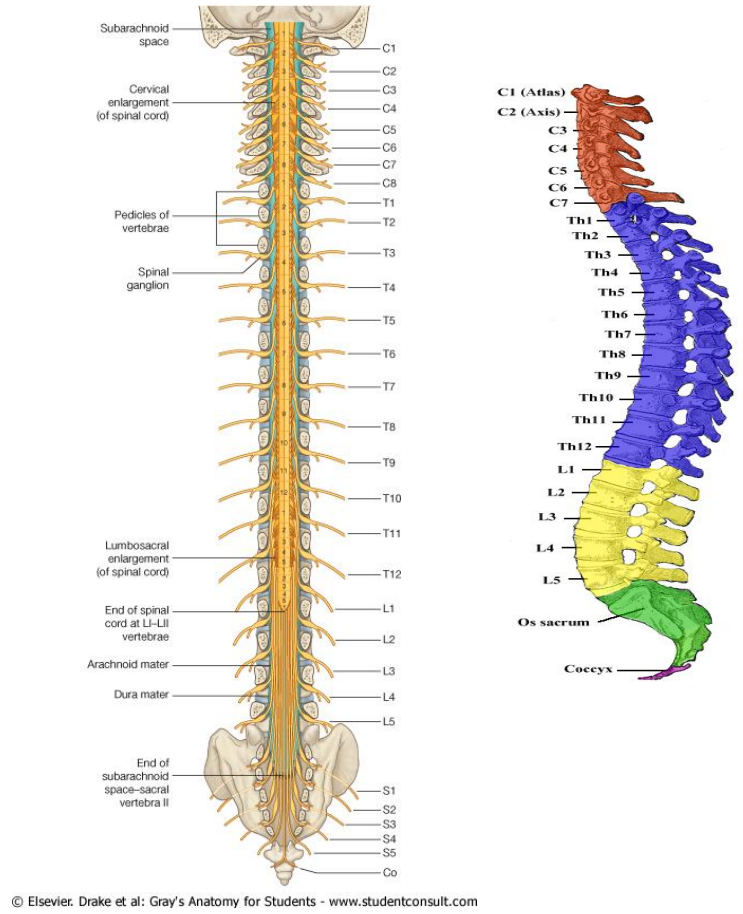
SPINAL CORD

- It represents the lower part of CNS, 17 inches (42 cm) long, continuation of the brain stem (Medulla).
- Enclosed within the vertebral column, extends from the foramen magnum of the skull to and ends at Lumbar 1 vertebra in adults and at Lumbar 3 in infants.
- It is surrounded by the 3 meningeal sheaths: dura mater, arachnoid mater and lastly the inner pia mater.
- It is cylindrical in shape having two enlargements:
    - Cervical one, opposite upper limb.
    - Lumbar one, opposite lower limb.
- Ends inferiorly in tapering end called c**onus medullaris**, and from its apex extends the **filum terminale**, till the back of 1st coccygeal vertebra.



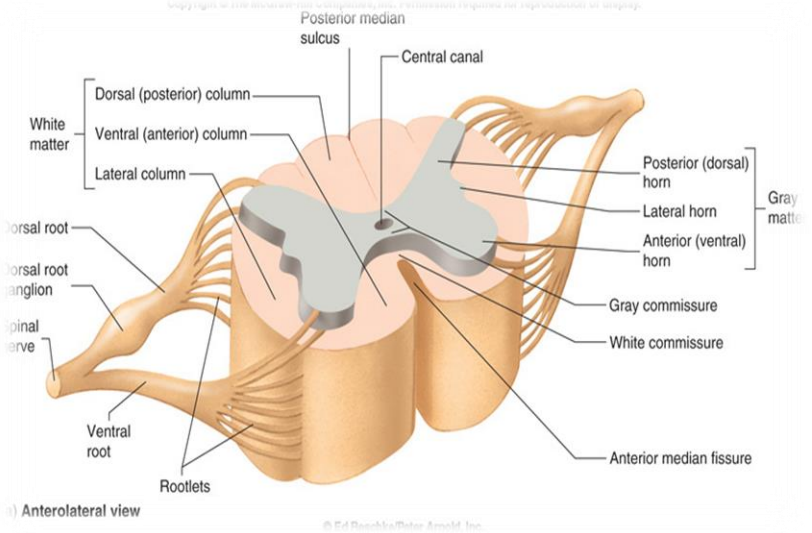
SPINAL CORD

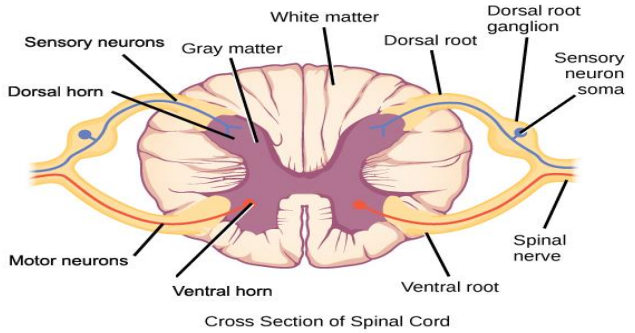
- On each lateral aspect the roots of the spinal nerves are attached.
- There are 31 pairs of spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and one coccygeal).
- Each spinal nerve exits from the intervertebral foramen, except the lower lumbar and sacral nerves that form a collection like the horse's tail, the **cauda equina.**



GRAY MATTER

- Gray matter of the spinal cord looks like a butterfly or the letter H in cross section.
  - The two posterior projections are the **dorsal horns**, or posterior horns; contain cell bodies of the sensory neurons.
  - The two anterior projections are the **ventral horns**, or anterior horns, contain cell bodies of the motor neurons.
  - The gray matter surrounds the central canal of the cord, which contains CSF.
- Fibers enter the cord by the dorsal root (purely sensory), its cell bodies are found in an enlarged area called the dorsal root ganglion, which if damaged, sensation from the body area served
- The ventral horns of the gray matter send their axons through the ventral root (purely motor).
- The dorsal and ventral roots fuse to form the spinal nerves.

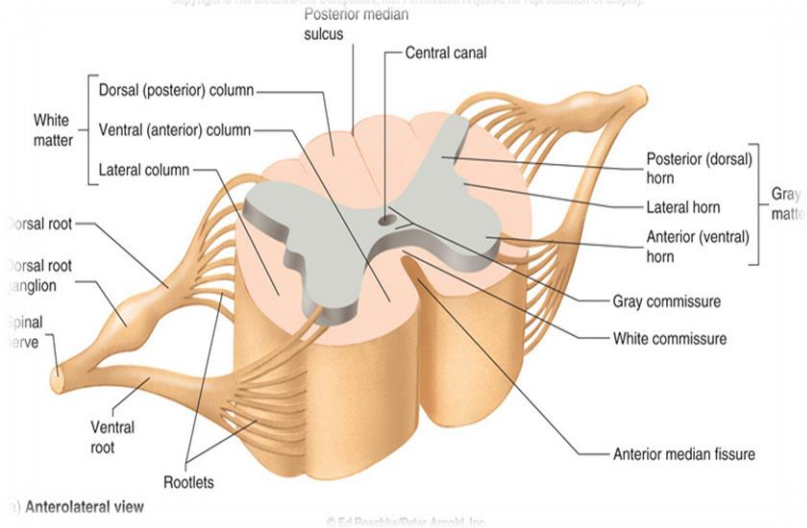




Cross Section of Spinal Cord

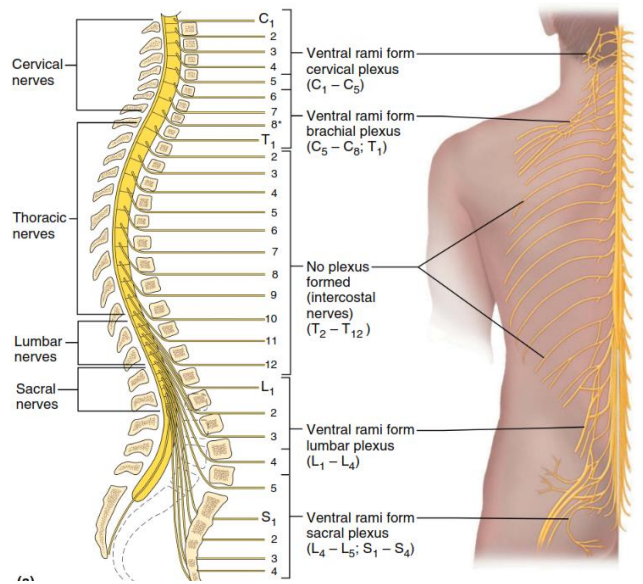
WHITE MATTER

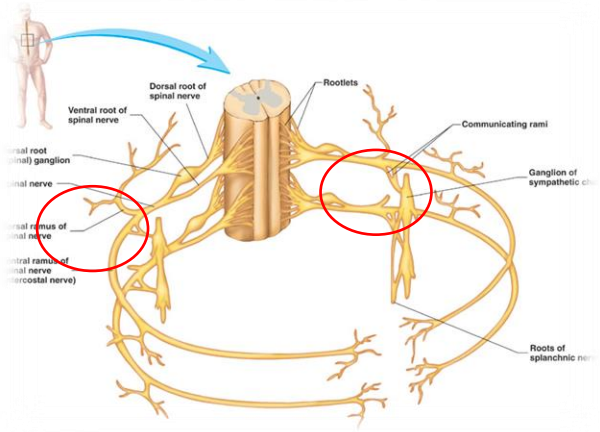
- Composed of myelinated fiber tracts.
- Some running to higher centers in the brain (Ascending Tracts) and some traveling from the brain to the cord (Descending Tracts).
- White matter on each side of the cord is divided into three regions:
    - dorsal column.
    - lateral column.
    - ventral column.



SPINAL NERVE

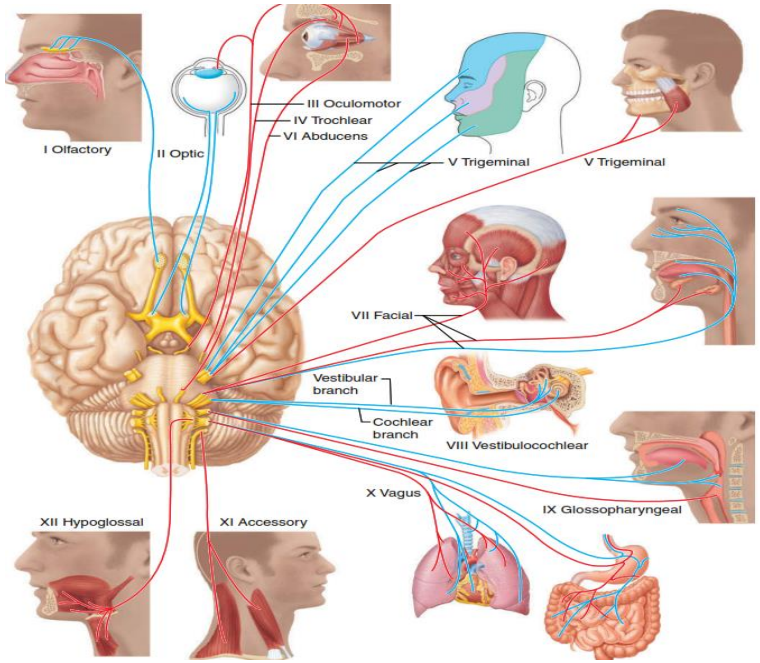
- Spinal nerve only about ½ inch long, and it divides into the dorsal ramus and ventral ramus.
- Rami contain both motor and sensory fibers.
- Dorsal rami supply the back
- The ventral rami of all other spinal nerves form complex networks of nerves called **plexuses**, which serve the motor and sensory needs of the limbs (Cervical, Brachial, Lumbar, Sacral).





CRANIAL NERVE

- The 12 pairs of cranial nerves primarily serve the head and neck.
- Only one pair (the vagus nerves) extends to the thoracic and abdominal cavities, Vagus N. considered the longest one.



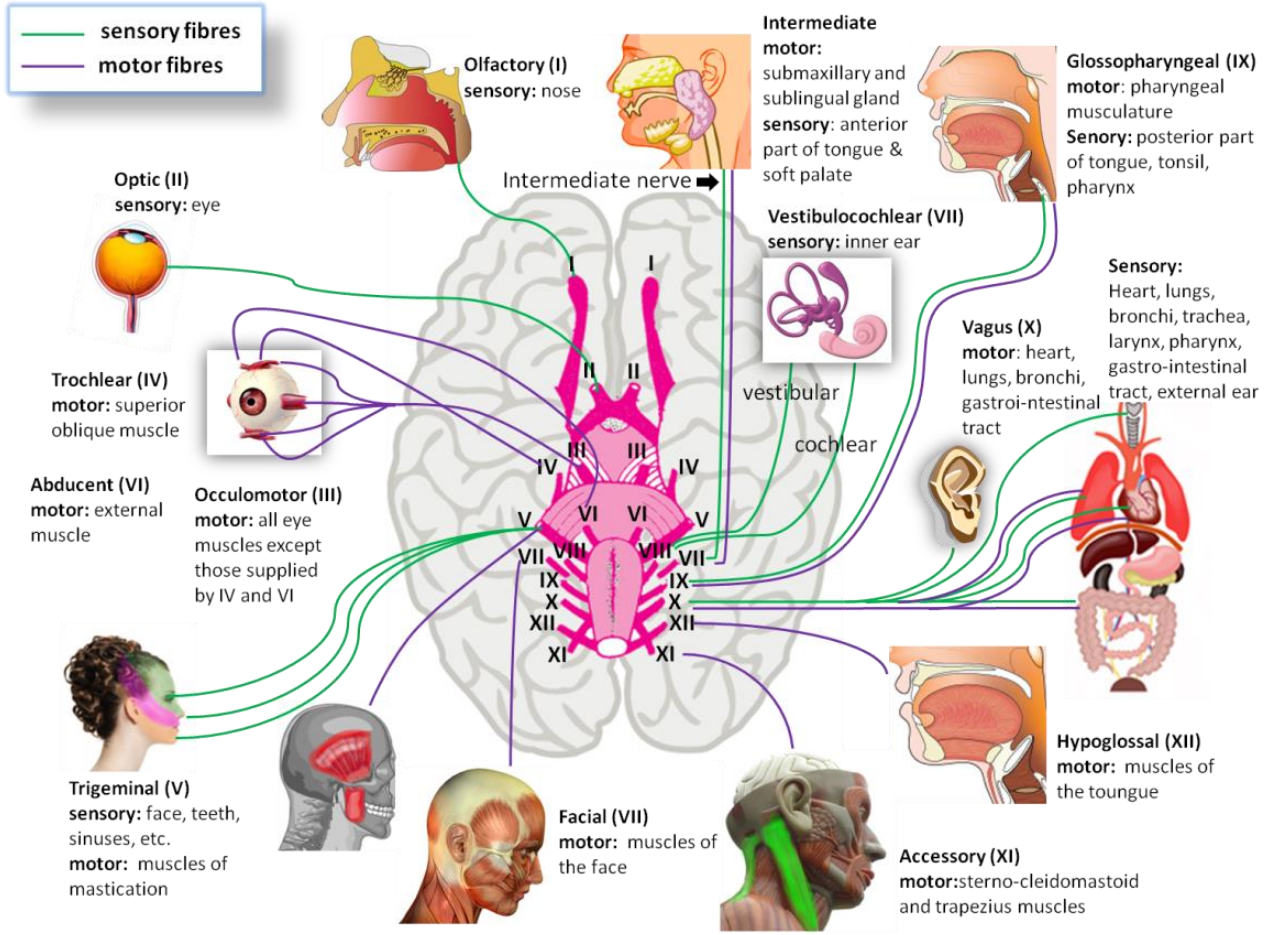


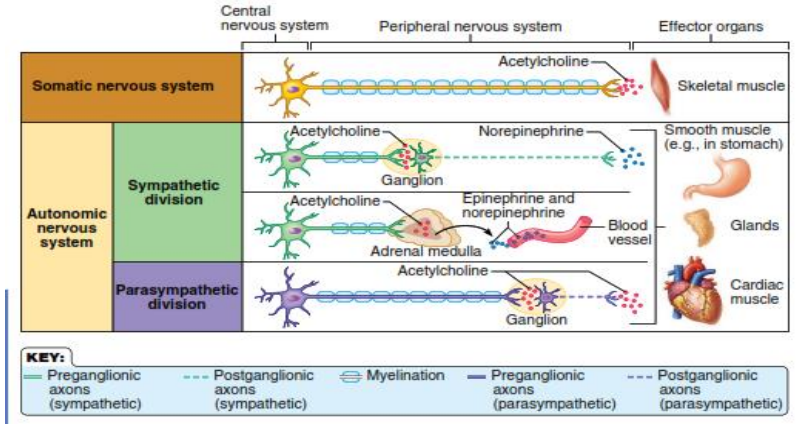
Table 7.2 **The Cranial Nerves**

Name/number	Origin/course	Function	Test
I. Olfactory	Fibers arise from olfactory receptors in the nasal mucosa and synapse with the olfactory bulbs (which, in turn, send fibers to the olfactory cortex)	Purely sensory; carries impulses for the sense of smell	Subject is asked to sniff and identify aromatic substances, such as oil of cloves or vanilla
II. Optic	Fibers arise from the retina of the eye and form the optic nerve. The two optic nerves form the optic chiasma by partial crossover of fibers; the fibers continue to the optic cortex as the optic tracts	Purely sensory; carries impulses for vision	Vision and visual field are tested with an eye chart and by testing the point at which the subject first sees an object (finger) moving into the visual field; eye interior is viewed with an ophthalmoscope
III. Oculomotor	Fibers run from the midbrain to the eye	Supplies motor fibers to four of the six muscles (superior, inferior, and medial rectus, and inferior oblique) that direct the eyeball; to the eyelid; and to the internal eye muscles controlling lens shape and pupil size	Pupils are examined for size, shape, and size equality; pupillary reflex is tested with a penlight (pupils should constrict when illuminated); eye convergence is tested, as is the ability to follow moving objects
IV. Trochlear	Fibers run from the midbrain to the eye	Supplies motor fibers for one external eye muscle (superior oblique)	Tested in common with cranial nerve III for the ability to follow moving objects
V. Trigeminal	Fibers emerge from the pons and form three divisions that run to the face	Conducts sensory impulses from the skin of the face and mucosa of the nose and mouth; also contains motor fibers that activate the chewing muscles	Sensations of pain, touch, and temperature are tested with a safety pin and hot and cold objects; corneal reflex tested with a wisp of cotton; motor branch tested by asking the subject to open mouth against resistance and move jaw from side to side
VI. Abducens	Fibers leave the pons and run to the eye	Supplies motor fibers to the lateral rectus muscle, which rolls the eye laterally	Tested in common with cranial nerve III for the ability to move each eye laterally

