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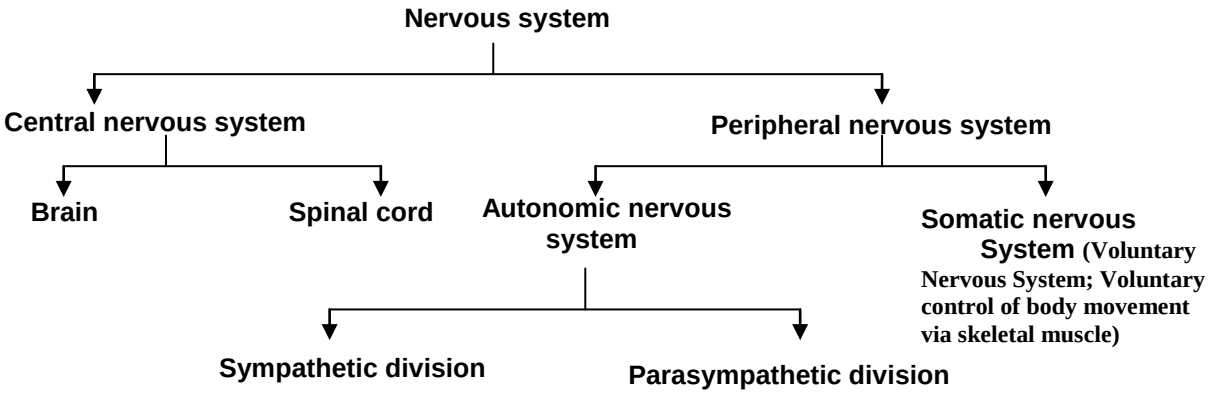
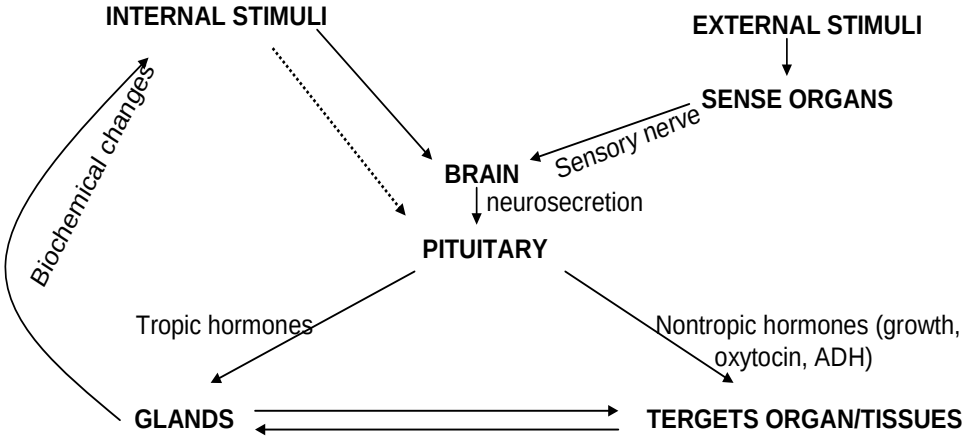
Physiology of Nervous System

Organization of nervous system



Function of nervous system

1.Co-ordination with other systems specially with endocrine system



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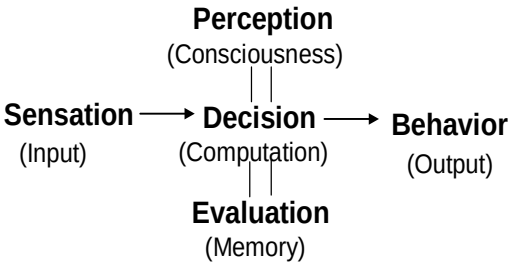


3. **Adjustment- By generation, propagation and integration of electrical activity, the nervous system detects changes in the external and internal environment and enable to adjust itself.**

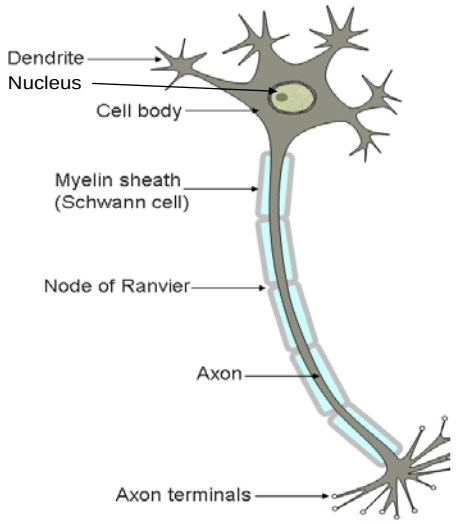
Neuron: It is the structural and functional unit of the nervous system, containing the nucleus and its surrounding cytoplasm, axon and dendrites.

