The Nervous System

The nervous system, in coordination with the endocrine system, provides the means by which cell and tissue functions are integrated into a solitary, surviving organism. The nervous system mediates a tremendous range of functions:

- the unconscious control of visceral functions
- sensory perceptions,
- voluntary movement,
- behavior, emotions, dreams,
- intelligence, anticipation, judgment..

Cells of the Nervous System

Nervous tissue consists of two principal types of cells

- neurons
- supporting cells.

I.Neurons

The neurons are the functional cells of the nervous system. They exhibit membrane excitability and conductivity and secrete neurotransmitters and hormones.The major parts of a neuron

1. A soma is the cell body of a neuron that contains the cell nucleus and the rough endoplasmic reticulum.
2. The axon is the cellular process that carries action potentials away from the soma. Axons are often long and may have multiple branches.
3. Dendrites have a structure similar to axons but receive impulses from other neurons. Many neurons have an extensive set of dendrites, referred to as the dendritic tree.

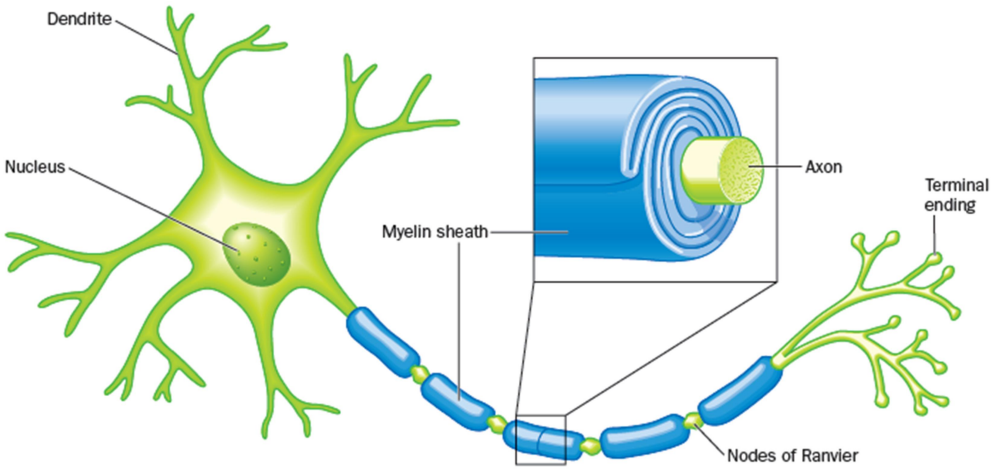


Figure: The neuron.

II.The Neuroglial cells(supporting cells**)**

1.Schwann cells are glial cells which produce the myelin sheath in peripheral nerve fibers. The myelin sheath insulates nerve fibers and increase the velocity of impulse conduction (**saltatory conduction**) and the ability of regeneration after injury.

2.Satellite cells,they surround neurons in the sensory, sympathetic and parasympathetic ganglia and help regulate the chemical environment.

3.the ependymal cells - these cells line the fluid-filled cavities of the brain and spinal cord. They play a role in production, transport, and circulation of the cerebrospinal fluid..

4.oligodendrocytes - produce the myelin sheath in the CNS which insulates and protects axons. Diseases which destroy the myelin sheath lead to inability to control muscles, perceive stimuli etc. One such disease is[**multiple sclerosis**], an autoimmune disorder in which your own lymphocytes attack the myelin proteins.

5.Astrocytes Astrocytes are star-shaped glial cells of the CNS which contribute to the blood-brain barrier.

6.Microglia function as macrophages when they migrate to damaged brain tissue.

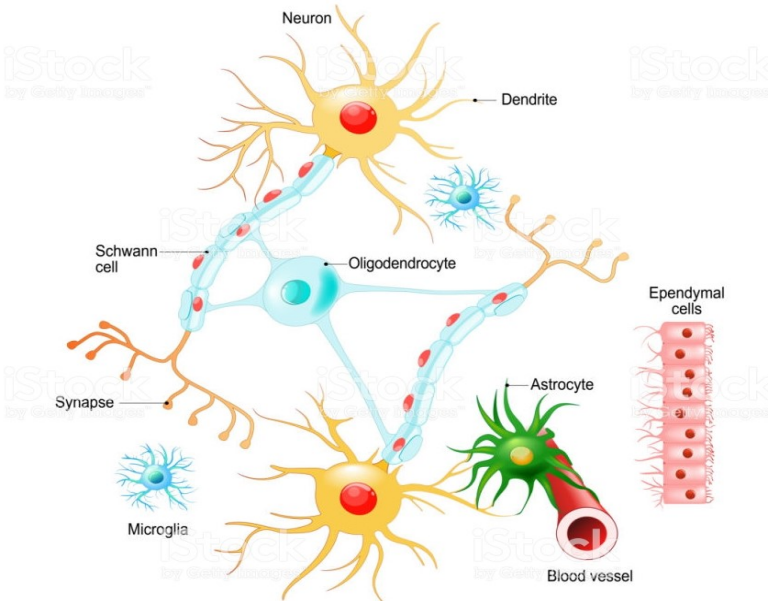


Figure: The supporting cells of the nervous system .

Functional Classes of Neurons

Functionally the neurons divided into

1.Interneurons connecting neurons which produce pathways from neurons to one another.

2.Motor neurons – send stimuli to muscles and other effectors, both voluntary and involuntary (efferent neurons).

3.Sensory neurons – bring stimuli from receptors to the CNS. (afferent neurons).

