THE NERVOUS SYSTEM

AGA 2110- ANATOMY & PHYSIOLOGY OF FARM ANIMALS
UNIVERSITY OF ZAMBIA
DEPARTMENT OF ANIMAL SCIENCE
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TERMINOLOGY

- Neuro – refers to the nervous system
- Neurology - The branch of science that studies the nervous system
- Neuron – Nerve cells (also called nerve fibers)
- Afferent – towards the CNS/cell body
- Efferent – Away from the CNS /cell body
- Neurotransmitter - endogenous substances that are released from neurons eg acetylcholine, dopamine that transmit an impulse from one cell to another

INTRODUCTION

- ❑Function – coordination animals response to the environment
- ❑ the NS gathers, sorts & stores information and initiates movement

Examples

- ✓sense the temperature of the surroundings, for example, so they can avoid the hot sun.
- ✓ They must also be able to identify food and escape predators

INTRODUCTION

- ❑ An animals body is complex
- ❑ In order to maintain homeostasis & therefore health, all those cells, tissues, organs & systems have to be able to communicate with each other & their functions have to be coordinated & controlled.
- ❑ Fortunately the body has two communication & control systems that help keep things working properly

i. the nervous system

ii. the endocrine system

- ❑ Both use chemicals to carry their messages, but they do it by different means, and on different timescales.

THE NERVOUS SYSTEM

- ✓The nervous system's chemical messengers are called neurotransmitters
- ✓Neurotransmitters are produced only by neurons (nerve cells).
- ✓The neurotransmitters travel only very short distances, across spaces between nerve cells called synapses
- ✓ This allows the system to react quickly, but the limited supplies of neurotransmitters in the cells do not allow it to sustain individual activities for long periods of time.

THE ENDOCRINE SYSTEM

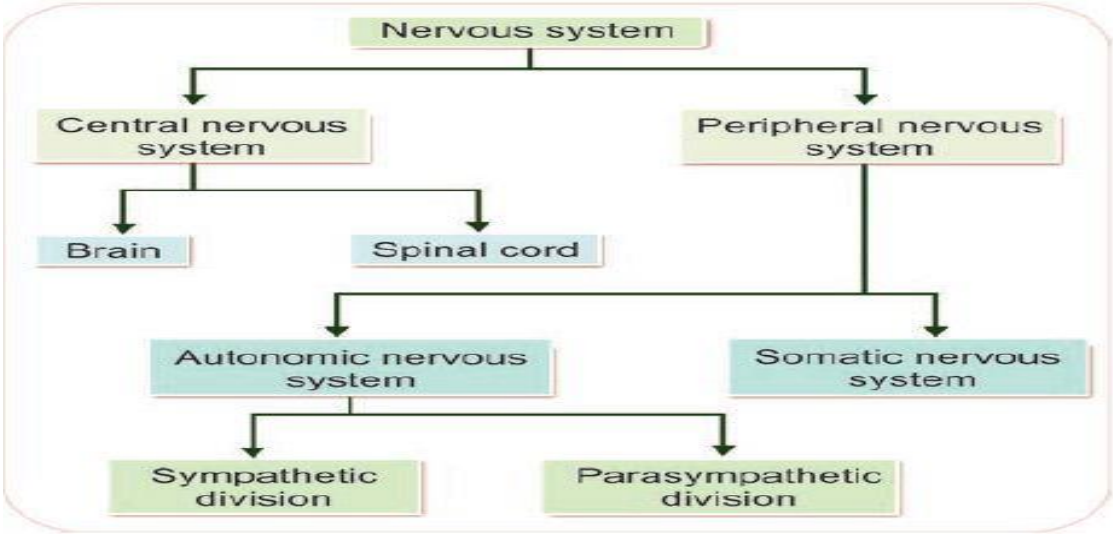
- ❑The chemical messengers of the endocrine system are called hormones
- ✓ Hormones are secreted directly into the bloodstream, where they travel comparatively long distances to reach their targets.
- ✓ The hormone targets, therefore, react more slowly to changes, but hormones can be secreted for long periods of time, so they can sustain individual activities for long periods of time

THE NERVOUS SYSTEM

- Structurally the nervous system (NS) has 2 major divisions

1. The central nervous system (CNS) - includes the brain & spinal cord.
2. The peripheral nervous system (PNS) - includes nerves found in all other regions of the body

NERVOUS SYSTEM DIVISIONS



FUNCTIONS OF THE NERVOUS SYSTEM

- Functionally, the nervous system's activities fall into 3 main categories:

(1) sensory functions

(2) integrating functions and

(3) *motor functions.*

FUNCTIONS OF THE NERVOUS SYSTEM

SENSORY FUNCTION

The NS senses changes from within the body or from outside the body & conveys this information to the spinal cord & brain.

INTERGRATING FUNCTION

In the brain & spinal cord, the sensory information is received, analyzed, stored, & integrated to produce an appropriate response

MOTOR FUNCTION

A motor response instructs the body to do something, such as contract a muscle or cause a gland to secrete its product

CELLS FOUND IN THE NERVOUS SYSTEM

- ❑ Neurons – sends & receive signals
- ❑ Glial cells (neuroglial cells) – support & protect the neurons

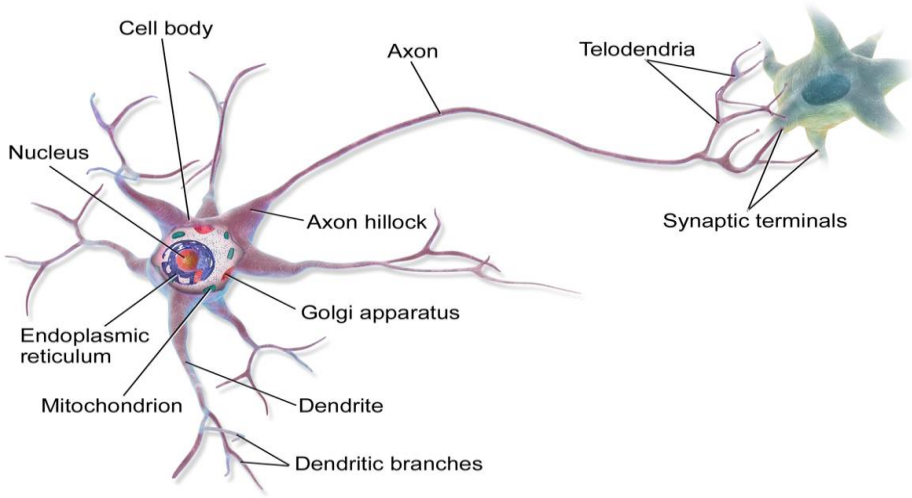
A NEURON

- ❑ The basic functional unit of the NS
- ❑ A neuron is a cell that have been adapted to carry nerve impulses (sends & receives signals)
- ❑ Although neurons in different parts of the NS vary somewhat in appearance, their basic structure is the same.
- ❑ A basic neuron has a cell body (soma) – also called perikaryon and 2 types of processes

i. Dendrites

ii. Axon

NEURON



TYPES OF NEURONS

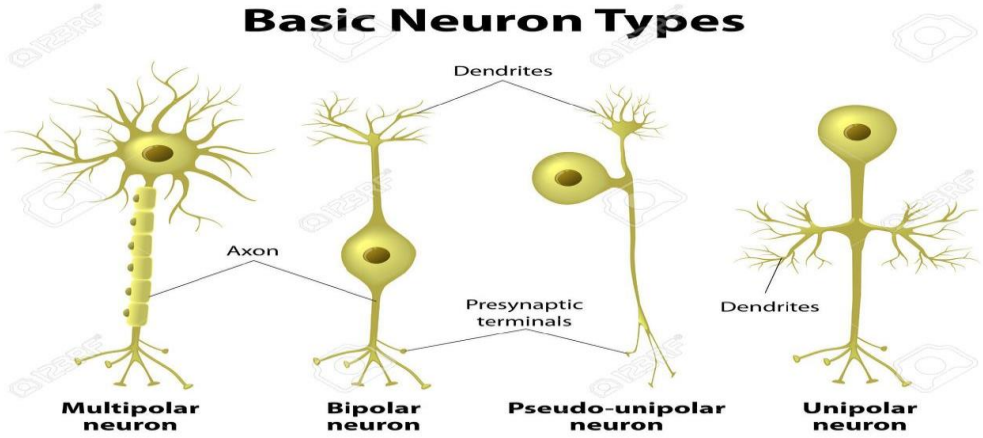
- ❑ Categorised according to the number of poles or processes that stem from its cell body.
- ❑ Mammalian neurons can be categorized as;

i. bipolar (1 axon, 1 dendrite) extending from the cell body

ii. pseudounipolar (in which the axon and dendrite of a bipolar neuron have fused near the cell body, giving the appearance of only one process),

iii. multipolar (many branching dendrites & 1 axon extending from the cell body

POLARITY OF NEURONS



DENDRITES

- Receive messages (stimuli, impulses) from other nerves or organs & conduct this stimulation to the cell body
- They can be referred to as afferent processes, because they conduct impulses toward the cell body.
- Dendrites also may be modified into sensory receptors that receive, or sense stimuli such as heat, cold, touch, pressure, stretch, or other physical changes from inside or outside the body
- Dendrites tend to be short, numerous & have many branches

AXON

- An axon is another type of process from the neuron cell body.
- Axons conduct nerve impulses away from the cell body towards another neuron or an effector cell
- They can be called efferent processes, because they conduct impulses away from the cell body
- An axon is a single process that can be long
- Axons are sometimes referred to as nerve fibers
- When talking about the components of nerve cells, the term axon is usually used. When talking about the bundles of axons that make up cordlike nerves in the body, they are usually called nerve fibers

MYELIN SHEATH

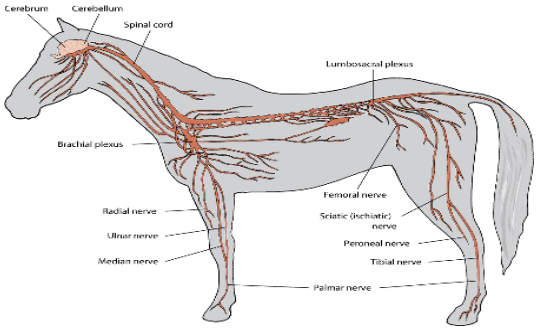
- A sheath of fatty substance that covers the axon
- On gross appearance, is white in color
- Nervous tissue containing many myelinated axons is called WHITE MATTER
- Nervous tissue made up of largely cell bodies appears darker & is called GRAY MATTER
- Myelin sheath is made of cell membranes of specialised glial cells called

✓ oligodendrocytes in the brain & spinal cord,

✓ and Schwann cells in the nerves outside of the brain & spinal cord

LOCATION OF CELL BODIES

- ❑ The cell body of neurons is usually located in the brain or spinal cord
- ❑ while the axon extends the whole distance to the organ that it supplies.
- ❑ The neuron carrying impulses from the spinal cord to the hind leg or tail of a horse, for example, can be several cms long



3 TYPES OF NEURONS (BASED ON FUNCTION)

❑ A sensory (afferent) neuron

✓is a nerve cell that transmits impulses from a sense receptor such as those in the eye or ear to the brain or spinal cord.

❑ A motor (efferent) neuron

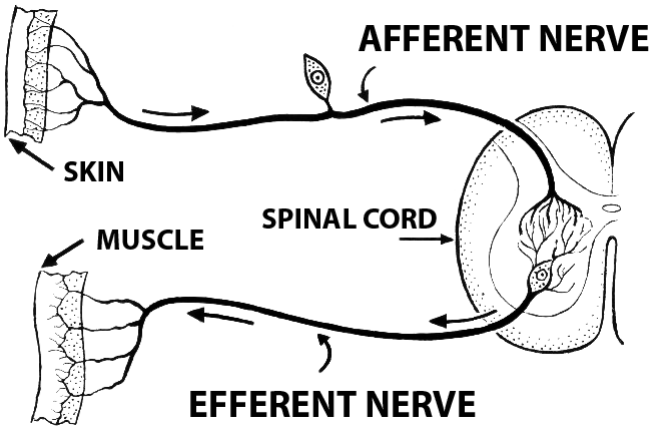
✓ is a nerve cell that transmits impulses from the brain or spinal cord to a muscle or gland.