Name/number	Origin/course	Function	Test
VII. Facial	Fibers leave the pons and run to the face	Activates the muscles of facial expression and the lacrimal and salivary glands; carries sensory impulses from the taste buds of anterior tongue	Anterior two-thirds of tongue is tested for ability to taste sweet, salty, sour, and bitter substances; subject is asked to close eyes, smile, whistle, etc.; tearing of eyes is tested with ammonia fumes
VIII. Vestibulocochlear	Fibers run from the equilibrium and hearing receptors of the inner ear to the brain stem	Purely sensory; vestibular branch transmits impulses for the sense of balance, and cochlear branch transmits impulses for the sense of hearing	Hearing is checked by air and bone conduction, using a tuning fork
IX. Glossopharyngeal	Fibers emerge from the medulla and run to the throat	Supplies motor fibers to the pharynx (throat) that promote swallowing and saliva production; carries sensory impulses from taste buds of the posterior tongue and from pressure receptors of the carotid artery	Gag and swallowing reflexes are checked; subject is asked to speak and cough; posterior tongue may be tested for taste
X. Vagus	Fibers emerge from the medulla and descend into the thorax and abdominal cavity	Fibers carry sensory impulses from and motor impulses to the pharynx, larynx, and the abdominal and thoracic viscera; most motor fibers are parasympathetic fibers that promote digestive activity and help regulate heart activity	Tested in common with cranial nerve IX because they both serve muscles of the throat
XI. Accessory	Fibers arise from the superior spinal cord (C_1–C_5)* and travel to muscles of the neck and back	Mostly motor fibers that activate the sternocleidomastoid and trapezius muscles	Sternocleidomastoid and trapezius muscles are checked for strength by asking the subject to rotate head and shrug shoulders against resistance
XII. Hypoglossal	Fibers run from the medulla to the tongue	Motor fibers control tongue movements; sensory fibers carry impulses from the tongue	Subject is asked to stick out tongue, and any position abnormalities are noted

AUTONOMIC NERVOUS SYSTEM

- The autonomic nervous system, consist of:
- **The preganglionic neuron** (first motor neuron).
    - It is in the brain or spinal cord.
    - The preganglionic "axon before the ganglion" leaves the CNS to form a synapse with the second motor neuron in a ganglion outside the CNS.
- **Postganglionic axon** (axon of the ganglionic neuron).
    - It extends to the organ, and it serves the autonomic nervous system (sympathetic and the parasympathetic).



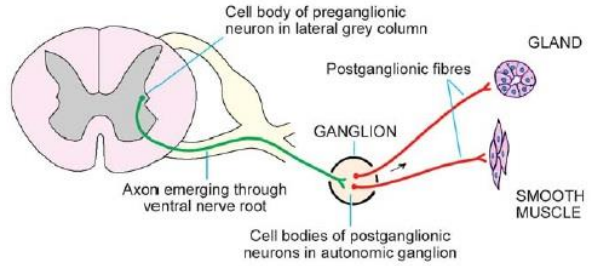
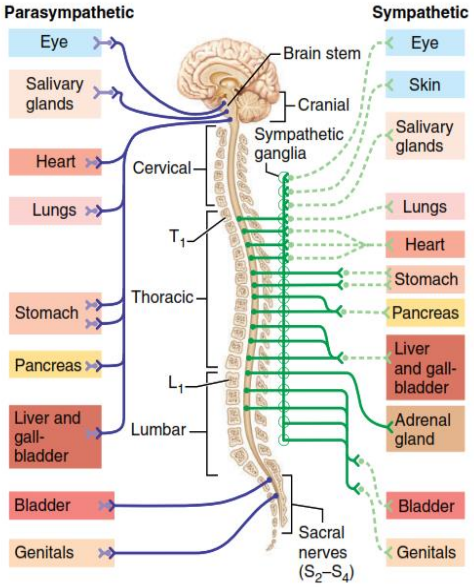
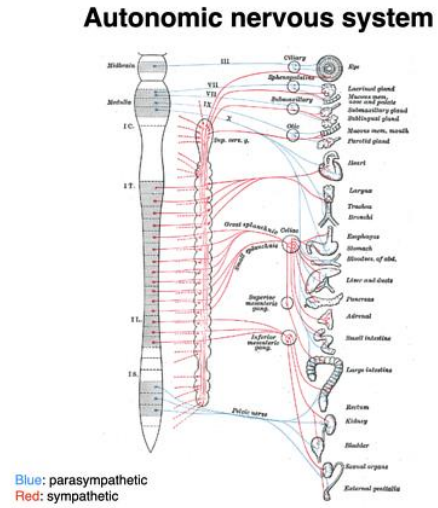


Fig. 3.2. Scheme to show the typical arrangement of a general visceral efferent neuron.

SYMPATHETIC NERVOUS SYSTEM

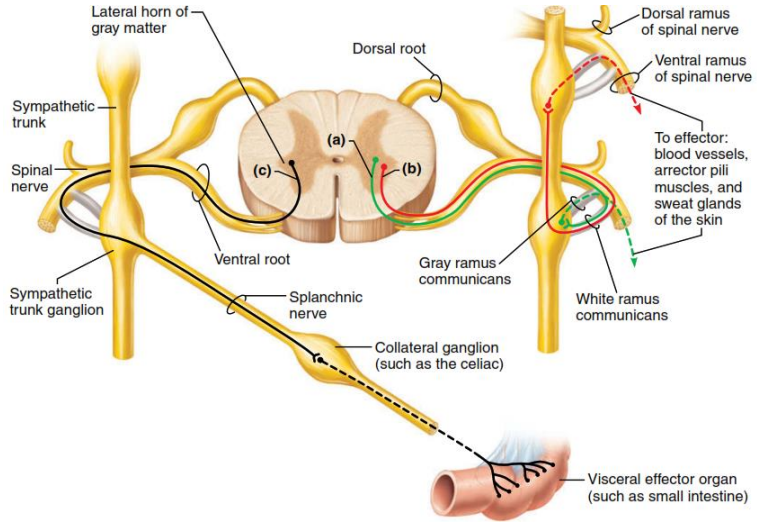
- **Sympathetic outflow** (thoracolumbar outflow):
  - Preganglionic neurons are located in the lateral gray columns (horns) of the spinal cord from the **first** thoracic segment (T1) to the **second** lumbar segment (L2).
  - Postganglionic neurons are located in one of the following sites:
    - Sympathetic trunks (paravertebral ganglia).
    - Prevertebral ganglia such as celiac and the superior and inferior mesenteric ganglia.





SYMPATHETIC PATHWAY

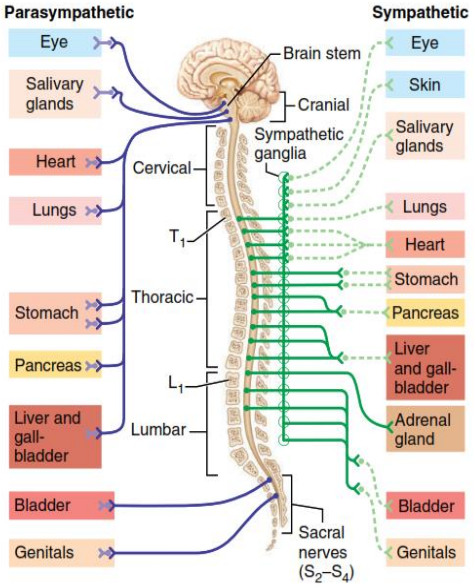
- The preganglionic axons leave the cord in the ventral root, enter the spinal nerve, and then pass through a ramus communicans, or small communicating branch, to enter a sympathetic trunk ganglion OR pass through the ganglion without synapsing and form splanchnic nerves to synapse with prevertebral collateral ganglia.

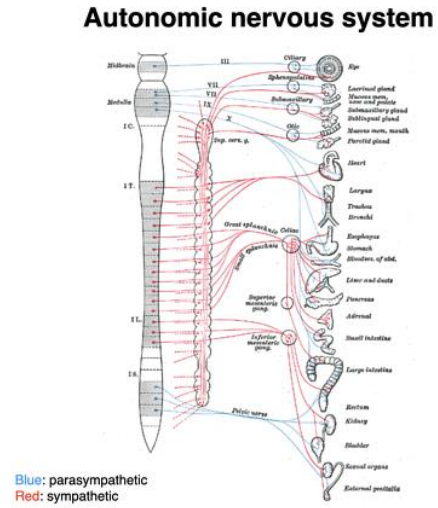


PARASYMPATHETIC NERVOUS SYSTEM

- Parasympathetic outflow (craniosacral):

1. The preganglionic neurons of are located in:
    - Nuclei in cranial nerves III, VII, IX, and X
    - Gray matter of the 2nd, 3rd, and 4th sacral segments of the spinal cord.
2. The postganglionic neurons
    - The are located in autonomic ganglia located close to the viscera they innervate or in autonomic ganglia associated with the III, VII, IX, and X cranial nerves.
    - Postganglionic parasympathetic fibers are short in length compared to sympathetic postganglionic fibers.

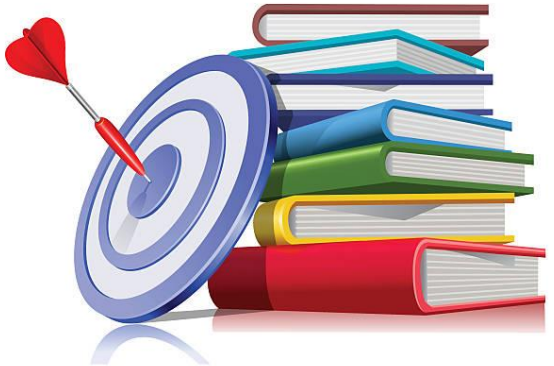




PHYSIOLOGY

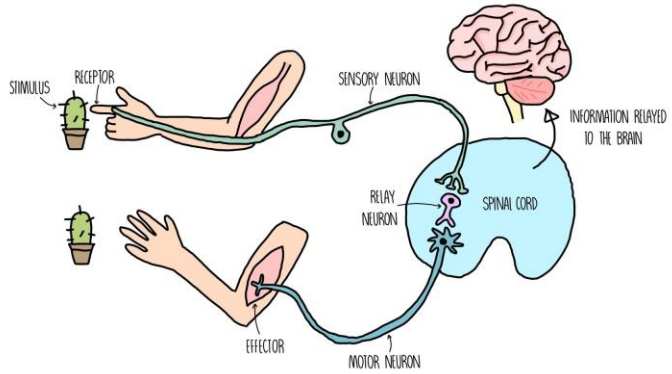
OBJECTIVES

- Classify neurons according to structure and function.
- List the types of general sensory receptors and describe their functions.
- Describe the events that lead to the generation of a nerve impulse and its conduction from one neuron to another.
- Describe the events of synaptic transmission.
- Define reflex arc and list its elements.
- Contrast the effect of the parasympathetic and sympathetic divisions on the following organs: heart, lungs, digestive system, blood vessels.
- Describe the major ascending and descending pathways between brain and spinal cord.



FUNCTIONS

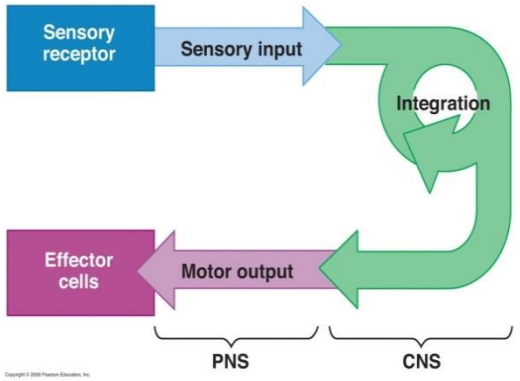
1. Maintenance of Homeostasis
    - The body's ability to maintain a relatively stable internal environment.
    - Nervous system, along with the endocrine system, is responsible for integration and control in the body.
    - Nervous system is capable of much more rapid and specific responses than the endocrine system.
2. The nervous system responsible for sensations.
3. The nervous system is also responsible for our perceptions, intellect, memories and emotions.

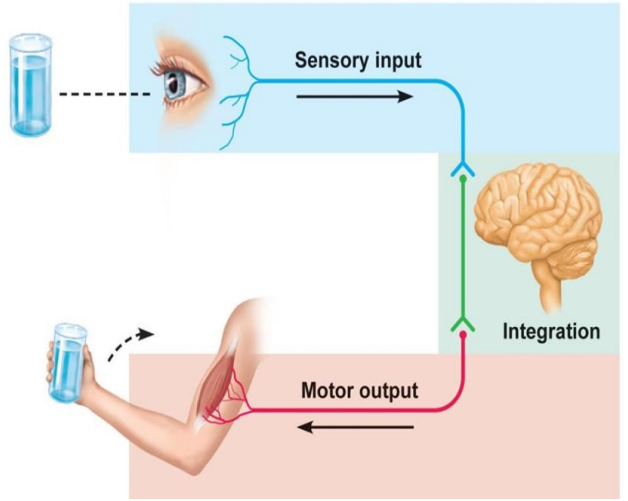


FUNCTIONS

4. The nervous system carries out the task of communication by performing three basic functions:

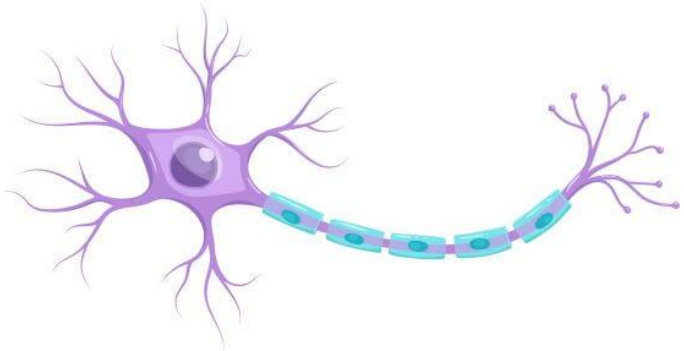
1. Receiving stimuli = sensory function
    - Sensory receptors gather information
    - Information is carried to the CNS
2. Deciding about stimuli = integrative function
    - Sensory information used to create:
        - Sensations
        - Memory
        - Thoughts
        - Decisions
3. Reacting to stimuli = motor function
    - Decisions are acted upon
    - Impulses are carried to effectors



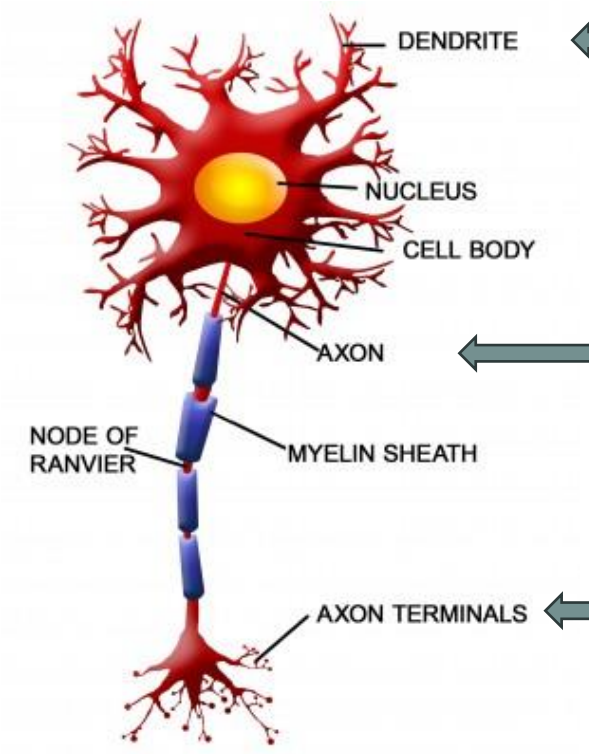


NEURONS (NERVE CELLS)

- Are specialized for internal communication.
- Are electrically excitable cells that are able to:
    - respond to stimuli by producing electrical signals.
    - rapidly conduct electrical signals to other cells throughout the body.



