NEUROSCIENCE

LECTURE 02: The nervous system

The nervous system is responsible for coordinating all of the body's activities. It controls not only the maintenance of normal functions but also the body's ability to cope with emergency situations.

Function

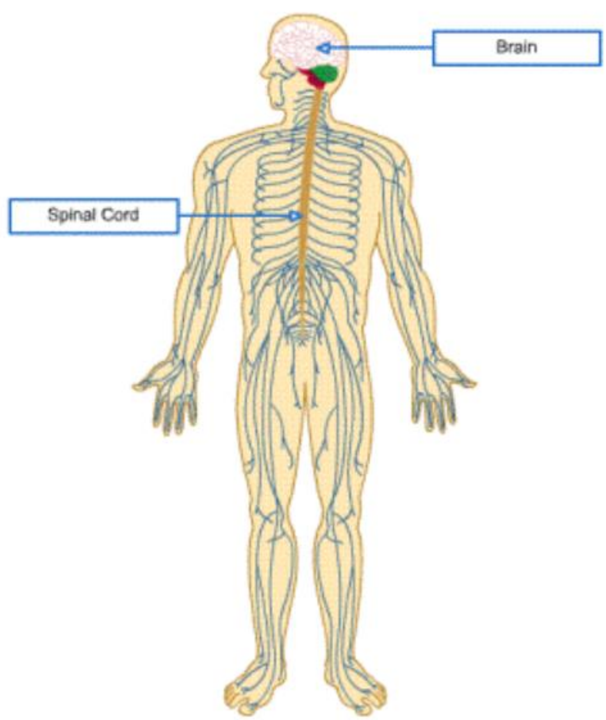
The nervous system has three general functions: a sensory function, an interpretative function and a motor function.

1. Sensory nerves gather information from inside the body and the outside environment. The nerves then carry the information to central nervous system (CNS).
2. Sensory information brought to the CNS is processed and interpreted.
3. Motor nerves convey information from the CNS to the muscles and the glands of the body.

Structure

The nervous system is divided into two parts:

1. the central nervous system consisting of the brain and spinal cord. These structures are protected by bone and cushioned from injury by the cerebrospinal fluid (CSF)
2. the peripheral system which connects the central nervous system to the rest of the body.



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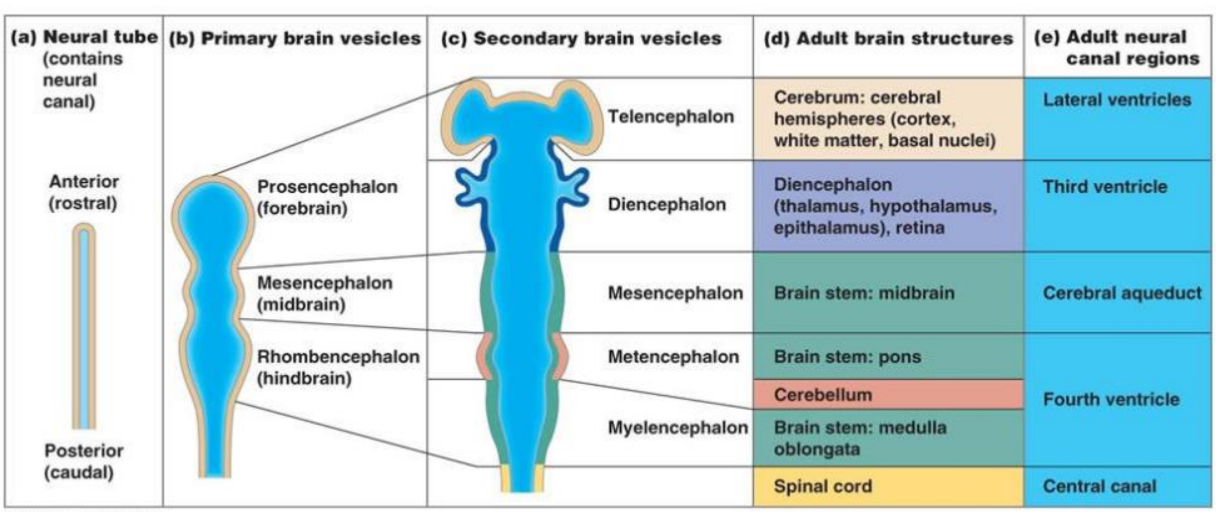
Central Nervous System (CNS) –

I. Development of the CNS

- Key to understanding anatomy of CNS is to recognize that CNS starts as a straight tube (i.e., a hollow cylinder) with walls of uniform thickness. The CNS ends up as a bent tube with a split at its rostral end and walls of varying thickness. Nevertheless, it remains a tube, albeit a highly complex one.
- Nervous system derives from ectoderm which also gives rise to epidermis of skin
  - - notochord induces formation of neural plate, a dorsal midline thickening of the ectoderm
  - - in a process known as neuralation, neural plate folds up creating a hollow neural tube which forms the CNS
  - - during neuralation neural crest cells pinched off and migrate to form peripheral ganglia of PNS (and other structures, e.g., melanocytes)
- Brain development
  - Following neural tube formation, differentiation of brain marked by three rostral swellings, the primary vesicles (I-III), which subsequently elaborate to form the five (1-5) anatomical divisions of the brain
    - I) forebrain (prosencephalon)
      - - gives rise to (1) telencephalon (cerebral hemispheres) and (2) diencephalon
    - II) midbrain - (3) mesencephalon
    - III) hindbrain (rhombencephalon)
      - - gives rise to (4) metencephalon (pons and cerebellum) and (5) myelencephalon (medulla oblongata)
  - - cavity of neural tube in the brain elaborates as ventricles through which cerebro-spinal fluid (CSF) flows
    - - in spinal cord cavity persists as central canal