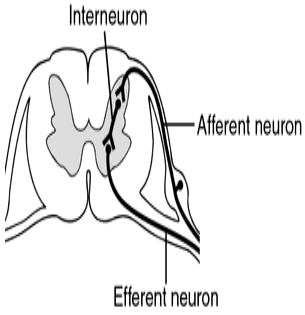
✓ ie begins in the CNS and ends in the PNS

❑ A relay neuron (interneuron)

✓connects sensory and motor neurons and is found in the brain or spinal cord

SENSORY, MOTOR & RELAY NEURONS



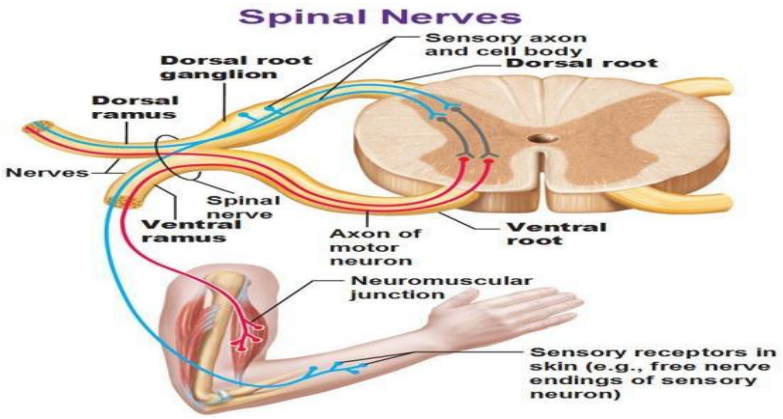


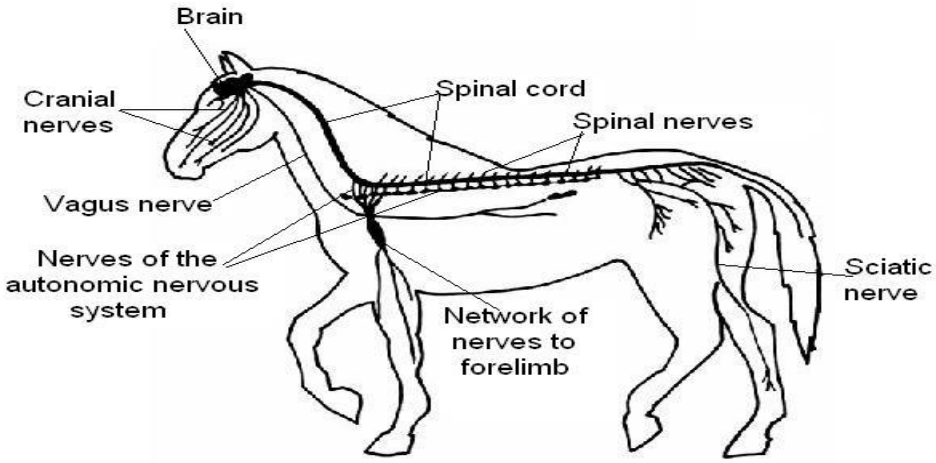
TERMINOLOGY

- CNS – Only has interneurons
- PNS – has afferent (sensory) and efferent (motor) neurons

- NUCLEUS - A collection of nerve cell bodies within the brain.
- GANGLION - A "nucleus" that occurs outside the brain is known as a ganglion
- Nerves occur as single neurons or in bundles, called nerve trunks.
- Ganglions are the nerve bundles that occur outside of the brain and spinal cord

SPINAL NERVES





NEUROGLIAL CELLS & MYELIN SHEATH

- ❑ **Glial cells** are the non-neuronal cellular elements of the CNS.
- ❑ The are 10 to 1 ratio when compared to neurons in numbers
- ❑ Not involved in the transmission of impulses through the NS
- ❑ Main role is to support & protect neurons
- ❑ Glial cells include;
  - ✓Oligodendrocytes
  - ✓Astrocytes
  - ✓ependymal cells
  - ✓and microglia.
- ❑ The most significant role of oligodendrocytes is their involvement in myelin sheath formation in the CNS.

GLIAL CELLS & MYELIN SHEATH

- ❑ Schwann cells are involved in myelin sheath formation in the PNS.
- ❑ Astrocytes
  - ✓are the most prominent glial cell
  - ✓Star shaped
  - ✓Are associated with neuronal synapses
  - ✓They regulate transmission of impulses and provide neurons with nutrients.
- ❑ Ependymal cells
  - ✓Form the epithelial lining of the the ventricles of the brain
  - ✓Cerebral spinal fluid is formed in the ventricles

GLIAL CELLS & MYELIN SHEATH

❑ The **microglia**

✓ have a phagocytic function.

✓ They enter the CNS from blood vessels & increase in numbers during inflammatory processes or where neuron injury has occurred.

SUMMARY ROLES OF GLIAL CELLS (SUPPORT & PROTECT)

i. Formation of myelin sheath

ii. Phagocytise/ digest debri

iii. help supply nutrients of neurons by connecting them to blood vessels

iv. Regulate transmission of impulses

GLIAL CELLS & MYELIN SHEATH

❑ The special glial cells wrap themselves around the axon

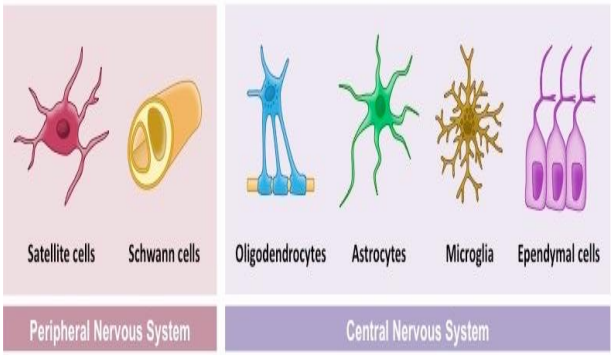
❑ Because the axon of most neurons is fairly long, it takes multiple Schwann cells or oligodendrocytes lined up end to end to cover the entire length of the axon.

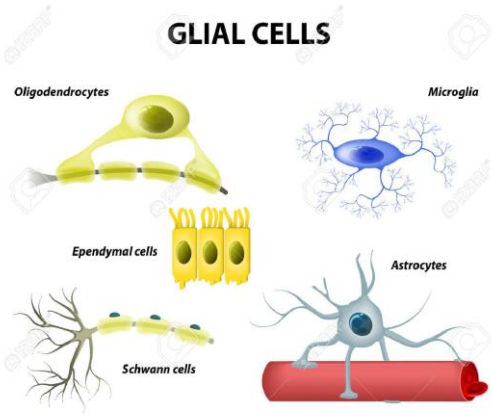
❑ Between adjacent glial cells are small gaps in the myelin sheath called nodes of Ranvier.

❑ The myelin sheath & nodes of Ranvier work together to enhance the speed of conduction of nerve impulses along the axon

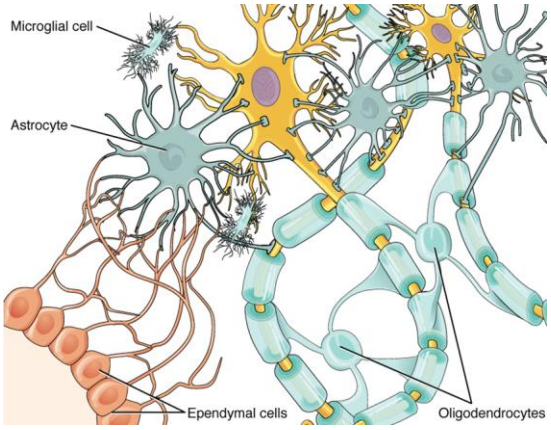
❑ Myelinated axons conduct nerve impulses faster than unmyelinated axons

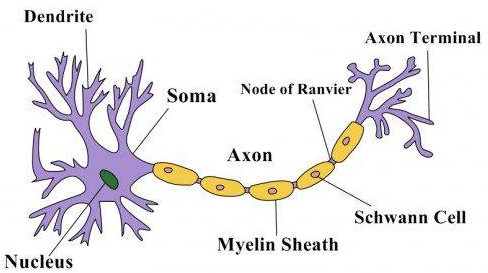
GLIAL CELLS – NEURON SUPPORT CELLS



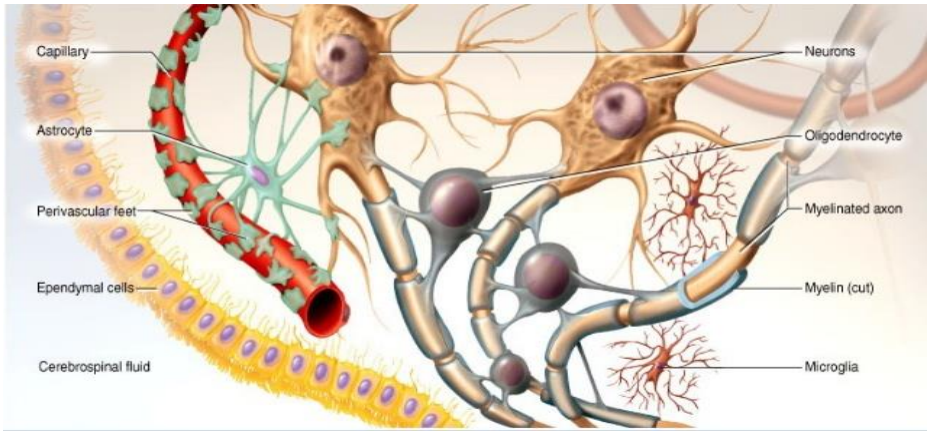


GLIAL CELLS – NEURON SUPPORT CELLS





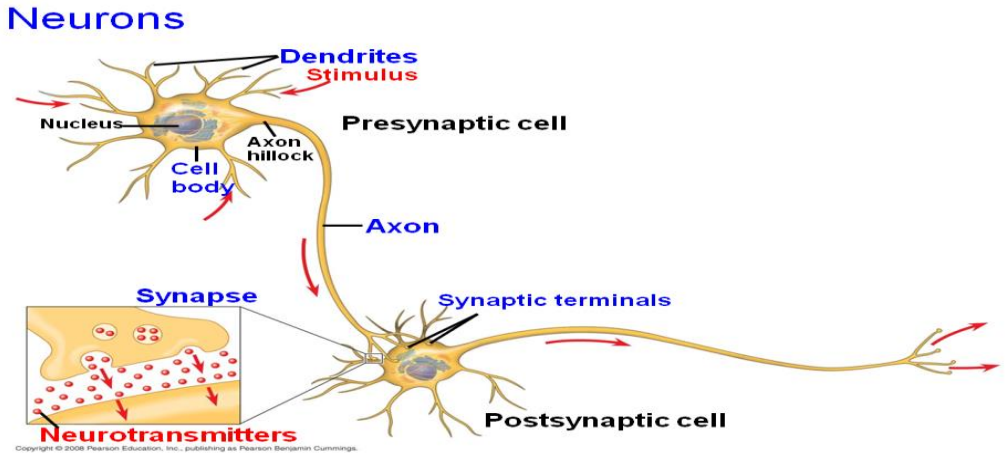
GLIAL CELLS – NEURON SUPPORT CELLS



CONNECTION BETWEEN NEURONS (How neurons communicate)

- ❑ The connection between adjacent neurons is called a synapse.
- ❑ Nerve cells do not touch each other there is a microscopic space between them.
- ❑ The electrical impulse in the neurone before the synapse stimulates the production of chemicals called neurotransmitters (such as acetylcholine), which are secreted into the gap.
- ❑ The neurotransmitter chemicals diffuse across the gap & when they contact the membrane of the next nerve cell they stimulate a new nerve impulse
- ❑ After the impulse has passed the chemical is destroyed & the synapse is ready to receive the next nerve impulse

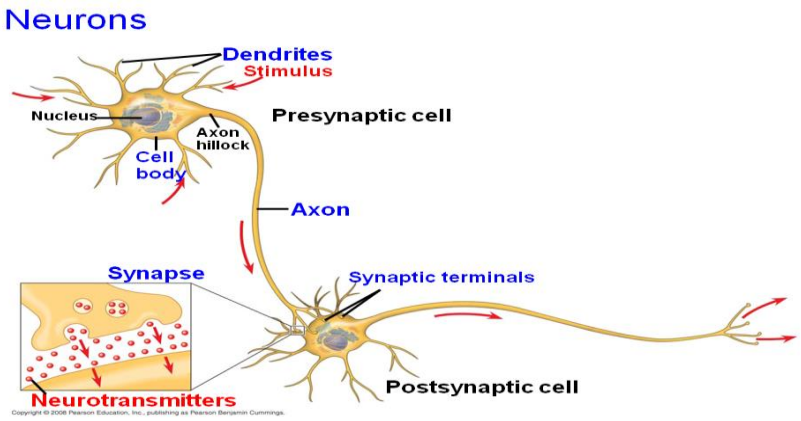
HOW NEURONS COMMUNICATE



TYPES OF NEUROTRANSMITTERS

- **Acetylcholine** is one of the most commonly studied neurotransmitter in the body
- **Norepinephrine** - is associated with arousal and fight-or flight reactions of the sympathetic nervous system.
- **Epinephrine** – Epinephrine is released from the adrenal gland and therefore plays more of a role as a hormone in the fight-or-flight reactions
- **Dopamine** - Dopamine is found in the brain, where it is involved with autonomic functions & muscle control.

HOW NEURONS COMMUNICATE



REFLEX ACTION

❑ A reflex is a rapid automatic response to a stimulus.

Examples of reflex actions

✓ when you touch a hot object & automatically jerk your hand away, this is a reflex action.

✓ Animals automatically blink when an object approaches the eye

✓ cats twist bodies in the air when falling so that they land their paws

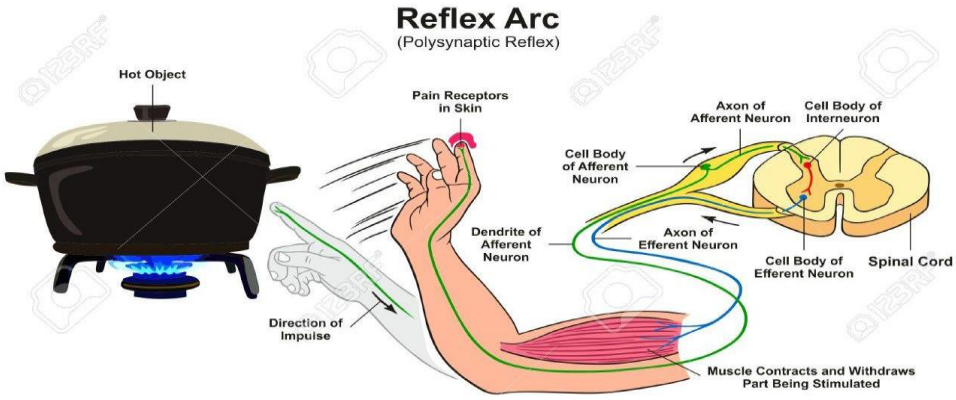
✓ Swallowing, sneezing

✓ constriction of the pupil of the eye in bright light

REFLEX ARC

- The path taken by the nerve impulses in a reflex is called a reflex arc.
- Most reflex arcs involve only 3 neurons
- The stimulus (a pin in the paw) stimulates the pain receptors of the skin, which initiate an impulse in a sensory neuron. This travels to the spinal cord where it passes, by means of a synapse, to a connecting neuron called the relay neuron situated in the spinal cord. The relay neuron in turn makes a synapse with one or more motor neurons that transmit the impulse to the muscles of the limb causing them to contract & remove the paw from the sharp object.
- Reflexes do not require involvement of the brain although you are aware of what is happening and can, in some instances, prevent them happening. Animals are born with their reflexes.