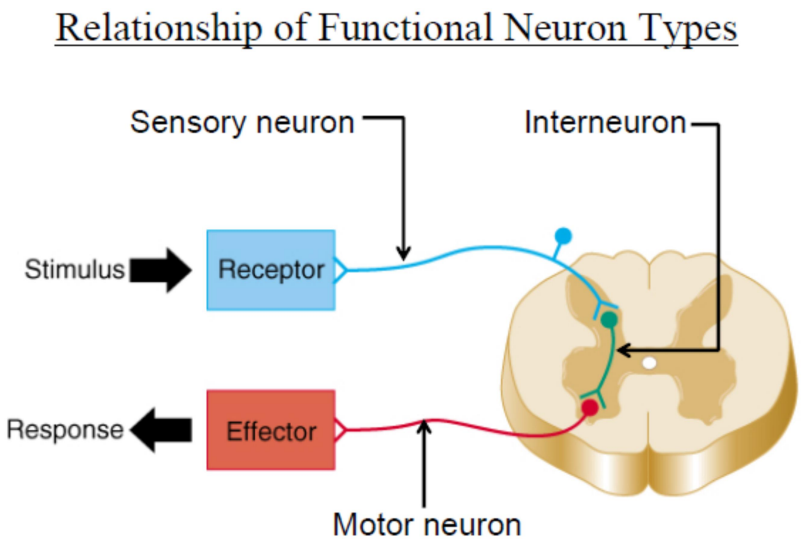


Figure: Functional Classes of Neurons.

Divisions of the nervous system

The nervous system has two major divisions:

I.The **central nervous system**, which consists of the:

- brain
- spinal cord,

II. The **peripheral nervous system,** includes nerves that carry sensory messages to the central nervous system and nerves that send information from the CNS to the muscles and glands.

The peripheral nervous system is further divided into :

1.The *somatic system* consists of

- sensory receptors in the head and extremities,
- nerves that carry sensory information to the central nervous system,
- nerves that carry instructions from the central nervous system to the skeletal muscles.

2.The *autonomic system* controls

- glandular secretions .
- the function of the smooth.
- the function of the cardiac muscles.

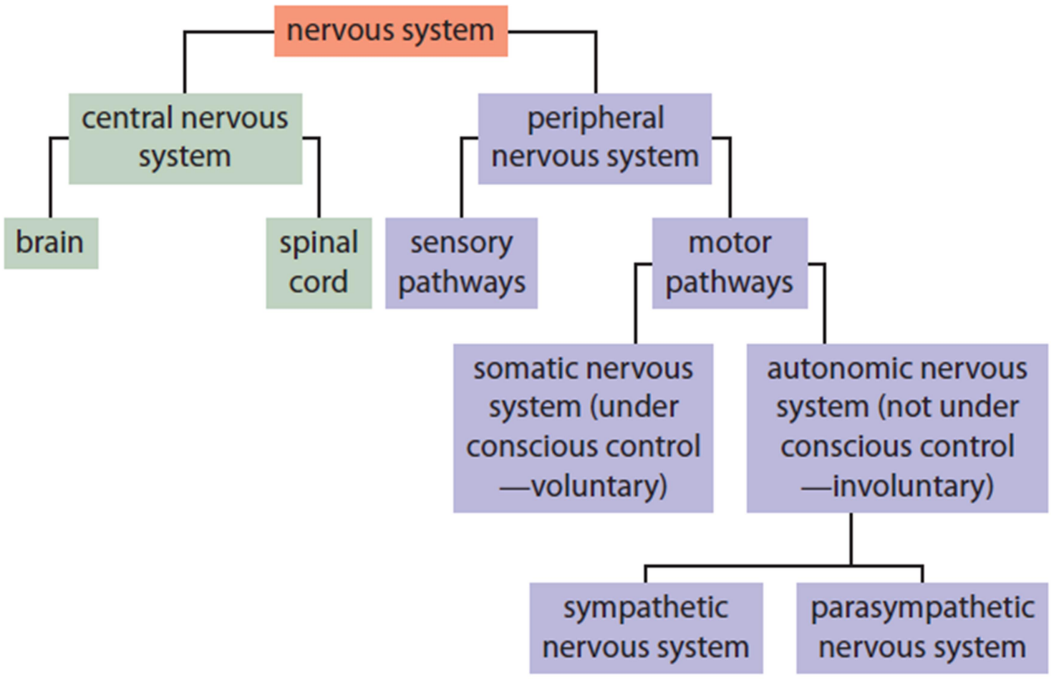


Figure: divisions of the human nervous system.

Meninges

Inside the skull and vertebral column, the brain and spinal cord are loosely suspended and protected by several connective tissue sheaths called the meninges:

1. pia mater(inner layer), the surfaces of the spinal cord, brain, are covered with a delicate connective tissue layer called the pia mater "delicate mother".
2. Arachnoid, it is very delicate, nonvascular, and waterproof layer, encloses the entire CNS. The arachnoid layer is named for its spider-web appearance. The cerebrospinal fluid (CSF) is contained in the subarachnoid space.
3. Dura mater (outer layer) "tough mother" , lie immediately outside the arachnoid it is a continuous sheath of strong connective tissue, ,

Ventricular System

The ventricular system is a series of interconnected chambers inside the CNS that are filled with CSF.

1.The RT and LT lateral ventricles of the cerebrum, .
2.The slit-like third ventricle, located in the midline and is closely associated with the thalamus. The lumen of the third ventricle is continuous with each lateral ventricle .

3.The fourth ventricle located in the hind brain and connected to the third ventricle by cerebral aqueduct. The fourth ventricle is continuous inferiorly with the central canal of the spinal cord.

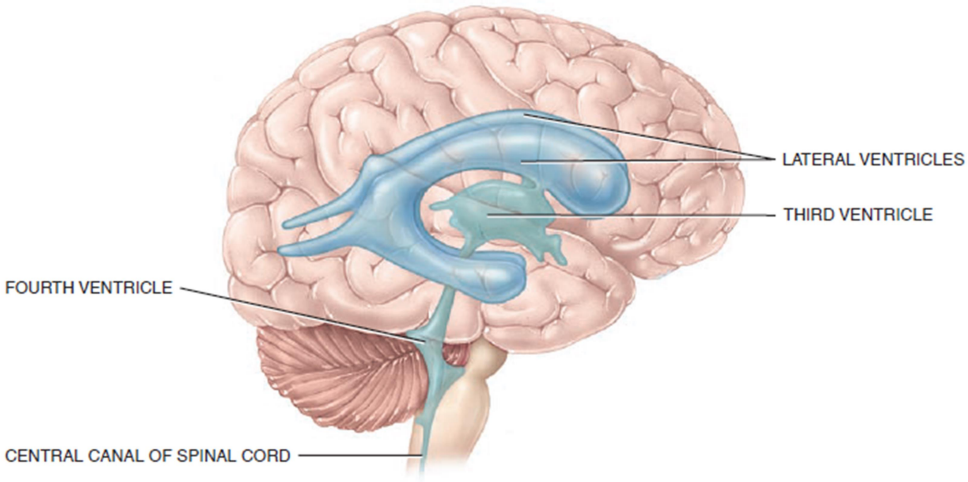


Figure : The ventricular system of the brain.