Types of neuron:

1. On the basis of **structure**
    - Unipolar - having a single process present only in embryonic stage in human being
    - Bipolar- having two process, one axon and one dendrite
    - Multipolar - having one axon and many branching dendrites
2. On the basis of **function**
    - Sensory or afferent- conduct impulses from periphery to CNS.
    - Motor or efferent - conduct impulses from CNS to periphery
    - Interneuron's or central neurons- which establish complex connection between afferent and efferent neurons

COMPOSITION OF MULTIPOLAR NEURON

A multipolar neuron consists of



Glial cells/ Supporting Cells of Nervous System:

In CNS:

1. **Oligodendrocytes:** Form Myelin Sheath
2. **Astrocytes:** Brace & anchor neuron to nutritive supply line, control chemical environment, Guide the migration of young neuron.
3. **Microglia:** Acts as phagocytic macrophage.
4. **Ependymal cells:** Lining epithelium of CNS & form Choroid plexus which secrets CSF.

In PNS:

1. **Schwan Cells:** form myelin sheath in PNS.
2. **Satellite cells:** surround neuron cell bodies, they have similar role to astrocytes.

Axon- The axon is the longer process of the nerve cell. Each neuron has only one axon. The axon arises from the axon hillock and it extends for a long distance away from the nerve cell body. The length of the longest axon is about one meter.

Dendrite- The dendrite is the branched process of the neuron and it is branched repeatedly. The dendrite may be absent or if present, it may be one or may in number. Dendrite is conductive in nature. It transmits impulses towards the nerve cell body.

Myelin sheath- It is a thick lipoprotein sheath that insulates the myelinated nerve fiber. It is not a continuous sheath. It is absent at regular interval. The area where the myelin sheath is absent is called node of Ranvier. The formation of myelin sheath around the axon is called the myelinogenosis. It is formed by Schwann cells in neurilemma.

Nerve- A microscopic, cord like structure comprising a collection of nerve fibers, closely enveloped in tough connective tissue that convey impulses between a part of the Central nervous system and some other body region.

Types of Nerves

1. On the basis of impulses conduction : Sensory, motor, mixed
2. On the basis of development : Somatic and visceral
3. On the basis of origin : Cranial and spinal
4. On the basis of secretion : Adrenergic and cholinergic
5. On the basis of structure: Myelinated and non-myelinated

Properties of nerve /nerve fiber

1. **Excitability**- It is defined as the physiochemical change that occurs in a tissue when a stimulus is applied.
2. **Conductivity**- It is the ability of nerve fibers to transmit the impulse from the area of stimulation to the other area.
3. **All or none law**- It states that when a nerve is stimulated by a stimulus it gives maximum response or does not give response at all.
4. **Refractory period**- It is the period at which the nerve does not give any response to a stimulus.
5. **Infatigability**- A nerve fiber cannot be fatigued, even if it is stimulated continuously for a long time.
6. **Summation**- When two or more stimuli are applied within a short interval of about 0.5 sec produced strong response due to summed up the stimuli together. This phenomenon is known as summation.
7. **Adaptation**- At stimulating a nerve fiber continuously, the excitability of nerve fiber is greater in the beginning while later decrease slowly and finally does not show any response at all. This phenomenon is known as adaptation or accommodation.

Stimuli

It is the form of energy which produces change in the internal or external environment, causes the protoplasm to give raises its characteristics response.

A thing or event that evokes a specific functional reaction in an organ or tissue.

Types of Stimuli:

- Mechanical -Touch, prick, pressure etc.
- Osmotic - Sensation of thirst
- Chemical - CO_2, H^+ ion, H_2CO_3
- Thermal - Heat, Cold
- Electro-magnetic-Wave length of the electro-magnetic spectrum that excite retinal receptors
- Electric- Shock, condenser discharges

Sensitivity:

Ability of an organism to respond to external stimuli is called sensitivity.

Shock:

It is a potentially life threatening condition that occurs when the body is not getting enough blood flow.

Common Symptoms of Shock:

- **Earlier:** Weakness, Fast Breathing, Fast Heart Rate, Sweating, Anxiety, Increased Thirst.
- **Later:** Confusion, Unconsciousness, and Cardiac Arrest.

Types of Shock:

- **Anaphylactic Shock:** by allergic reaction of medicine, bee stings, foods etc.
- **Cardiogenic Shock:** typically by myocardial infarction.
- **Hypovolemic shock:** when body loses 20% or more of its blood by any injury or accident.
- **Neurogenic Shock:** after damage to the pathways of CNS particularly to spinal cord.
- **Septic Shock:** result of system-wide bacterial, viral or fungal infection known as sepsis.