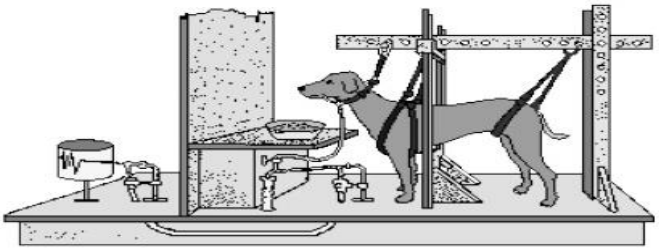
REFLEX ARC

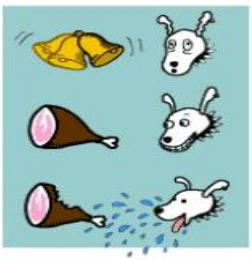


CONDITIONED REFLEXES

- In most reflexes the stimulus and response are related.
- For example the presence of food in the mouth causes the salivary glands to release saliva.
- However, it is possible to train animals to respond to different & often quite irrelevant stimuli. This is called a conditioned reflex.
- A Russian biologist called Pavlov carried out the classic experiment to demonstrate such a reflex when he conditioned dogs to salivate at the sound of a bell ringing.
- Almost every pet owner can identify reflexes they have conditioned in their animals. Perhaps you have trained your cat to associate food with the opening of the fridge door or accustomed your dog to the routines you go through before taking them for a walk.

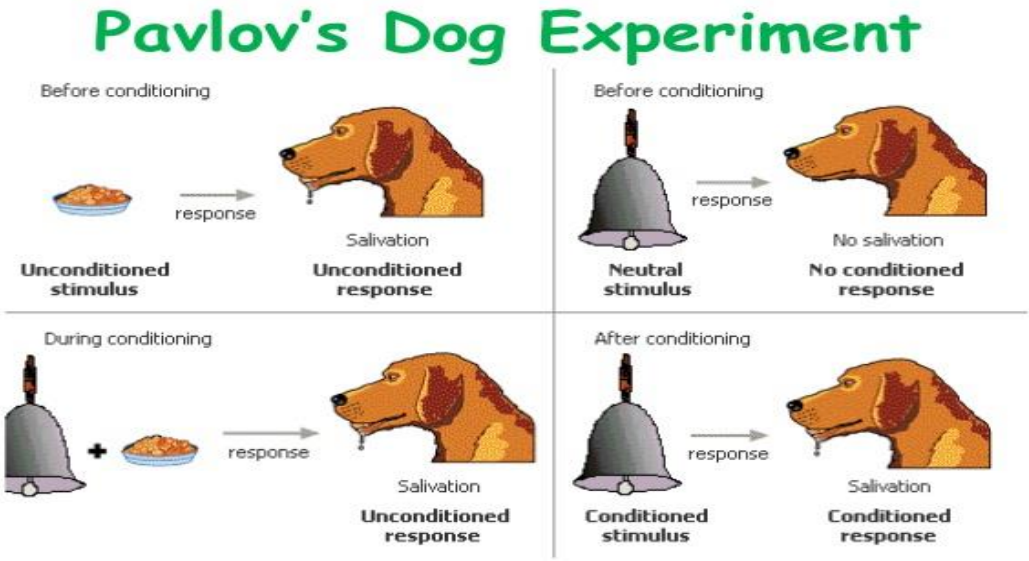
Pavlov's Experiment



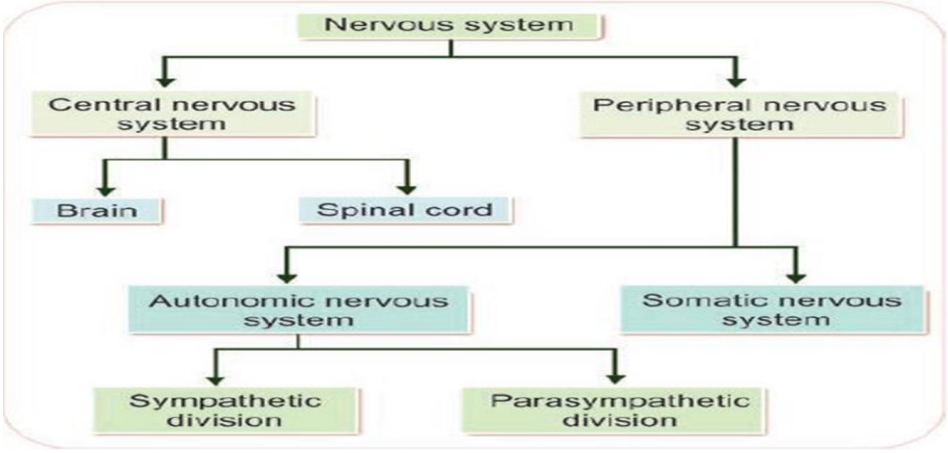


The dog's salivation to meat powder is an **unconditional reflex** (no learning is involved)

Over time, however, the dog comes to salivate at the sounding of the tone alone. When this occurs, a **conditional reflex** has developed



DIVISIONS OF THE NERVOUS SYSTEMS



CENTRAL & PERIPHERAL NERVOUS SYSTEMS

CENTRAL NERVOUS SYSTEM (CNS)

- ❑ Consists of brain & spinal cord
- ❑ Contains neural tissue, connective tissue & blood vessels
- ❑ Functions of CNS: To process & coordinate
  - ✓Receives sensory data
  - ✓Sends motor commands; control activities of peripheral organs eg skeletal muscles
  - ✓ Higher functions of the brain: intelligence, memory, learning, emotions

CENTRAL & PERIPHERAL NERVOUS SYSTEMS

PERIPHERAL NERVOUS SYSTEM (PNS)

- ❑ Includes all neural tissue outside CNS
- ❑ Functions
  - ✓ deliver sensory information to the CNS
  - ✓ carry motor commands to peripheral tissues & systems
- ❑ PNS is made up of nerves called peripheral nerves
- ❑ Nerves carry sensory information & motor commands
  - ✓ cranial nerves – connect to the brain
  - ✓ spinal nerves – attach to the spinal cord

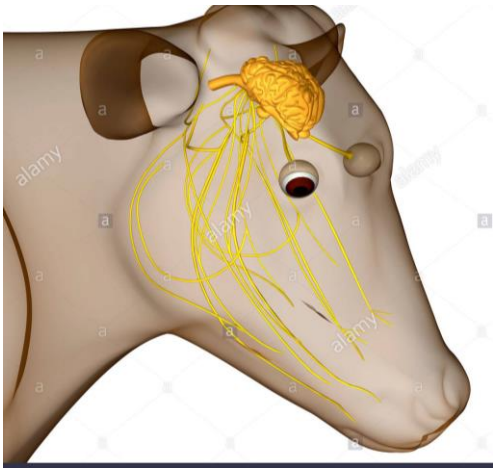
CRANIAL NERVES

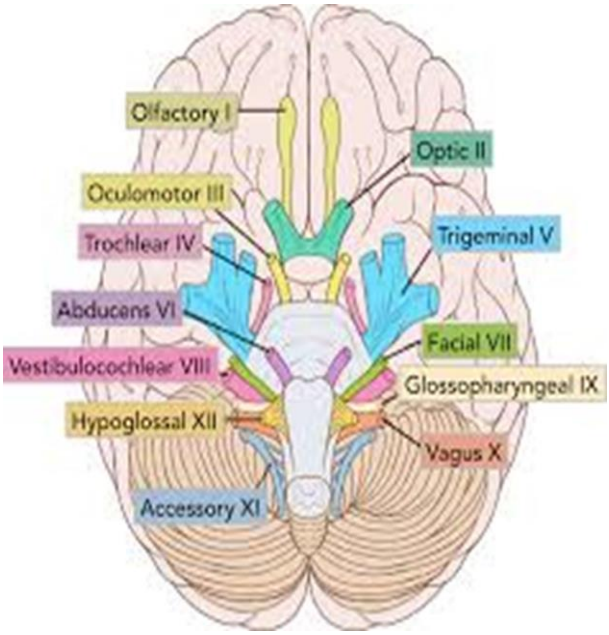
- 12 pairs arise from the brain
- Are designated by Roman numerals, numbered from most rostral (I) to most caudal (XII).
- With the exception of cranial nerves I (olfactory) & II (optic), the cranial nerves arise from the midbrain, pons, & medulla oblongata and in general resemble ordinary spinal nerves.

CRANIAL NERVES SUMMARY

#	Name	Nerve type	Function
I	Olfactory	Sensory	Smell
II	Optic	Sensory	Vision
III	Oculomotor	Motor	Most eye movement
IV	Trochlear	Motor	Moves eye
V	Trigeminal	Both	Face sensation, mastication
VI	Abducens	Motor	Abducts the eye
VII	Facial	Both	Facial expression, taste
VII	Vestibulocochlear	Sensory	Hearing, balance
IX	Glossopharyngeal	Both	Taste, gag reflex
X	Vagus	Both	Gag reflex, parasympathetic innervation
XI	Accessory	Motor	Shoulder shrug
XII	Hypoglossal	Motor	Swallowing, speech

CRANIAL NERVES



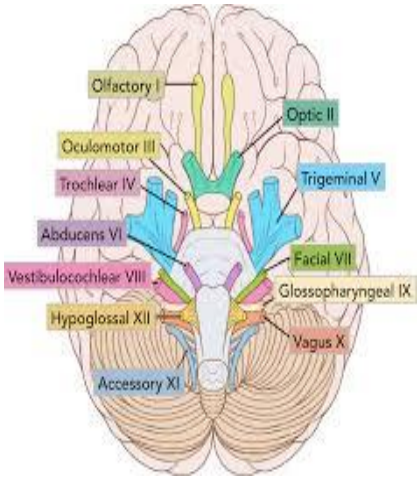


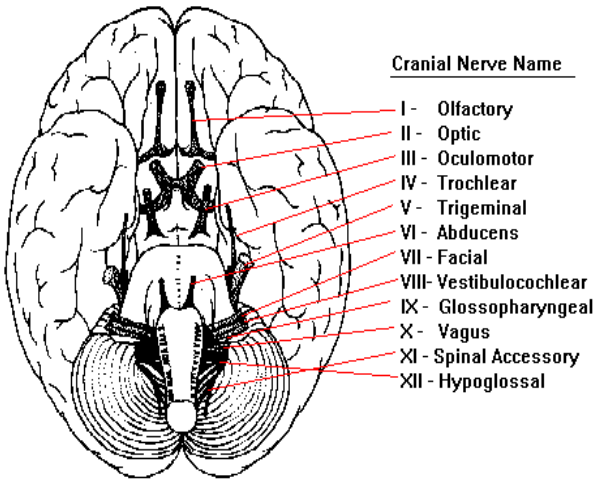
CRANIAL NERVES

❑Each passes through a hole in the cranium (brain case). The most important of these are the olfactory, optic, acoustic and vagus nerves.

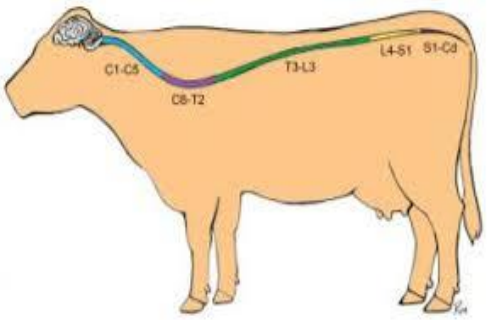
- The **olfactory nerves** - (smell) carry impulses from the olfactory organ of the nose to the brain.
- The **optic nerves** - (sight) carry impulses from the retina of the eye to the brain.
- The **auditory (acoustic) nerves** - (hearing) carry impulses from the cochlear of the inner ear to the brain.
- The **vagus nerve** - controls the muscles that bring about swallowing. It also controls the muscles of the heart, airways, lungs, stomach and intestines

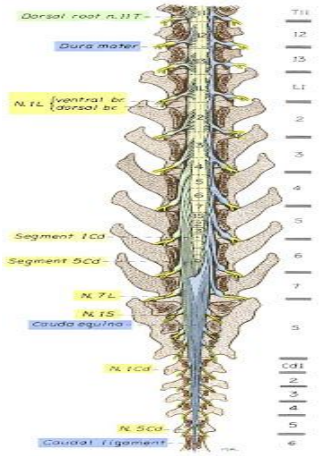
CRANIAL NERVES



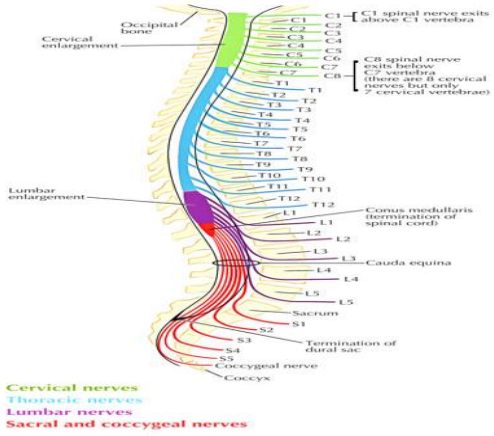


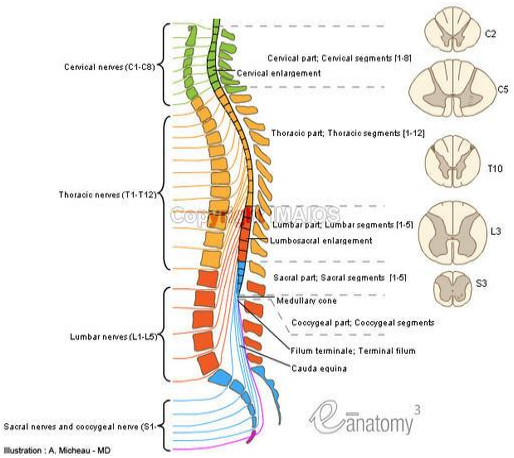
BRAIN AND SPINAL CORD





SPINAL NERVES





THE BRAIN – MENINGES

- ❑ Meninges are 3 protective layers of the brains;
- ❑ Function of the meninges

✓is to cover & protect the brain from mechanical injury

✓ Provide blood supply to the skull and the brain

✓Provide space for flow of CSF between pia & arachnoid maters

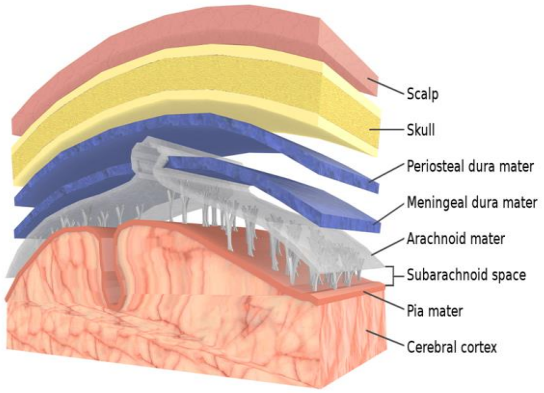
- ❑ The 3 meninges are;

A. Dura mater
B. Arachnoid mater
C. Pia mater

MENINGES

1. DURA MATTER

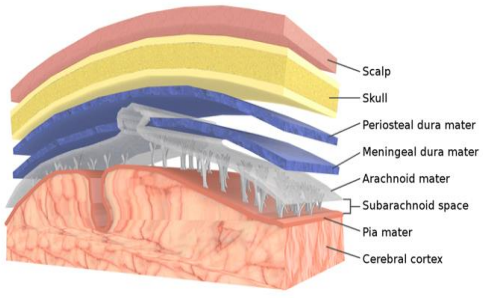
- ❑Outermost of the 3 layers
- ❑ Tough, fibrous layer
- ❑ Closest to the skull
- ❑ Fused to the skull just as the periosteum is fused to the bone



A . MENINGES

2. ARACHNOID MATER

- ❑Deep to the dura mater is the subdural space
- ❑ deep to which is the arachnoid membrane (spiderweb like)
- ❑ The space deep to it, the subarachnoid space, is where the cerebrospinal fluid (CSF) circulates around the brain.