Cerebrospinal Fluid(CSF)

Watery solution similar in composition to blood plasma (about 80-150 ml), but contains less protein and different ion concentrations than plasma. The CSF is produced by the ***choroid plexus***, that project into the ventricles. Reabsorption of CSF into the vascular (blood) system occurs by the ***arachnoid villi***.

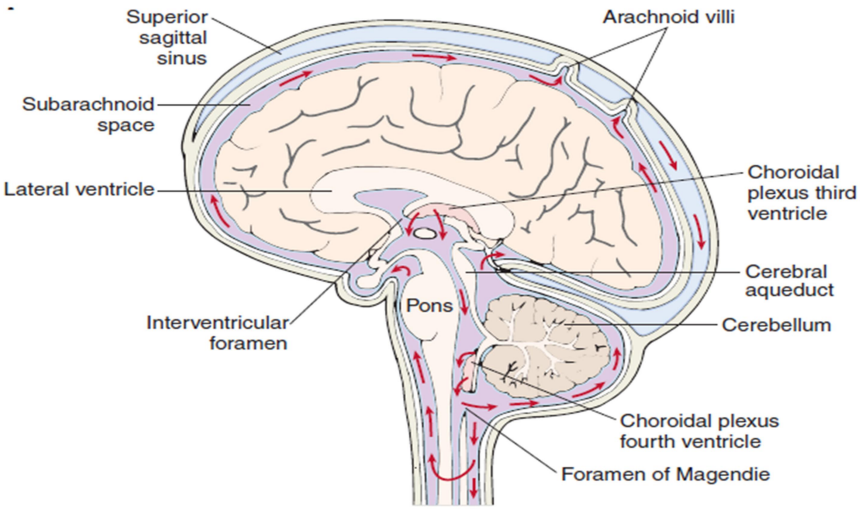


Figure: site of production and reabsorption of CSF.

Function of CSF

- Forms a liquid cushion that gives buoyancy to the CNS organs.
- Prevents the brain from crushing under its own weight.
- Protects the CNS from blows and other trauma.
- Nourishes the brain and carries chemical signals throughout it.

Hydrocephalus

Hydrocephalus can be defined in general terms as an increase in CSF volume or pressure as a result of an imbalance in CSF production, flow, or absorption.

Figure: hydrocephalus.

The Cerebral Circulation

The arterial blood flow to the brain is supplied by

- The anterior cerebral arteries (branch of internal carotid artery) .
- The middle cerebral artery(branch of internal carotid artery)
- The posterior cerebral arteries (branch of vertebral artery)

The distal branches of the cerebral arteries communicate at the base of the brain through the circle of Willis.

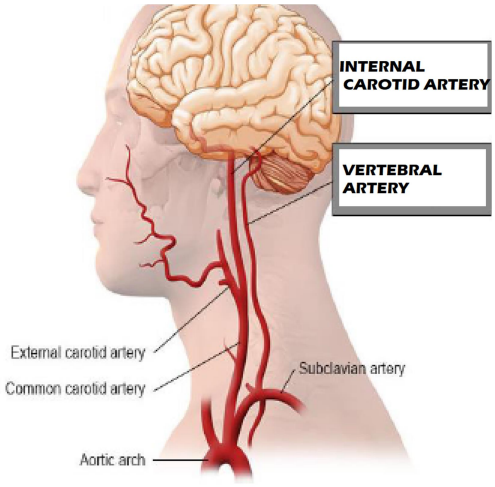


Figure: vertrebral and internal carotid arteries.

Venous Return

The venous blood from the brain is collected into channels called the dural venous sinuses. The dural venous sinuses of the brain are formed by two layers of dura mater lined with endothelium:

- The superior sagittal sinus runs in the groove of the longitudinal fissure, where it absorbs CSF from the meninges.
- occipital sinuses
- straight sinus
- the transverse sinuses,. the transverse sinuses connect to the sigmoid sinuses, which then connect to the internal jugular veins.

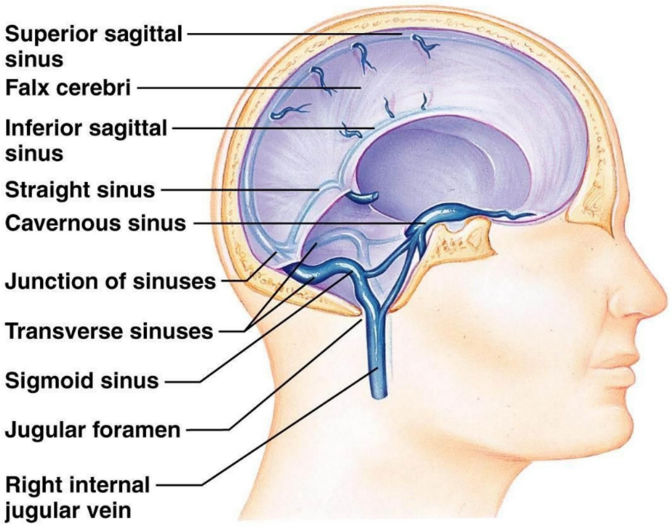


Figure: dural sinuses.

Blood-Brain Barrier.

The cerebral capillaries allow only to few substance to diffuse into cerebral tissues(like O2, CO2,Glucose) and prevent the passage of toxic substance to protect delicate neuron, this character is called blood-brain barrier applied to the depends on

- the tight junctions between endothelial cells of brain capillaries
- most brain capillaries are completely surrounded by a basement membrane
- the processes of supporting astrocyte cells of the brain.