Receptors:

A receptor is specialized nervous tissue sensitive to a specific change in the environment. Actually receptors function like a transducer, which convert one form of energy (stimuli) in the environment into another.

Types of receptors-

Receptors are classified into two types- **Exteroceptors & Interoceptors**

(A) **Exteroceptors**- Exteroceptors are the receptors which give response to stimuli arising from the outside the body. The Exteroceptors are divided into three groups-

a. **Cutaneous receptors**-
   - The receptors situated in the skin are called the cutaneous receptors.
   - It is also called mechanoreceptors because of their response to mechanical stimuli such as touch, pressure and pain.

b. **Chemoreceptors**-
   - The receptors, which give response to chemical stimuli, are called the chemoreceptors.
   - Taste buds for taste, olfactory receptors for smell.

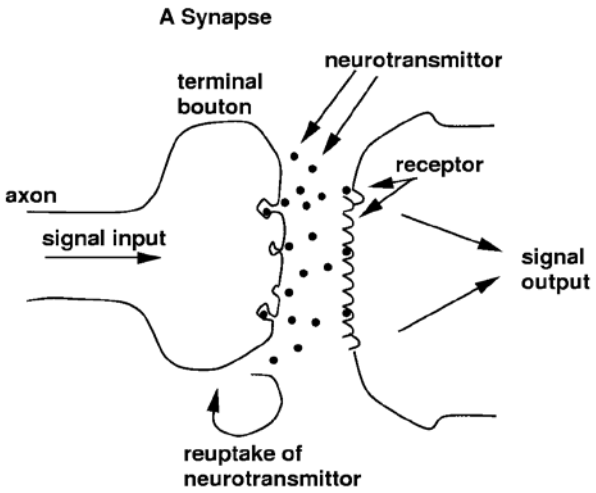
c. **Telereceptors**-
   - Telereceptors are the receptors that give response to stimuli arising away from the body.
   - It also called the distance receptors.
   - Rods and cones in retina for vision, Hair cells in the organ of Corti for hearing.

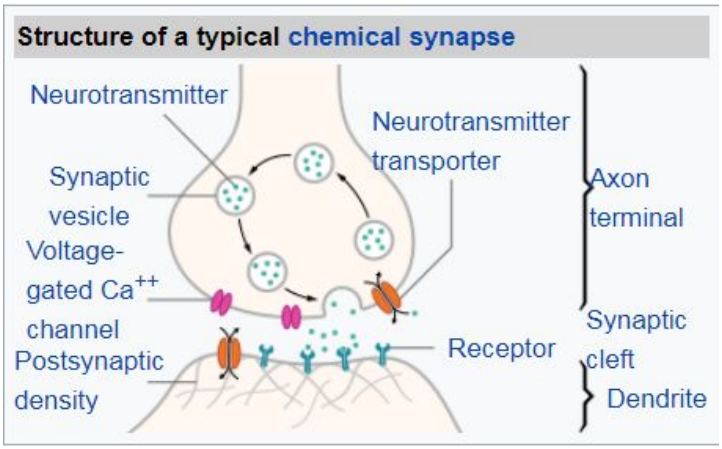
(B) **Interoceptors**- Interoceptors are the receptors which give response to stimuli arising from within the body. They are two types-

a. **Visceroceptors**-The receptors situated in the viscera are called visceroceptors. **e.g.**
   - Stretch receptors (in urinary bladder)
   - Baroreceptors or pressure receptor (in carotid sinus & aortic arch)
   - Chemoreceptors

b. **Proprioceptors**- Proprioceptors are the receptors which give responses to change in position & movement of different parts of the body. **e.g.**
   - **Muscle spindle**: stretch receptor- detect change in length of muscle
   - **Golgi tendon organ/ GTO/ Tendon organ/ neurotendinous organ or spindle**: sense change in muscle tension, lies in origin & insertion of skeletal muscle fibers into tendons
   - **Pacinian corpuscle or lamellar corpuscle**: mechanoreceptor cells in **glabrous/hairless** mammalian skin, respond to vibration & pressure, also found in pancreas that detect vibration & possibly very low frequency sound.

Synapse: Information in the nervous system is generally transmitted over a chain of neurons. The junction between one neuron to the next is termed the synapse. There is no protoplasmic continuity between neurons but the do exist in close proximity which permits one neurons to influence another. Each of the axon has a terminal knob which is





close contact with the dendrite and cell bodies of the secondary neurons. Between the knob and the post-synaptic neuron there is a space, about **200A** in wide, called the synaptic cleft.