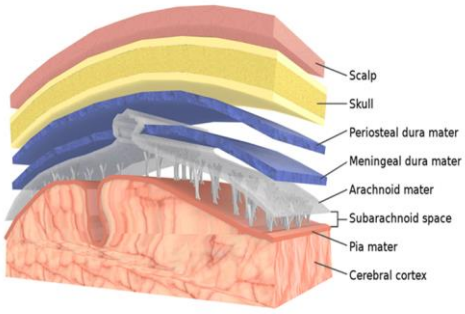


A . MENINGES

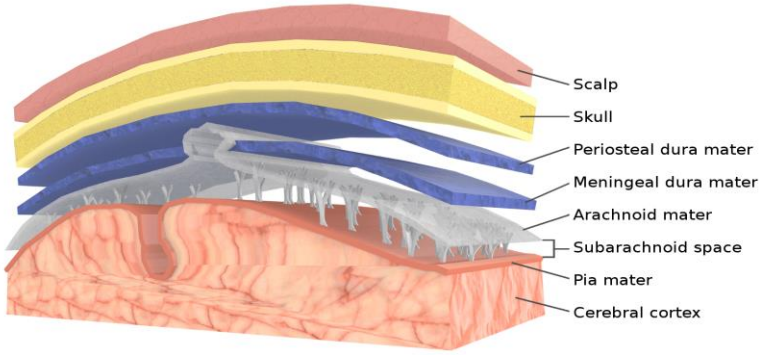
2. **PIA MATER**

The innermost layer, which sits directly on the brain, is called the pia mater

(lies directly on surface and spinal cord surface)



MENINGES



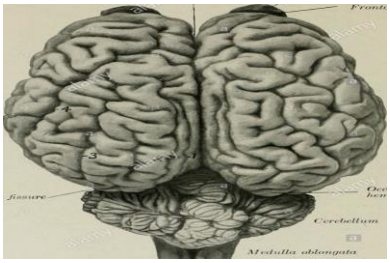
GYRI & SULCI

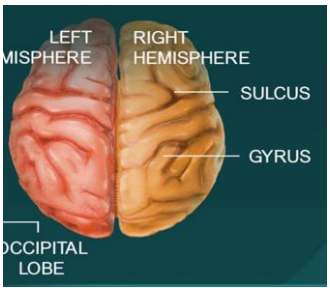
GYRI

✓ The surface of the mammalian brain is composed of a series of folds called gyri (singular: gyrus).

✓ the valleys between the gyri are called sulci (sulcus).

✓ The gyri help increase the surface area of the brain & allow for more brain function





SUMMARY - HOW IS THE BRAIN PROTECTED

❑ The brain is protected by bones of the skull & a covering of 3 thin membranes called meninges

❑ The brain is also cushioned and protected by the CSF

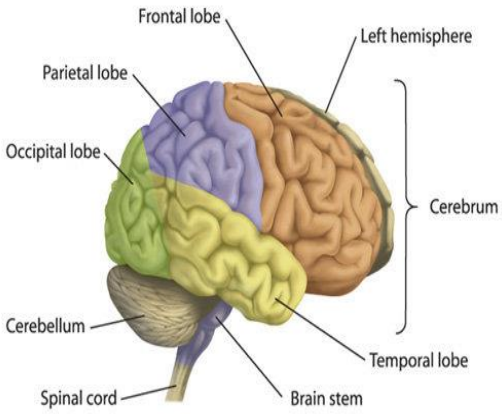
❑ CSF is produced by special cells in the 4 hollow spaces in the rain called ventricles

THE BRAIN

- ❑ is made up of 4 major parts:

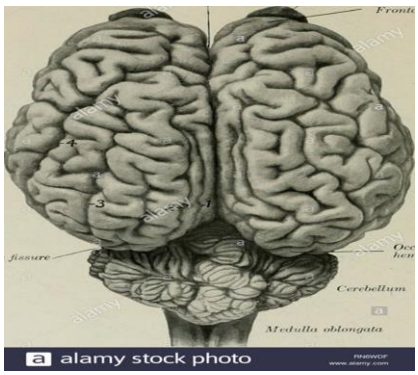
I. Cerebrum
II. Cerebellum
III. Pons
IV. Medulla oblongata

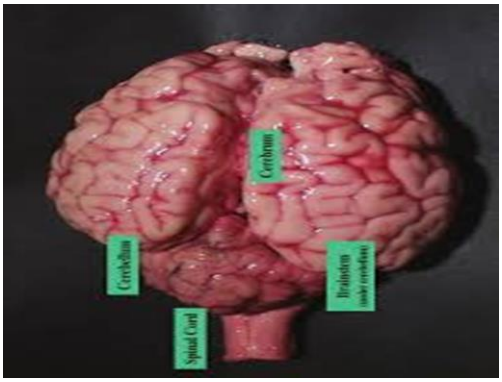
III & IV makeup the brainstem



1. THE CEREBRUM -

- ❑ The largest part of the brain
- ❑ Is divided into left & right hemispheres
- ❑

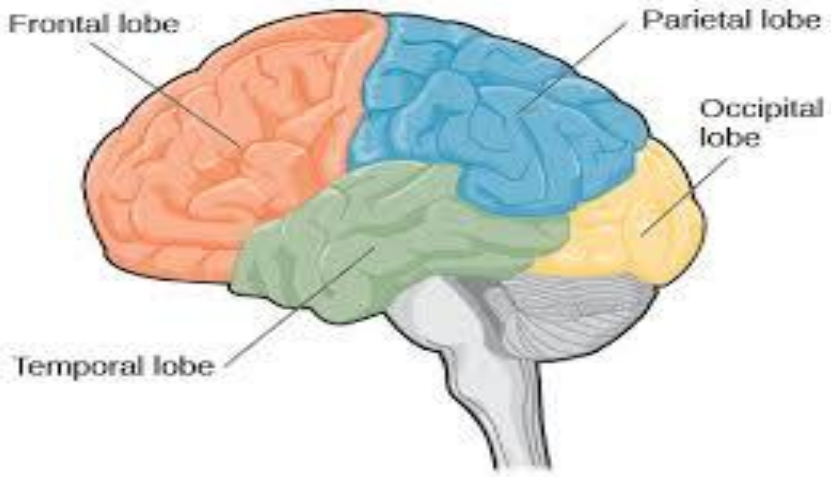




THE CEREBRUM - LOBES OF THE BRAIN

- ❑ Each cerebral hemisphere is divided into 4 lobes
- ❑The lobes are areas named for their location relative to the skull.
- ❑ The 4 lobes are;
- ✓ frontal
- ✓ parietal
- ✓ temporal
- ✓ occipital lobes.
- ❑ The term cerebrum refers to the areas that overlap from the frontal into the parietal area.
- ❑ All of these lobes are paired (one on each side). There is no clear demarcation of each lobe when looking at the superficial brain surface

LOBES OF THE CEREBRUM

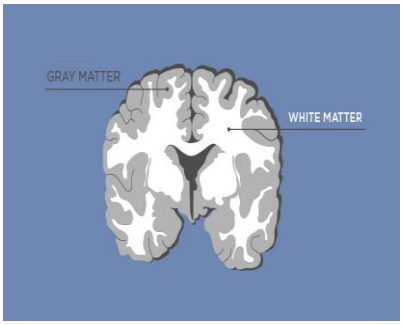


1. THE CEREBRUM -

❑ is made up of;

i. gray matter in the **cerebral cortex** (outer-most superficial layer of the brain)

ii. And white matter beneath the cortex,

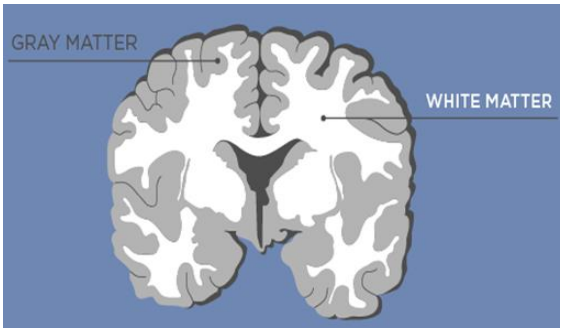


1. THE CEREBRUM

GRAY MATTER

✓grey color in the living brain

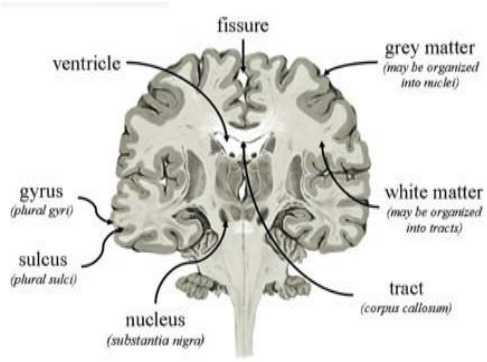
✓ contains the cell bodies, dendrites & axon terminals of neurons, so it is where all synapses are



THE CEREBRUM

WHITE MATTER

✓White matter is made of axons connecting different parts of grey matter to each other



1. THE CEREBRUM - ROLES

❑ responsible for those functions most commonly associated with higher-order behaviours, such as learning, reasoning & intelligence.

✓ receives & interprets sensory information

✓ initiates conscious (voluntary) nerve impulses to skeletal muscles

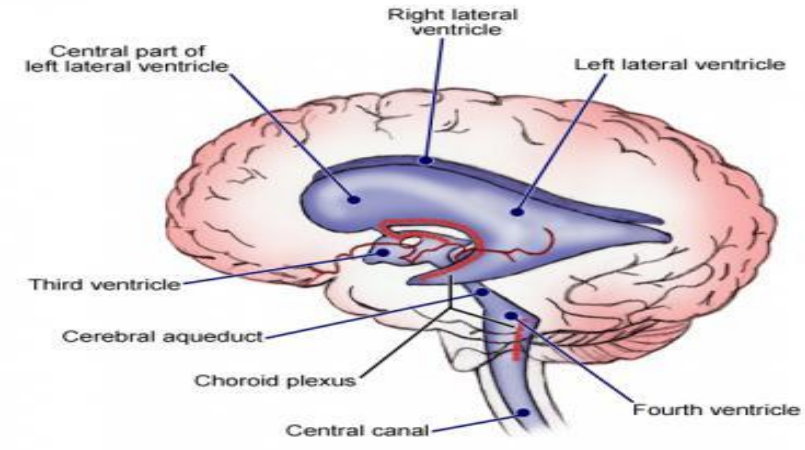
✓ also responsible for expression of emotional responses, learning, memory and recall, & other behaviours associated with conscious activity

❑ The right side controls the left side of the body & the left side controls the right.

VENTRICLES

- The brain has 4 interconnected cavities (ventricles) where CSF is produced
- 2 lateral ventricles, 3rd ventricle & 4th ventricle
- Ventricles are continuous with the central canal of the spinal cord
- They are numbered & drain different areas of the brain depending on their location
- Another role is to cushion

THE VENTRICLES

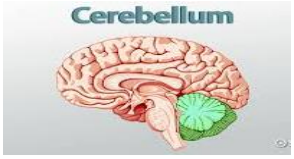


ROLE OF CSF

- Cerebrospinal fluid is a clear, colorless body fluid found in the brain and spinal cord.
- Role of CSF
- ✓ providing basic mechanical protection (cushion) i.e shock absorber
- ✓ CSF also circulates nutrients and chemicals filtered from the blood
- ✓ Removes waste & toxic products from the brain
- ✓ immunological protection to the brain inside the skull

2. THE CEREBELLUM

- A rounded structure caudal to the cerebrum
- A longitudinal incision into the cerebellum reveals a series of channels that resembles branches of a tree
- Also has gray mater cortex & white mater beneath it
- Serves as a coordinator of messages from other parts of the brain to the body.
- Coordinates the action of voluntary muscles in activities such as walking, running, eating



2. THE CEREBELLUM

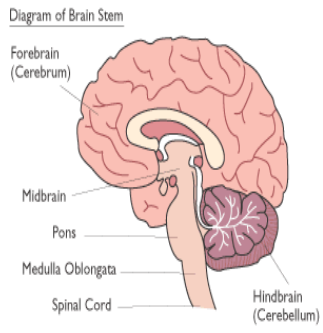
FUNCTIONS

- ❑ Allows the body to have coordinated movement, balance, posture & complex reflexes

- ❑ Essentially, the cerebellum compares the movement the body intends to make with the actual position of muscles & joints to determine whether the intentions of the cerebral cortex are actually being carried out.