STRUCTURAL COMPONENTS OF A NEURON



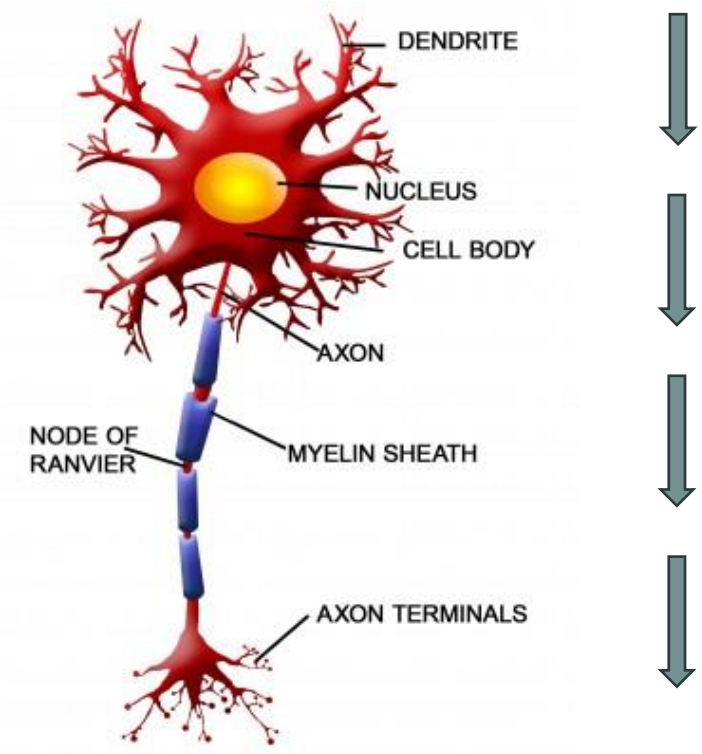
Dendrites receive signals

Cell body integrates signal sending towards the axon

Axon sends signal to axon terminals

Axon terminal passes signal onto another neuron, or a muscle or gland

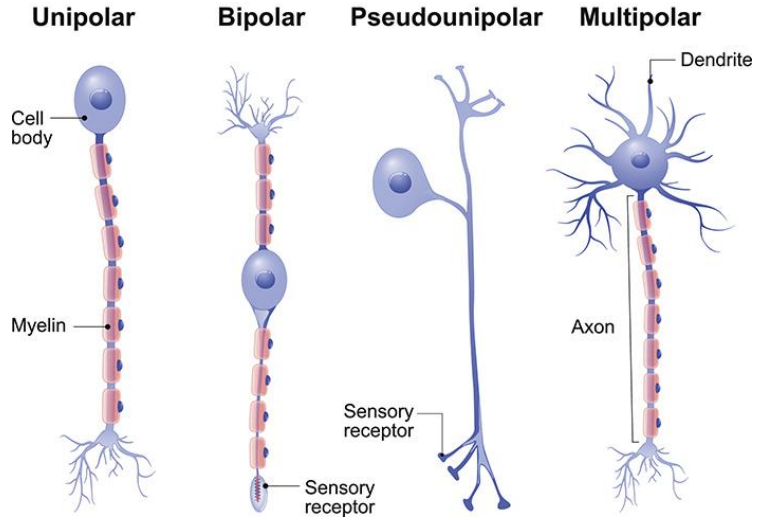
STRUCTURAL COMPONENTS OF A NEURON



Direction of Signal Transmission in the Nerve Cell

CLASSIFICATION OF NEURONS

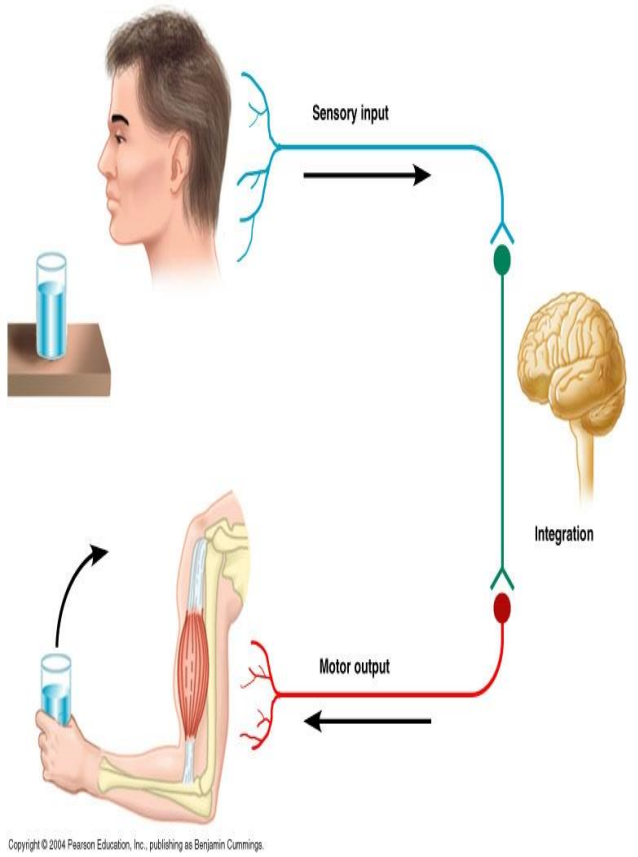
- Neurons can be classified according to their structure and function.
- Structurally neurons can be classified as:
    1. Multipolar : common in CNS
        - A multipolar neuron has the highest number of structures extending from the cell body. There is only one axon, but each cell has many dendrites, making it easier for the neuron to exchange information.
    2. Bipolar : rare
        - A bipolar neuron has two distinct structures extending from the cell body. One is an axon, and the other is a dendrite.
    3. Unipolar : common in PNS
        - A unipolar neuron has only one nerve process extending from the cell body.



FUNCTIONAL CLASSIFICATION OF NEURONS

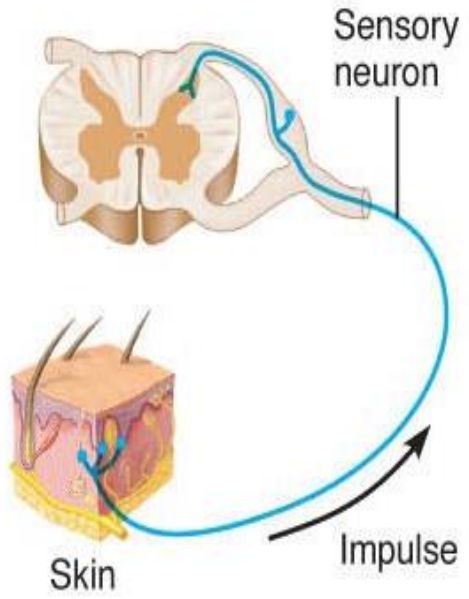
- Functionally neurons can be classified as:

1. ⟶ sensory neurons
2. ⟶ interneurons
3. ⟶ motor neurons



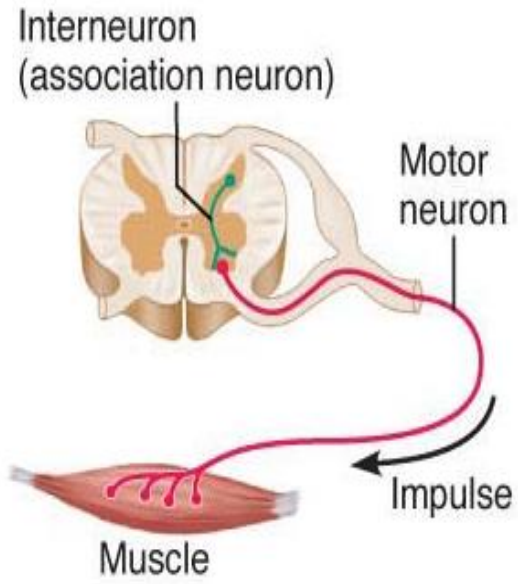
SENSORY NEURONS

- Form the sensory division of the PNS.
- Conduct sensory signals from receptors to the CNS.
- Are unipolar in structure.
- Their dendrites can act as sensory receptors.



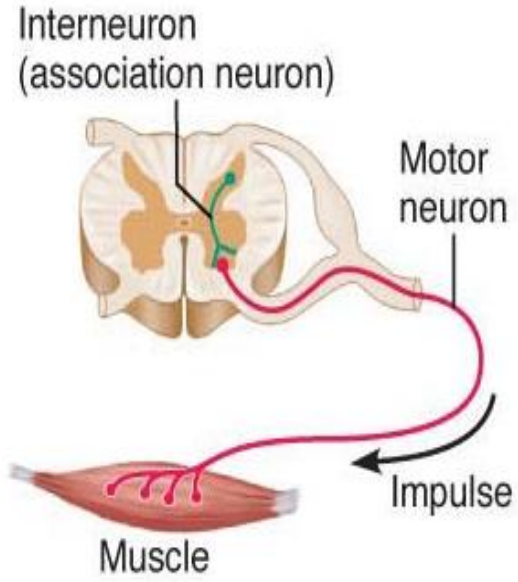
INTERNEURONS

- Make up 99% of the neurons in the body.
- Located in, and conduct signals around the CNS.
- Perform the integrative function of the nervous system.
- Mainly multipolar in structure.



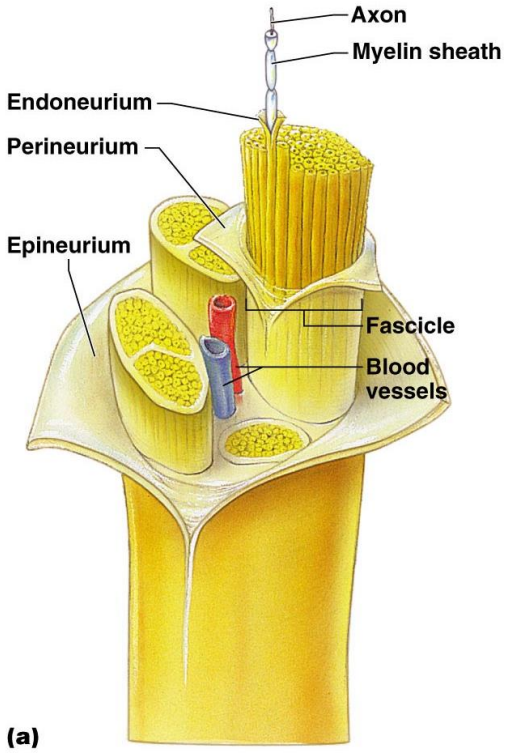
MOTOR NEURONS

- Form the motor division of the PNS.
- Carry motor signals away from the CNS to an effector muscle or gland.
- Mainly multipolar in structure.



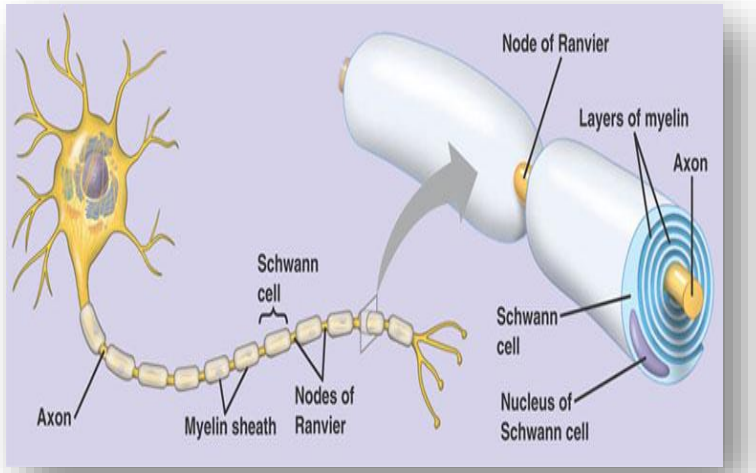
STRUCTURE OF A NERVE

- Connective tissue coverings include:
  - **Endoneurium:** loose connective tissue that surrounds each individual axon.
  - **Perineurium:** rough connective tissue that bundles axons into fascicles.
  - **Epineurium:** tough fibrous connective tissue around a nerve.



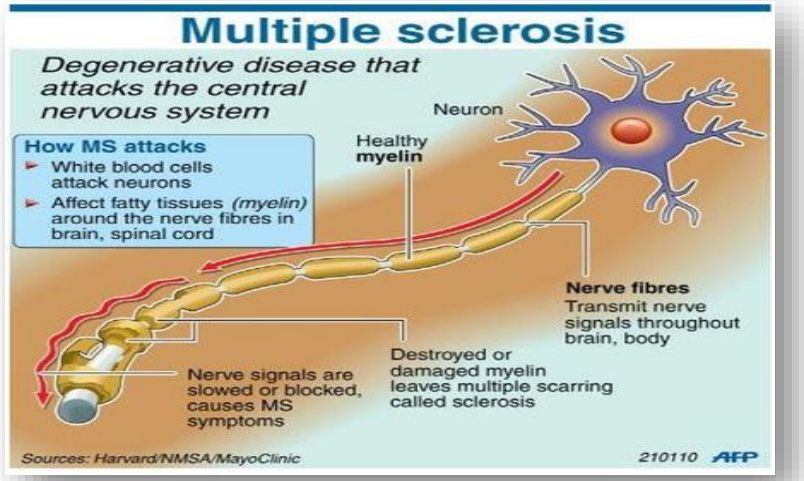
MYELIN

- Axons may be covered with a segmented myelin sheath.
  - produced by Schwann cells and oligodendrocytes.
  - segments are separated by gaps called Nodes of Ranvier.
- Q: If one neuron transmits a nerve impulse at the rate of 1m/s and another neuron conducts at the rate of 120 m/s. **Which neuron has the myelinated axon?**



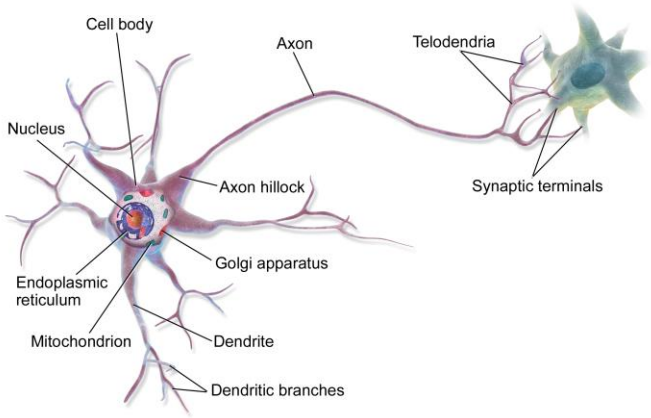
FUNCTIONS OF MYELIN SHEATH

- Protection of the axon.
- Electrically insulating fibers from one another.
- Increasing the speed of nerve impulse transmission with a segmented myelin sheath.
- Repairing Damaged Nerves
    - Nerves in the PNS are surrounded by a thin membrane called the **neurilemma** which helps to regenerate damaged axons.
    - Nerves in CNS lack **neurilemmas** and cannot be repaired.
- Multiple Sclerosis
    - immune system (T cells) attacks myelin coating.
    - loss of signal.



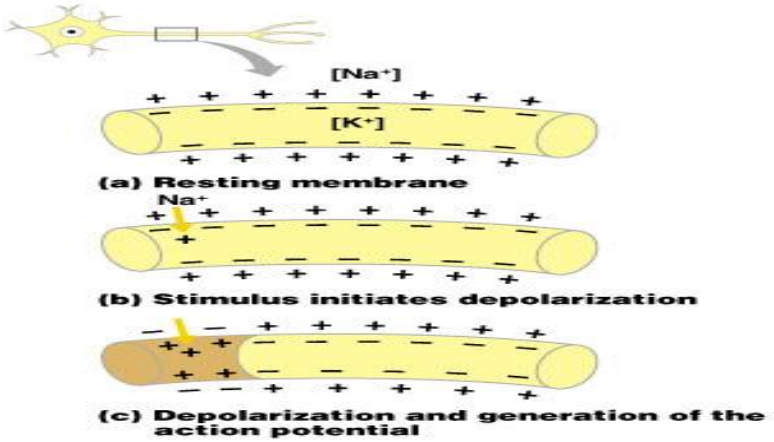
NEURONS CHARACTERISTICS

- **Irritability:** ability to respond to stimulus and convert to nerve impulse.
- **Conductivity:** transmit impulse (action potential) to other neurons, muscles, or glands.