The Spinal Cord

The spinal cord lies in the vertebral canal it is about 42 to 45 cm in length, it extends from the foramen magnum at the base of the skull to a cone-shaped termination, the conus medullaris, usually at the level of the first or second lumbar vertebra (L1 or L2). Below this level the terminal end of spinal cord called the *cauda equine* (“horse’s tail”). The pia mater of spinal

cord, continues caudally and attaches to the second sacral vertebra (S2) this portion called the filum terminale.

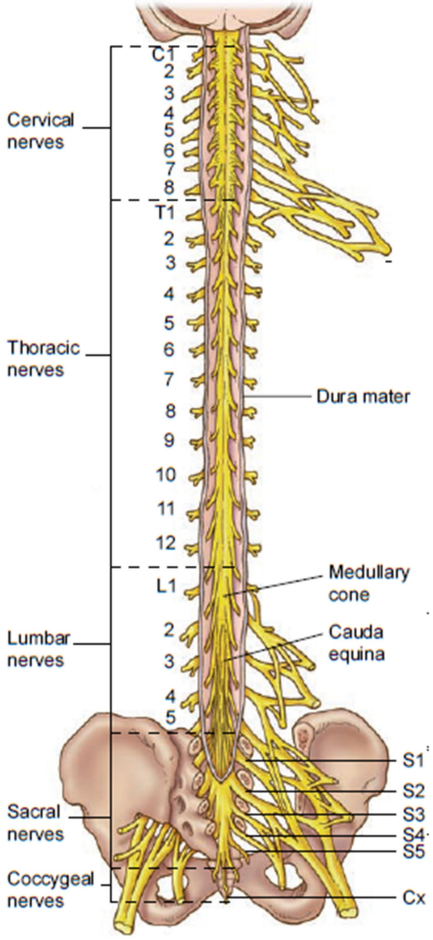


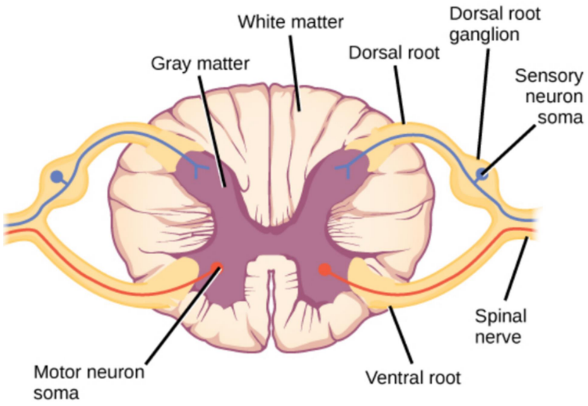
Figure: Spinal cord.

Cross-Sectional Anatomy

Like the brain, the spinal cord is covered by meninges and bathed in CSF within bony vertebral canal.. The spinal cord is somewhat oval on transverse section and consist of

I. gray matter, the spinal cord has a central core of gray matter that looks somewhat butterfly- or H-shaped in cross sections, with the central canal in the midline, the central canal filled with CSF.

II.The white matter, contains bundles of myelinated nerve fibers ascending and descending through the spinal cord.



Cross Section of Spinal Cord

1. Ascending tracts

- Dorsal column, it carry sensory signals of vibration, visceral pain, touch, and proprioception from different part of body to brain.
- The spinothalamic tract, carries signals for pain, temperature, from different part of body to brain.
- The spinocerebellar tracts carry proprioceptive signals from the limbs and trunk to the cerebellum. the tracts provide the cerebellum with feedback needed to coordinate muscle action.

2.Descending Tracts

Descending tracts carry motor signals down the brainstem and spinal cord to different muscle of the body , like corticospinal tracts.

Spina bifida

About one baby in 1,000 is born with spina bifida, a congenital defect resulting from the failure of one or more vertebrae to form a complete vertebral arch for enclosure of the spinal cord. Its only external sign is a dimple or hairy pigmented spot.

Figure: Spina bifida

Poliomyelitis (شلل الاطفال)

Poliomyelitis is caused by the poliovirus, which destroys motor neurons in the brainstem and ventral horn of the spinal cord leading to paralysis of muscle of lower limb.

A lumbar puncture (spinal tap)

During a lumbar puncture, a needle is inserted between two lumbar bones (vertebrae) to remove a sample of cerebrospinal fluid. A lumbar puncture can help diagnose serious infections, such as meningitis; other disorders of the central nervous system, such as Guillain-Barre syndrome and multiple sclerosis; or cancers of the brain or spinal cord.

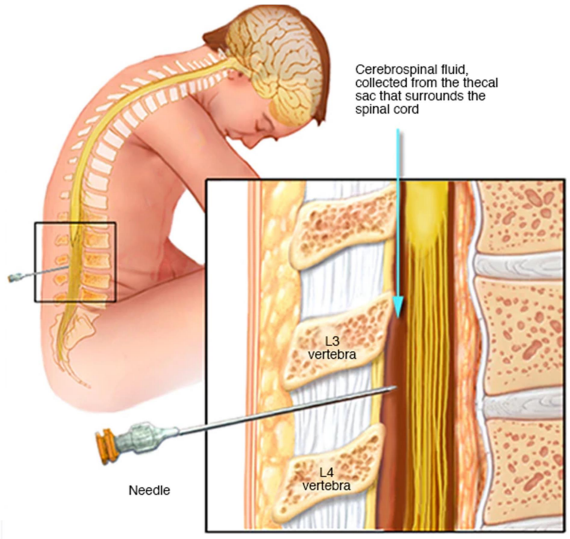


Figure: spinal tap

figure: poliomyelitis

Spinal Nerves

The peripheral nerves that carry information to and from the spinal cord are called spinal nerves. There are 32 or more pairs of spinal nerves (i.e., 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 2 or more coccygeal).Each spinal cord had two roots:

- dorsal root, carrying the axons of afferent neurons into the CNS.
- ventral root, carrying the axons of efferent neurons into the periphery.