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II. Anatomical directions in the brain

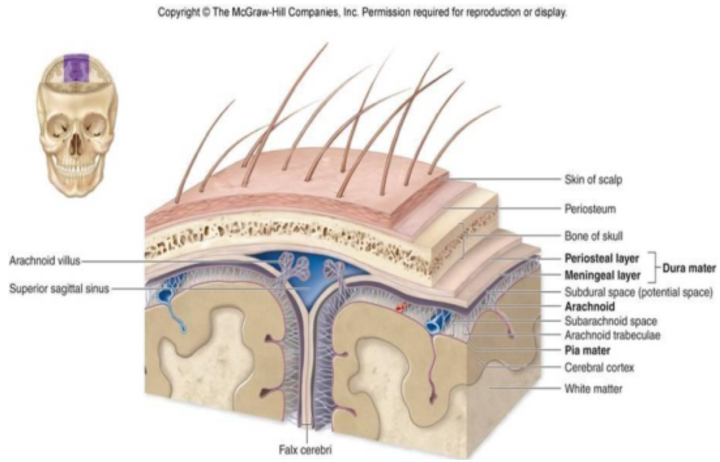
- In most vertebrates CNS is organized along a straight line with long axis running rostro-caudally
  - - in humans rostral-caudal axis curves due to rotation of viscerocranium under the neurocranium, thus causing shift in orientation of axes relative to body
  - - therefore directions in human CNS are intrinsic and refer to original embryonic positions, independent of their position in the adult body.
- rostral - toward the muzzle (rostrum) along axis defined by original neural tube cavity (ventricles and central canal of adult CNS)
- caudal - towards the tail along axis defined by original neural tube cavity
- dorsal - orthogonal (at right angle) to rostral-caudal axis; toward site of neural plate fusion
- ventral - orthogonal to rostral-caudal axis; towards site of notochord

III. Blood Flow and the Blood-Brain Barrier

1. Blood flows to the brain mainly via blood vessels that branch from the cerebral arterial circle (circle of Willis) at the base of the brain ; the veins that return blood from the head to the heart are seen in Figure
2. Although the brain comprises only about 2% of the total body weight, it utilizes about 20% of the oxygen used by the entire body..
3. When activity of neurons and neuroglia in a region of the brain increases, blood flow th that area increases
4. An interruption of blood flow for 1 or 2 minutes impairs neuronal function. A total deprivation of oxygen for 4 minutes causes permanent injury.
5. Because carbohydrate storage in the brain is limited, the supply of glucose to the brain must be continuous. Glucose deficiency may produce mental confusion, dizziness, convulsions, and unconsciousness.
6. A blood-brain barrier (BBB) protects brain cells from harmful substances and pathogens by serving as a selective barrier to prevent passage of many substances from the blood to the brain.
7. An injury to the brain due to trauma, inflammation, or toxins causes a breakdown of the BBB, permitting the passage of normally restricted substances into brain tissue.
8. The BBB may also prevent entry of drugs that could be used as therapy for brain cancer or other CNS disorders, so research is exploring ways to transport drugs past the BBB.

IV. Protective Covering of the Brain

1. The brain is protected by the *cranial bones* and the *cranial meninges*
2. The cranial meninges are continuous with the spinal meninges and are named*dura mater, arachnoid*, and *pia mater*.
3. Three extensions of the dura mater separate parts of the brain: the falxcerebri, falxcerebelli, and the tentorium cerebelli.
4. Bleeding into the subdural space (subdural hemorrhage) leads to a hematoma. Symptoms include drowsiness, confusion, and coma. This condition is life threatening and requires immediate attention.



V. CEREBROSPINAL FLUID

A. *Cerebrospinal fluid* (*CSF*) is a clear, colorless liquid that protects the brain and spinal cord against chemical and physical injuries and carries oxygen, glucose, and other needed chemicals from the blood to neurons and neuroglia.

B. There are four CSF filled cavities within the brain called *ventricles*.
   1. A lateral ventricle is located in each hemisphere of the cerebrum. The lateral ventricles are separated by the septum pellucidum.
   2. The third ventricle is a narrow cavity along the midline superior to the hypothalamus and between the right and left halves of the thalamus.
   3. The fourth ventricle is between the brain stem and the cerebellum.