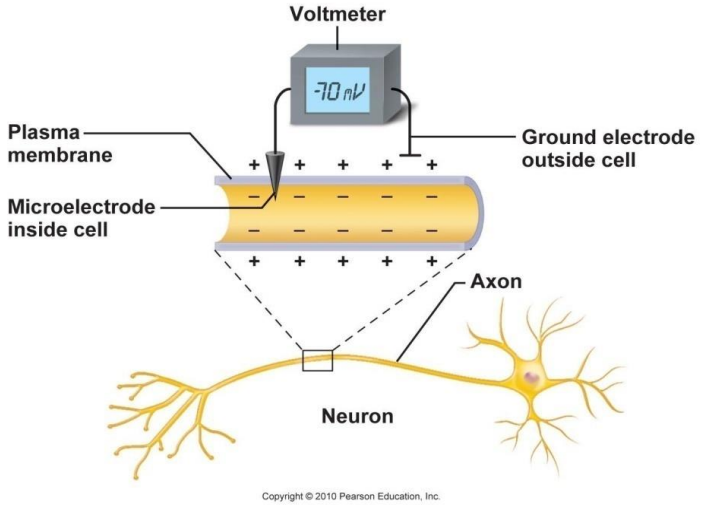
NEURONS FUNCTION (PHYSIOLOGY)

- **What is a nerve impulse?**
- Transmitted electrical charge
  - An impulse that travels along an axon is an ACTION POTENTIAL



THE RESTING MEMBRANE POTENTIAL

- It is the difference in charge between inside/outside of the neuron during the resting state **= -70 mV**
    - The minus sign indicates that the inside of a cell is negative relative to the outside.
- Na+ outside cell, K+ inside cell.
- Resulting in a difference in voltage across the cell membrane.
- Causes of resting membrane potential:
    - Selective permeability.
    - Sodium potassium pump.
- Changes in membrane potential lead to (action potential).

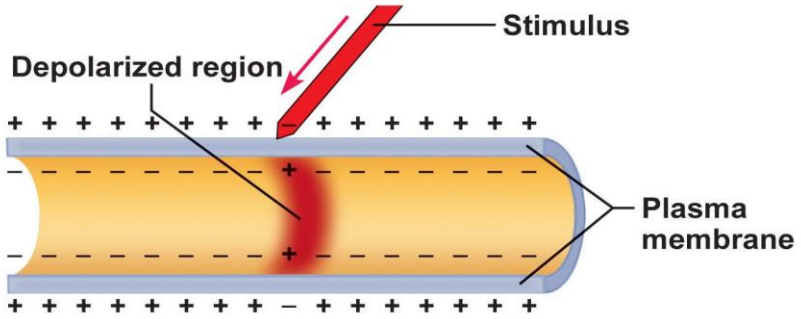


Na^+

K^+

DEPOLARIZATION

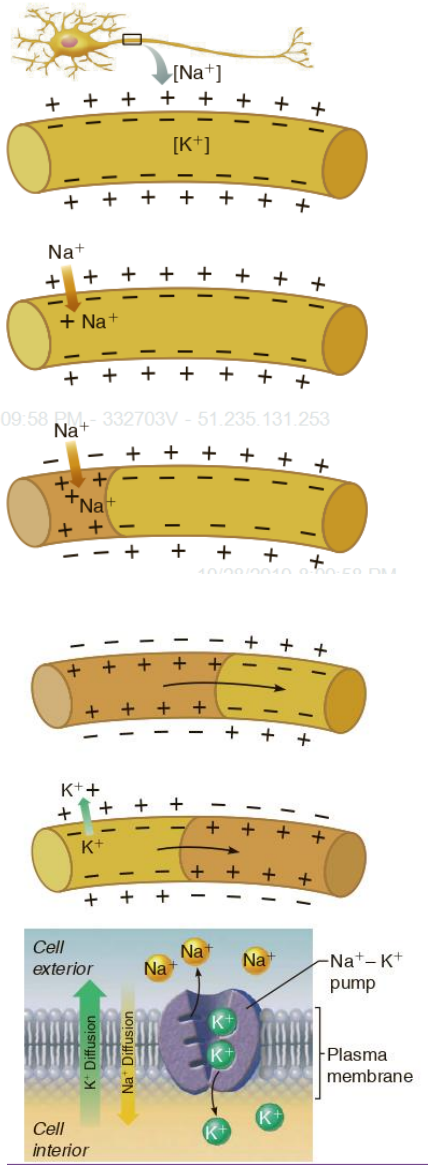
- Depolarization means Reversal of the RMP from –70 mV to +30mV.
- A stimulus depolarizes the neuron's membrane.
- A depolarized membrane allows sodium (Na+) to flow inside the membrane.
- The exchange of ions initiates an action potential in the neuron.
- Depolarization activates neuron to transmit an action potential (nerve impulse).



(a) Depolarization: A small patch of the membrane (red area) has become depolarized.

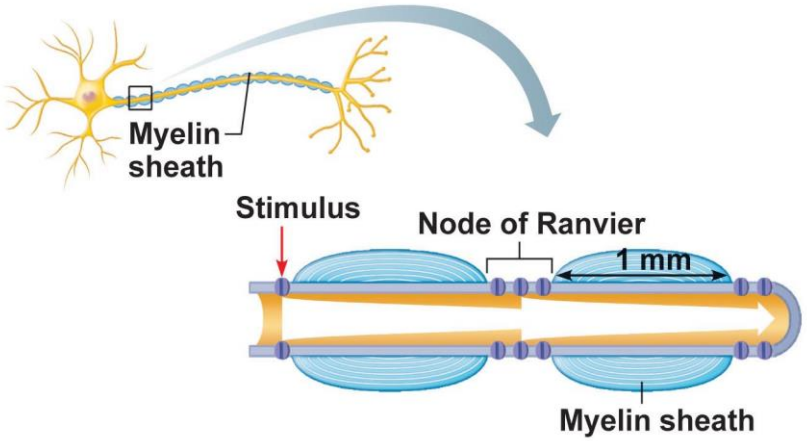
REPOLARIZATION

- Repolization means Return of the RMP to –70 mV.
- **K**+ diffuses out → repolarization of membrane.



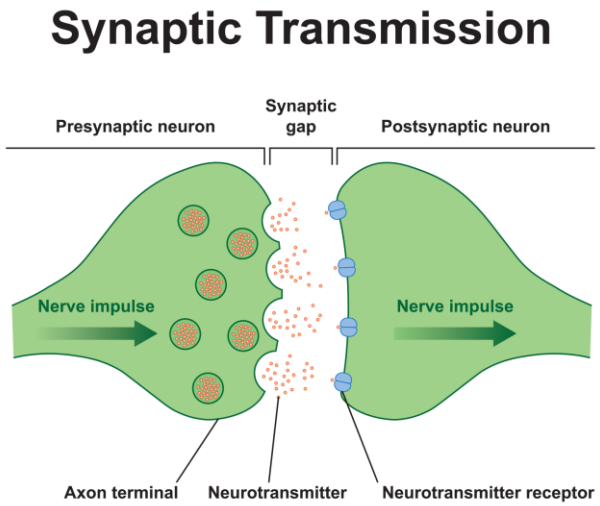
NERVE IMPULSE PROPAGATION

- In unmyelinated nerves: AP once begun, its sequential events spread along the entire neuronal membrane, in one direction.
- In myelinated nerves: impulses travel faster by Saltatory conduction.
- In Saltatory conduction: electrical signal jumps from node to node along myelinated axon (30x faster!).



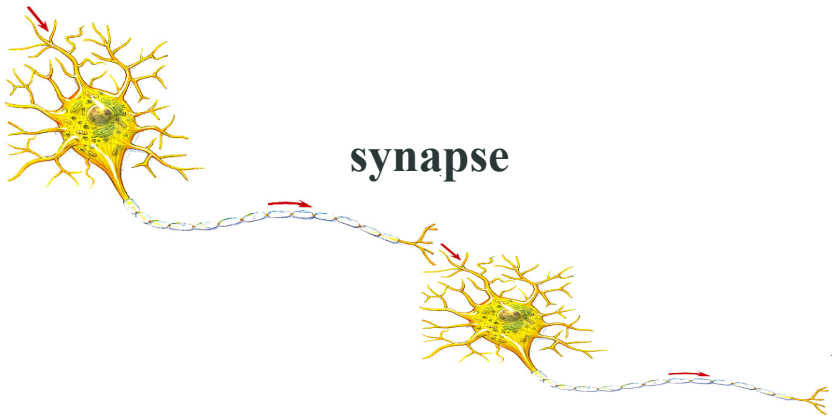
SYNAPTIC TRANSMISSION

- Impulses are able to cross the synapse to another nerve.
- Action potential reaches axon terminal → vesicles release neurotransmitters (NT) into synaptic cleft.
- NT diffuse across synapse → bind to receptors of next neuron.
- The dendrite of the next neuron has receptors that are stimulated by the neurotransmitter.
- Transmission of a nerve impulse = electrochemical event.



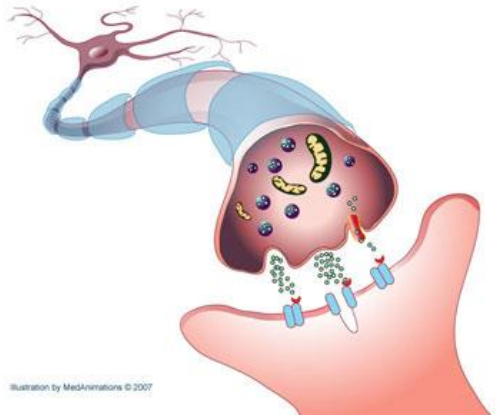
SYNAPSE

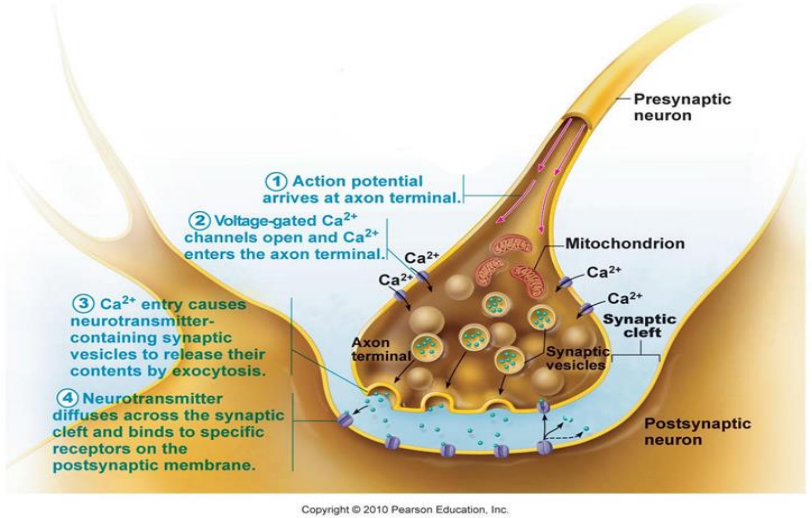
- Junction between nerve cells.
- Nerve impulses travel from one neuron to another across synapses, or spaces in between the cells.
- The “jumping across” the synapse is facilitated (helped) by chemicals called Neurotransmitters.
- It is s a junction that mediates information transfer from one neuron to:
  - ⟶ another neuron.
  - ⟶ a muscle = neuromuscular junction.
  - ⟶ a gland = neuroglandular junction.
- The neuron transmitting the signal = presynaptic neuron.
- The cell receiving the signal = postsynaptic cell.
- Two main types of synapses → electrical and chemical.



CHEMICAL SYNAPSES

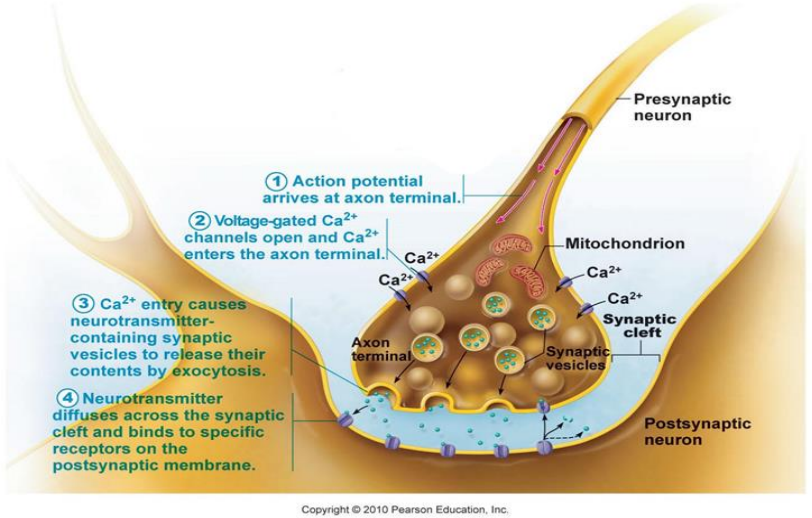
- Most abundant type of synapse.
- Presynaptic and postsynaptic membranes are separated by a synaptic cleft.
- Signal transmission involves chemical neurotransmitters.
- Signal transmission is slower and less efficient compared to electrical synapses.





SIGNAL TRANSMISSION ACROSS A CHEMICAL SYNAPSE

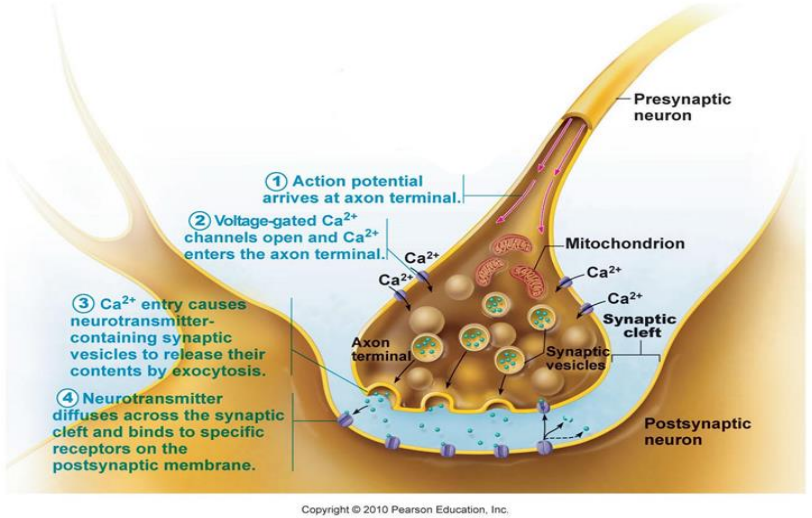
1. Action potential arrives at the presynaptic axon terminal and depolarizes the membrane.
2. Voltage-gated Ca2+ channels open and Ca2+ enters the axon terminal.
3. Ca2+ surge triggers synaptic vesicles to release their neurotransmitter (e.g. ACH) into the synaptic cleft.
4. Neurotransmitter diffuses across synaptic cleft and binds to receptors (chemically-gated ion channels) on the postsynaptic membrane.



SIGNAL TRANSMISSION ACROSS A CHEMICAL SYNAPSE

5. Chemically-gated ion channels open and a graded potential is produced.

- If an influx of Na+ ions → a depolarizing graded potential called an excitatory postsynaptic potential (EPSP) is generated.
  - ⟶ EPSP depolarizes the postsynaptic membrane to threshold → an action potential is generated and the signal transmitted.
- If an efflux of K+ ions → postsynaptic membrane hyperpolarized → an inhibitory postsynaptic potential (IPSP) generated→ signal not transmitted.

