Neuroanatomy 10: Cerebrum

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The cerebrum (telencephalon) is the largest, most rostral, & most advanced parts of the human brain. It is made up by 2 hemispheres, separated by a deep midline fissure (the longitudinal cerebral fissure). Posteriorly, the hemispheres are separated from the cerebellum by the transverse cerebral fissure. Inferomedially, each hemisphere is continuous with the diencephalon of its side, & is connected to the lower parts of the brain by the cerebral peduncles. The cerebrum has an outer gray matter (cortex) & an inner white matter.

Embryologically, the hemispheres develop as 2 lateral bulges from the cephalic end of the neural tube, which grow extensively more than the rest of the brain. The cavity of each bulge develops into a lateral ventricle, which keeps communication with the midline cavity of the diencephalon (the third ventricle) via the interventricular foramen (of Monro).

Cerebral Gray Matter (Cerebral Cortex)

The cerebral cortex is the thin, outer zone of cerebral hemispheres, which consists of millions of nerve cell bodies with their dendrites & supporting glial cells. The cerebral cortex is thickest in the motor area (4.5 mm) & thinnest in the visual area (1.5 mm). Each cerebral hemisphere is divided into 4 lobes:

- Frontal lobe: the largest, anteriorly;
- Parietal lobe: superolaterally;
- Temporal lobe: inferolaterally;
- Occipital lobe: the smallest, posteriorly.

Note the following:

- The outer surface of the cerebral hemispheres is highly convoluted. It contains tortuous bulges (gyri), separated from each other by relatively shallow grooves (sulci).
- The area of the cerebral cortex is approximately 2200 square centimeters. Its convoluted nature increases the cortical surface area to three times what it would be if the surface was smooth.
- Deep grooves (fissures) exist in the hemispheres, usually separating different cerebral lobes, or same lobes on different sides.
- The longitudinal & transverse cerebral fissures were mentioned above.
- The lateral cerebral fissure (of Sylvius) is a deep cleft on the lateral aspect of the hemisphere. It separates the temporal lobe (below) from the frontal & parietal lobes (above).
- Between its anterior & middle thirds, the lateral fissure has 2 short branches: the anterior ramus (anteriorly) & the ascending ramus (superiorly). The posterior 2 thirds of the fissure continue as the posterior ramus.
- The central sulcus is a long prominent groove that begins above the midpoint of the lateral fissure, passes posterosuperiorly to terminate on the medial surface of the hemisphere. It separates the frontal & parietal lobes from each other.
- The hemisphere has 3 poles: The most anterior point in the frontal lobe is the frontal pole, the most posterior point in the occipital lobe is the occipital pole, & the most anterior point in the temporal lobe is the temporal pole.
- The cerebral lobes are named according to the cranial bones related to each lobe.

Frontal lobe:

This lobe is the most anterior part of the cerebrum. It is separated from the parietal lobe (posteriorly) by the central sulcus, & from the temporal lobe (inferiorly) by the lateral fissure, & from the corpus callosum (medially) by the callosal sulcus. The frontal lobe has a medial, lateral, & inferior surfaces. The following are the main features of each of its surface:

Lateral surface:

- The precentral gyrus lies just anterior & parallel to the central sulcus, it is limited anteriorly by the precentral sulcus. This gyrus contains the primary motor cortex.

- Anterior to the precentral sulcus, the lateral surface has 2 horizontal sulci: the superior & inferior frontal sulci. These sulci divide the area around them into superior, middle, & inferior frontal gyri.
- Pars orbitalis: the triangular area between the lateral fissure & its anterior ramus.
- Pars triangularis: the triangular area between the anterior & ascending rami of the lateral fissure.
- Pars opercularis: the triangular area between the ascending & posterior rami of the lateral fissure.