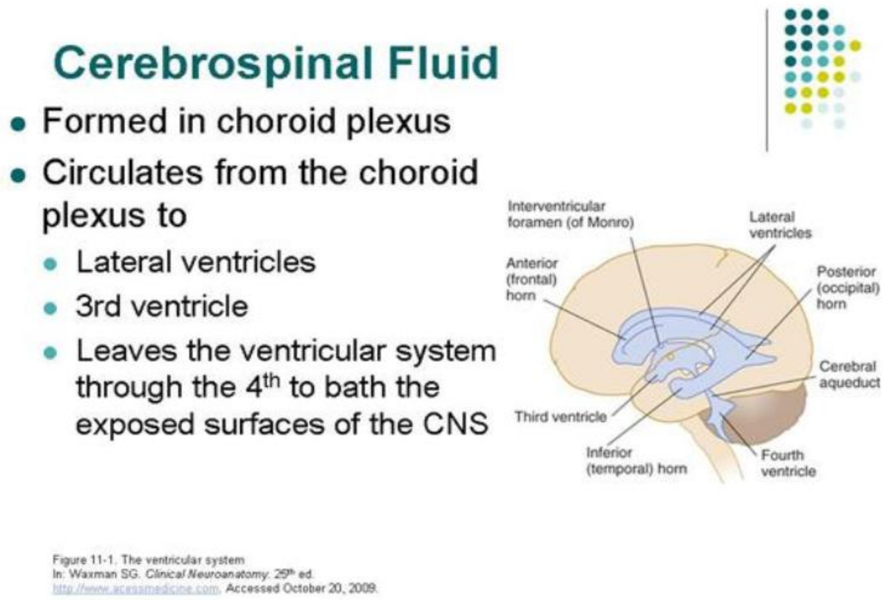
C. CSF contributes to homeostasis by providing mechanical protection, chemical protection, and circulation.

D. CSF is formed by filtration from networks of capillaries called choroid plexuses (found in the ventricles) and circulates through the subarachnoid space, ventricles, and central canal.

E. Materials entering CSF from the choroid capillaries cannot leak between the surrounding ependymal cells; these constitute the blood-cerebrospinal fluid barrier, which permits certain substances to enter the fluid but excludes others and protects the brain and spinal cord from harmful elements .

F. Most of the fluid is absorbed by the arachnoid villi of the superior sagittal blood sinus; this absorption normally occurs at the same rate at which CSF is produced in the choroid plexuses, thereby maintaining a relatively constant CSF volume and pressure

G. If CSF cannot circulate or drain properly due to some obstruction in the ventricles or subarachnoid space, a condition called *hydrocephalus* develops. The fluid buildup that occurs causes increased pressure on the brain, either internally or externally, depending on where the blockage is present. Surgically draining the ventricles and diverting the flow of CSF by an implanted shunt can positively and dramatically affect the individual's prognosis.



Brain

Brain one of largest organs in body:

men: 1,600 g (3.5 lbs) women: 1,450g (3.2 lbs) [size is proportional to body size not intelligence ! Neanderthals had larger brains than us!!]

early thoughts on function of brain:

ancient Greeks weren’t particularly impressed with the brain

where snot was generated

cooling device for blood

Neurons divide only during prenatal development and a few months after birth after that they increase in size, but not numbers

one of most metabolically active organs in body

comprises only 2% of total body weight it yet !

gets 15% of blood !

consumes 20% of our oxygen need at rest (more when mentally active)

blood flow and O2 increase to active brain areas

1-2 min interruption of blood flow may impair brain cells

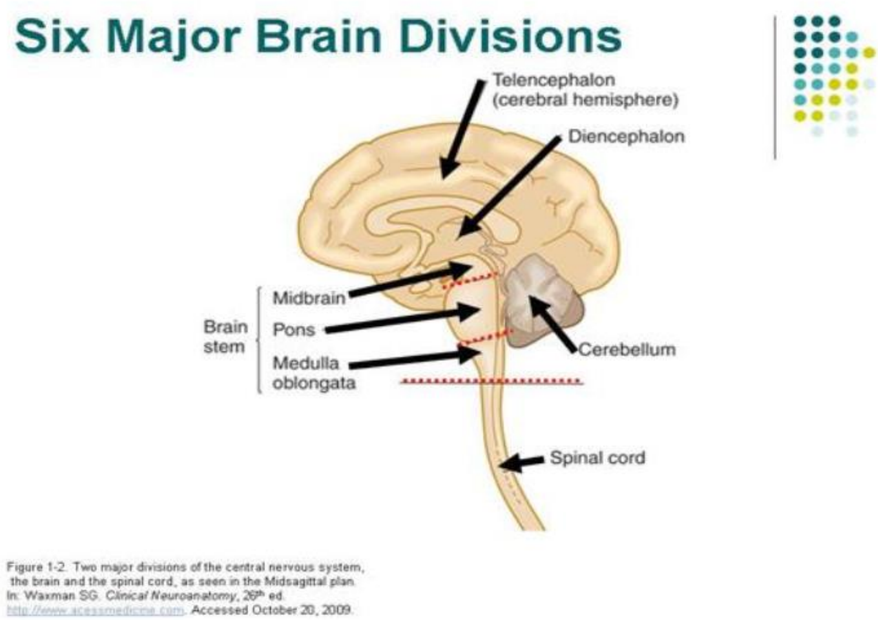
>4 min w/o oxygen leads to permanent damage

besides O2 must get continuous supply of glucose very little in reserve

decrease in glucose: dizziness convulsions unconsciousness

The Brain is Subdivided Into:

1. Cerebral Hemispheres (60% of brain mass) - “human” part: thought, creativity, communication
2. Diencephalon moods, memory, manages internal environment
   Epithalamus
   thalamus
   hypothalamus
3. Cerebellum – coordinating movement and balance
4. Brain Stem – oldest and smallest region, basic bodily functions = vegetative functions
   Midbrain, Pons, medulla