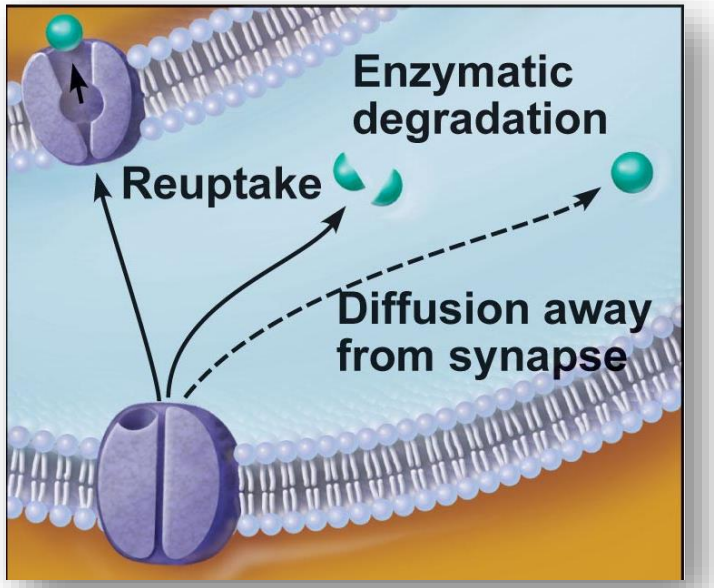


SIGNAL TRANSMISSION ACROSS A CHEMICAL SYNAPSE

6. Neurotransmitter effects are terminated.

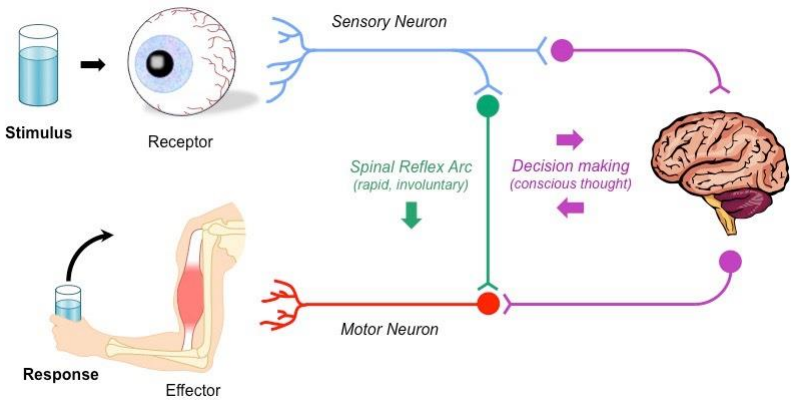
- Within a few milliseconds the neurotransmitter is either:

1. **degraded by enzymes.**
2. **re-enters axon terminal.**
3. **diffuses away from synaptic cleft.**



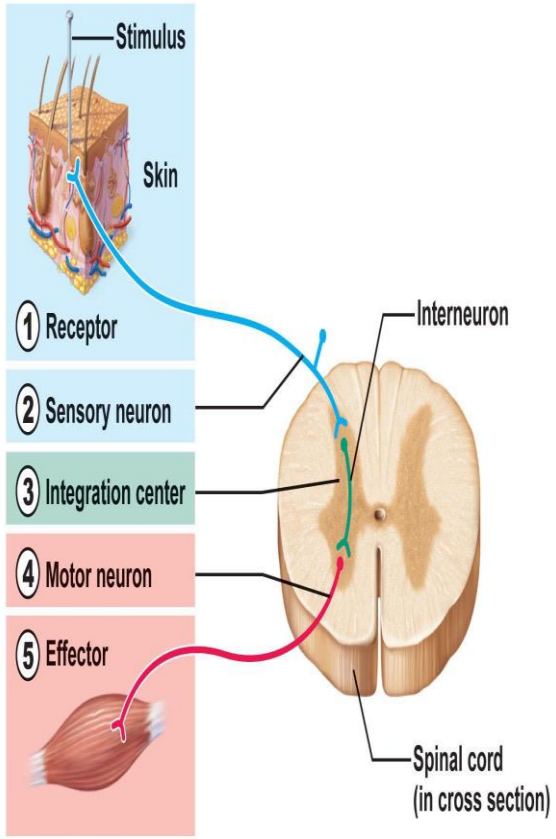
REFLEXES

- **Definition:**
  - Basic functional unit of nervous system and simplest portion capable of receiving a stimulus and producing a response.
  - Reflexes are rapid, automatic, subconscious involuntary motor responses to stimuli within or outside the body through pathways called reflex arcs.

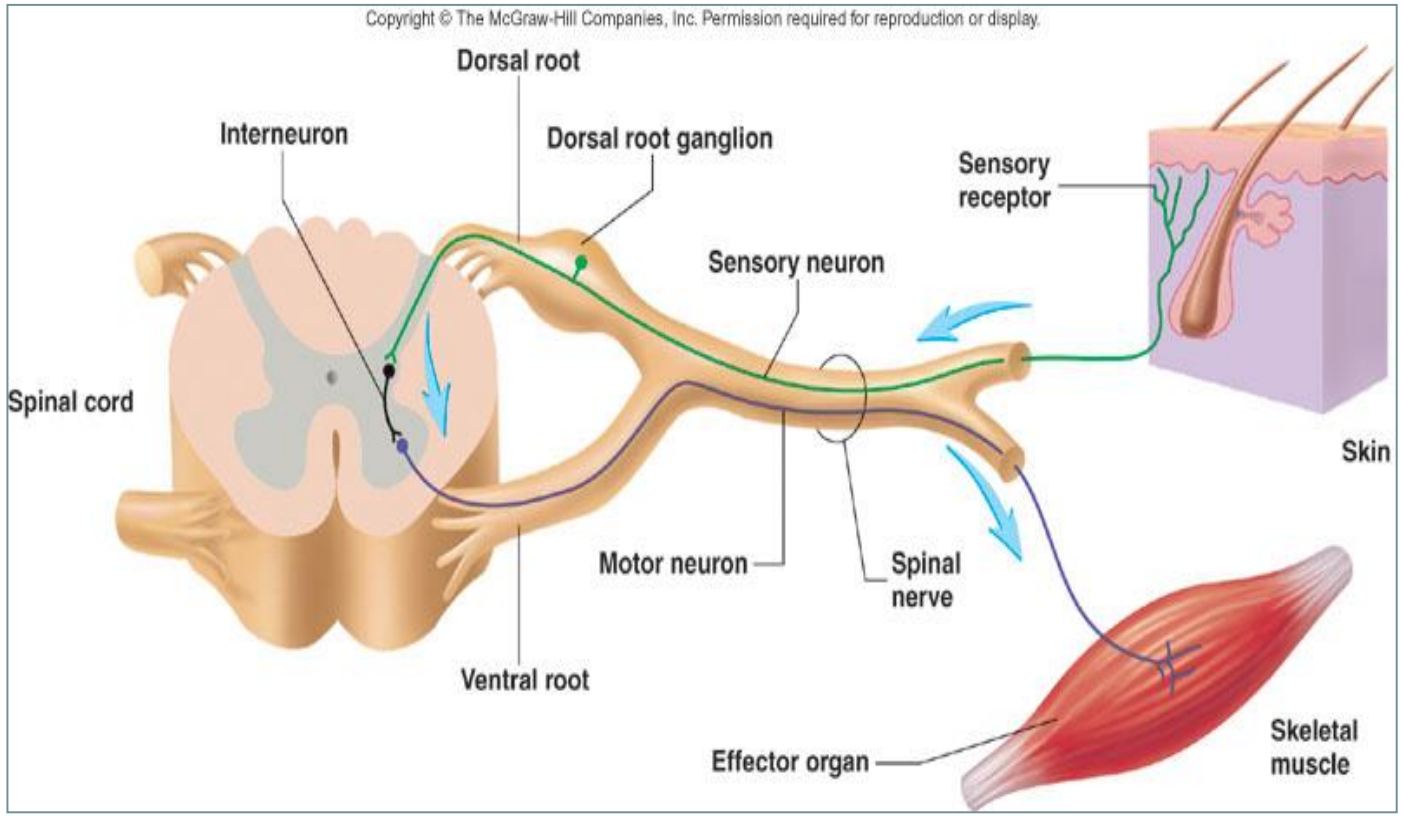


REFLEXES ARC

- **Reflex arc** – direct route from a sensory neuron, to an interneuron, to an effector.
- Reflex arcs have five essential components.
    1. Receptor receiving the stimulus.
    2. Sensory neuron.
    3. Integration center (interneurons).
    4. Motor neuron.
    5. Effector.

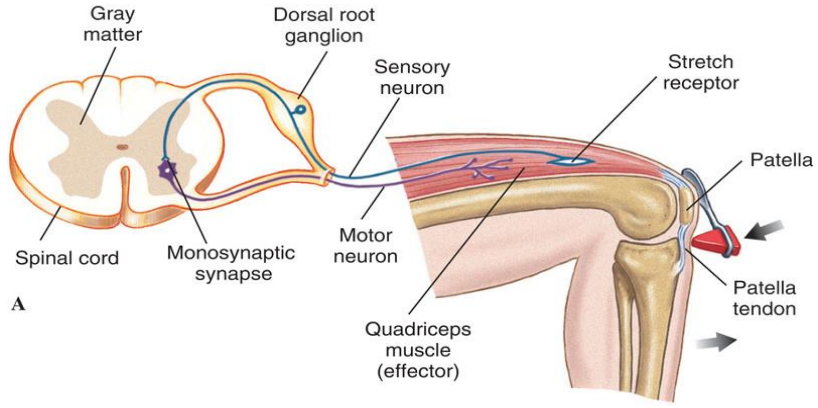


REFLEX ARCS COMPONENTS



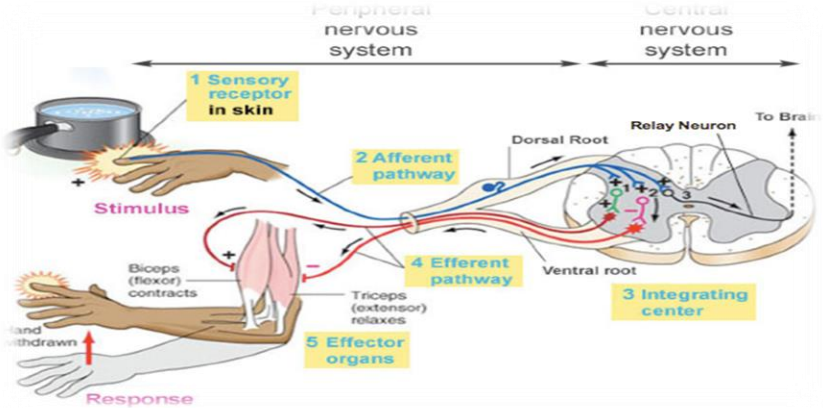
SIMPLE REFLEX ARC (SENSORY –MOTOR)

- It produces a very fast motor response to a stimulus because the sensory neuron bringing information about the stimulus passes the information directly to the motor neuron.
- Stretch reflex:
  - Results in the contraction of a muscle when it is stretched suddenly.
  - Example: patellar tendon reflex.



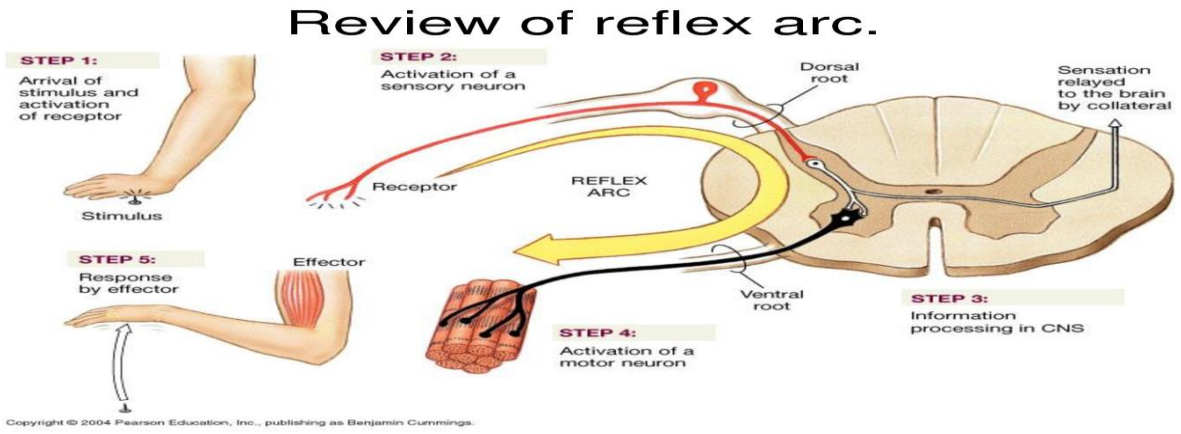
WITHDRAWAL REFLEX

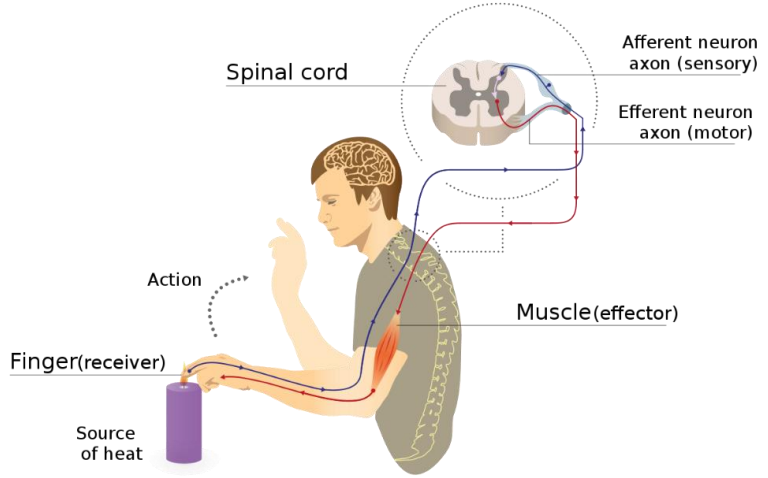
- Sudden contraction and removal of a body segment as the result of a painful stimulus.
    - Example: hot stove reflex.
- E.g. pulling your hand away when you touch something hot.

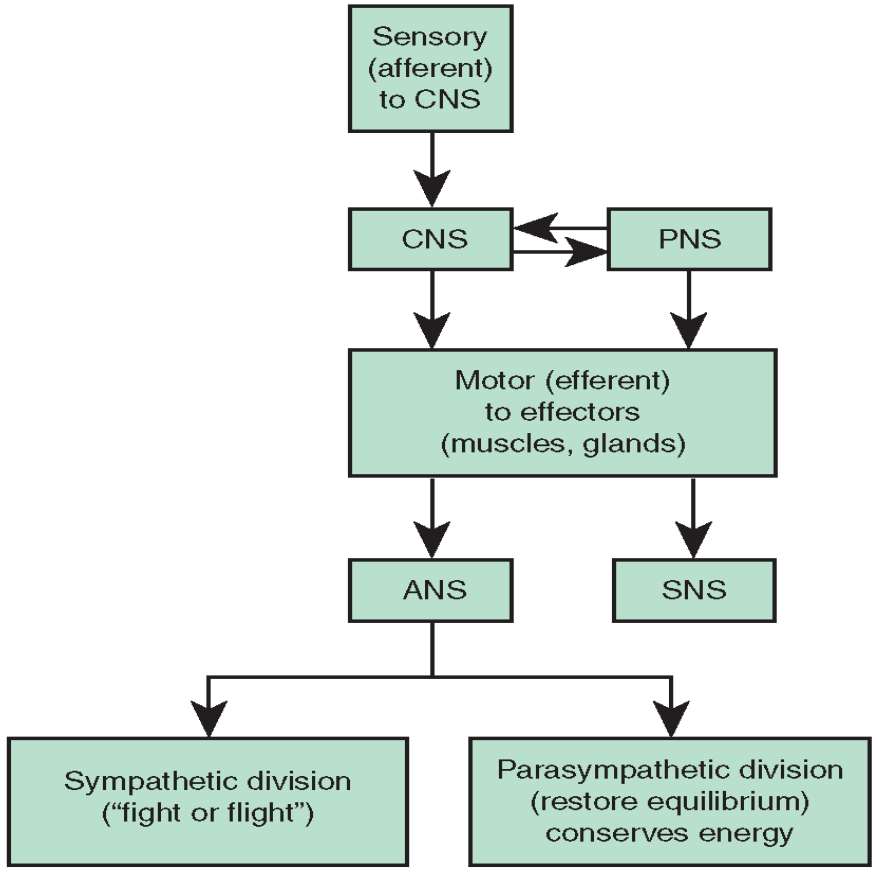


CHARACTERISTICS OF REFLEX ARC

- Does not immediately involve the brain.
- Allows quicker reaction times to a potentially harmful stimulus.