Medial surface:

- The medial surface surrounds the anterior half of the corpus callosum, separated from it by the callosal sulcus.
- The cingulate sulcus is a long, curved sulcus that starts below the rostrum of corpus callosum, runs parallel to corpus callosum, & terminates in the medial surface of the parietal lobe as the marginal sulcus that reaches the superomedial cerebral border.
- The cingulate gyrus lies between the cingulate & callosal sulci.
- The medial frontal gyrus lies between the cingulate sulcus & superomedial cerebral border.
- In front of the lamina terminalis (the anterior wall of 3rd ventricle), is the paraterminal gyrus, a narrow triangle of grey matter separated from the rest of the cortex by a shallow posterior paraolfactory sulcus.
- A short vertical sulcus, the anterior paraolfactory sulcus, may occur a little anterior to the paraterminal gyrus. The cortex between these two sulci is the subcallosal area (paraolfactory gyrus).

Inferior (orbital) surface:

- The olfactory sulcus extends anteroposteriorly in the medial part of the orbital surface, hidden by the olfactory bulb & tract.
- The gyrus rectus lies medial to the olfactory sulcus.
- The rest of the surface is roughly divided into 4 gyri by the H-shaped frontal sulcus: medial, lateral, anterior, & posterior frontal gyri.
- The anterior perforated area is a triangular area in the posterior part of the orbital surface between the medial & lateral stria of the olfactory tract.

Parietal lobe:

The parietal lobe occupies the posterosuperior aspect of the lateral surface of the cerebrum (posterior to the central sulcus), & the area posterior to the frontal lobe on the medial cerebral surface.

Lateral surface:

- The postcentral gyrus lies just posterior & parallel to the central sulcus, it is limited posteriorly by the postcentral sulcus. This gyrus contains the primary sensory cortex.
- Posterior to the postcentral sulcus, the parietal lobe has the intraparietal sulcus that runs parallel to the superomedial border of the hemisphere, separating the superior & inferior parietal lobules (above & below it) from each other.
- The lateral cerebral fissure (posterior ramus) ends in the parietal lobe. The area surrounding its end is the "supramarginal gyrus".
- The superior temporal sulcus (of the temporal lobe) ends also in the parietal lobe, posterior to the end of the lateral fissure. The area surrounding its end is the "angular gyrus".
- The parietal lobe is separated posteriorly from the occipital lobe by the parieto-occipital sulcus, which extends anteroinferiorly from the superomedial cerebral border to a short distance.

Medial surface:

- The medial surface of parietal lobe is superior to the body & splenium of corpus callosum, separated from it by the callosal sulcus.
- The central sulcus extends from the lateral cerebral surface to the medial surface where it terminates. The area around its termination is the "paracentral lobule", which is shared between the frontal & parietal lobes, above the cingulate sulcus.
- Posterior to the paracentral lobule, the parietal lobe is represented by the "precuneus", limited posteriorly by the parieto-occipital sulcus.

- The posterior part of the cingulate sulcus extends to the parietal lobe. The posterior part of the cingulate gyrus extends into the parietal lobe, loops around the splenium of corpus callosum, where it becomes very narrow between it & the calcarine sulcus (called here the "isthmus"), & then becomes continuous with the parahippocampal gyrus of the temporal lobe.

Occipital lobe:

The occipital lobe is the most posterior part of the cerebral hemisphere. It resembles a rough pyramid, having a lateral, medial, & inferior surfaces.

Lateral surface:

- The occipital lobe lies posterior to the parietal lobe. The parieto-occipital sulcus (on the medial surface of cerebrum) extends to a very short distance on the lateral surface. On the inferolateral border of cerebral hemisphere, there is a notch separating the occipital lobe from the temporal lobe (the preoccipital notch). An imaginary line between this notch & the parieto-occipital sulcus separates the parietal & occipital lobes.
- The lunate sulcus is a curved sulcus in the lateral surface of the occipital lobe.
- the calcarine sulcus is present in the medial surface of occipital lobe. Its tip usually extends into the lateral surface at the occipital pole.