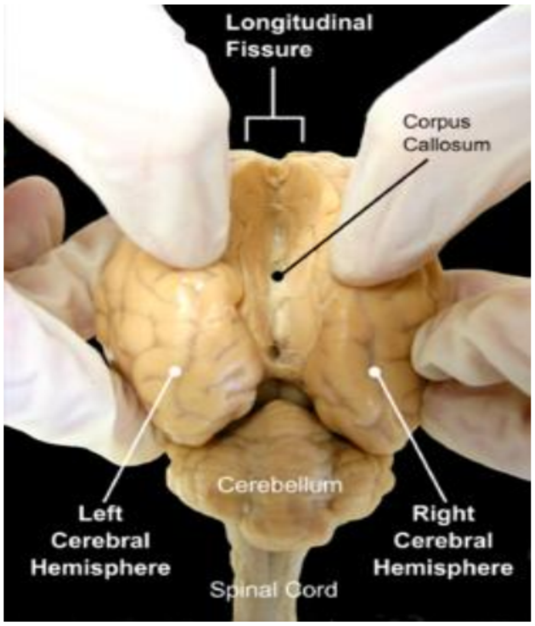


Some General Terminology for CNS:
gray matter = thin myelin; mostly cell bodies dendrites & synapses
-outer layer of brain = cortex
-inner layer of spinal cord
-nuclei: small areas of gray matter deeper inside the brain

White matter = thick insulation; mostly axons
-inner layers of brain: nerve tracts = bundles of axons that interconnect various parts of the brain
-outer layer of spinal cord

CEREBRAL HEMISPHERES AND CORTEX

Cerebral Hemisphere



The vertebrate cerebrum (brain) is formed by two **cerebral hemispheres** that are separated by a groove, the medial longitudinal fissure. The brain can thus be described as being divided into left and right cerebral hemispheres.

Function

Hemispheric Interaction

Recent studies have since discredited the paradigm that no major lateralization exists between cerebral hemispheres.

The following chart highlights the overarching differences without making specific reference to neuron clusters.

Left Hemisphere (LHS)	**Right Hemisphere (RHS)**
Goes forward without regard to consequence	Inhibits left hemisphere
Doesn’t make good decisions	Reflective & protective
Selfish	Greater good
Goes forward	Pulls back
Risks	If danger is visible halts action

The right hemisphere’s main function is to inhibit the left hemisphere.The LHS “is all go”, it is the cause of all action.[4] LHS has no ability to consider consequence, longevity or risk it merely acts. RHS is the opposite of LHS; it calculates risk versus reward and inhibits LHS based off these calculations among other things. An overdeveloped LHS leads to the inability to control one's actions and emotions as well as volatility. An overdeveloped RHS leads to inaction, reclusive behavior and phobias.

Hemisphere lateralization

Broad generalizations are often made in popular psychology about certain functions (e.g. logic, creativity) being lateralized, that is, located in the right or left side of the brain. These claims are often inaccurate, as most brain functions are actually distributed across both hemispheres. Most scientific evidence for asymmetry relates to low-level perceptual functions rather than the higher-level functions popularly discussed (e.g. subconscious processing of grammar, not "logical thinking" in general).[9]

The best evidence of lateralization for one specific ability is language. Both of the major areas involved in language skills, Broca's area and Wernicke's area, are in the left hemisphere.

Perceptual information is processed in both hemispheres, but is laterally partitioned: information from each side of the body is sent to the opposite hemisphere (visual information is partitioned somewhat differently, but still lateralized). Similarly, motor control signals sent out to the body also come from the hemisphere on the opposite side. Thus, hand preference (which hand someone prefers to use) is also related to hemisphere lateralization.

Neuropsychologists, including Roger Sperry and Michael Gazzaniga, have studied split-brain patients to better understand lateralization. Sperry pioneered the use of lateralized tachistoscopes to present visual information to one hemisphere or the other. Scientists have also studied people born without a corpus callosum to determine specialization of brain hemispheres.

The magnocellular pathway of the visual system sends more information to the right hemisphere, while the parvocellular pathway sends more information to the left hemisphere.

In some aspects, the hemispheres are asymmetrical; one side is slightly bigger. There are higher levels of the neurotransmitter norepinephrine on the right and higher levels of dopamine on the left. There is more white matter (longer axons) on right and more grey matter (cell bodies) on the left.