Properties of synapse-

1. The synapse follows the law of one way direction that means from presynaptic neurons to postsynaptic neurons.
2. Synaptic delay- Synaptic delay is a short delay that occurs during the transmission of impulses through the synapse. The normal duration of synaptic delay is **0.3-0.5 msec**. It is due to- Release of neurotransmitter, Passage of neurotransmitter from axon terminal to postsynaptic membrane.
3. Nerve fiber or neurons doe's not fatigue but synapse do. The fatigue at the synapse is due to the depletion of neurotransmitter.
4. The synapse is very sensitive to the action of drugs, acidosis and alkalosis.
5. Convergence and divergence properties

Synaptic Vesicle:

- ✓ Contains neurotransmitter in axon terminal/ bouton
- ✓ Upto 130 vesicles can be released per bouton over 10 minutes @ 0.2 Hz stimuli
- ✓ Diameter: 39.5 nm
- ✓ Essential for propagating nerve impulses

Neurotransmitter:

- Endogenous chemical messenger
- Released from synaptic vesicle into synaptic cleft
- Synthesized from amino acid (maximum)
- More than 200 in number

Types of Neurotransmitter:

- **Amino acids:** glutamate, aspartate, D-serine, γ-aminobutyric acid (GABA), glycine
- **Gasotransmitters**: NO, CO, H_2S
- **Monoamines:** dopamine (DA), norepinephrine (noradrenaline; NE, NA), epinephrine (adrenaline), histamine, serotonin (SER, 5-HT)
- **Trace amines:** phenethylamine, *N*-methylphenethylamine, tyramine, 3-iodothyronamine, octopamine, tryptamine, etc.
- **Peptides:** oxytocin, somatostatin, substance P, cocaine and amphetamine regulated transcript, opioid peptides
- **Purines:** adenosine triphosphate (ATP), adenosine
- **Catecholamines:** dopamine, norepinephrine (noradrenaline), epinephrine (adrenaline)
- **Others:** acetylcholine (ACh), anandamide, etc.

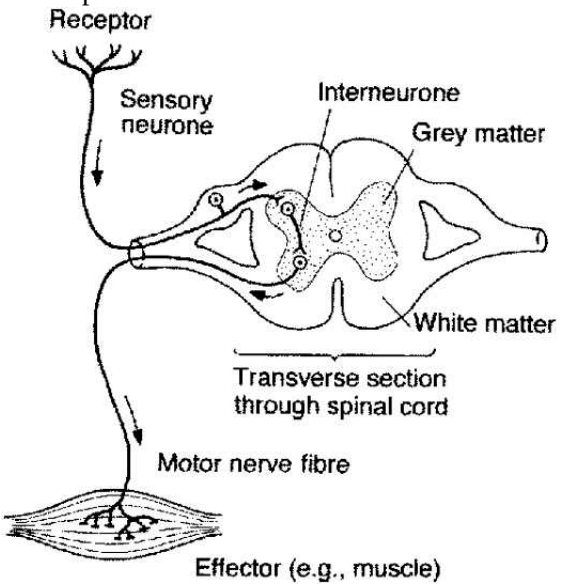
Reflex-Reflex activity is the response to a peripheral nervous stimulation that occurs without our consciousness. In other word, reflex is the involuntary production of activity in some effectors by the stimulation of receptors. For example- when the hand is placed on a hot object, it is withdrawn immediately.

Reflex may be two types-

- **Unconditioned or inborn reflex-** Unconditioned reflexes are the natural reflexes which are present since the time of birth hence the name inborn reflexes. The best example is the secretion of saliva when a drop of honey is kept in the mouth of a newborn baby for the first time. The baby does not know the taste of the honey but still saliva is secreted.
- **Conditioned or acquired reflex-** Conditioned or acquired reflexes are the reflexes that are developed after conditioning or training. It depends on many conditions for their formation and maintenance. Briefly, it is a habit. Example- When a food is placed in the mouth of a dog, saliva is secreted. This is an inborn reflex. He acquires a response that causes him to secrete saliva, if he is hungry, when he sees food with which he is familiar or smell of a food. This is a natural conditioned reflex. If when a dog is fed, a certain sound is made, for example a whistle is blown and this association of sound and food is frequently repeated, there comes a time when the sound along will causes the secretion of saliva, that is acquired or conditioned reflex.

Reflex arc- A complete pathway for any reflex action is known as reflex arc. There are five components required to complete a reflex activity. The components are-

1. **Receptor organ**- located either in the soma or viscera.
2. **The afferent neuron**- the cell body of which is located in dorsal root ganglion and provided by sensory neuron
3. **Synapse**
4. **The efferent neuron**- the cell body of which is located in the spinal cord or brain stem and provided by motor neuron
5. **Effector organ**- The effector organ is the structure such as the muscle of gland where the activity occurs in response to the stimulus.



All these structures together form an arc in the central nervous system known as reflex arc.