Medial surface:

- the occipital lobe is the most posterior part of the medial surface of the cerebrum, lying posterior to the parieto-occipital sulcus.
- The calcarine sulcus extends from the occipital pole, runs anteriorly, joins the parieto-occipital sulcus posterior to the splenium of corpus callosum, & continues into the inferior surface of cerebrum where it ends.
- The triangular area between the calcarine & parieto-occipital sulci is the cuneus.
- The lingual gyrus lies inferior to the calcarine sulcus.
- The upper & lower banks of the calcarine sulcus (ie: the lower part of cuneus & the lingual gyrus) are the primary visual cortex.

Inferior surface:

- The inferior surface of occipital lobe is continuous with that of the temporal lobe, & shares with it sulci & gyri. It is separated from the temporal lobe by an imaginary line between the end of calcarine sulcus & the preoccipital notch.
- Two longitudinal sulci begin here: the collateral sulcus (medially) & the occipitotemporal sulcus (laterally).
- The lingual gyrus lies between the calcarine & collateral sulci.
- The medial & lateral occipitotemporal gyri lie medial & lateral to the occipitotemporal sulcus respectively. Both extend along the inferior surfaces of the occipital & temporal lobes.

Temporal lobe:

The temporal lobe occupies the inferolateral part of the cerebral hemisphere, lying below the lateral cerebral fissure. The temporal lobe has a lateral surface & an inferior (inferomedial) surface.

Lateral surface:

- This surface has 2 longitudinal sulci: the superior & inferior temporal sulci.
- The 2 sulci separate 3 gyri: the superior, middle, & inferior temporal gyri.

Inferomedial surface:

- This surface is continuous posteriorly with the occipital lobe.
- It has the continuation of the 2 longitudinal sulci (collateral & occipitotemporal) & the 2 gyri (medial & lateral occipitotemporal) that start in the occipital lobe.
- The collateral sulcus ends somewhere in the middle of the inferior surface of the temporal lobe.

- Medial to the collateral sulcus, the temporal lobe has the parahippocampal gyrus (which is continuous posteriorly with the cingulate gyrus at the isthmus). Anteromedially, the parahippocampal gyrus ends as a bulge, the uncus, which is limited laterally by the rhinal sulcus.
- Superior to the parahippocampal gyrus, there is a narrow, serrated gyrus, the dentate gyrus, separated from the parahippocampal gyrus by the hippocampal sulcus.
- Superior to the dentate gyrus, a small part of the hippocampus can be seen.
- The lateral occipitotemporal gyrus (on the inferior surface) is continuous with the inferior temporal sulcus (on the lateral surface) around the inferolateral margin of the hemisphere.

The Insula

The insula is a cortical region hidden within the depths of the lateral fissure by overhanging parts (opercula) of the frontal, parietal and temporal lobes. Its circumference is limited by the circular sulcus. Its floor has the gyrus longus (posteroinferiorly, parallel to the direction of the lateral fissure), & the gyri breves (anterosuperiorly, in almost vertical direction). The superior (opercular) surface of the temporal lobe; hidden in the lateral fissure, has the anterior & posterior transverse temporal gyri.

The limbic lobe:

The limbic system is a term that describes a group of cerebral structures related to specific functions (discussed later). Many parts of the cerebral cortex constitute important components of the limbic system, including: the paraterminal & paraolfactory gyri, the cingulate gyrus, the parahippocampal gyrus, uncus, dentate gyrus, & the hippocampus. Those structures, collectively, are considered by some authors as the "limbic lobe".