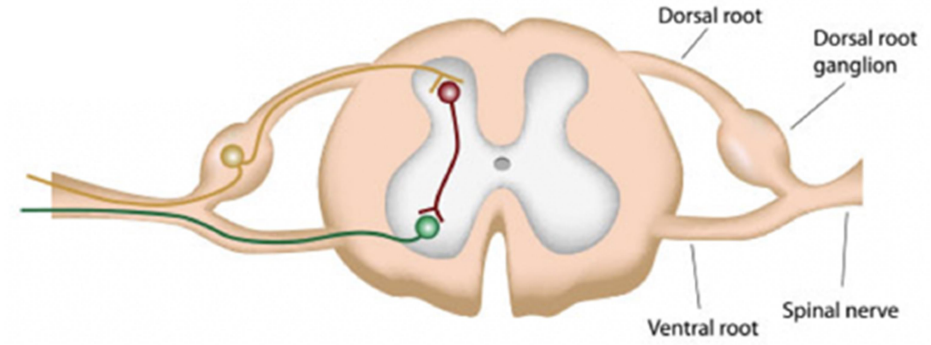


Figure: spinal nerve roots

Functions

The spinal cord serves three principal functions:

1. conduct information up and down between the brain and periphery.
2. Locomotion, motor neurons in the brain initiate walking and determine its speed, distance, and direction, but the simple repetitive muscle contractions that put one foot in front of another, over and over, are coordinated by groups of neurons called central pattern generators in the cord.
3. Reflexes. Reflexes are involuntary stereotyped responses to stimuli.

Reflex

Reflexes are sudden, , subconscious response to changes within or outside the body. Spinal reflexes concerned with unlearned skeletal muscle reflexes. They result in the involuntary contraction of a muscle—for example, the quick withdrawal of your hand from a hot stove .the spinal reflex arc, in which signals travel along the following pathway:

1. somatic receptors in the skin, a muscle, or a tendon.
2. afferent nerve fibers, which carry information from these receptors into the spinal cord.
3. interneurons in spinal cord.
4. efferent nerve fibers, which carry motor impulses from spinal cord to the skeletal muscles.
5. effector, like skeletal muscles, that carry out the response..

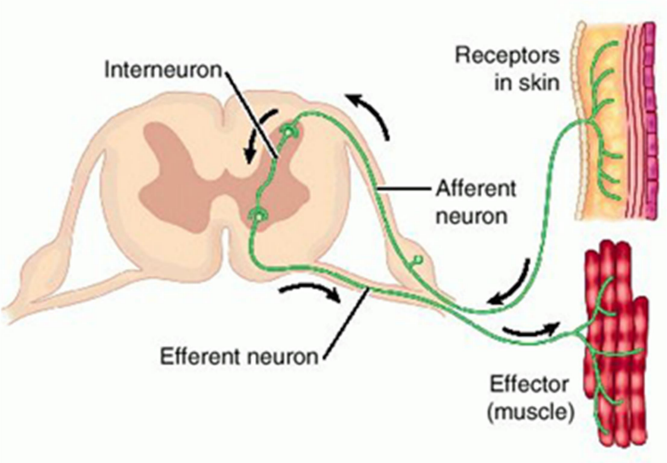


Figure: reflex arc.

Dermatome

A dermatome is an area of skin that is mainly supplied by afferent nerve fibers from a single dorsal root of spinal nerve which forms a part of a spinal nerve. Dermatomes are important because symptoms that occur along a specific dermatome may indicate a problem with a specific nerve root in the spine

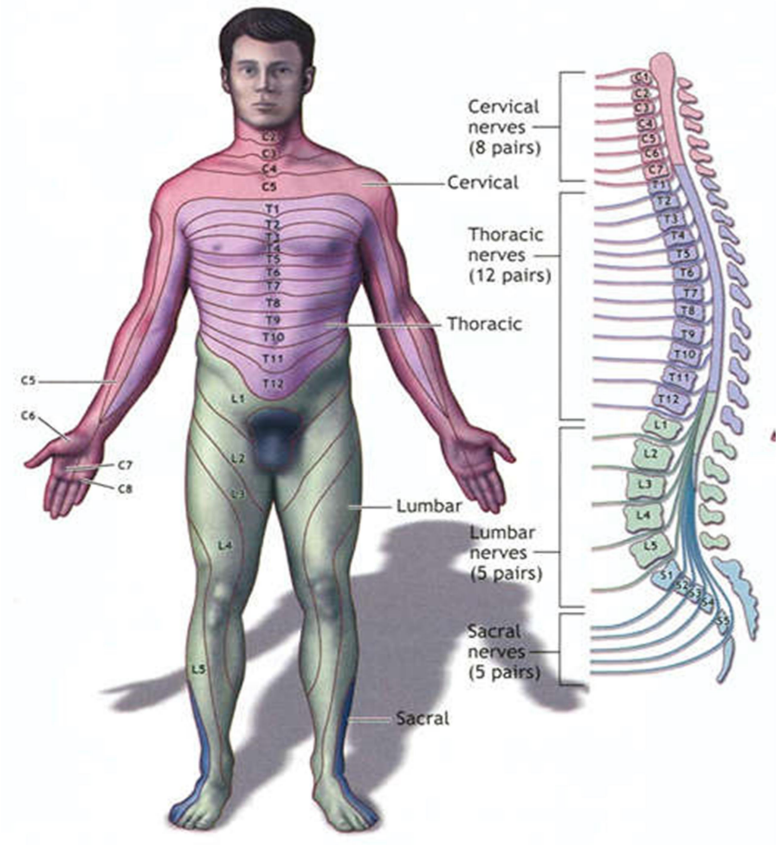


Figure: A dermatome map

The brain

The brain is contained in skull and weighs 1300 - 1400 g , it made up of about 100 billion neurons . The brain consists of four parts

- cerebrum
- cerebellum
- Diencephalon
- Brain stem

The cerebral hemispheres

The cerebrum is the largest part of the human brain, it consist of two hemispheres and account for ~ 85% of total brain mass. The cerebrum forms the superior part of the brain, covering and obscuring the diencephalon and brain stem similar to the way a mushroom cap covers the top of its stalk. Elevated ridges of tissue, called gyri (singular: gyrus), separated by shallow groves called sulci (singular: sulcus) mark nearly the entire surface of the cerebral hemispheres. Deeper groves, called fissures, separate large regions of the brain.