3. THE BRAIN STEM

- ❑ is the connection between the rest of the brain & the spinal cord
- ❑ most primitive part of the brain
- ❑ composed of 3 parts
  - ✓ medulla oblongata
  - ✓ pons
  - ✓ midbrain
- ❑ does not have clear layers of gray and white matter

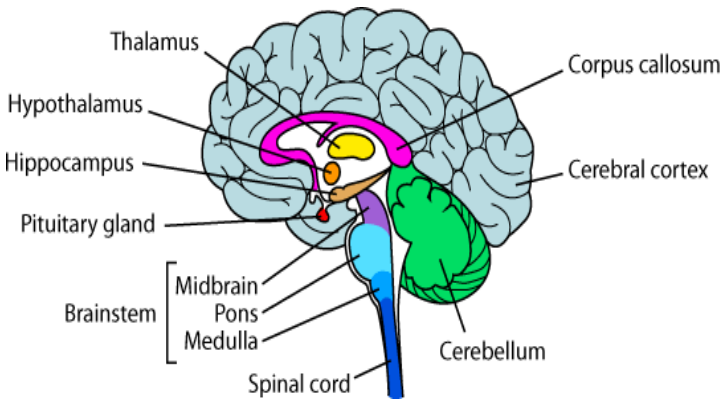


THE BRAIN STEM

- ❑ Controls the flow of messages between the brain & the rest of the body
- ❑ Controls basic body functions eh breathing, swallowing, heart rate, blood pressure
- ❑ Consists of

i. Interbrain
ii. Midbrain
iii. Pons
iv. Medulla oblongata

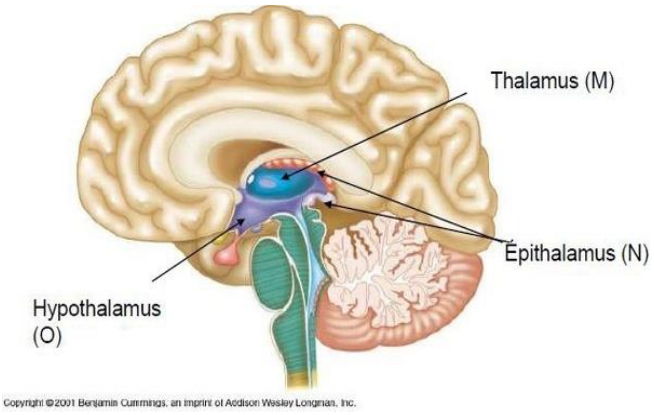
BRAINSTEM



THE BRAINSTEM – THE INTERBRAIN

- ❑ Composed of;

i. Hypothalamus
ii. Thalamus
iii. Epithalamus



3. THE BRAIN STEM - FUNCTIONS

- ❑ Role is to maintain basic functions of the body. I.e. operates at the subconscious level
- ❑ Involved in autonomic control functions eg
- ✓ Heartbeat
- ✓ respiration (including coughing, sneezing & hiccupping),
- ✓ blood vessel diameter (vasomotor control),
- ✓Swallowing & vomiting
- ❑ Cranial nerves originate from this area
- ❑ Damage to the area results in respiratory failure or cardiovascular collapse

THE BRAIN

HYPOTHALAMUS

Hormones released by the hypothalamus

a. growth hormone releasing hormone (GHRH)

b. Gonadotropin releasing hormone

c. thyrotropin releasing hormone

i. Also regulates body temperature, controls thirst, hunger & blood pressure and sleep

BRAIN STEM – MEDULA OBLONGATA & THE PONS

- ❑ Contain all the sensory & motor nuclei of all cranial nerves originating in the brain (except 2 located in the mid brain)
- ❑ Major structure in the upper part of the brainstem
- ❑ Important nerves originate from the pons
- ❑ Controls many of the visceral functions such as;

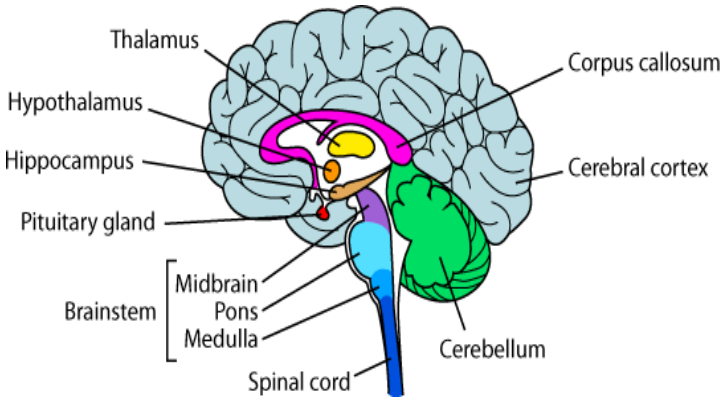
✓ heart rate

✓ blood vessel muscle tone (vasomotor tone)

✓Respiration

✓ motor and secretory activities of the digestive tract.

POSITION OF THE MIDBRAIN



THE MIDBRAIN

- ❑ The topmost part of the brain stem
- ❑ The nuclei of cranial nerves III and IV are located in the midbrain
- ❑ Oculomotor and trochlear
- ❑ Concerned with movement of the eye

BRAIN STEM– MEDULA OBLONGATA & PONS

❑Control the following:
✓ breathing (respiration)
✓ muscles responsible for biting, chewing & swallowing
✓Bladder control
✓Hearing equilibrium (balance)
✓Taste
✓Eye movements
✓ Facial expressions, sensation
✓ Posture
✓ controls sleep cycles

THE BRAINSTEM – THE INTERBRAIN

THE THALAMUS

✓ Is a relay center

✓ A small structure above the brain stem bt cerebrum cortex & midbrain

✓The thalamus contains many nuclei

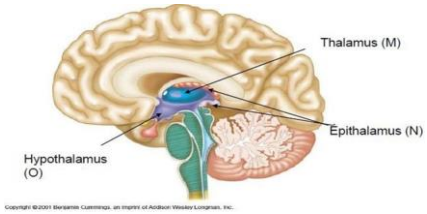
✓Has extensive nerve connections to both.

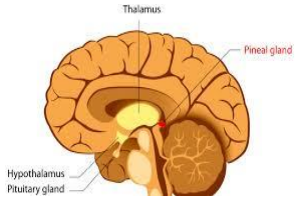
✓The main function of the thalamus is to relay motor and sensory signals to the cerebral cortex.

THE BRAINSTEM – THE INTERBRAIN

EPITHALAMUS

- ✓ Contains an olfactory (smell) correlation center & the pineal gland.
- ✓ The latter is a neurosecretory organ that regulates gonadal hormones & certain daily rhythms
- ✓ Pineal gland secrete melatonin (regulates sleep patterns)





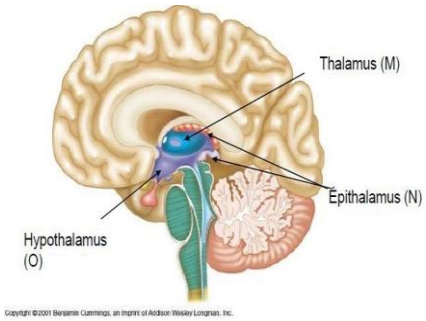
3. THE PONS AND MEDULLA OBLONGATA

- ❑ Control Involuntary (reflex actions), such as blinking, vomiting, breathing, and swallowing
- ❑ act independently of the other two parts of the brain

THE BRAINSTEM – THE INTERBRAIN

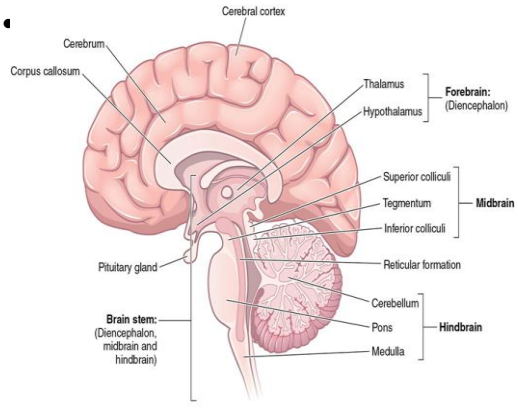
HYPOTHALAMUS

- ✓ located below thalamus
- ✓contains the hypophysis (pituitary gland) an endocrine organ
- ✓ Pituitary gland – master gland – controls several hormone producing glands. It produces many hormones that travel throughout the body.
- ✓ Links the endocrine & nervous systems



THE SPINAL CORD

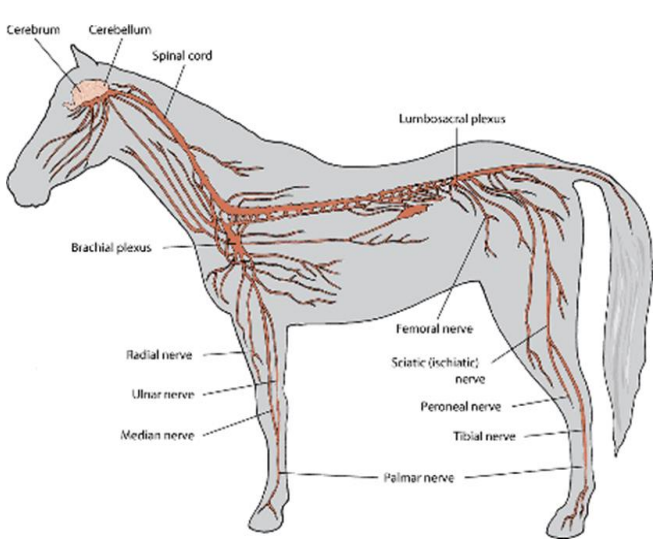
- ❑ The brain stem narrows as it runs caudally, but it widens again slightly as it approaches the foramen magnum
- ❑ This swelling is known as the medulla oblongata & is considered to be the cranial origin of the spinal cord.

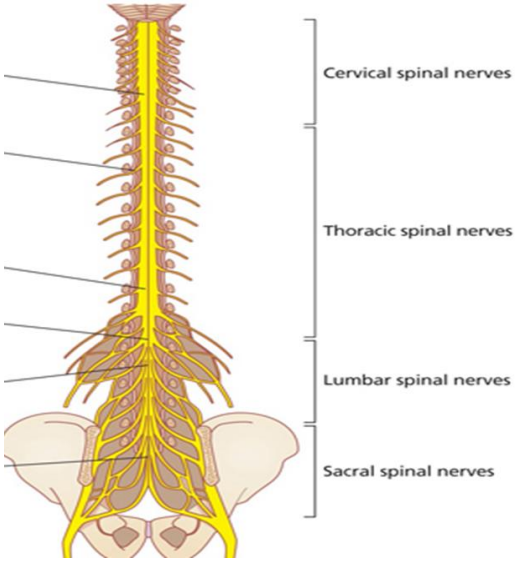


SPINAL CORD

- A thick, whitish cord of nerve tissue which is a major part of the vertebrate central nervous system.
- It extends from the brain stem down through the spine, with nerves branching off to various parts of the body.
- Spinal cord is divided into spinal cord segments
- Each segment to paired spinal nerves

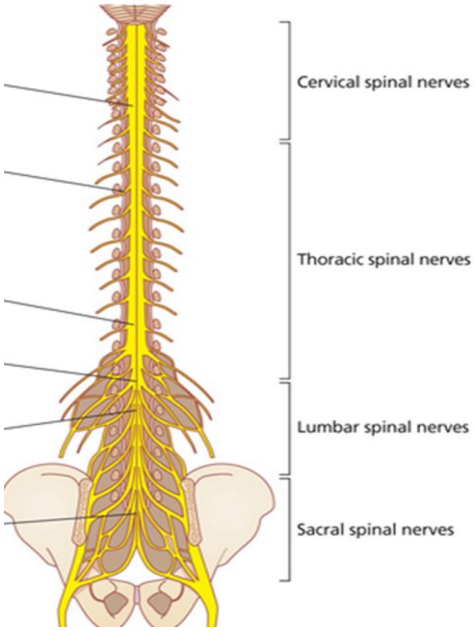
SPINAL NERVES





SPINAL NERVES

- In vertebrates, the paired peripheral nerves arise from the spinal cord.
- There are approx 31 pairs of spinal nerves: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral & 1 coccygeal (species differences)
- Each pair connects the spinal cord with a specific region of the body.



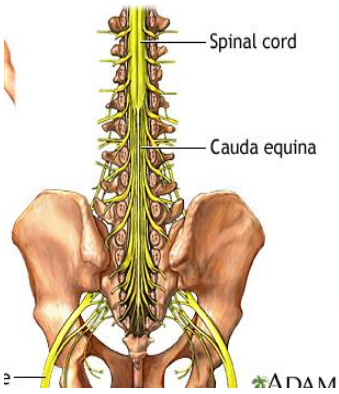
THE SPINAL CORD

- Each segment of the spinal cord is associated with a pair of ganglia called dorsal root ganglia, which are situated just outside of the spinal cord and contain cell bodies of sensory neurons. These neurons travel into the spinal cord via the dorsal roots.
- Ventral roots consist of axons from motor neurons, which bring information to the periphery from cell bodies within the CNS. Dorsal roots and ventral roots come together and exit the intervertebral foramina as they become spinal nerves.

CAUDAL EQUINA (horse's tail)

- At the base of the spinal column, near the 1st lumbar vertebra, is a collection of nerves called the cauda equina.
- They are called this because they resemble a horse's tail. Just above the cauda equina, the spinal cord ends and it continues on as this collection of spinal nerves through the vertebral canal.
- The cauda equina has approximately 10 fiber pairs at its base.
- The primary function of the cauda equina is to send & receive messages between the lower limbs & the pelvic organs, which consist of the bladder, the rectum & the internal genital organs.

CAUDAL EQUINA



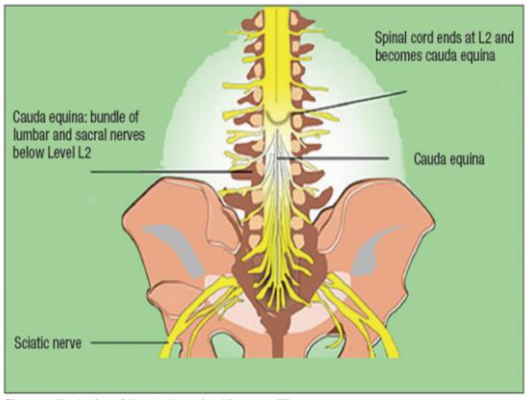
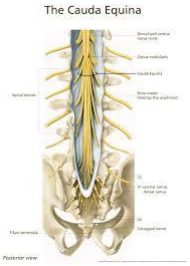
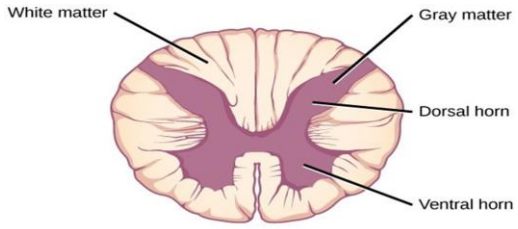


Figure 1. Illustration of the cauda equina ("horses tail").