Possible combination of neurons in reflex arc-

1. **Simple reflex arc**- It is also known as monosynaptic reflex arc as it has only one synapse. This reflex arc consisting of two neurons and the afferent neuron synapse directly with the efferent neuron. It is used by the myotatic or stretch reflex.

2. **Chain reflex arc**- Several simple reflex arcs may be united in a series, so as to give a chain of reflex arc. The neural activity in the first simple arc stimulates in the second, which is turning stimulated the third and so on.

3. **Diverging reflex arc**- Neurons may be arranged in a diverging way so that more that one effector organ are stimulated by the activity of one afferent neurons.

4. **Converging reflex arc**- Neurons may be organized in a converging pathway so that more than one afferent neuron stimulates the same effector organ.

5. **Interneuron reflex arc**- Interneuron may be organized in their projection so that patterns of activity resulting which may involves both excitation and inhibition of various effector organs activity.

Cranial Nerves:

No.	Name	Type	origin	emerge	Key Function
I	Olfactory	Sensory	Nasal mucosa	Enters the cranial cavity through	Smell

				cribriform plate of ethmoid bone	
II	Optic	Sensory	Ganglion cell of retina	Optic foramen	Vision
III	Oculomotor	Motor	Cerebral peduncle	Foramen orbitale	Eye movement, pupil size, focusing lens
IV	Trochlear	Motor	Dorsal part of the midbrain (caudal to the caudal colliculus)	Foramen orbitale	Eye movement
V	Trigeminal	Both	Lateral part of the pons	Opthalmic-Foramen orbitale Maxillary-Foramen rotundum mandibular -Foramen lacerum (Foramen ovale)	Sensations from the head and teeth, chewing
VI	Abducens	Motor	Caudal to the pons	Foramen orbitale	Eye movement
VII	Facial	Both	Lateral side of the trapezoid body	stylomastoid	Face and scalp movement, salivation, tears, taste
VIII	Vestibulocochlear	Sensory	Inner ear	Lateral side of the medulla	Balance and equilibrium, hearing
IX	Glossopharyngeal	Both	Lateral side of the medulla	Jugular foramen	Tongue movement, swallowing, salivation, taste
X	Vagus	Both	Lateral side of the medulla	Jugular foramen	Innervates visceral organs
XI	Accessory	Motor	Spinal root Cranial root (Lateral side of the medulla)	Jugular foramen	Head movement
XII	Hypoglossal	Motor	Ventral surface of the medulla	Hypoglossal foramen	Tongue movement

Spinal Nerves

Dorsal and **ventral roots** of spinal cord unite to form a spinal nerve and emerge through the intervertebral foramen, from which it exits the vertebral canal. The number of spinal nerve pairs in each section of the vertebral column corresponds to the number of vertebrae with the exception of cervical nerves and caudal nerves. Same no of pairs of thoracic, lumbar and sacral nerves. Eight pairs of cervical spinal nerves & fewer pairs of caudal nerves than caudal vertebrae. Length is short (less than1 cm).

- Dorsal root — composed of afferent (sensory) axons; the site of a spinal ganglion.
- Ventral root — composed of efferent axons that innervate muscle & gland.

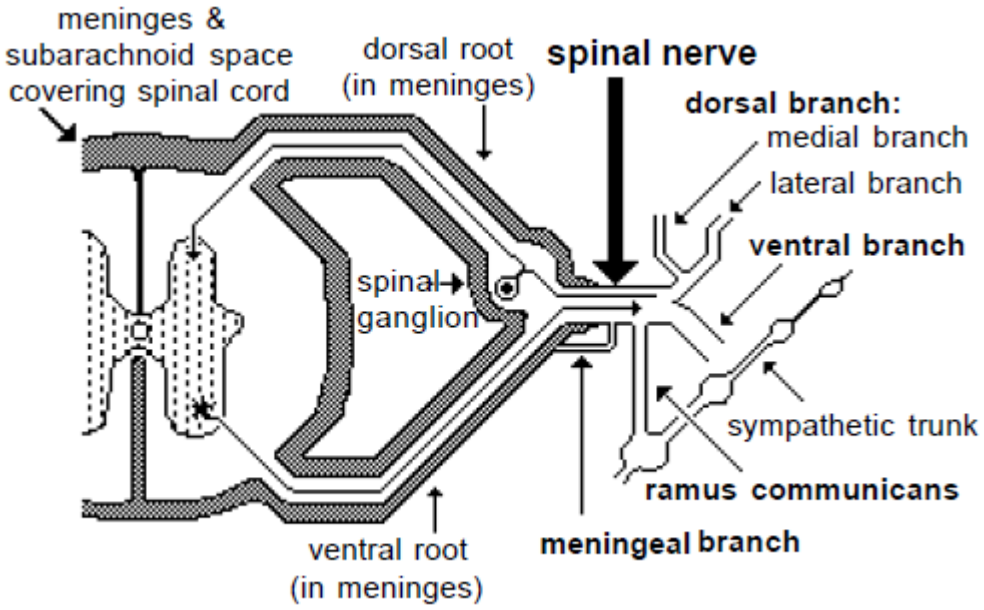


Fig. Formation of Spinal nerve

Primary branches of spinal nerve: 4 in number.