Linear reasoning functions of language such as grammar and word production are often lateralized to the left hemisphere of the brain. In contrast, holistic reasoning functions of language such as intonation and emphasis are often lateralized to the right hemisphere of the brain. Other integrative functions such as intuitive or heuristic arithmetic, binaural sound localization, emotions, etc. seem to be more bilaterally controlled

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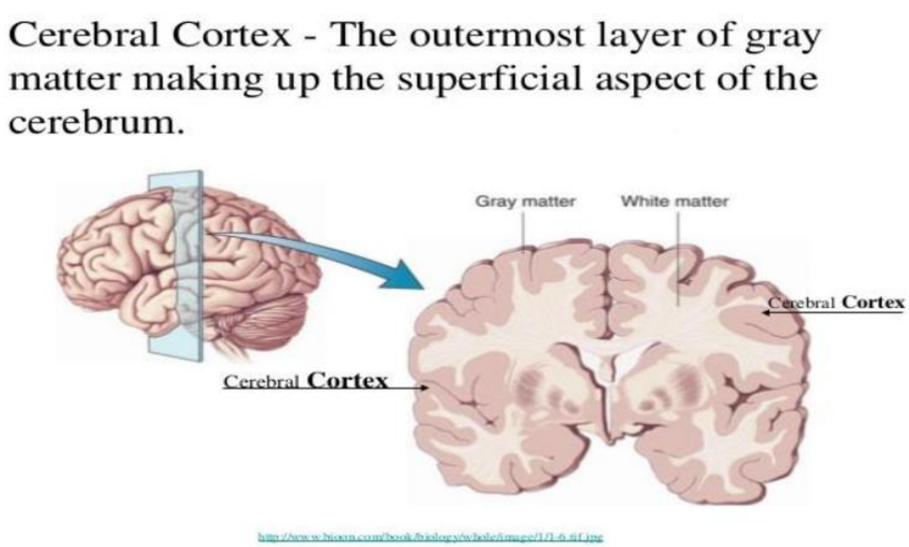
Left hemisphere functions	Right hemisphere functions
numerical computation (exact calculation, numerical comparison, estimation) left hemisphere only: direct fact retrieval	numerical computation (approximate calculation, numerical comparison, estimation)
language: grammar/vocabulary, literal	language: intonation/accentuation, prosody, pragmatic, contextual

Each of these hemispheres has an outer layer of grey matter, the cerebral cortex, that is supported by an inner layer of white matter.

Right & left cerebral hemispheres are derived from the embryonic telencephalon.
They are composed of gray and white matter.



Gray Matter: Cerebral Cortex — layer of gray matter at the surface of the cerebral hemisphere. Three phylogenetic categories of cerebral cortex are:

• archicortex — (hippocampus) oldest, composed of two layers
• paleocortex — (piriform lobe) old, three layers, olfaction related
• neocortex — new, six layers, detailed perception, learning, intelligence

Basal Nuclei — gray matter nuclei located deep within the white matter of the cerebral hemisphere.

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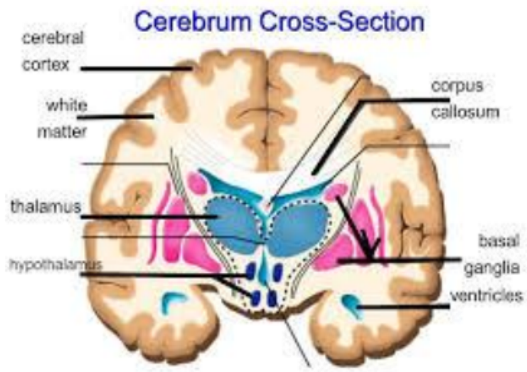


The basal ganglia consist of:

a. Globus pallidus and the putamen which are referred to as the lentiform nucleus
b. Caudate nucleus
c. Lentiform and cuadate nuclei are known as the corpus striatum.
d. Nearby structures functionally linked to the basal ganglia are the substantianigra and the subthalamic nuclei.

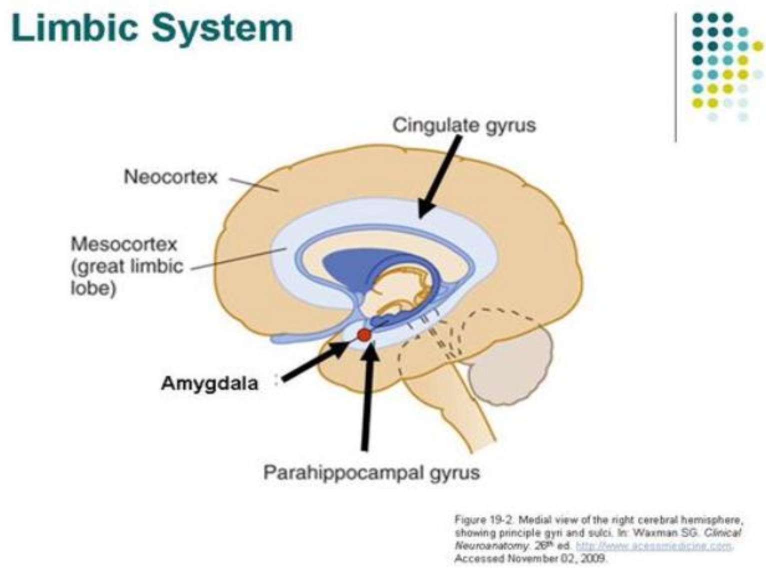
They are responsible for helping to control muscular movements.

Damage to the basal ganglis results in tremor, rigidity, and involuntary muscle movements. In Parkinson's disease neurons from the substantianigra to the putamen and cuadate nucleus degenerate.