Much of the cerebrum is involved in the processing of somatic sensory and motor information as well as all conscious thoughts, memory and intellectual functions. The cerebrum consist of two layers

- The outer cortex of the cerebrum is composed of gray matter – billions of neuron cell bodies and unmyelinated axons arranged in six discrete layers. Although only 2 – 4 mm thick, this region accounts for ~ 40% of total brain mass.
- The inner region is composed of white matter – tracts of myelinated axons.

Deep within the cerebral white matter is a third basic region of the cerebrum, a group of sub-cortical gray matter called basal nuclei. These nuclei, the caudate nucleus, putamen, and globus pallidus, are important regulators of skeletal muscle movement.

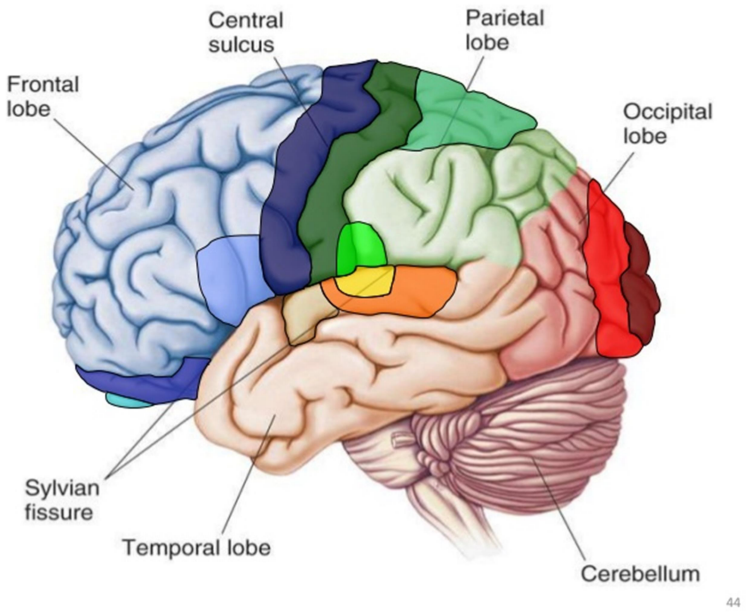


Figure: the lobes of brain.

The main area of cortex

Motor area

1.Primary (somatic) motor cortex, the primary motor cortex is located in the precentral gyrus of the frontal lobe of each hemisphere . This area consciously control the precise or skilled voluntary movements of skeletal muscles.

2.Premotor cortex, Just anterior to the precentral gyrus in the frontal lobe is the premotor cortex. This region controls learned motor skills of a repetitious or patterned nature, such as playing a musical instrument and typing.

3. Broca's area, lies anterior to the inferior region of the premotor area , it directs the muscles involved in speech production.

4. frontal eye field - A specific motor area within the frontal cortex which controls the voluntary scanning movements of the eyes, such as tracking a bird in flight, by sending impulses to the extrinsic muscles of the eyes.

5.Primary somatosensory cortex. This cortex resides in the postcentral gyrus of the parietal lobe, just posterior to the primary motor cortex. It concerned with conscious awareness of sensation of different part of the body.

6.Visual areas. The primary visual (striate) cortex located on the occipital lobe, concerned with visual sensation.

7.Auditory areas. Each primary auditory cortex is located in the superior margin of the temporal lobe, concerned with hearing sensation.

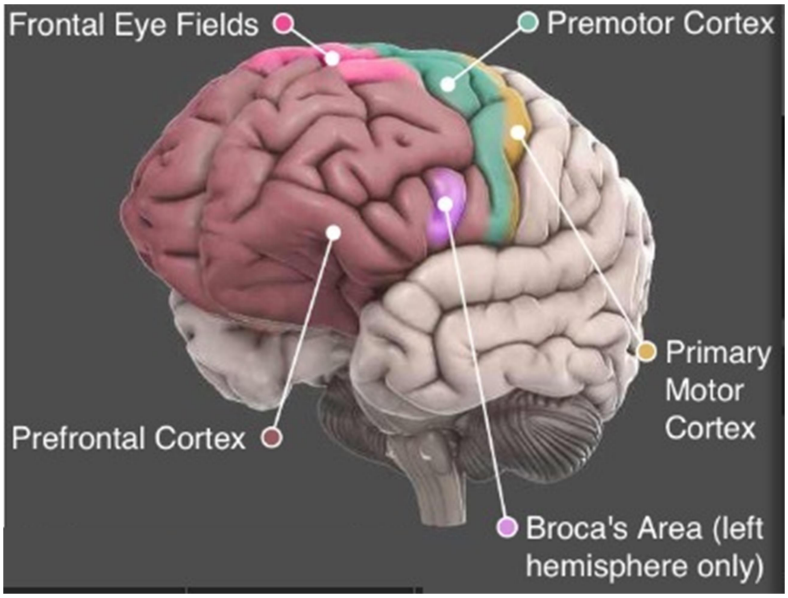


Figure: Motor areas of the cerebrum.

Basal ganglia

The basal ganglia, like the cerebellum, constitute another *accessory motor system* that functions usually not by itself but in close association with the cerebral cortex and corticospinal motor control system. The basal ganglia include: caudate nucleus, putamen, and globus pallidus,. There also are associated nuclei, including the subthalamic nucleus of the diencephalon, and the substantia nigra of the midbrain. They are located mainly lateral to and surrounding the thalamus, occupying a large portion of the interior regions of both cerebral hemispheres.

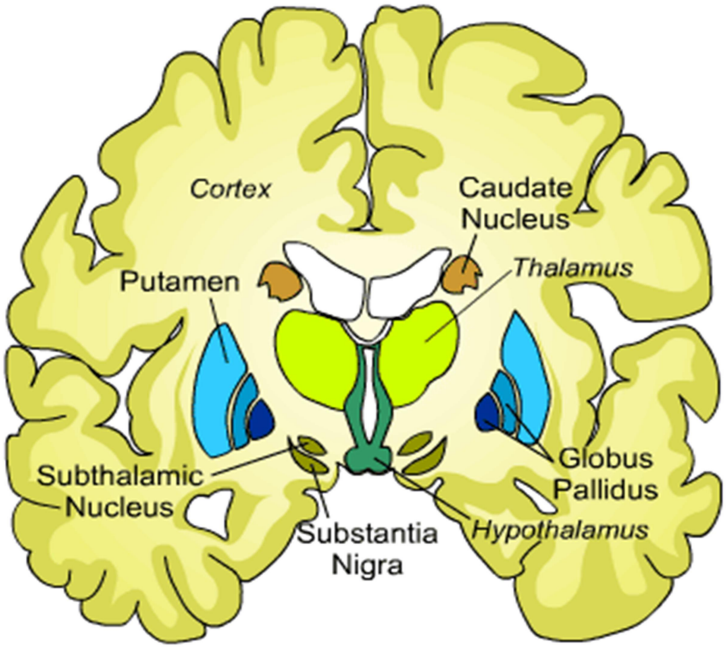


Figure: The basal ganglia.