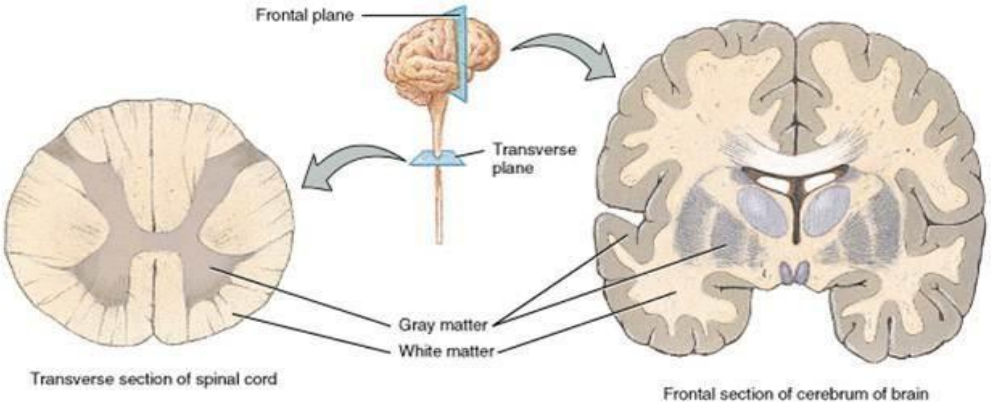


SPINAL CORD - GRAY & WHITE MATTER

- Unlike that of the cerebrum, the spinal cord's gray matter is found at the center of the cord, forming a butterfly shape on cross-section
- The white matter, surrounds the gray matter
- A spinal cord segment is defined by the presence of a pair of spinal nerves.



GRAY & WHITE MATTER IN BRAIN & SPINAL CORD



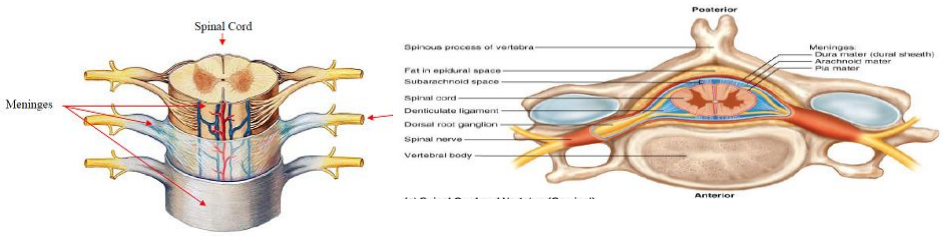
MENINGES OF THE SPINAL CORD

- ❑ Spinal cord is part of the CNS while spinal nerve is part of the PNS
- ❑ Spinal cord has gray matter (center) and white matter surrounding it
- ❑ Central canal is in the center of the grey matter & contains CSF
- ❑ CSF helps to nourish nervous tissue & is a shock absorber
- ❑ Spinal nerves has 3 layers of membrane

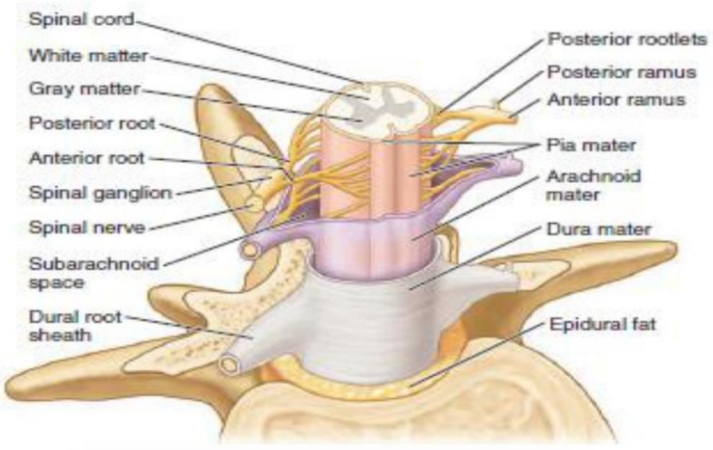
i. Pia matter
ii. Arachnoid
iii. Dura matter

MENINGES OF THE SPINAL CORD

- ❑ The pia mater is the innermost protective layer and is tightly associated with the surface of the spinal cord
- ❑ The middle layer is called the arachnoid mater
- ❑ Space between arachnoid and pia maters is called the subarachnoid space and is where the CSF is located. It is from this location at the level of the lumbar region that CSF fluid is obtained in a spinal tap.



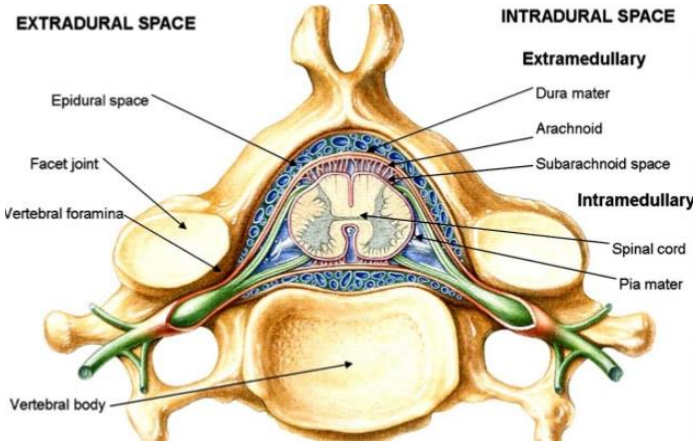
MENINGES OF THE SPINAL CORD

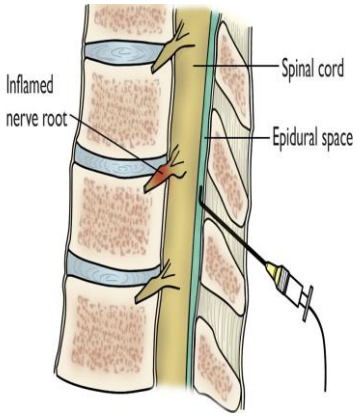


EPIDURAL SPACE

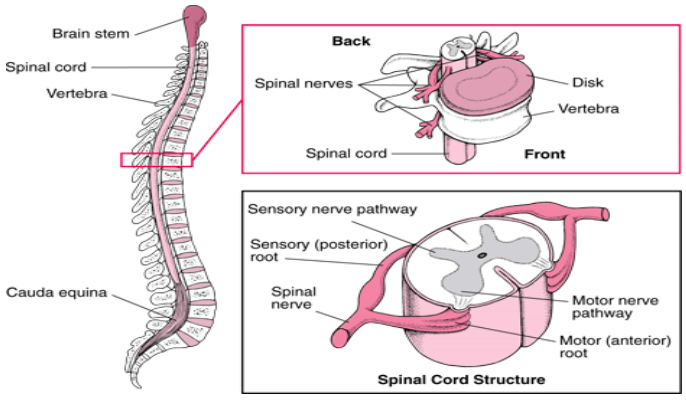
- The space between the dura mater & the surrounding bone of the vertebrae is called the epidural space.
- The epidural space is filled with adipose tissue & contains a network of blood vessels.
- The epidural space is an area in which local anesthetic is often injected prior to surgical procedures in the area.

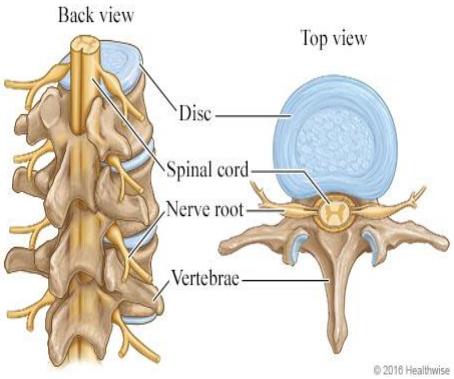
EPIDURAL SPACE





POSITION OF SPINAL CORD



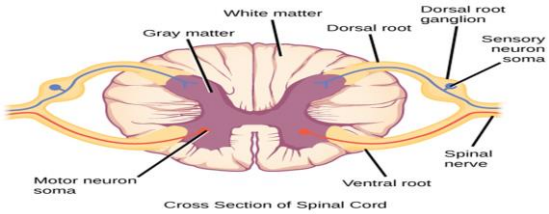


ROLE OF THE SPINAL CORD

- The spinal cord is located at the center of the vertebral column.
- The spinal cord is the main avenue for message transferal between the brain & the other parts of the body.
- The spinal cord receives messages from sensory nerve fibers in various parts of the body & transmits them to the brain.
- Motor nerve fibers in the spinal cord then transmit the response from the brain back to the body.

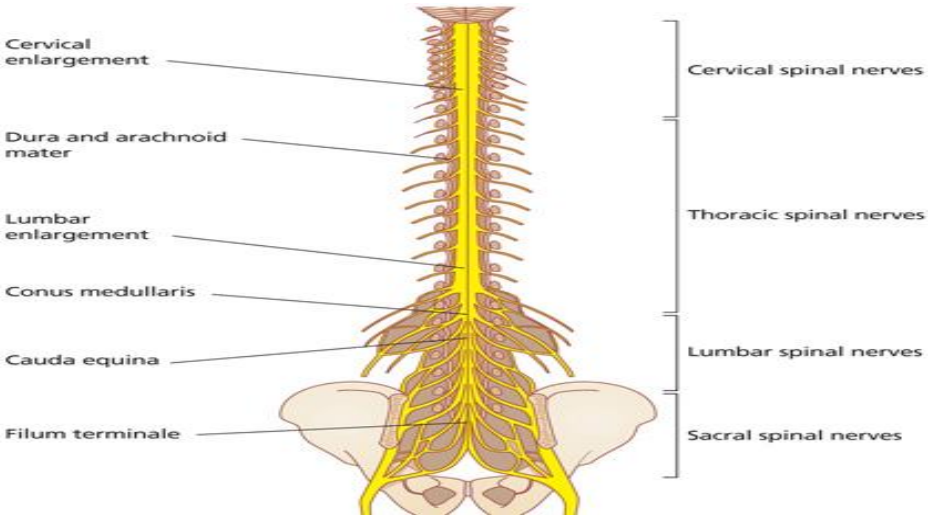
SPINAL NERVES

- Near the spinal cord each spinal nerve branches into two roots.
- One, composed of sensory fibres, enters the spinal cord via the dorsal root its cell bodies lie in a spinal ganglion that is outside the spinal cord.
- The other, composed of motor fibres, leaves the spinal cord via the ventral root; its cell bodies lie in specific areas of the spinal cord itself.



Cross Section of Spinal Cord

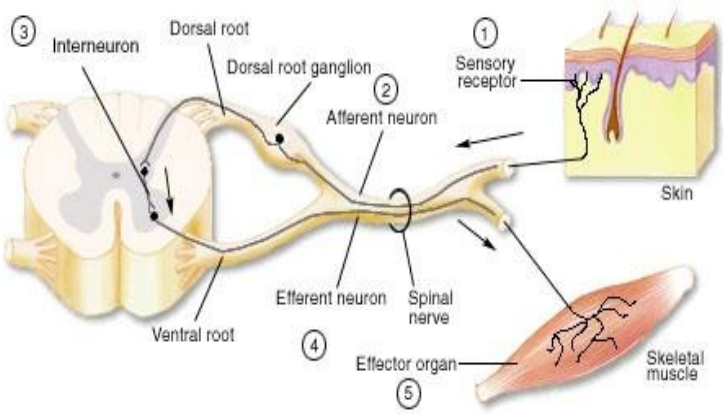
THE SPINAL NERVES



SPINAL NERVES ARE MIXED NERVES

- Dorsal & ventral roots arise from the spinal cord & fuse, generally close to the intervertebral foramen
- FIbers of the dorsal root & motor fibers of the ventral root become the spinal nerve, characterized as a mixed nerve, since it has both sensory and motor elements

SPINAL NERVES ARE MIXED NERVES



SPINAL NERVES ARE MIXED NERVES

- **DORSAL BRANCHES** – of the spinal nerves innervate structures that are dorsal to the transverse processes of the vertebrae (muscles & skin)
- **VENTRAL BRANCHES** - The ventral branches supply structures ventral to the transverse processes & most of the thoracic and pelvic limbs.