Basal ganglia also help initiate and terminate some cognitive processes. Obsessive compulsive disorder, schizophrenia, chronic anxiety are thought to involve dysfunction of the circuits between the basal ganglis and limbic system

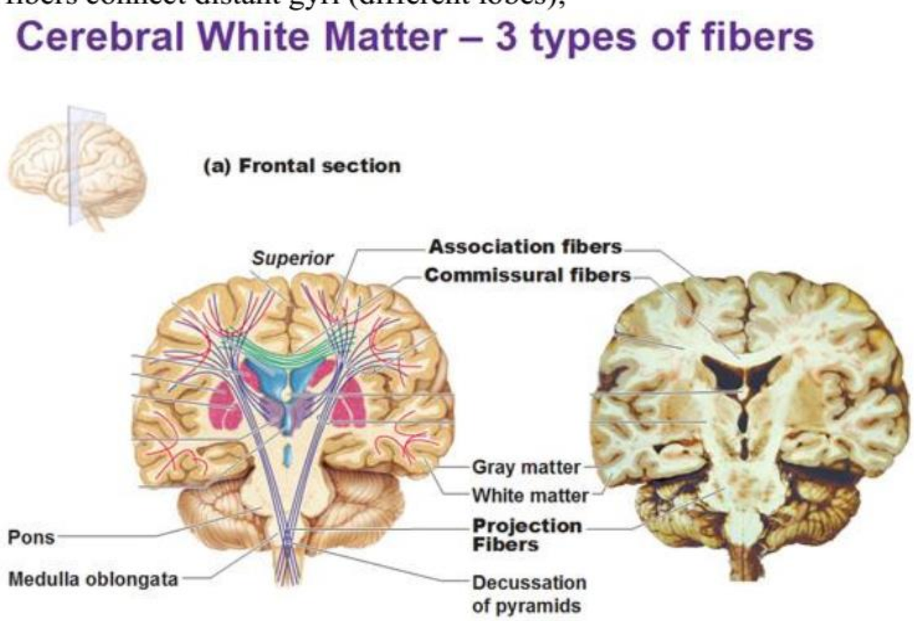
Limbic System

1. The *limbic system* is found in the cerebral hemispheres and diencephalon .
2. Components are the limbic lobe, dentate gyrus;, amygdala, septal nuclei, mammilary bodies, anterior and medial nuclei of the thalamus, olfactory bulbs, fornix, striaterminalis, striamedulllaris, medial forebrain bundle, and mammilothalmic tract.
3. It functions in emotional aspects of behavior and memory, and is associated with pleasure and pain.



White Matter:

Myelinated axons which connect cerebral cortex with other brain regions.
Three categories of white matter fibers are recognized:
Projection Fibers — fibers that leave the cerebral white matter. Projection fibers form the internal capsule. Two categories of projection fibers are:
1] corticofugal: terminate in the basal nuclei, brainstem, or spinal cord;
2] corticopedal: typically originate in thalamus & terminate in cerebral cortex.
Commissural Fibers—fibers that connect cortices of right and left cerebral hemispheres. The largest bundle forms the corpus callosum.
Association Fibers—fibers that connect regions of the cerebral cortex within one hemisphere. Two categories are recognized: short association fibers connect adjacent gyri; long association fibers connect distant gyri (different lobes);



Cerebral Cortical (Neocortex)

Neocortex, the phylogenetically most recent cortex, is only found in mammals. It is organiz horizontally into six layers and varies in thickness among different regions of the hemispher Neocortex is involved in detailed sensory perception, in performing rapid sequences of fi movements, and in learning and intelligent behavior. It is most abundant in the human brai It forms about 85% of the dog cerebral cortex (the remaining 15% being archicortex a paleocortex).

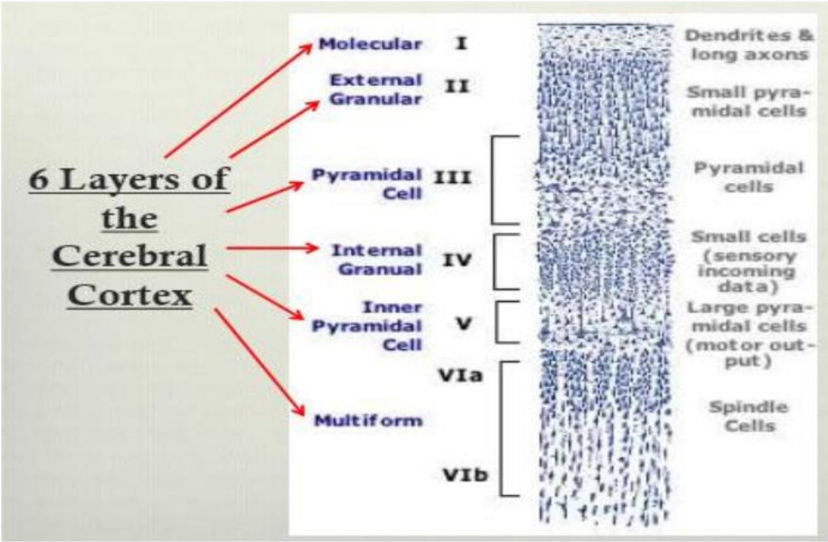
Two neuron types predominate in the neocortex:
pyramidal cell — conical cell body (>30 μm in diameter) with apical and basal dendrites a an axon that leaves the base of the cell to enter white matter. Pyramidal cells vary in siz They are the output cells of the cerebral cortex.
granule cell — small, round cell body (<10 μm in diameter). Granule cells serve interneurons, receiving input from cortical afferent fibers and synapsing on output neuro (pyramidal cells) of the cortex.