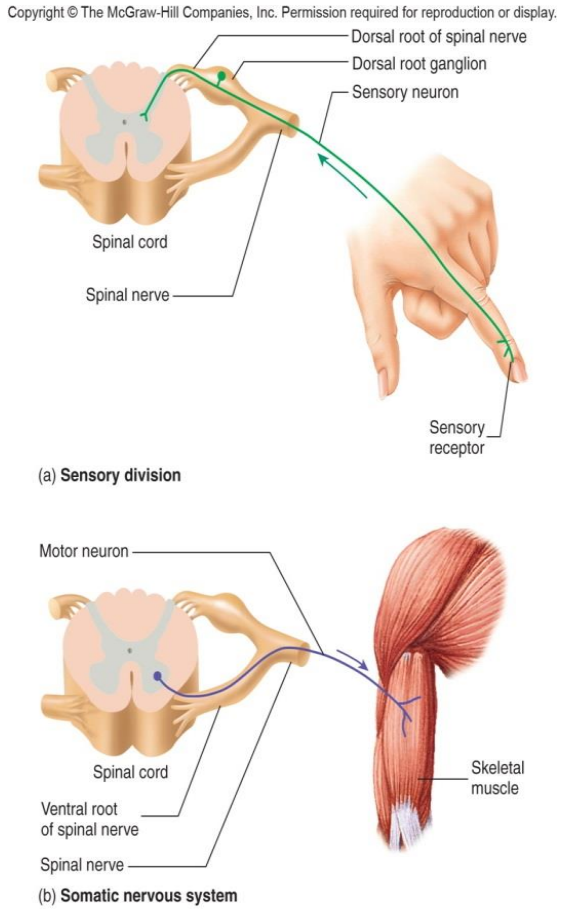




CNS = Central nervous system
PNS = Peripheral nervous system
ANS = Autonomic nervous system
SNS = Somatic nervous system

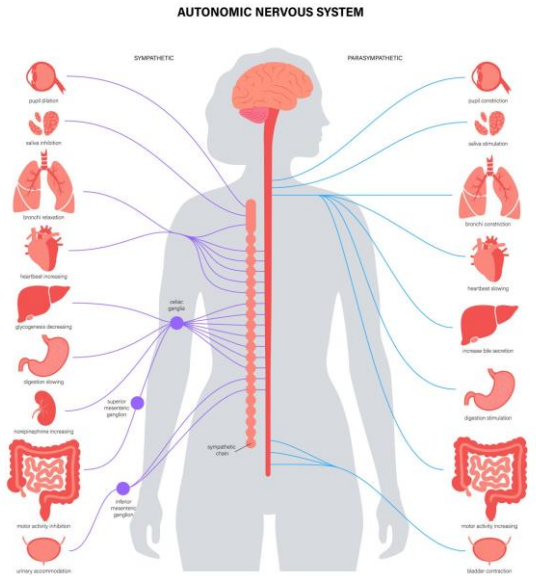
SOMATIC NERVOUS SYSTEM (VOLUNTARY)

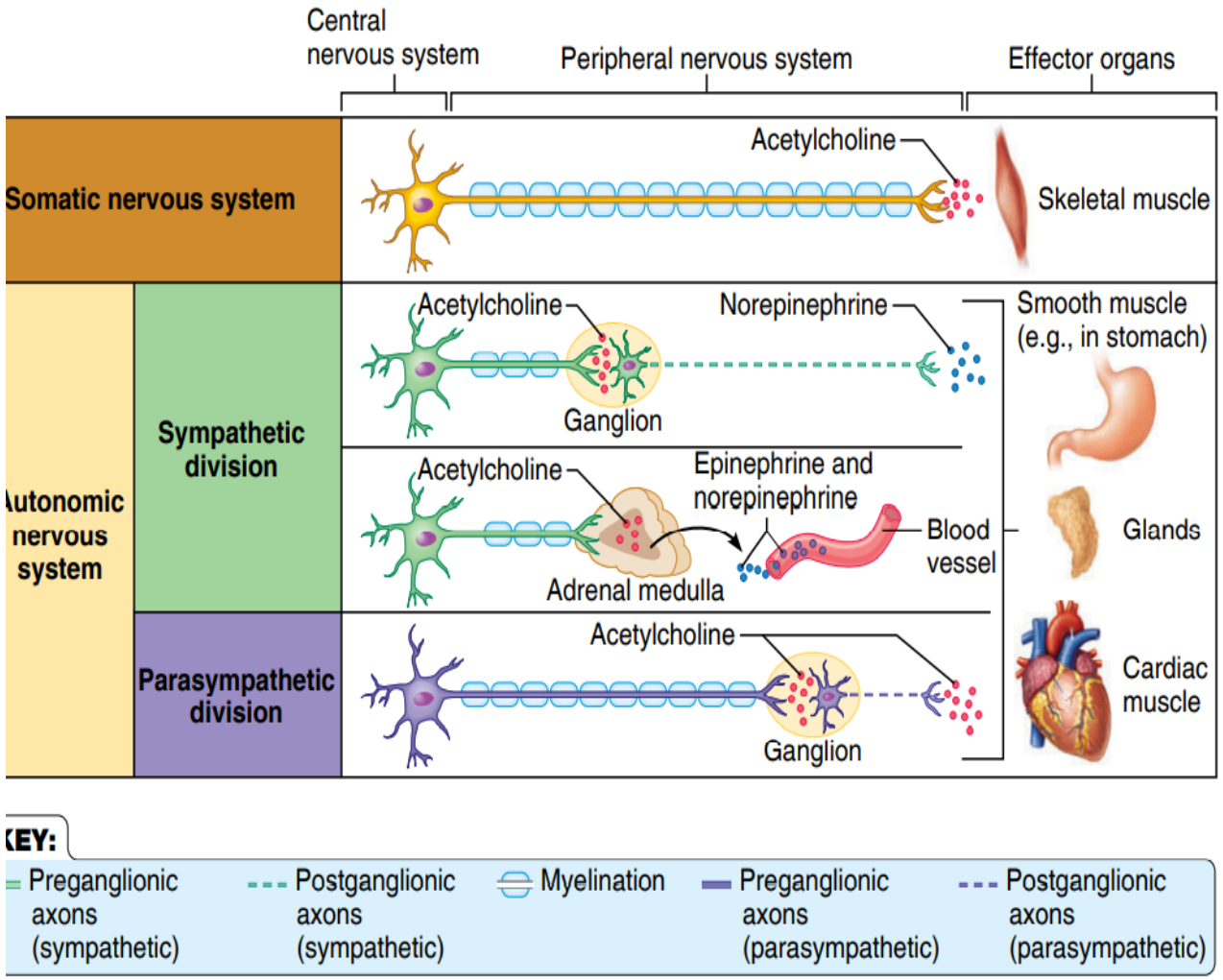
- The somatic nervous system consists of peripheral nerve fibers that allows voluntary control of skeletal muscles.
    - **Sensory receptors:** specialized cells that detect such things as temperature, pain, touch, pressure, light, sound, odors.
    - **Sensory (afferent):** transmits action potentials from receptors to CNS.
    - **Motor (efferent):** transmits action potentials from CNS to effectors (muscles, glands).



AUTONOMIC NERVOUS SYSTEM

- The autonomic or involuntary nervous system is that portion of the nervous system which regulates the activity of cardiac muscle, smooth muscle, and the glands. ANS works largely without our awareness.
- The ANS has two parts:
    - Sympathetic (fight and flight response).
    - Parasympathetic (rest and digest).
- The sympathetic division increases alertness, metabolic rate, and muscular abilities; the parasympathetic division reduces metabolic rate and promotes visceral activities such as digestion.

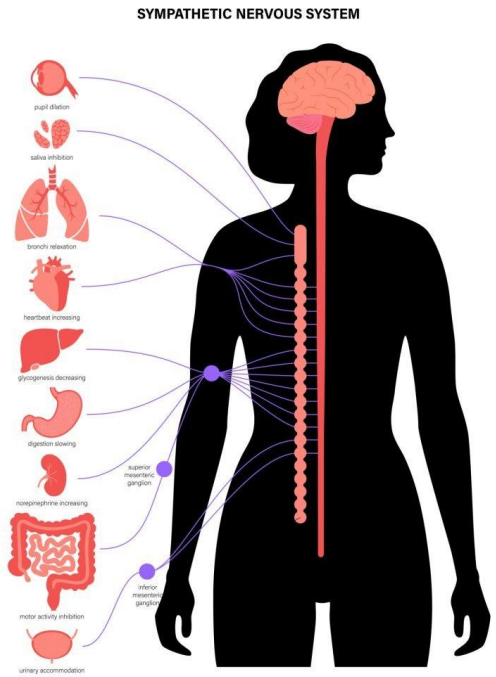




gure 7.26 Comparison of the somatic and autonomic nervous systems.

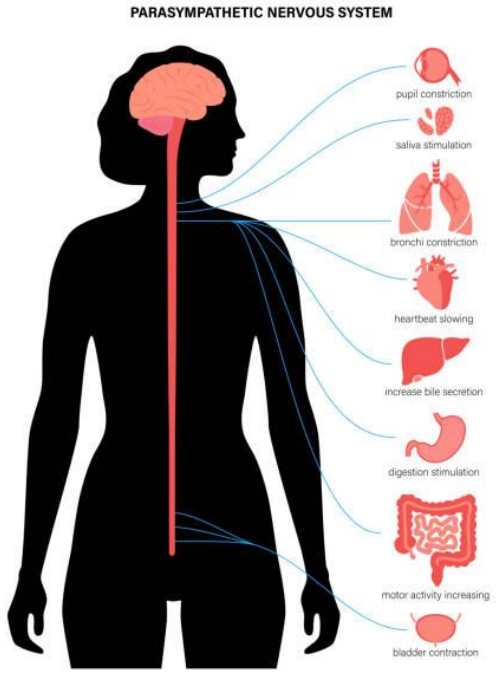
SYMPATHETIC – STIMULATES VISCERA

- Prepares the body for emergency situations (response to stress). “fight and flight” activities ⟶ Involves **E** activities: exercise, excitement, emergency, and embarrassment are responded to by this system.
- This system shifts energy and blood toward the skeletal muscles, cardiac muscles, and respiration:
  - ⇉ increases heart rate, respiratory airflow & blood flow to skeletal muscles.
  - ⇉ increases sweat gland activity.
  - ⇉ inhibits digestive functions.
  - ⇉ inhibits urination and defecation.



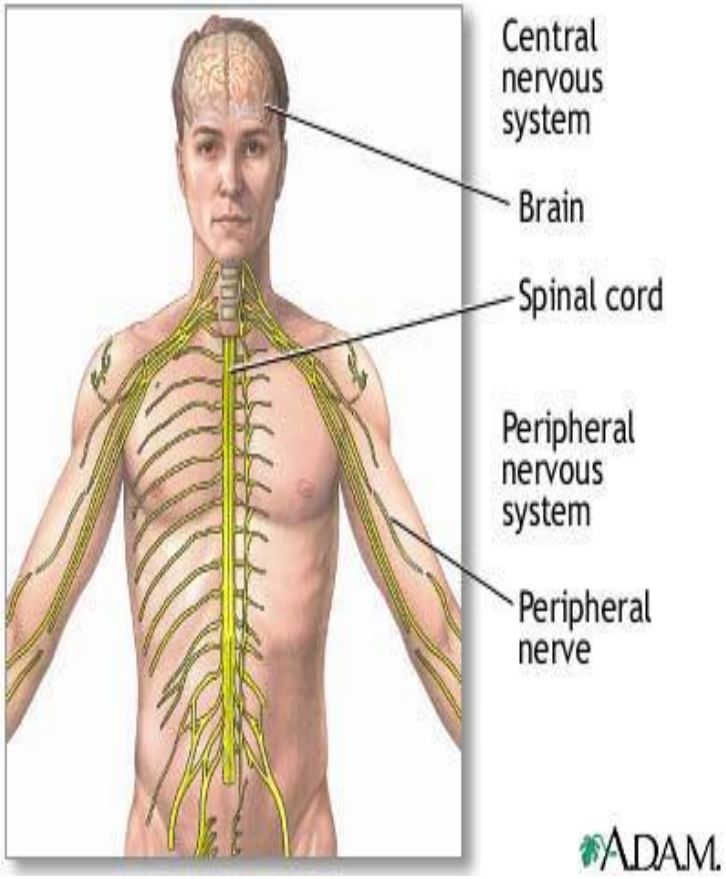
PARASYMPATHETIC – INHIBITS ORGANS

- Controls "rest and digest" activities ⟶ i.e., conserves energy for example:
- Involves the **D** activities digestion, defecation, and diuresis (urination).
    - ⇉ stimulates digestive functions, urination and defecation.
    - ⇉ decreases heart rate.

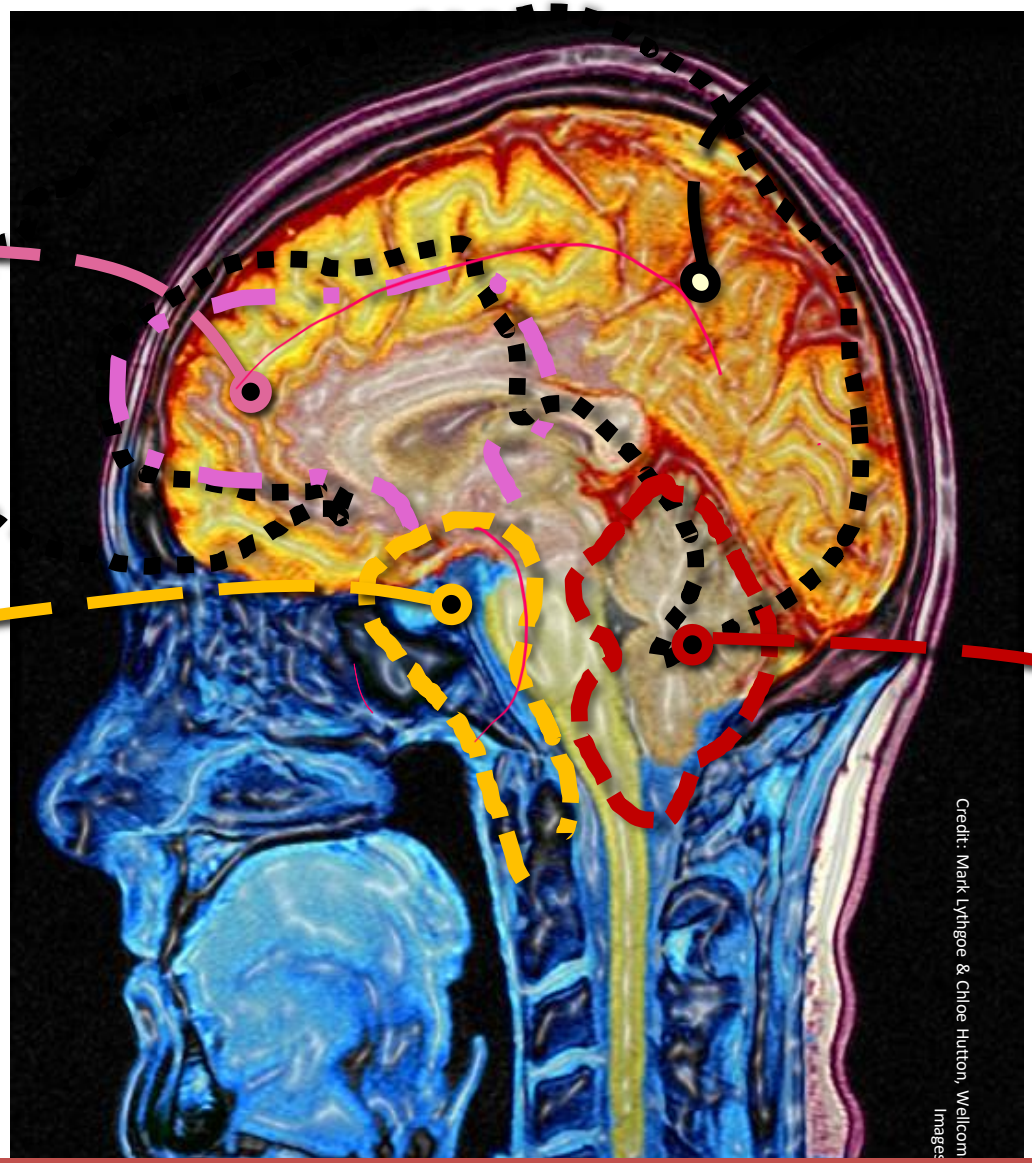


FUNCTIONS OF CENTRAL NERVOUS SYSTEM

- CNS includes the brain and spinal cord.
- The brain interprets the information it gets though your senses in order to monitor and regulate your body as well as being responsible for thinking, learning, memory and emotion
- Different parts of your brain have different functions



Brain stem
regulates heart rate, breathing, sleep cycles and emotions



Cerebral cortex
Functions include: planning; reasoning; language; recognising sounds and images; memory.