1. Meningeal branch-small; sensory to meninges
2. Ramus communicans-connects to sympathetic trunk & innervates viscera
3. Ventral branch-largest branch; hypaxial mm. & lateral and ventral cutaneous nn.
4. Dorsal branch-medial & lateral branches; epaxial mm. & dorsal cutaneous nn.

Fiber types of Spinal Nerves:

1. Afferent (sensory) — axons associated with receptors.
    - General Somatic Afferent (GSA): receptors in skin & muscles, tendons, joints
    - General Visceral Afferent GVA): receptors in viscera
2. Efferent (motor) — axons that innervate muscle & gland
    - Somatic Efferent (SE): innervates skeletal muscle
    - Visceral Efferent (VE): innervates cardiac m., smooth m., & gland

Brachial Plexus

- The brachial plexus is the result of anastomosis of the ventral branches of the sixth, seventh and eight cervical and the first and second thoracic spinal nerves.
- It appears as a thick white band between the dorsal and ventral sclaneous muscle and supply mainly the thoracic limb.

Lumbosacral plexus

- Lumbosacral plexus is formed by the anastomosis of the ventral branches of the last three lumbar and first two sacral spinal nerves.

Autonomic nervous system

The autonomic nervous system is that part of the nervous system which innervates smooth muscle, cardiac muscle, visceral organs and glands of the body. It is therefore, a motor or Visceral Efferent (VE) system which maintenance the internal environment of the body, also known as homeostasis.

The ANS differ anatomically from the somatic mechanism. The ANS originate in the spinal cord and brain stem but not innervated directly the effector organs. In the somatic system the neuron originates in the spinal cord or brain stem and goes directly to the effector organs.

Visceral Efferent (VE) Pathway of ANS: involves 2 neurons

- **Preganglionic neuron**- cell body located in CNS; axon synapses in an autonomic ganglia
- **Postganglionic neuron**-cell body in an autonomic ganglion; axon innervates smooth muscle, cardiac muscle or gland

Ganglia- A group of nerve cell bodies outside the brain and spinal cord are usually called ganglia.

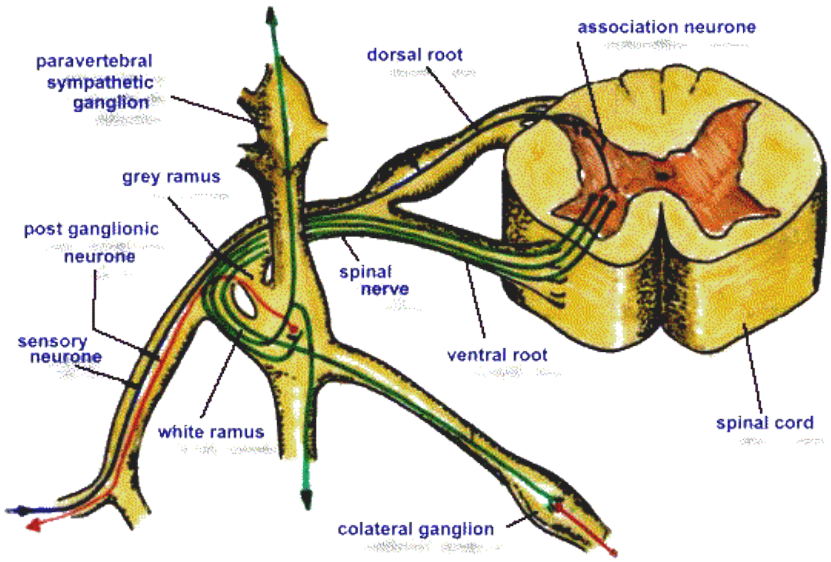
Classification of ANS Division:

On anatomical, pharmacological and physiological bases ANS divided into:

1. Sympathetic and
2. Parasympathetic

Sympathetic nervous system (SNS)

- The preganglionic neurons of the sympayhetic nervous system arise from the intermedio-lateral bundle of the **thoroco-lumber segment**, of the spinal cord and leave the cord in the spinal nerve of all the thoracic and the first ¾ lumber segments, to go to the respective sympayhetic ganglia.
- **Sympathetic trunk:** consists of two chains of vertebral ganglia that have a segmental arrangement and are interconnected both longitudinally and transversely**.**
- The connection between the spinal nerves and the ganglia are called **white communicants/ramus**.
- The preganglionic axon may end at the level of entrance in the chain, ascend or descend the chain, or pass through the chain to end in special ganglion outside the chain.
- The axons of the postganglionic neurons leave the sympathetic chain in one of two ways:
    1. to return the spinal nerves via the **gray rami communicants** or
    2. to go directly to visceral organ