Two types of afferent projection fibers from the thalamus enter the neocortex:

specific afferents — modality specific input; terminate in inner granule cell layer
non-specific afferents — background excitation; terminate in molecular layer.

Horizontal Layers of Cerebral Cortical

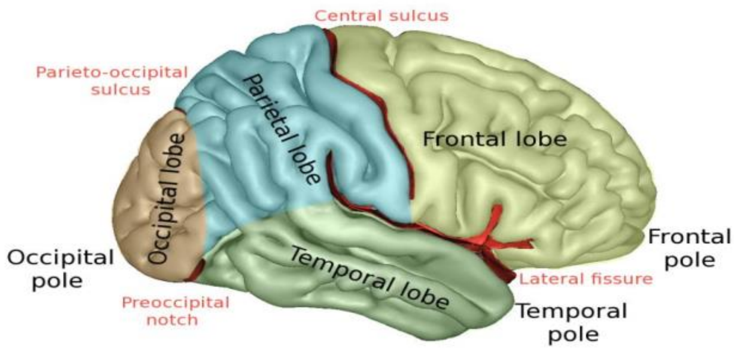
The cerebral cortex is organized into six horizontal layers (although layer boundaries are n very obvious in routine sections). The individual layers have different roles and vary relative thickness among cortical regions (e.g., a sensory region has a thick internal granu layer; a motor area has a thick internal pyramidal cell layer). From superficial to deep, the s layers are:
1] Molecular layer — fi ber layer; apical dendrites & non-specifi c afferents;
2] Outer granule cell layer — interneurons for non-specifi c afferent input;
3] Outer pyramidal cell layer — small and medium cells; short association output
4] Inner granule cell layer — interneurons for specifi c afferent input
5] Inner pyramidal layer — large cells; projection & long association output
6] Multiform layer — variably shaped cells; projection & long association output



Division of the Cerebral Cortex into Lobes

The most conspicuous features on the surface of each hemisphere are numerous folds called **gyri**(jī_rī;sing. gyrus, *gyros,* circle), which greatly increase the surface area ofthe cortex, and intervening grooves called **sulci** (sŭl_sī; sing. sulcus,a furrow or ditch).

The brain is separated into four lobes: the frontal, temporal, occipital, and parietal lobes.



The Frontal Lobe

The frontal lobe is associated with executive functions and motor performance. Executive functions are some of the highest-order cognitive processes that humans have. Examples include:

- planing and engaging in goal-directed behavior;
- recognizing future consequences of current actions;
- choosing between good and bad actions;
- overriding and suppressing socially unacceptable responses;
- determining similarities and differences between objects or situations.

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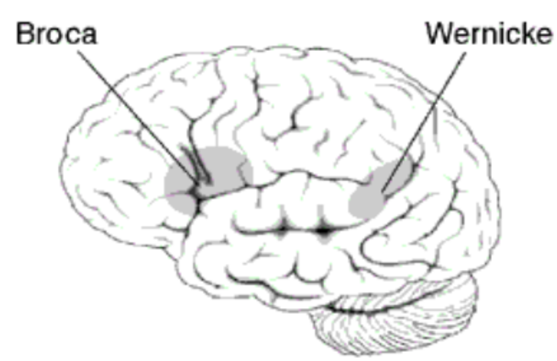
The frontal lobe is considered to be the moral center of the brain because it is responsible for advanced decision-making processes. It also plays an important role in retaining emotional memories derived from the limbic system, and modifying those emotions to fit socially accepted norms.

The Temporal Lobe

The temporal lobe is associated with the retention of short- and and long-term memories. It processes sensory input including auditory information, language comprehension, and naming. It also creates emotional responses and controls biological drives such as aggression and sexuality.

The temporal lobe contains the hippocampus, which is the memory center of the brain. The hippocampus plays a key role in the formation of emotion-laden, long-term memories based on emotional input from the amygdala. The left temporal lobe holds the primary auditory cortex, which is important for processing the semantics of speech.

One specific portion of the temporal lobe, Wernicke's area, plays a key role in speech comprehension. Another portion, Broca's area, underlies the ability to produce (rather than understand) speech. Patients with damage to Wernicke's area can speak clearly but the words make no sense, while patients with damage to Broca's area will fail to form words properly and speech will be halting and slurred. These disorders are known as Wernicke's and Broca's aphasia respectively; an aphasia is an inability to speak.



Broca's and Wernicke's areas

The Occipital Lobe

The occipital lobe contains most of the visual cortex and is the visual processing center of the brain. Cells on the posterior side of the occipital lobe are arranged as a spatial map of the retinal field. The visual cortex receives raw sensory information through sensors in the retina of the eyes, which is then conveyed through the optic tracts to the visual cortex. Other areas of the occipital lobe are specialized for different visual tasks, such as visuospatial processing, color discrimination, and motion perception. Damage to the primary visual cortex (located on the surface of the posterior occipital lobe) can cause blindness, due to the holes in the visual map on the surface of the cortex caused by the lesions.

The Parietal Lobe

The parietal lobe is associated with sensory skills. It integrates different types of sensory information and is particularly useful in spatial processing and navigation. The parietal lobe plays an important role in integrating sensory information from various parts of the body, understanding numbers and their relations, and manipulating objects. Its also processes information related to the sense of touch.