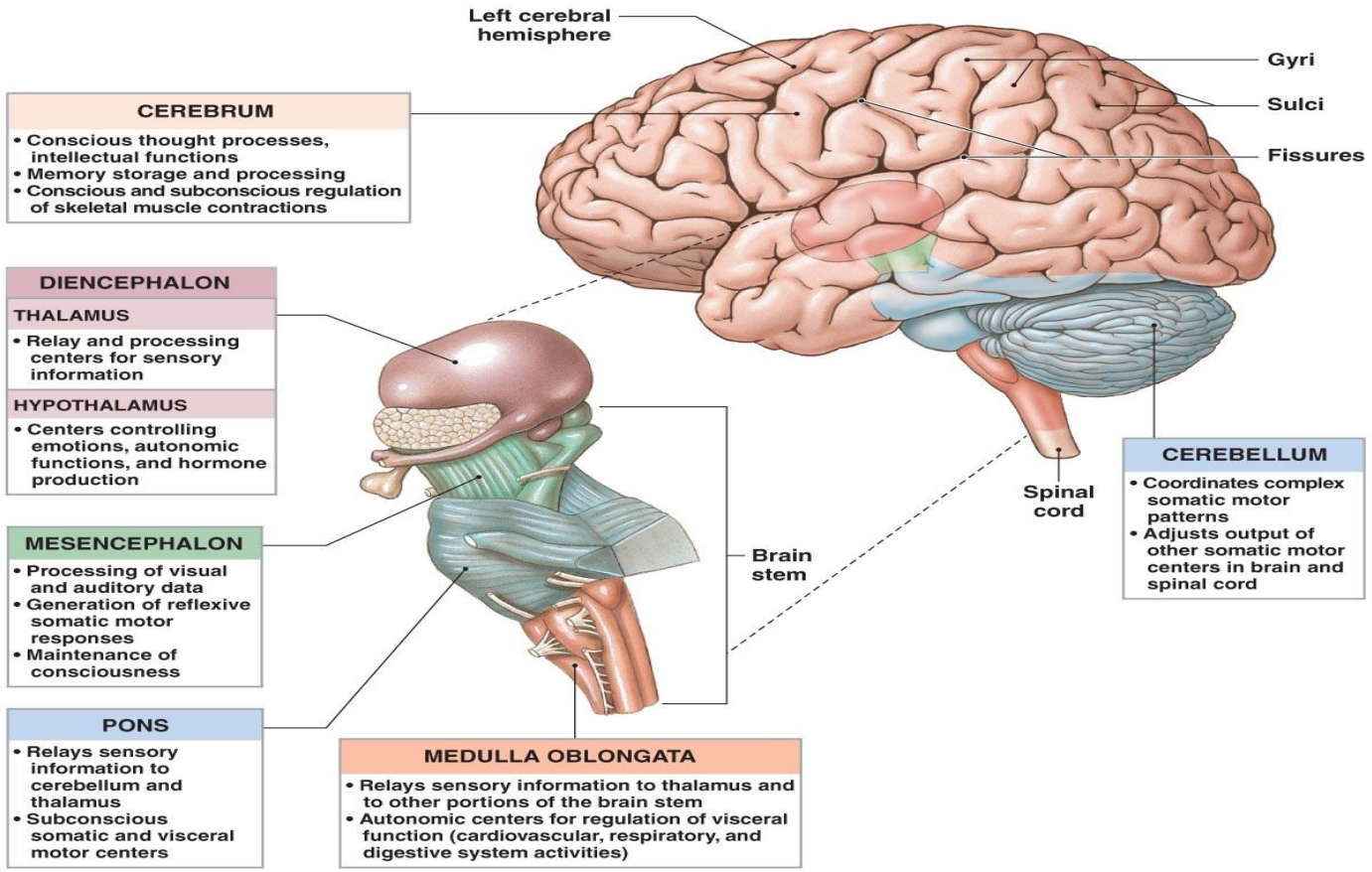
Cerebellum
important for coordination, precision and timing of movement

Different Regions Have Different Functions

BRAIN BASICS

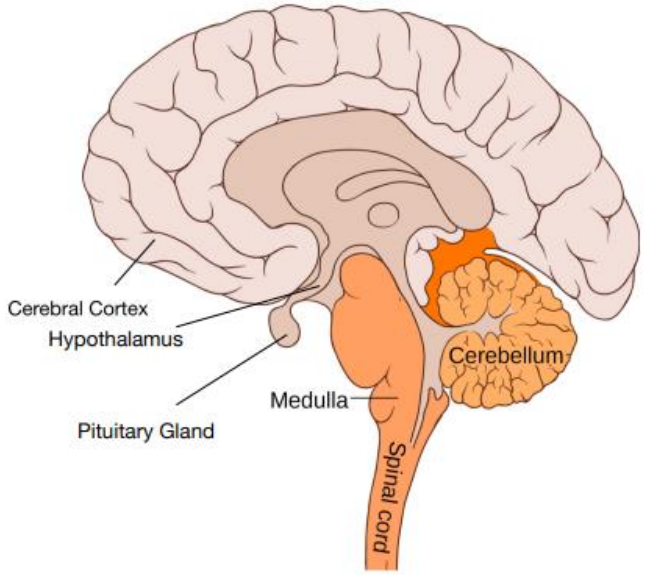
- Weighs about 1.5 kg (2% of body weight).
- Consists of billions of neurons and supporting cells (glial cells).
- The brain requires constant blood flow because it has high energy demands.
    - ⟶ requires 15% of the cardiac output (~ 5 L/min).
    - ⟶ consumes 70% of blood glucose.
        - ⇉ does not store glucose.
        - ⇉ cannot produce glucose.
    - ⟶ accounts for 20% of the body's oxygen consumption.
- Lack of blood for just a few minutes causes irreversible damage.

MAJOR DIVISIONS OF THE BRAIN



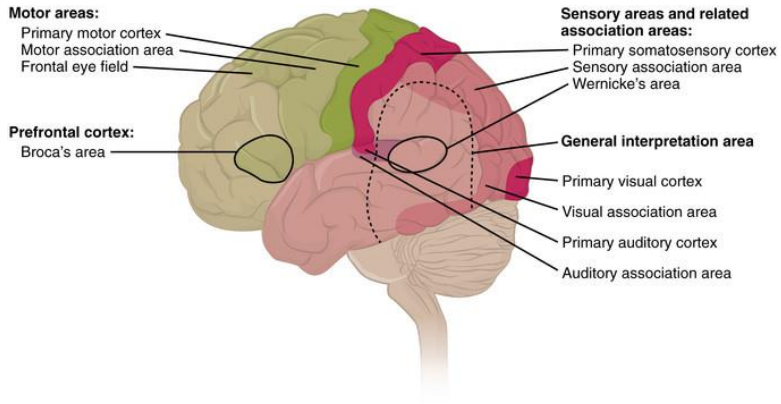
CEREBRAL CORTEX

- Makes up 40 % of brain mass.
- Location of the conscious mind.
    - Localizes and interprets sensory inputs.
    - Self awareness.
    - Communication.
    - Memory.
    - Understanding.
    - Voluntary movements (skeletal muscles).



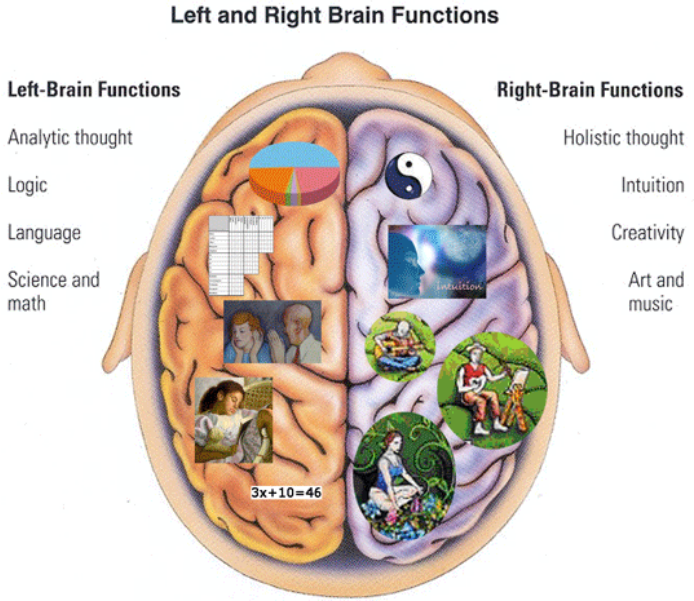
CEREBRAL CORTEX

- The cortex of each cerebral hemisphere has three functional areas
  - ⟶ motor areas
  - ⟶ sensory areas
  - ⟶ association areas
- The cortex of each hemisphere deals with the sensory and motor functions of the opposite (contralateral) side of the body.
- The cortex of each hemisphere has distinct functions (lateralization).



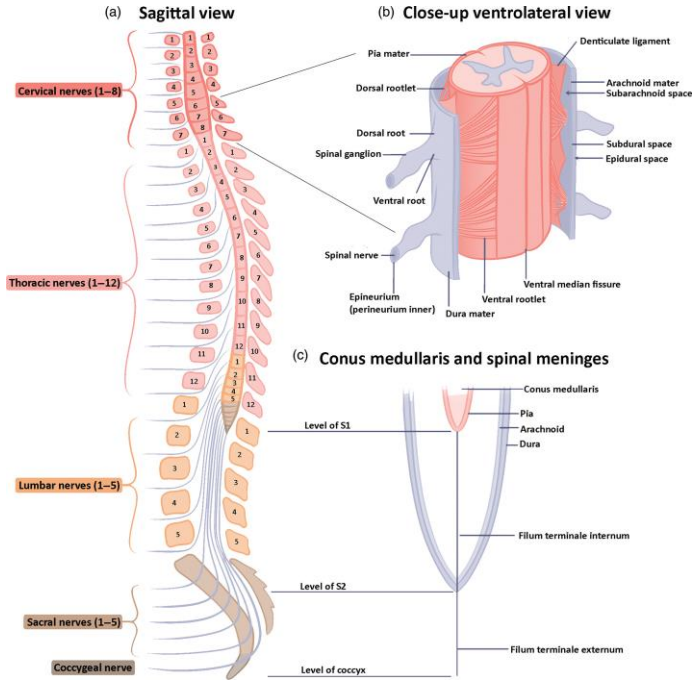
HEMISPHERIC LATERALIZATION

- Although each hemisphere has many functions in common, they each have unique abilities.
- 90% of people are represented by the diagram = left cerebral dominance.
- 10% of people have the reverse = right cerebral dominance.



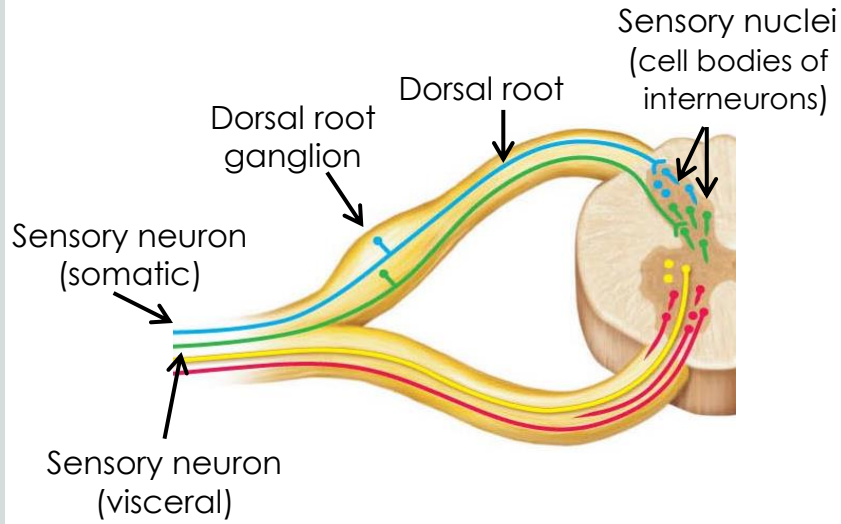
SPINAL CORD

- The spinal cord is structurally and functionally integrated with the brain.
- The spinal cord:
    - It is composed of interneurons.
    - Receives and directs incoming sensory information to processing centers in the brain.
    - Receives and relays outgoing messages that instruct motor responses.
    - Initiates spinal reflex.



SENSORY NUCLEI

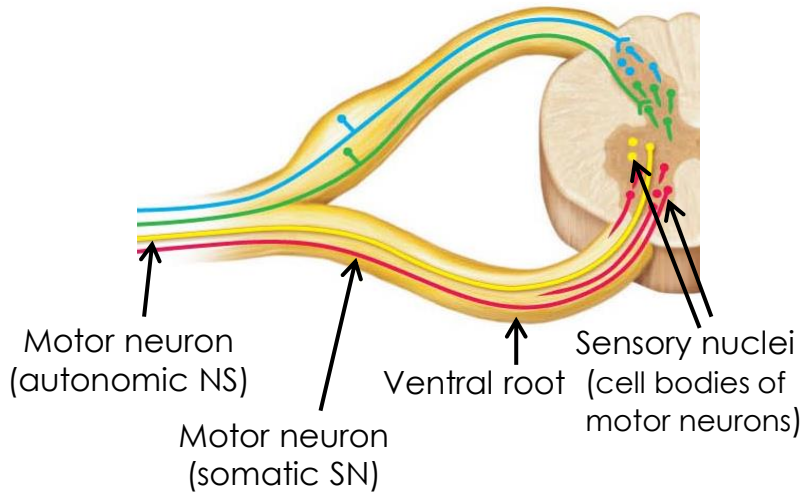
- Contain the cell bodies of spinal cord interneurons.
  - Receive sensory information (somatic and visceral) entering the spinal cord.
  - Integrate and process incoming sensory information.



MOTOR NUCLEI

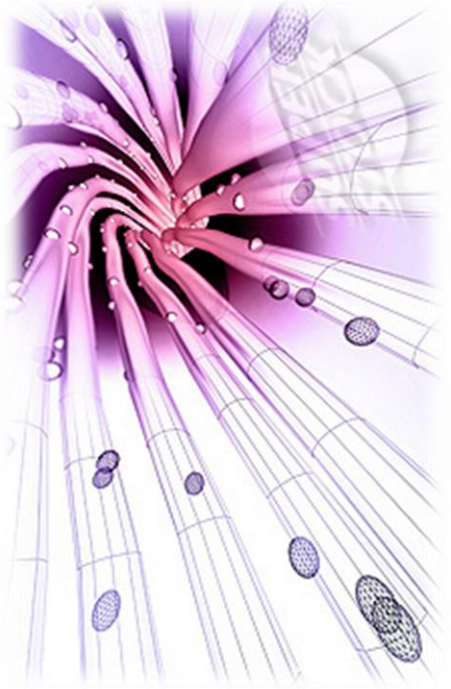
Contain the cell bodies of motor neurons.

- Receive motor output from the brain.
- Generate motor output that mediates spinal or autonomic reflexes.



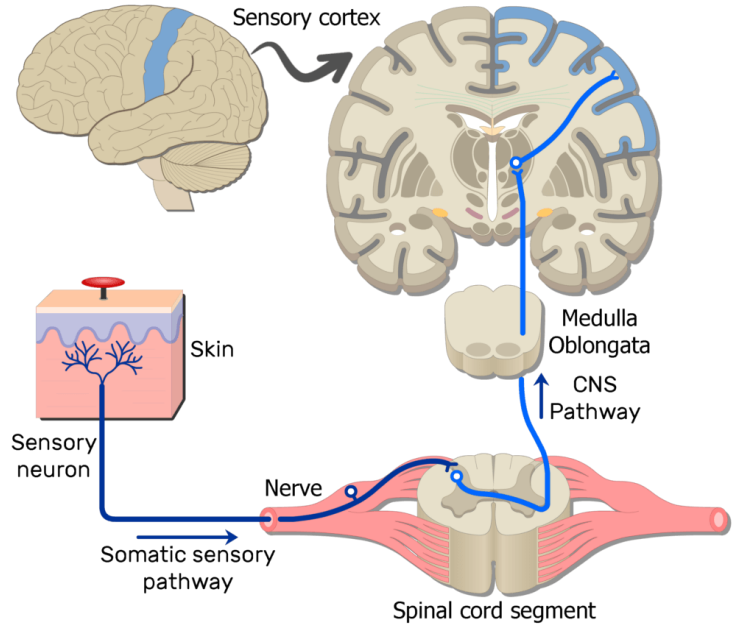
WHITE MATTER

- Each white column contains spinal tracts → bundles of axons that relay:
    - The same type of information.
    - In the same direction.
    - To the same destination.
    - At the same conduction speed.



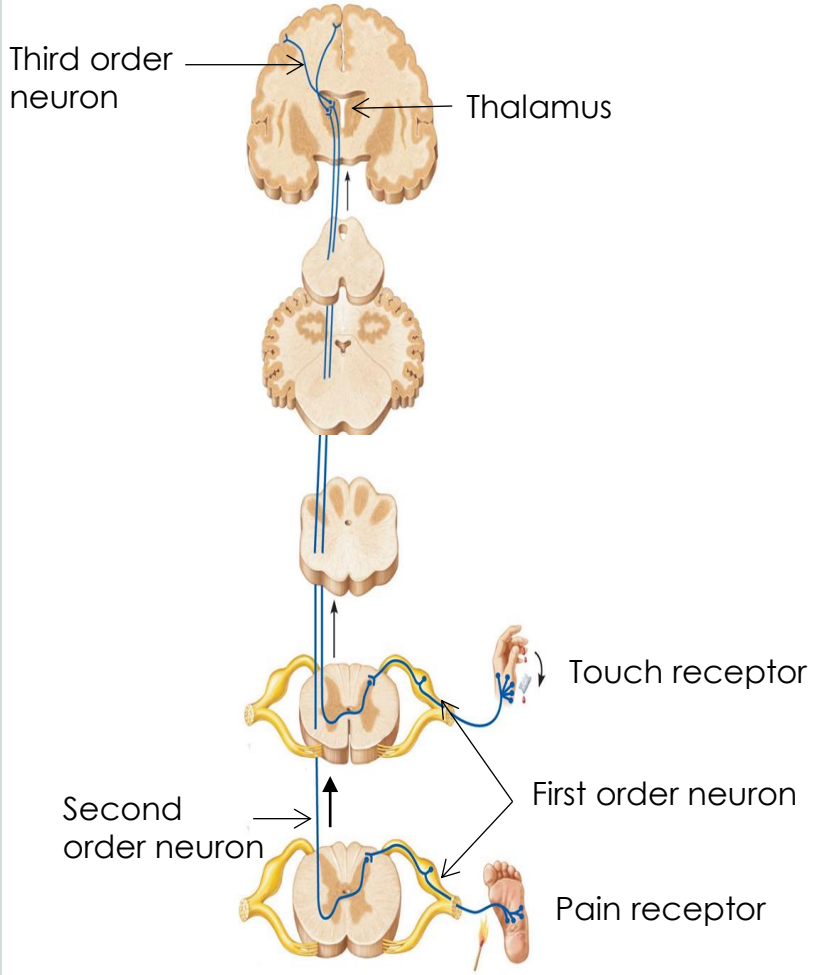
CLASSIFICATION BY LOCATION

- **Sensory Pathways**
  - Relay sensory signals from the receptor to the brain.
  - Conduct specific sensory input, to a specific brain destination at a specific conduction speed.
  - Are multi-neuron pathways, involving a chain of neurons called:
    - ⟶ first order neuron.
    - ⟶ second order neuron.
    - ⟶ third order neuron.