The spinal nerves tend to innervate the region of the body in the area adjacent to where they emerge from the vertebral column

SPINAL CORD & SPINAL NERVES

- ❑ Spinal nerves consists of ventral root & dorsal roots
- ❑ Both roots join the spinal cord

DORSAL ROOT

- ✓Contains sensory neurons
- ✓Contains a ganglion
- ✓Ganglion – where cell bodies are located & also where synapse are located
- ✓ Sensory neurons bring sensory information to the spinal cord

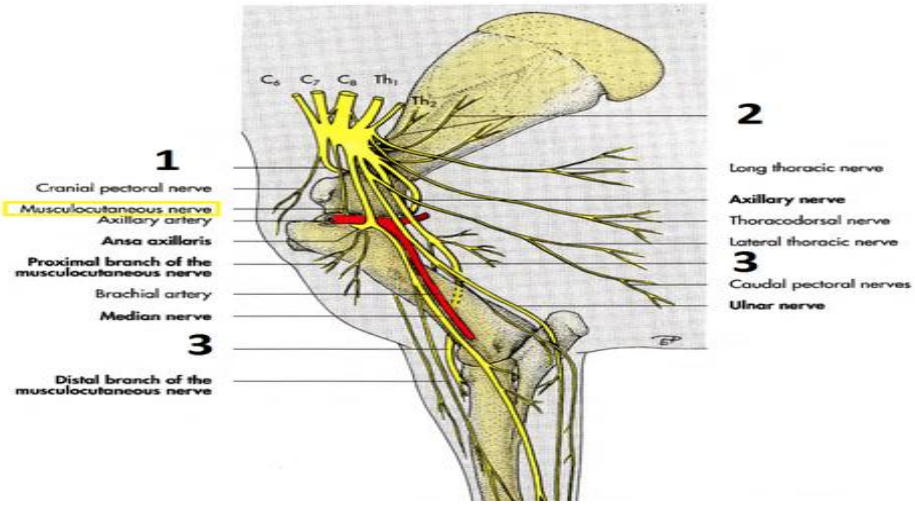
VENTRAL ROOT

- ✓ For the motor or efferent neuron
- ✓ The efferent neuron is can either be somatic or autonomic depending on the target organ/tissue

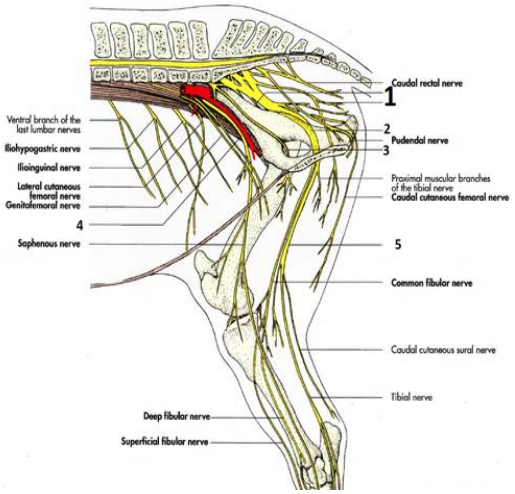
PLEXUS

- ❑ A network of nerves supply a particular region of the body
- ❑ Examples are Brachial plexus and Lumbosacral plexus
- ❑ Brachial plexus (C6 –C8, T1),
- ❑ LUMBOSACRAL PLEXUS (L4-L6, S1-S4)

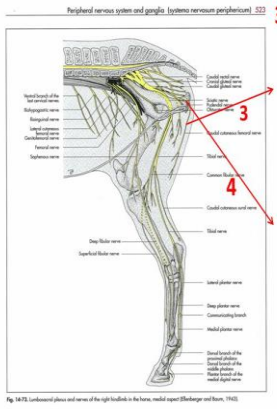
BRACHIAL PLEXUS



PLEXUS



Lumbosacral Plexus



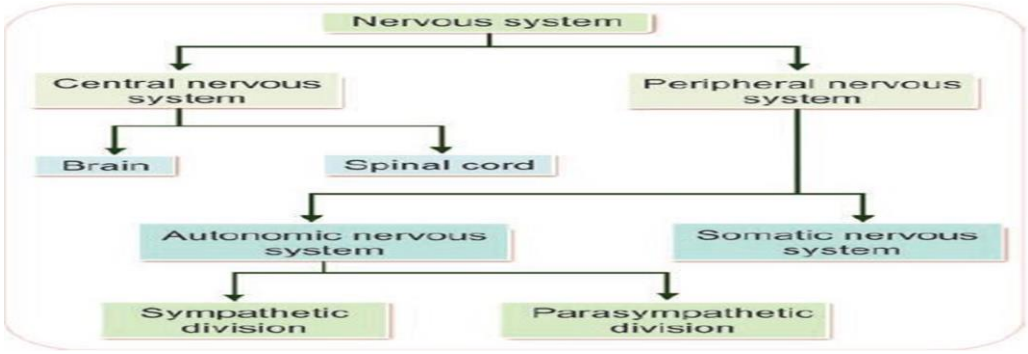
3.Caudal Cutaneous Femoral n. : Skin of the thigh and knee joint

4. Pudendal n.

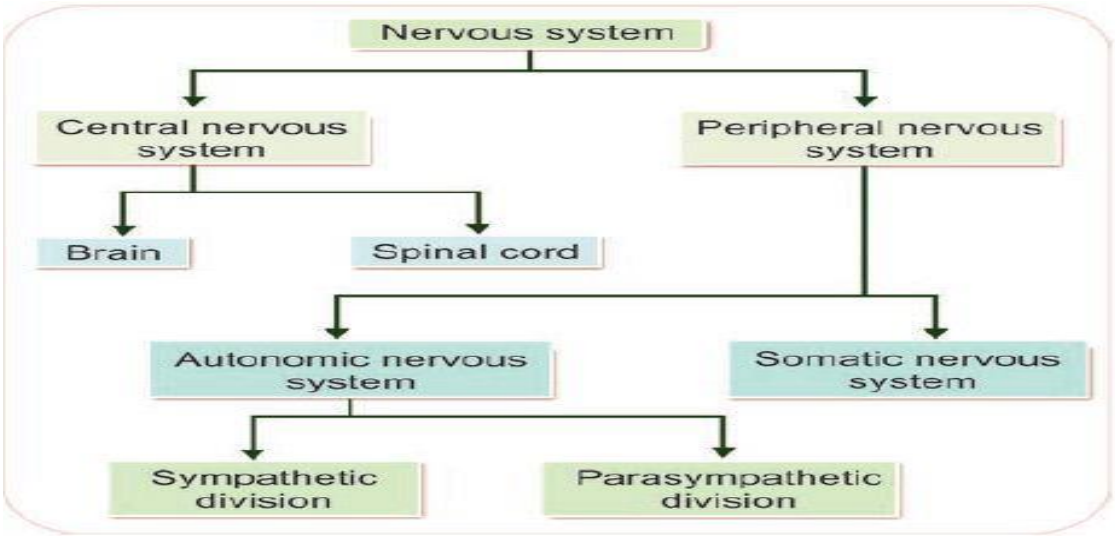
- In the male: Penile muscles and glans penis.
- In the female: Vulva.
- Both in male and female: skin around the anus.

THE PERIPHERAL NERVOUS SYSTEM

- Divided into Autonomic and Somatic nervous system
- Consists of nerves that are connected to the brain (**cranial nerves**), and nerves that are connected to the spinal cord (**spinal nerves**)



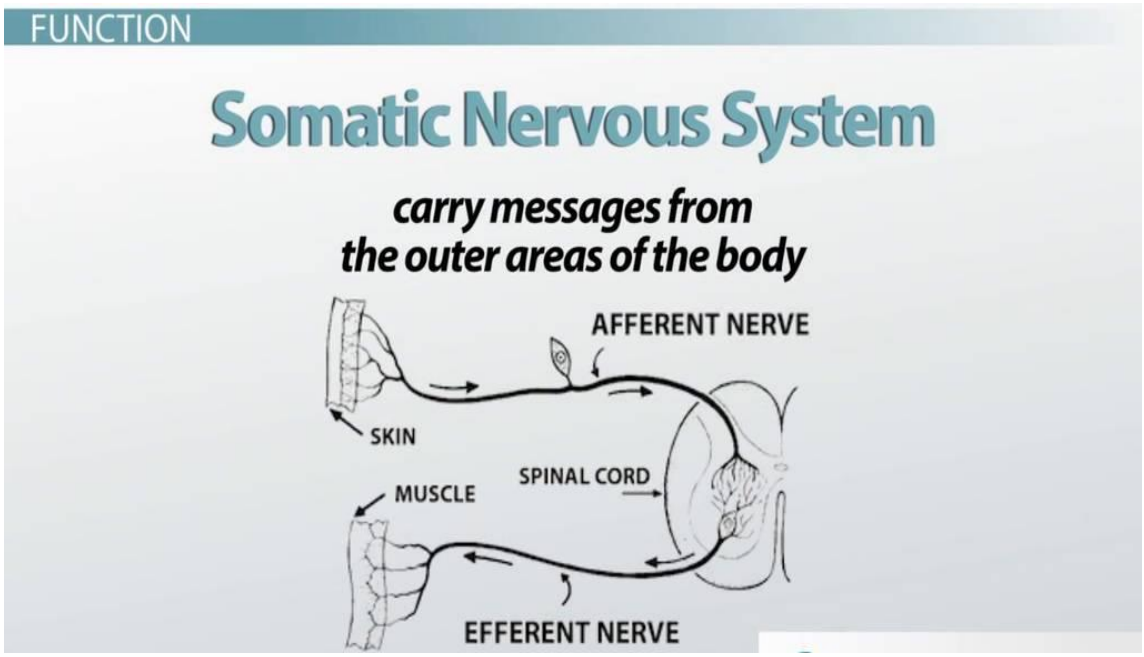
NERVOUS SYSTEM DIVISIONS



THE PERIPHERAL NERVOUS SYSTEM (PNS)

SOMATIC NERVOUS SYSTEM

- ❑ Is the part of the PNS associated with the voluntary control of body movements via skeletal muscles
- ❑ Consists of afferent nerves (Sensory nerves) and efferent nerves or (motor nerves)
- ❑ Afferent nerves are responsible for relaying sensation from the body to the CNS
- ❑ Efferent nerves are responsible for sending out commands from the CNS to the body, stimulating muscle contraction;



THE AUTONOMIC NERVOUS SYSTEM

- Controls internal body functions that are not under conscious control (at subconscious level)
- Has motor nerves & sensory nerves
- Engaged in Involuntary control of body tissues e.g. Smooth muscles & cardiac muscles, glands, intestines, lungs, kidneys etc

THE AUTONOMIC NERVOUS SYSTEM (ANS)

- Autonomic Nervous system is divided into;

1. Sympathetic NS (FIGHT OR FRIGHT response)
2. Parasympathetic NS (REST & DIGEST response)

- The 2 systems generally have opposite effects on organs or tissues
- ANS arises from the brain and spinal cord
- Spinal cord has 31 segment
- Segments are important because sympathetic & parasympathetic nerves arise from the spinal cord segments

ANATOMICAL DIFFERENCES BETWEEN THE SYMPATHETIC & PARASYMPATHETIC SYSTEMS

❑ Where the peripheral nerves of each system emerge from the CNS.

SYMPATHETIC SYSTEM

✓ Nerves emerge from the thoracic & lumber regions

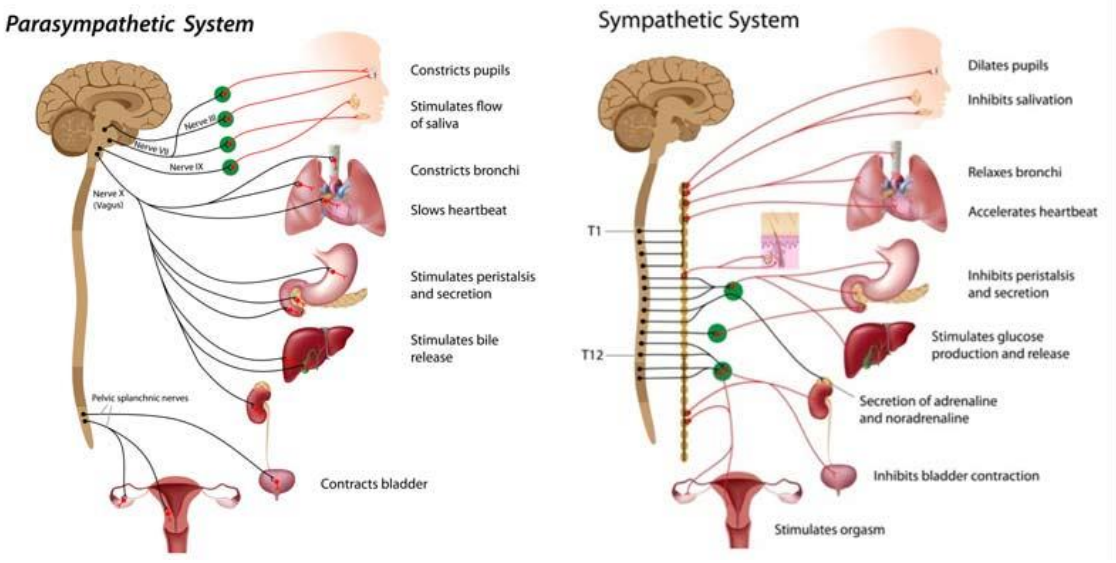
✓ referred to as the thoracolumbar system

PARASYMPATHETIC SYSTEM

✓Emerges from the brain & the sacral vertebral regions

✓ therefore is called the cranial–sacral system.

THE AUTONOMIC NERVOUS SYSTEM



FUNCTIONAL DIFFERENCES BETWEEN THE SYMPATHETIC & PARASYMPATHETIC SYSTEMS

SYMPATHETIC NS

- ❑ Prepares for animal for activity eg running
- ✓ Supply glucose for energy
- ✓ Increases the heart rate
- ✓ Dilates the pupils for increased vision
- ✓ Relax airways
- ✓ Prevents activity of digestion
- ✓Inhibit salivation

PARASYMPATHETIC NS

- ❑ REST & DIGEST RESPONSE
- ✓Conserves body energy
- ✓ Increases gut motility
- ✓ Stimulate digestive secretions
- ✓ Slow down heart rate

SYMPATHETIC NERVOUS SYSTEM

Stimulate s'flight or fight' response

ORGANS TARGETED

- ❑ Heart – increase heart rate
- ❑ Pupils – to dilate pupils
- ❑ Adrenal glands – adrenaline/noraadrenaline production
- ❑ Liver – to stimulate glucose production
- ❑ Digestive organs – to inhibit digestion (reduced blood flow)
- ❑ bladder – cause it to relax to inhibit micturition

THE SYMPATHETIC SYSTEM

- stimulates the " fight or flight" response
- So also called ''flight or fight system''
- allows an animal to face up to an attacker or make a rapid departure.