The parietal lobe is comprised of the somatosensory cortex and part of the visual system. The somatosensory cortex consists of a "map" of the body that processes sensory information from specific areas of the body. Several portions of the parietal lobe are important to language and visuospatial processing; the left parietal lobe is involved in symbolic functions in language and mathematics, while the right parietal lobe is specialized to process images and interpretation of maps (i.e., spatial relationships).

Diencephalon

The **diencephalon** (dī_en-sef_ă-lon) is the part of the brain between the brainstem and the cerebrum. Its main components are the thalamus, the epithalamus, and the hypothalamus.

Thalamus

1. The *thalamus* is located superior to the midbrain and contains nuclei that serve as relay stations for all sensory impulses, except smell, to the cerebral cortex
2. There are seven major groups of thalamic nuclei on each side. The are the Anterior nucleus, medial nuclei, lateral group, ventral group, intralaminar nuclei, midline nucleus, and the reticular nucleus.
3. It also registers conscious recognition of pain and temperature and some awareness of light touch and pressure.
4. It plays an essential role in awareness and the acquisition of knowledge, which is termed cognition.

Hypothalamus

1. The *hypothalamus* is found inferior to the thalamus, has four major regions (*mammillary, tuberal, supraoptic, and preoptic*), controls many body activities, and is one of the major regulators of homeostasis .
2. The hypothalamus has a great number of functions.
   a. It controls the ANS.
   b. It produces hormones.
   c. It functions in regulation of emotional and behavioral patterns.
   d. It regulates eating and drinking through the feeding center, satiety center, and thirst center.
   e. It aids in controlling body temperature.
   f. It regulates circadian rhythms and states of consciousness.

Epithalamus

1. The *epithalamus*lies superior and posterior to the thalamus and contains the *pineal gland* and the *habenular nuclei*

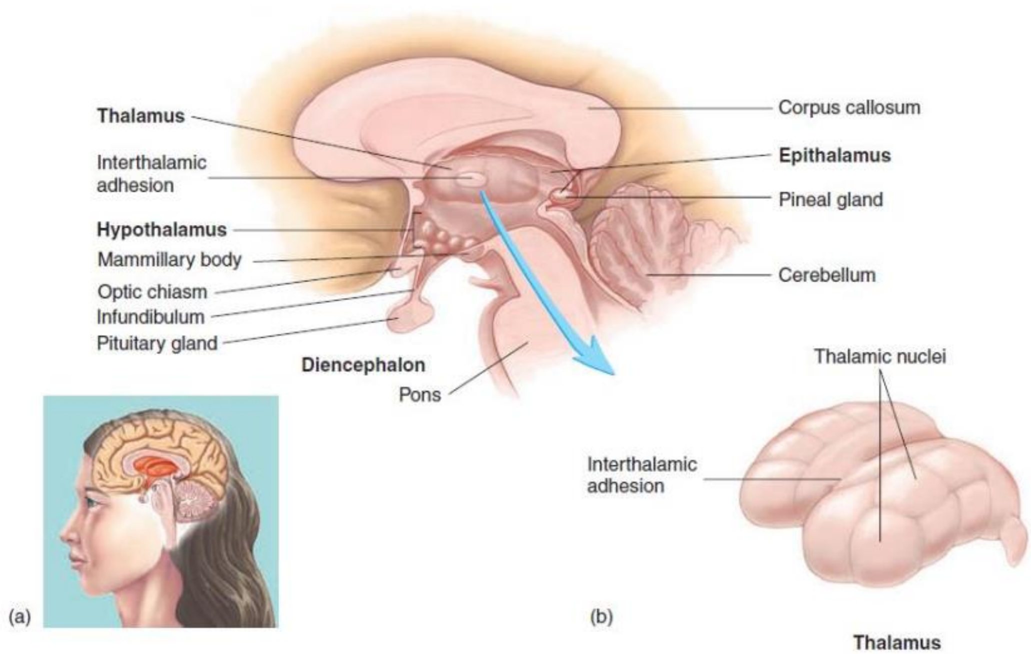
2. The *pineal gland* secretes *melatonin* to influence diurnal cycles in conjunction with the hypothalamus.
3. The *habenular nuclei* are involved in olfaction, especially emotional responses to odors.

Subthalamus

1. The *subthalamus* lies immediately inferior to the thalamus and includes tracts and the paired subthalamic nuclei, which connect to motor areas of the cerebrum.
2. The subthalamic nuclei and red nucleus and substantianigra of the midbrain work together with the basal ganglia, cerebellum, and cerebrum in control of body movements.

Circumventricular Organs

1. Parts of the diencephalon, called *circumventricular organs* (*CVOs*), can monitor chemical changes in the blood because they lack a blood-brain barrier.
2. CVOs include part of the hypothalamus, the pineal gland, the pituitary gland, and a few other nearby structures.
3. They function to coordinate homeostatic activities of the endocrine and nervous systems.
4. They are also thought to be the site of entry into the brain of HIV.



(*a*) Median section of the diencephalon showing the thalamus, epithalamus, and hypothalamus. (*b*) Both halves of the thalamus as seen from an anterior, dorsolatera view with the separations between nuclei depicted by indentations on the surface.