Parasympathetic nervous system (PNS)

The origin of the parasympathetic neurons is much more diverse than the case of sympathetic system. The Parasympathetic neurons originate from three major levels

1. **Spinal cord, Brain stem, Tectal region/ midbrain region**
2. **Sacral Region**

Function of the Autonomic Nervous System:

The autonomic nervous system plays an important role in the maintenance of the constancy of the internal environment that means it is an important homeostatic mechanism.

SNS- Most of the post-ganglionic neurons of sympayhetic nervous system liberates **norepinephrine** at their axon endings, such neurons are termed **adrenergic**. Sympathetic activity **excites some effectors and inhibits others**.

- For example- myocardium beats more rapidly and forcibly but gut is inhibited. It is suggested that the effectors cell has either an excitatory or an inhibitory substance which combine with the catecholamine to produce new compounds termed **sympathin E (for excitatory) and sympathin I (for inhibitory)**. Recently, the idea has been resurrected in the form of **alpha and beta receptors** in the effectors organs. The interaction with **alpha receptors causes vasoconstriction**, whereas interaction with **beta receptors causes vasodilatation, cardiac stimulation and bronchio-dilation**.

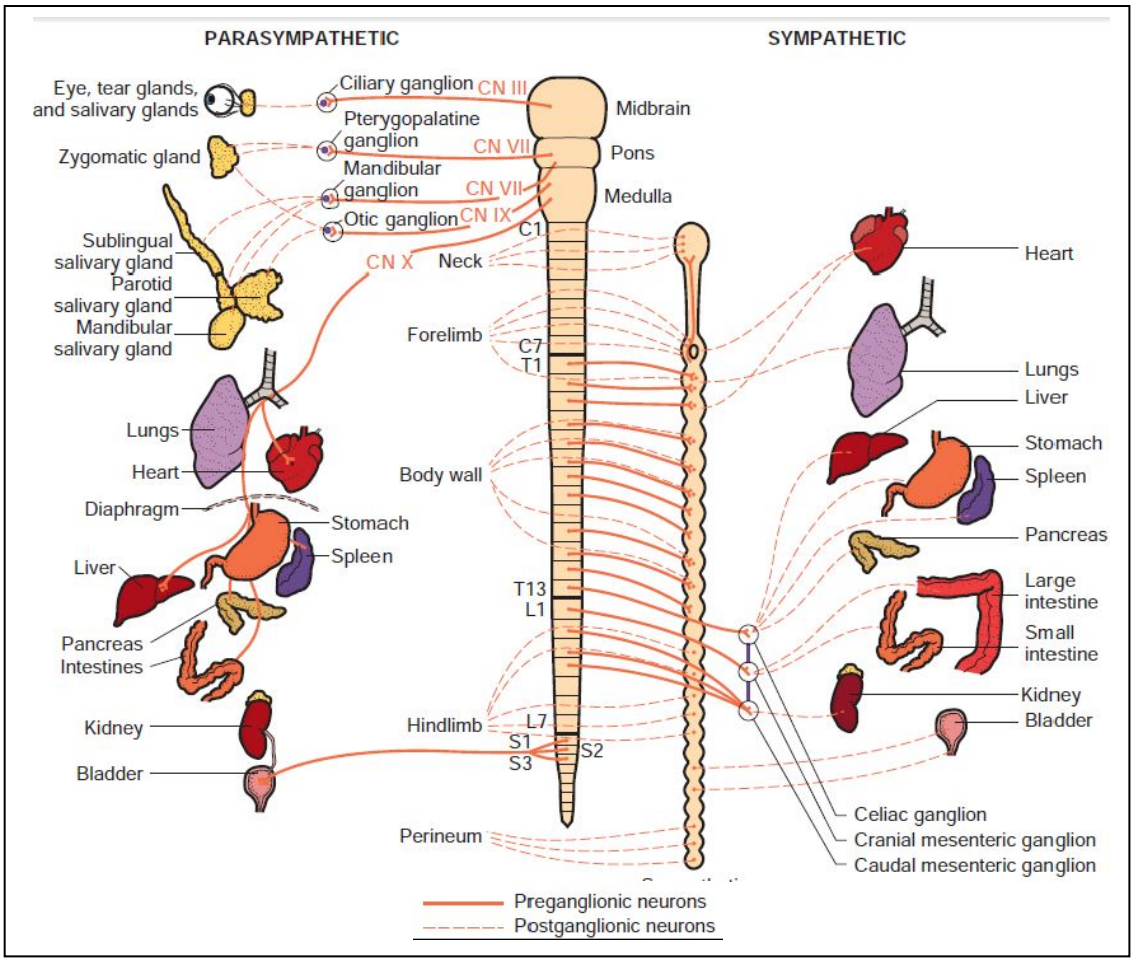
PNS- All pre-ganglionic neurons as well as all post-ganglionic neuron of parasympayhetic nervous system liberate **acetylcholine** at the axon ending, so it is called **cholinergic neurons**. Innervations of this nerves results on **both excitation and inhibition** of the effectors organs.