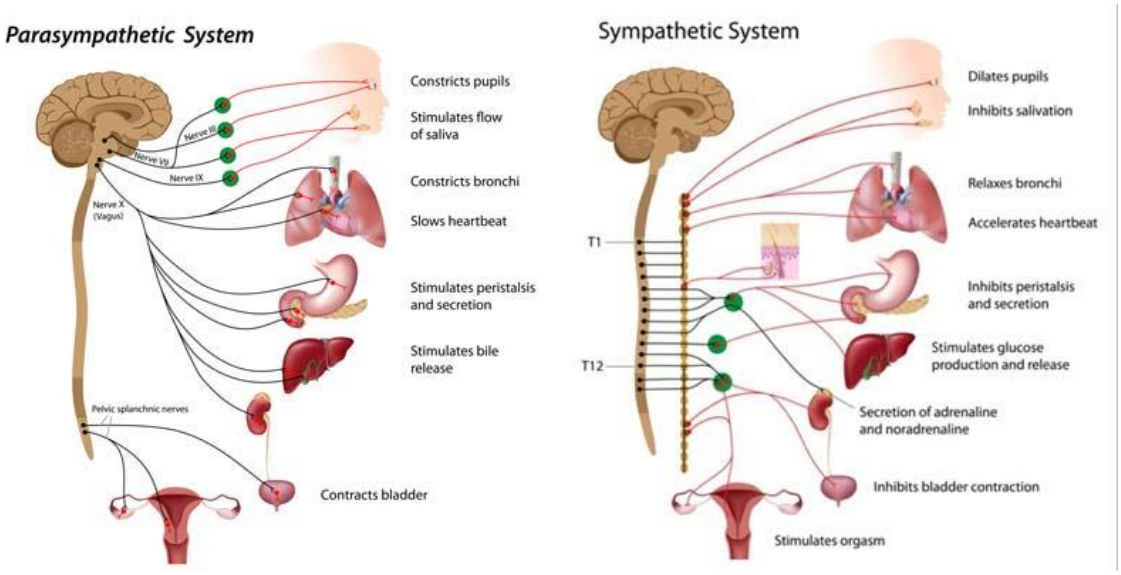
PARASYMPATHETIC NERVOUS SYSTEM (REST & DIGEST

- System has to do with what happens when an animal eats and is lying down to rest

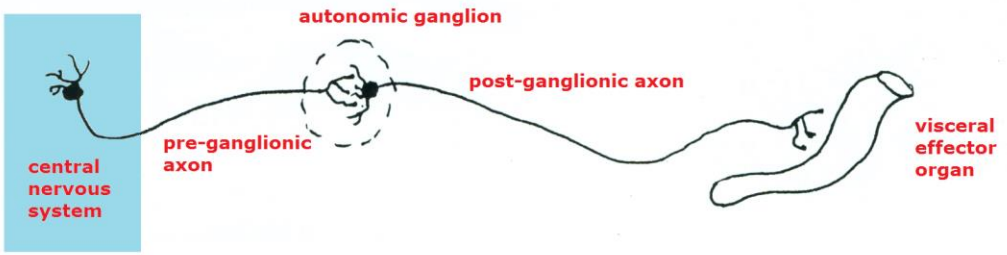
Organs targeted

- Pupils - constrict
- Salivary glands – stimulate salivation
- Airway – constrict
- heart – slows down
- Stimulates digestions
- Dilates intestinal blood flow
- Rectum – relaxes
- Bladder – constricts initiating micturition

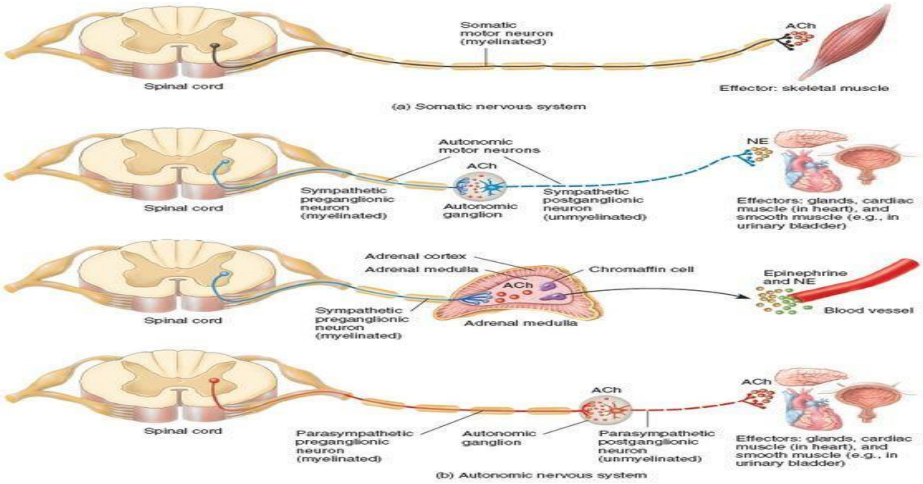
THE AUTONOMIC NERVOUS SYSTEM



PRE & POST GANGLIONIC AXONS OF AUTONOMIC NERVOUS SYSTEM



SOMATIC & AUTONOMIC NERVOUS SYSTEM



EFFERRENT MOTOR NEURONS OF THE AUTONOMIC NERVOUS SYSTEM

- ❑ The efferent motor nerves of both the sympathetic and parasympathetic nervous systems are composed of a sequence of two neurons
- ❑ The first neuron has its cell body in the brain OR spinal cord & extends its axon out from the CNS to a cluster of neuronal cell bodies outside of the CNS called an autonomic ganglion.
- ❑ Here the first neuron synapses with 1 or more second neurons, which then connect to the target organ (e.g., endocrine gland, smooth muscle).
- ❑ The first neuron is called the preganglionic neuron, because it is before the ganglion. The second neuron is the postganglionic neuron, because it carries the impulse from the ganglia to the target organ.

THE PARASYMPATHETIC SYSTEM

- ❑ does the opposite to the sympathetic system
- ❑ also called ''rest & restore system''.
- ❑ It maintains the normal functions of the relaxed body. These are sometimes known as the "housekeeping" functions.
- ❑ It promotes effective digestion, stimulates defaecation & urination
- ❑ maintains a regular heartbeat and rate of breathing.

✓decreased heart rate

✓pupil constriction

✓ increased gut activity.

THE ANS IN PERSPECTIVE

- ❑ In a fight-or-flight situation, the animal needs to move rapidly

✓the bronchioles (airway passages) increase in diameter *(bronchodilation)* to allow a greater exchange of O_2 & CO_2.

✓ Heart rate & force of cardiac contractions increase to increases the rate at which blood is moved around the body.

✓Small blood vessels (arterioles) supplying the muscles dilate (vasodilation).

✓ Small blood vessels supplying the skin, GIT & kidney constrict →blood is redirected to the muscles

✓The decreased blood supply to the skin also means that superficial wounds will bleed less.

✓ Pupils dilate – to increase peripheral vision

THE ANS IN PERSPECTIVE

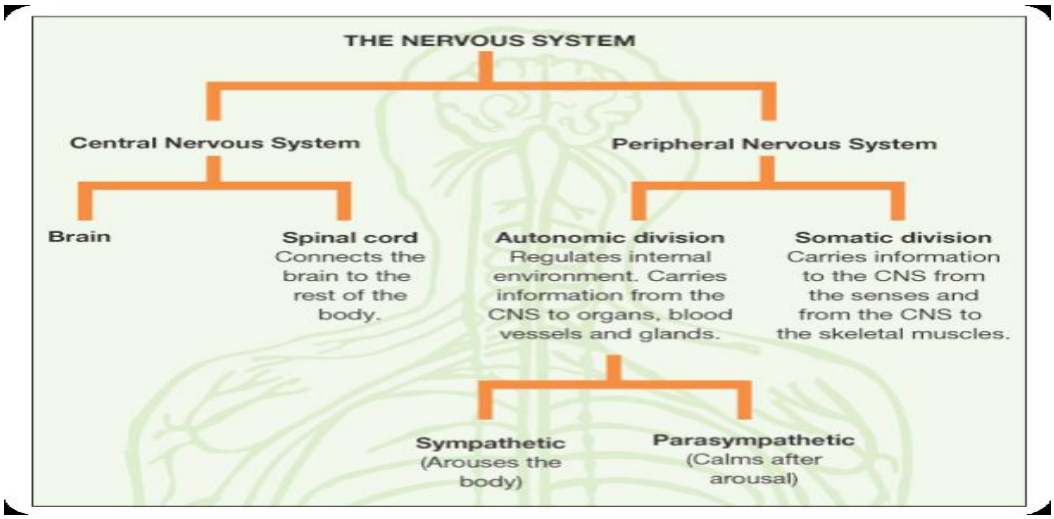
The parasympathetic system causes following reactions;

- ✓GI tract to increase its activity, thus digesting & absorbing nutrients that are needed to replenish the energy resources used during the fight-or-flight situation.
- ✓ reduces the heart rate and
- ✓reduces the sympathetic system's dilation of the bronchioles.

ACTIONS OF THE SYMPATHETIC & PARASYMPATHETIC NERVOUS SYSTEMS

System/function	Parasympathetic	Sympathetic
Cardiovascular	Decreased cardiac output and heart rate	Increased contraction and heart rate; increased cardiac output
Pulmonary	Bronchial constriction	Bronchial dilatation
Musculoskeletal	Muscular relaxation	Muscular contraction
Pupillary	Constriction	Dilatation
Urinary	Decreased urinary output; sphincter contraction	Increased urinary output; sphincter relaxation
Gastrointestinal	Decreased motility of stomach and gastrointestinal tract; decreased secretions	Increased motility of stomach and gastrointestinal tract; increased secretions
Glycogen to glucose conversion	Increased	No involvement
Adrenal gland	Release epinephrine and norepinephrine	No involvement

SUMMARY – THE NERVOUS SYSTEM



BLOOD BRAIN BARRIER (BBB)

- ❑ is a highly permeable border that separates the circulating blood from the brain.
- ❑ Separates the blood from the brain tissue
- ❑ Barrier is composed of 3 layers;

i. Endothelial cells (simple squamous cells) – have tight cell to cell junctions

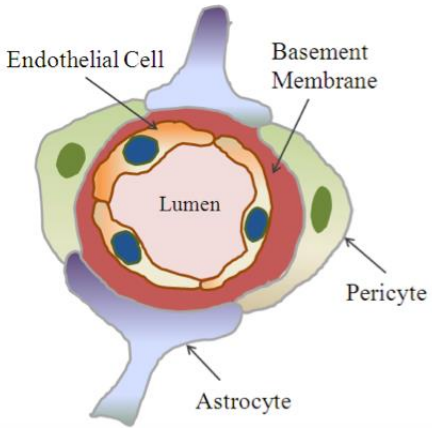
ii. Basement membrane – found on the base of the endothelial cells

iii. Astrocytes – surround the endothelial cells

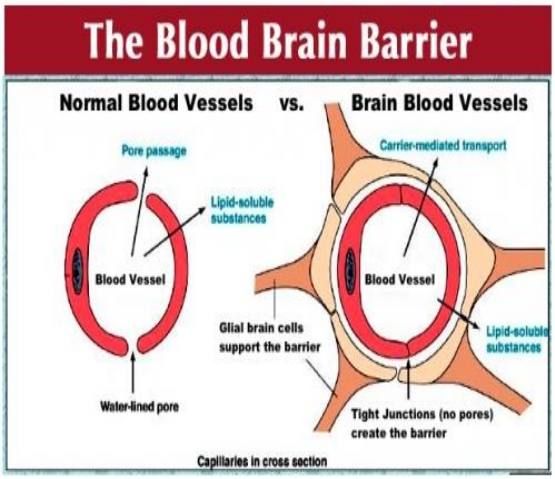
BASEMENT MEMBRANE

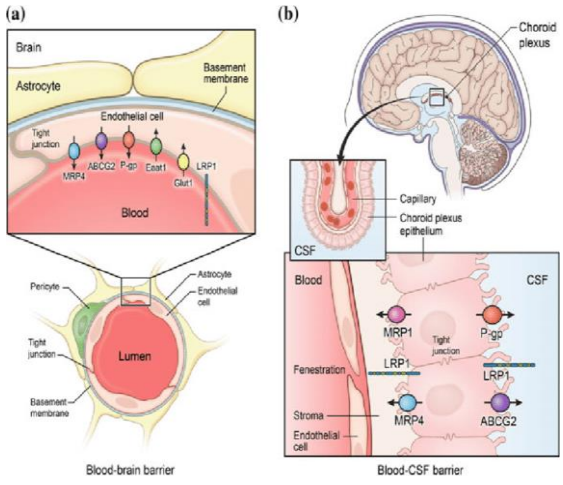
3 LAYERS OF THE BBB

i. Endothelial cells
ii. Basement membrane
iii. Glial cells (astrocytes & pericytes)

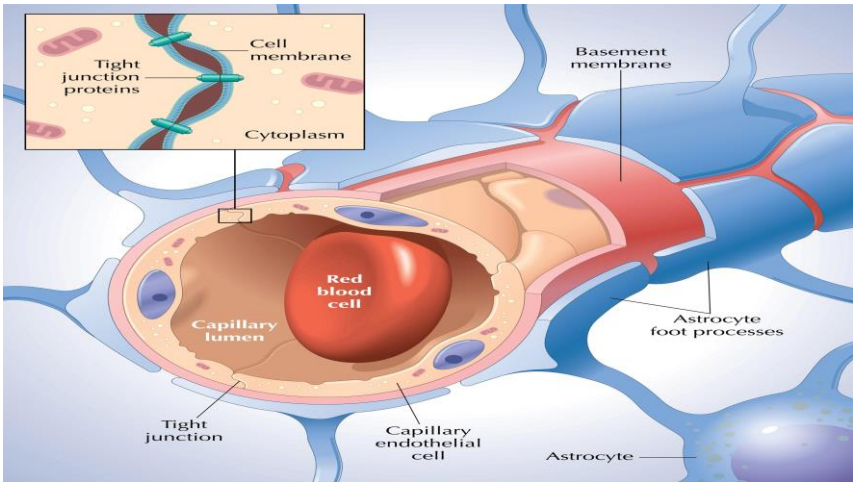


BLOOD BRAIN BARRIER





BLOOD BRAIN BARRIER



BLOOD BRAIN BARRIER (BBB)

- ❑ Is semipermeable membrane
- ❑ Basement membrane is composed of collagen and other proteins
- ❑ Pericytes & astrocytes envelop blood microvessels
- ❑system allows passge of some molecules by passive diffusion
- ❑System allows selective passage of some molecules such as glucose, water and aa that are crucial for neural function

BLOOD BRAIN BARRIER (BBB)

ROLES

- ✓Mechanism for protecting the brain from fluctuations in plasma concetration, compostion, and from circulating agents
- ✓Prevents neurotoxic materials, blood cells & pathogens from entering the brain
- ✓Regulates transport of molecules into and out of the CNS