Parkinson's disease, results from widespread destruction of that portion of the substantia nigra that sends dopamine-secreting nerve fibers to the caudate nucleus and putamen. The disease is characterized by
(1) rigidity of much of the musculature of the body,
(2) involuntary tremor
(3) serious difficulty in initiating movement, called akinesia.

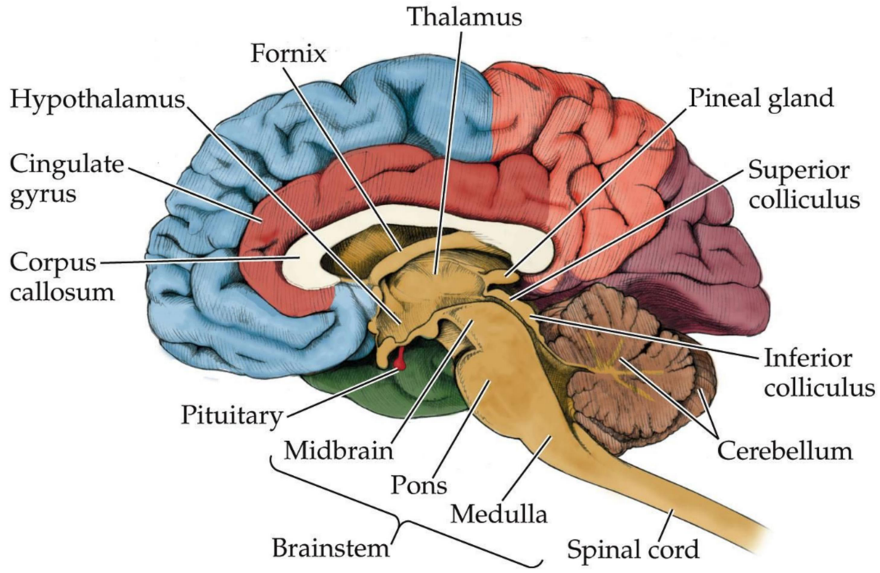
Huntington's Disease (Huntington's Chorea)

Huntington's disease is a hereditary disorder It is characterized by abnormal movements (motor dysfunctions) and severe dementia.

Cerebellum

The cauliflower-like cerebellum "small brain", exceeded in size only by the cerebrum, accounts for about 11% of total brain mass. The cerebellum is located dorsal to the pons and medulla (and to the intervening fourth ventricle). It protrudes under the occipital lobes of the cerebral hemispheres, from which it is separated by the transverse cerebral fissure, it has two lateral hemispheres and central vermis. The cerebellum smoothes and coordinates voluntary movements of skeletal muscles, regulates posture and balance. For example, when you walk, many muscles have to contract and relax at appropriate times. Your cerebellum

coordinates these activities. It also may have a role in cognition and language processing. The cerebellum also coordinates fine movements such as threading a needle, playing an instrument, and writing. It also May have a role in language processing and recognition.



Midsagittal (midline) view

Diencephalon.

The diencephalon is located between the cerebral hemispheres and is superior to the brainstem. The diencephalon includes :

I.The thalamus serves as a relay station for sensory information that heads to the cerebral cortex for interpretation. If sensory information does not pass through the thalamus before it reaches the cerebral cortex, it cannot be interpreted correctly. For example, say you are feeling pain in your left forearm. This information goes up the spinal cord and through the thalamus and then to the cerebral cortex for interpretation. If the information did not go through the thalamus, the cerebral cortex may interpret that you are feeling cold instead of pain in your left forearm.

II.THE HYPOTHALAMUS

The hypothalamus consists of **groups of nuclei** that orchestrates many homeostatic functions via the autonomic and endocrine systems.

Function of hypothalamus

1.regulation of food intake

2.regulation of body temperature

3.regulation of body water by ADH secretion

4.Regulation of Uterine Contractility and of Milk Ejection from the Breasts. By secretion of the hormone oxytocin.
5. Control of endocrine hormone secretion by the Anterior Pituitary Gland..

THE RETICULAR FORMATION AND DIFFUSE

The Reticular Formation, is a complex network of nuclei (masses of gray matter) and fibers that extend the length of the brain stem. The main function of reticular formation

- Modulates sensation of pain.
- Modulates certain postural reflexes and muscle tone.
- Helps control breathing and heartbeat.
- Regulates level of brain arousal and consciousness.

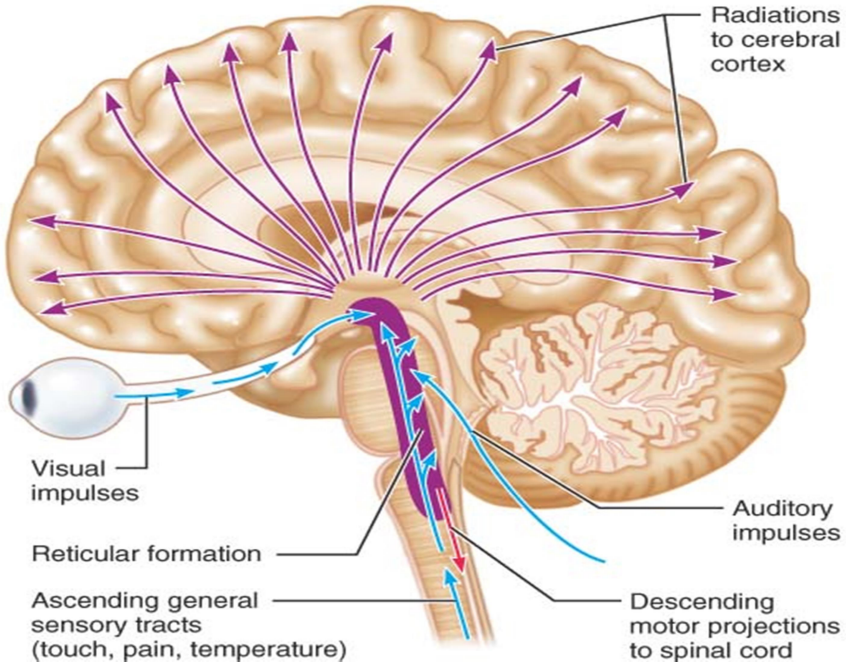


Figure: Excitatory-activating system of the brain.