- **For example-** the parasympathetic neurons of vagus inhibit the heart as a slow the heart rate and decrease the force of myocardial contraction. On the other hand, in the gut parasympathetic activity increases the rate and force of the smooth muscle contraction. But how acetylcholine can have both excitatory and inhibitory influences is not known. There is said to be some substances in the effectors cell that combines with acetylcholine to form a new compound that is responsible for the end result either excitatory or inhibitory.

Sympathetic and Parasympathetic interaction-

Two divisions of the autonomic nervous system differ not only anatomically but also in their functions. Stimulation of one division usually provides effects just opposite to those noted upon activation of other. This make for a convenient and effective mechanism. eg- if the blood pressure should fall, the sympathetic system activation will through reflex action, oppose the fall and quickly restore the blood pressure to within normal limits and vice-versa.

Distribution of ANS:



Basis for recognizing two divisions of ANS

	Feature	Sympathetic	Parasympathetic
1.	Distribution	Whole body	viscera in body cavities; in head
2.	Preganglionic origin	Thoracolumbar spinal cord	sacral spinal cord & brainstem
3.	Postganglionic neuron	usually adrenergic	always cholinergic
4.	Functional role	"fight or flight"	routine visceral operations

Functional Differences:

Structure	Sympathetic	Parasympathetic
iris (pupil)	dilate	constrict
heart	increase rate & force of contraction	decrease rate
bronchi	dilate	constrict
gut & bladder wall	inhibit motility	excite contraction
gut & bladder sphincters	contract	relax
cutaneous vessels	constrict	*doesn't innervate*
muscle vessels	dilate (cholinergic)	*doesn't innervate*
sweat glands	secrete	*doesn't innervate*
Also	semen ejaculation and penis erection	secretion of stomach/pancreas

Intramural System

- **Plexus & Ganglia** within the **tissue or organs**.
- Ensures independent functions of **viscera**
- In intestine, it consists of nerve **plexus at 3 different stages**:
    1. Subserosal nerve plexus
    2. Myenteric nerve plexus
    3. Submucosal nerve plexus

Cerebrospinal fluid

- Clear colorless fluid found in the ventricles of the brain.
- It is formed by the choroid plexus of the brain.

Function:

- Act as cushion and chemical buffer for the central nervous system and.
- Transports nutrients and waste products,

Choroid Plexus

- Consist of epithelium (ependymal cells) and the underlying pia mater.
- They are attached to the walls of the ventricle by the pia mater.

Route of passage of CSF

- CSF from two lateral ventricles through interventricular foramen drain into third ventricle.
- Then by cerebral aqueduct drain into fourth ventricle.
- Finally through the formina of Luschka CSF circulated into the subarachnoid space.

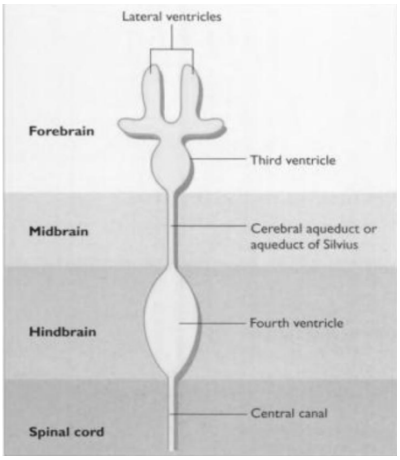


Fig. 5 Ventricles of the Brain and Circulation of CSF

Blood-Brain Barrier

Brain receives only the essential materials from the blood and CSF. Two structures acting as gatekeepers to the brain's interior are

(i) The **choroid epithelium** of the choroid plexus that acts as the **Blood–CSF barrier**

(ii) The **capillaries** of the nervous tissue that act as the **Blood–Brain barrier**

The capillaries of the CNS have tight junctions between their endothelial cells rather than slit pores, which limit the diffusion of substances from capillaries. Lipid-soluble substances, however, such as oxygen and carbon dioxide, readily diffuse. Transport for most substances is provided for by the CNS cells known as **astrocytes** (a glial cell), which are interposed between the capillaries and CNS cells.