CLASSIFICATION BY LOCATION

- First order neurons (sensory neurons)
  - Conduct signals from receptors to the spinal cord or brain stem.
- Second order neurons (interneurons)
  - Conduct signals to the thalamus → region of the brain that sorts incoming sensory information.
- Third order neurons (interneurons)
  - Conduct signals from the thalamus to a specific sensory area of the brain.

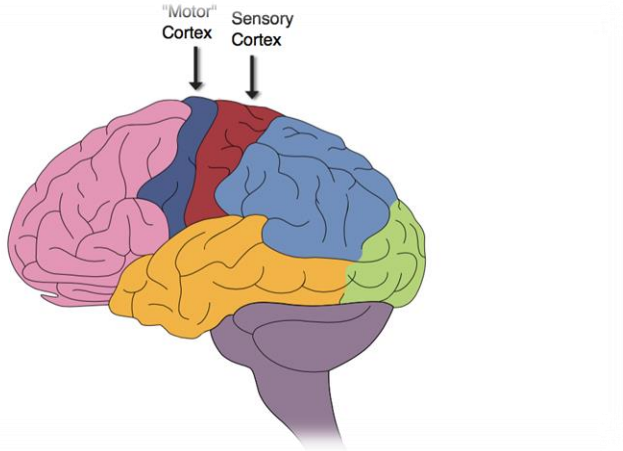


CENTRAL NERVOUS SYSTEM

- Integration primarily occurs in the brain.
  - Sensory areas of the brain:

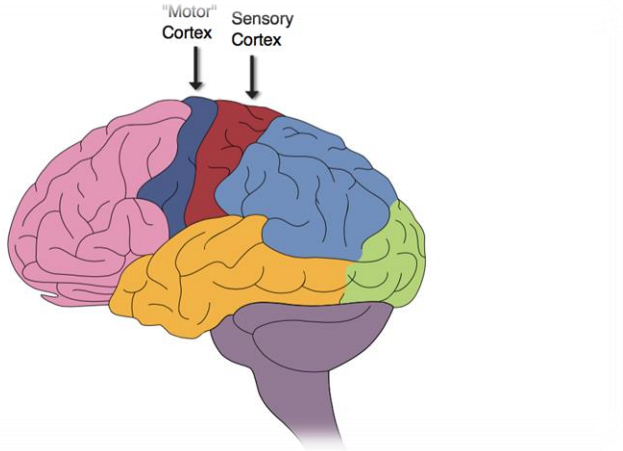
    ⇉ receive, interpret and integrate incoming sensory signals.
  - Motor areas of the brain:

    ⇉ decide on and initiate a motor response.



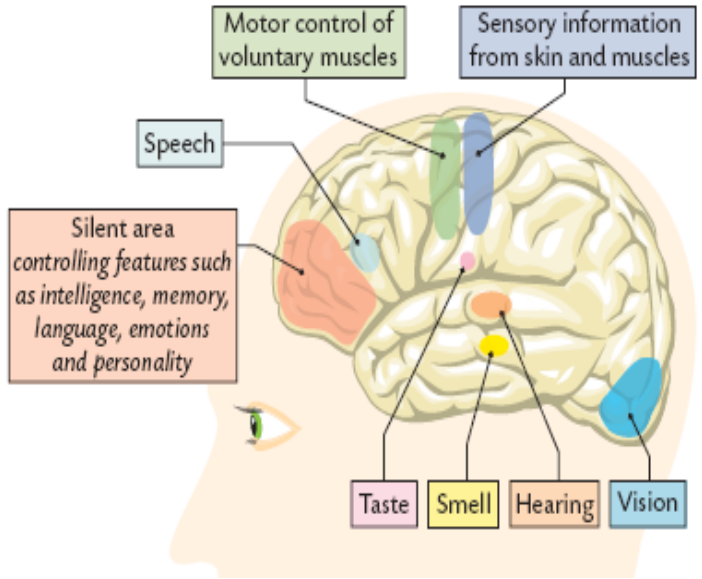
CENTRAL NERVOUS SYSTEM

- **Sensory areas of the brain**
  - Perceive a stimulus.
  - Determine the intensity of a stimulus.
  - Identify the location of a stimulus.
  - Discriminate qualities of a stimulus.
  - Integrate various stimuli to identify all aspects of a sensation.
  - Communicate with the motor centers of the brain.

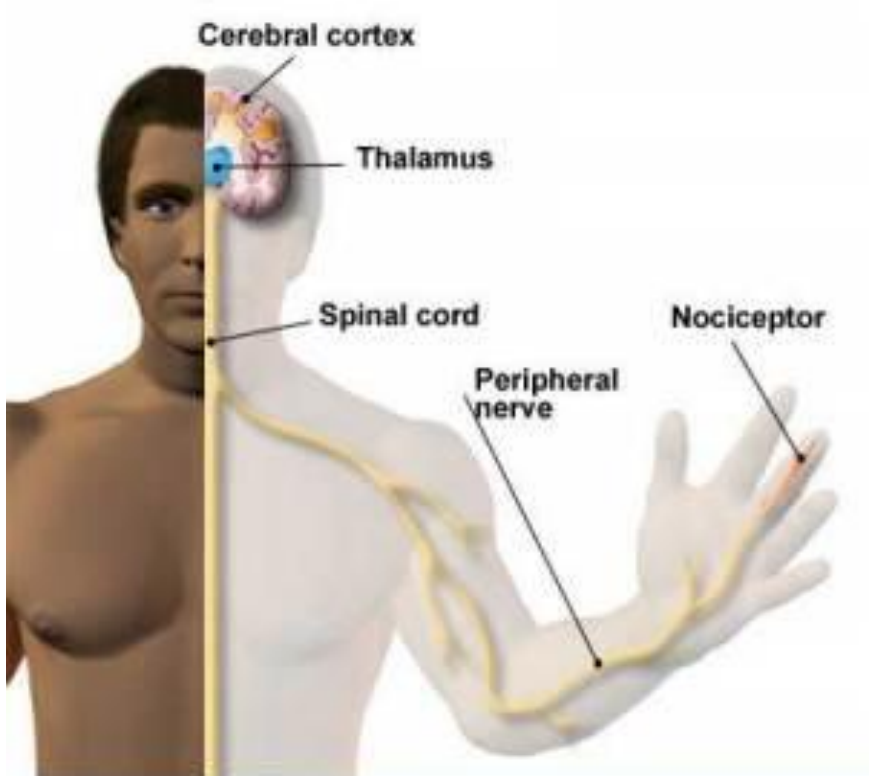


CENTRAL NERVOUS SYSTEM

- The ability to consciously perceive a stimulus depends on sensory input reaching the cerebral cortex of the brain.

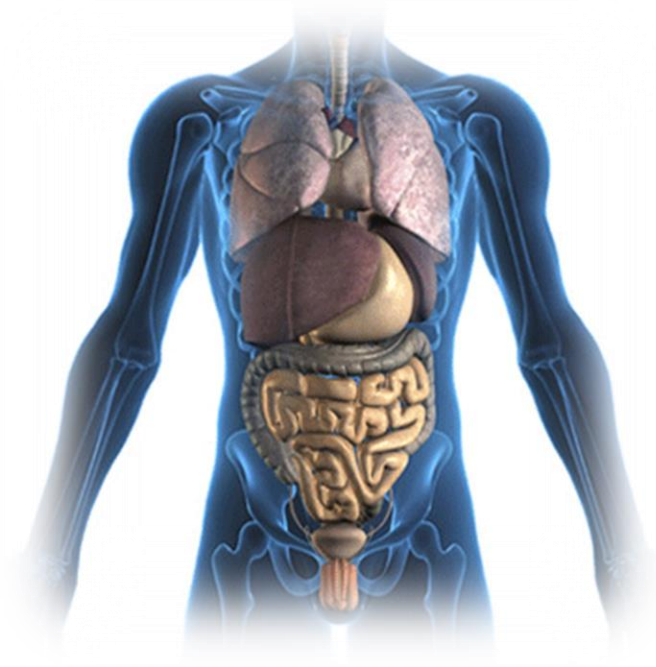


EXAMPLE: PAIN



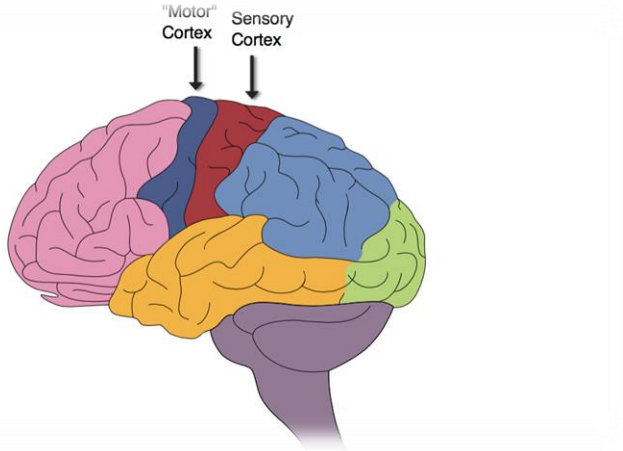
CENTRAL NERVOUS SYSTEM

- Not all stimuli are consciously perceived.
- Sensory input from receptors monitoring the body's internal organs is processed in other regions of the brain, thus never reaches our conscious awareness.



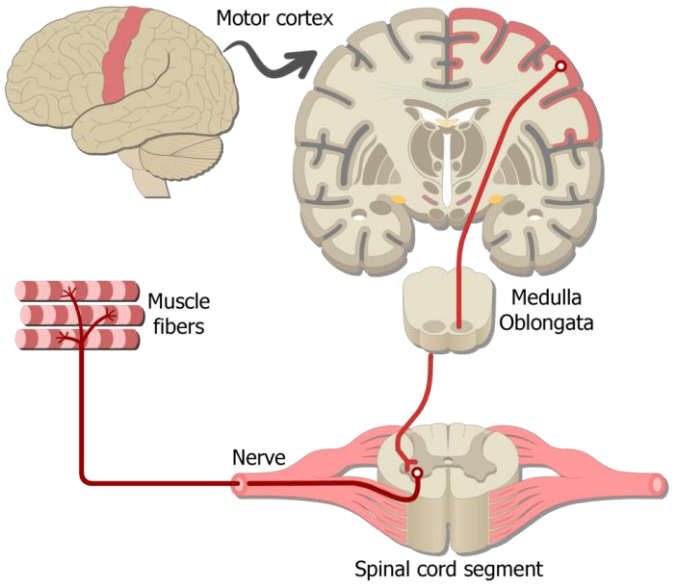
CENTRAL NERVOUS SYSTEM

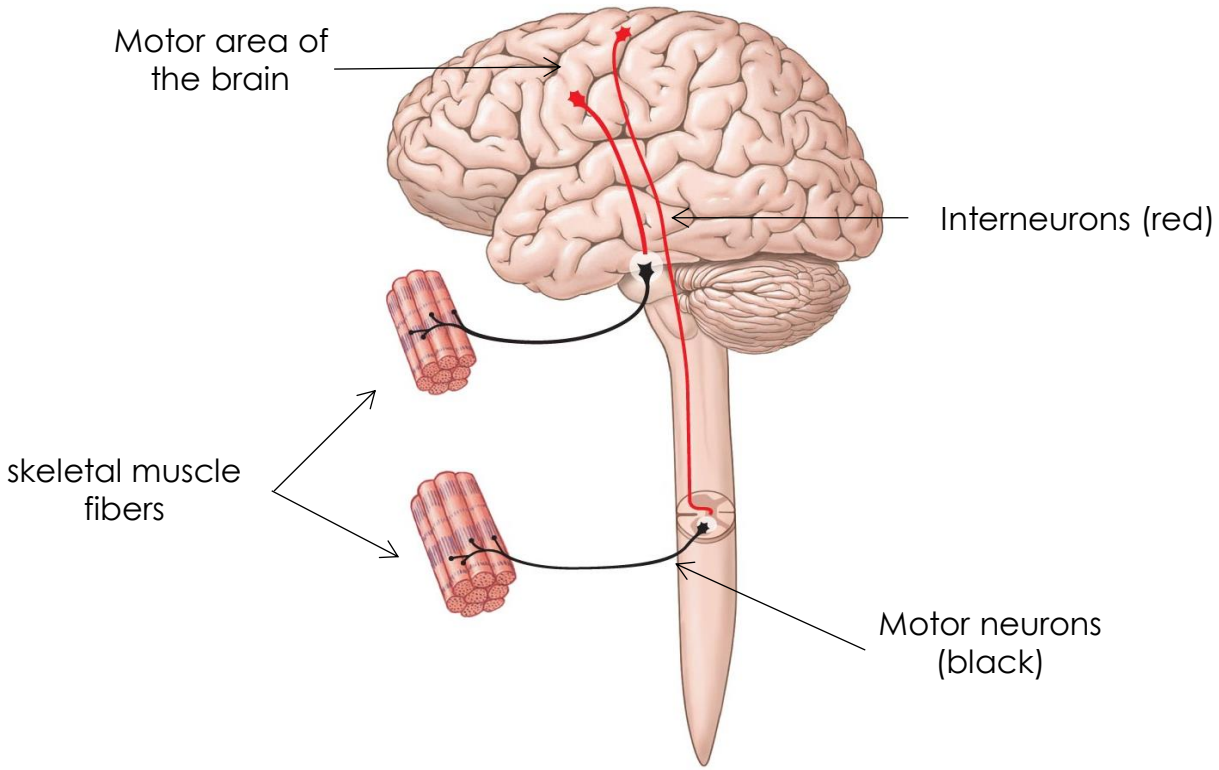
- **Motor areas of the brain**
  - Determine, coordinate and direct:
    - motor output that results in controlled voluntary skeletal muscle movements.
    - involuntary motor output that controls glands, cardiac and smooth muscles.
    - motor responses that take time to prepare and execute.



CENTRAL NERVOUS SYSTEM

- **Motor Pathways**
  - Relay signals from motor centers of the brain to an effector muscle or gland.
  - Are multi-neuron pathways, involving:
    - ⇉ interneurons of the brain and spinal cord.
    - ⇉ motor neurons that extend from the brain stem or spinal cord to the effector.



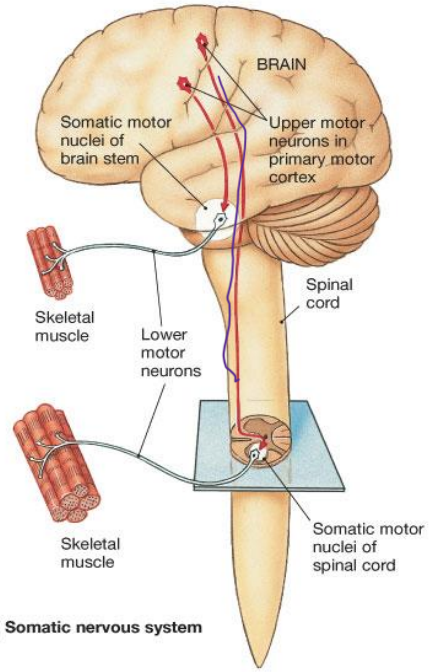


PATHWAYS WHICH DESCEND FROM THE BRAIN

- **Two neurons down**
- **Upper motor neuron (CNS)**
  - Primary motor cortex (precentral gyrus of frontal lobe).
  - Down corticospinal tract (cross over).
  - Anterior (ventral) gray horn of spinal cord.

⟶ synapse with:

- **Lower motor neuron (PNS)**
  - Cell bodies in ventral horn of spinal cord.
  - Reflexes synapse with lower motor neuron here.
  - Muscle (effector).



QUESTIONS?

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