Brainstem.

The brainstem is a structure that connects the cerebrum to the spinal cord. The three parts of the brainstem are:

- the midbrain, The midbrain lies just beneath the diencephalon.It controls both visual and auditory reflexes. An example of a visual

reflex is when you see something in your peripheral vision and you automatically turn your head to view it more clearly.

- the pons, The pons is a rounded bulge on the underside of the brain stem situated between the midbrain and the medulla oblongata. It contains nerve tracts to connect the cerebrum to the cerebellum. The pons also regulates breathing.
- the medulla oblongata. The medulla oblongata is the most inferior portion of the brain stem and is directly connected to the spinal cord. It controls many vital activities such as heart rate, blood pressure, and breathing. It also controls reflexes associated with coughing, sneezing, and vomiting.

The Autonomic Nervous System

The autonomic nervous system consists of nerves that connect the CNS to organs and other structures such as the heart, stomach, intestines, glands, blood vessels, and bladder (among others). The autonomic nervous system controls organs not under voluntary control, so it is often referred to as the "involuntary" nervous system.

Division of autonomic nervous system

The two divisions of the autonomic nervous system are

1.the sympathetic (thoracolumbar) division

The sympathetic division prepares organs for "fight-orflight" situations. In other words, it prepares them for stressful or emergency situations. For example, the sympathetic division prepares the heart for a stressful or frightening situation by increasing the heart rate.

2.the parasympathetic(craniosacral) division

The parasympathetic division prepares the body for resting and digesting. For example, the parasympathetic division prepares the heart for resting by keeping the heart rate relatively low.

Both systems have efferent pathways through peripheral ganglia; these ganglia serve as synaptic relay stations, accordingly we have presynaptic and postsynaptic neurons .

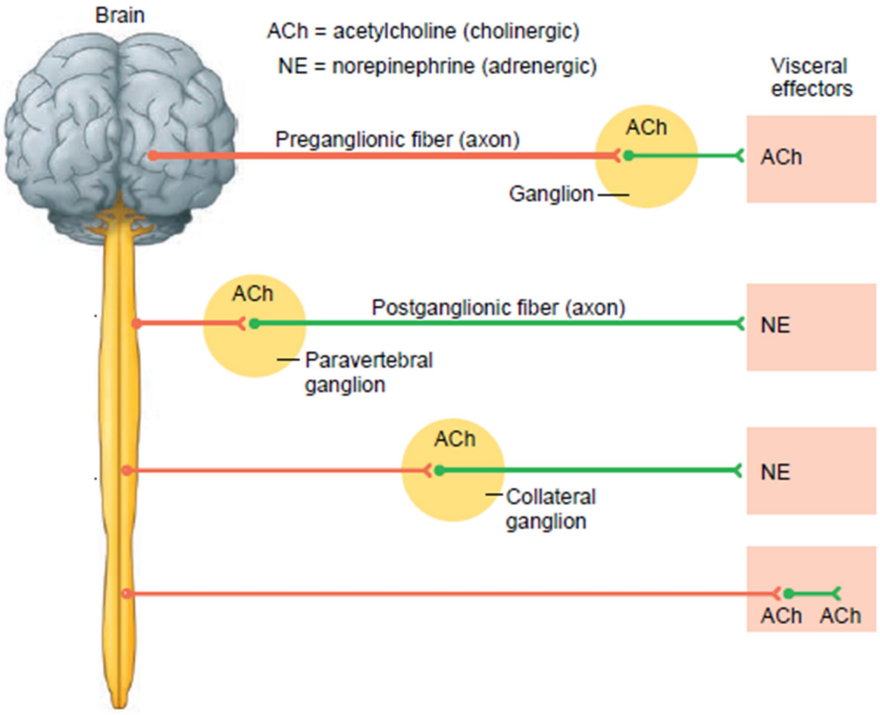


Figure:Divisions of the Peripheral Autonomic System

Notice: that sympathetic and parasympathetic actions are antagonistic, meaning that they function in opposite ways.

AUTONOMIC NEUROTRANSMITTERS

The two main neurotransmitters of autonomic nervous system are, acetylcholine and norepinephrine,

(1).Acetylcholine is the transmitter released at preganglionic synapses in both parasympathetic and sympathetic ganglia, parasympathetic postganglionic neuroeffector . Neurons that release acetylcholine are called cholinergic neurons. Drugs that mimic the actions of acetylcholine are termed cholinomimetic also called parasympathomimetic drugs. Drugs that antagonize the actions of acetylcholine are known as cholinoreceptor antagonists. The receptors with which acetylcholine and other cholinomimetic drugs interact are called cholinergic receptor . There are two types of Cholinoceptors:

1.Muscarinic (M-)cholinoceptors

2. Nicotinic cholinoceptors,

(2).Norepinephrine is the transmitter released at most sympathetic postganglionic neuroeffector junctions. Drugs that mimic the actions of epinephrine and/or norepinephrine are adrenomimetic also called sympathomimetic. Drugs that antagonize the actions of norepinephrine

are known as adrenoceptor antagonists. The receptors with which norepinephrine, epinephrine, are called adrenergic receptor(ARs).
The ARs divided into two distinct groups:

1.α receptors , which further subdivided into : α-ARs included α 1 and α 2

2. β receptors , which further subdivided into β 1, β 2 and β 3-ARs