Functional Anatomy of Cerebral Cortex

The cerebral cortex is the highest center in the brain which receives & integrates sensory stimuli & initiates appropriate motor response. Actually, this is a very simplified description to the function of cerebral cortex, which is much more complicated & not totally understood till now.
Each part of cerebral cortex is concerned with a specific function, that would be lost if that part was damaged. Loss of neurological functions following damage of specific parts of the brain has significantly helped us to understand the function of different brain parts. In 1909, a German anatomist (Brodmann) made a "brain map" for cerebral cortex, dividing it into 52 areas, with the function of many areas identified. We shall consider only the important areas, with clearly identified functions, in the following table:

Functional area	Brodmann area	Anatomical location	Clinical considerations
Primary motor cortex	4	The precentral gyrus (frontal lobe)	Destruction causes contralateral spastic paralysis.
Premotor areas	6, 8	Frontal lobe, anterior to the precentral gyrus	
Frontal eye field	**8** (& parts of 6 & 9)	Posterior part of the middle frontal gyrus	Destruction causes eye deviation to the affected side. Stimulation causes eye movement to the contralateral side.
Motor speech area (Broca's area)	44, 45	Pars triangularis & pars opercularis (frontal lobe) in the dominant hemisphere	Destruction causes expressive aphasia: the patient understands spoken & written language, but cannot talk or write normally.
Prefrontal cortex	9, 10, 11, 12	Anterior 2/3rd of frontal lobe	Destruction causes problems in concentration, orientation, judgment, problem-solving ability, & behavior.
Primary somtosensory cortex	3, 1, 2	Postcentral gyrus (parietal lobe)	Destruction causes contralateral hypesthesia (diminished sensibility)
Somatosensory association cortex	5, 7	Superior parietal lobule	Destruction causes contralateral astereognosis (inability to recognize objects by touch).

Somatosensory association cortex	40	Inferior parietal lobule	Destruction (in the dominant hemisphere) causes right-left confusion, dyscalculia, dysgraphia & dyslexia.
Sensory speech area (Wernicke's area)	22	Posterior part of superior temporal gyrus in the dominant hemisphere	Destruction causes receptive aphasia: the patient cannot understand spoken or written language, but his speech is fluent, rapid, & makes little sense.
Primary auditory cortex	41, 42	Temporal operculum (transverse temporal gyri)	Unilateral destruction causes little loss of hearing, bilateral destruction causes cortical deafness (total deafness).
Primary visual cortex	17	Upper & lower lips of calcarine sulcus	Unilateral destruction causes contralateral hemianopia or quadrantanopia. Bilateral destruction causes cortical blindness.
Visual association cortex	18, 19	Areas around the primary visual cortex in the occipital lobe	
Primary olfactory cortex	34	Uncus & surrounding areas	Destruction causes ipsilateral anosmia (loss of smelling). Stimulation causes olfactory & gustatory hallucinations.

Motor and sensory homunculi:

Within the primary motor cortex, each specific area is responsible for the movement of a specific body part. The arrangement & proportion of the motor areas is not identical to the arrangement & size of the corresponding body part: the body is represented upside down in the precentral gyrus, so that the areas moving the legs are in the medial surface of the hemisphere. Also, the size of motor cortex responsible for moving a body part is not proportional to the size of that part, eg: hand movement area is larger than the area moving the arm, trunk, pelvis & thigh. This arrangement is called the "motor homunculus". Similarly, the sensory cortex in the postcentral gyrus has a similar representation with minor differences, & this arrangement is called the "sensory homunculus".
Motor & sensory cortices are connected to the contralateral side of the body.

Cerebral dominance:

The right & left cerebral hemispheres are not symmetrical or identical to each other. Language centers (Broca's & Wernicke's areas) are located on one side of the brain, which is the dominant side. Dominant hemisphere is responsible for the functions of language, mathematics, analysis, etc. the non-dominant hemisphere is responsible for the functions of: 3-dimentional (special) perception & orientation, non-verbal ideas, music & other creative abilities, & visual memory. Right-handed people (who represent > 90% of people) have the left hemisphere dominance, while the right hemisphere is the dominant hemisphere in the majority (> 60%) of left-handed people.

Cerebral White Matter

The cerebral white matter lies interior to the cortex. It is made of the myelinated axons of cortical & other neurons, with their surrounding glial cells, arranged as bundles (tracts) that connect different areas of the CNS. Fibers of the cerebral white matter can be grouped into 3 categories: association fibers, commissural fibers, & projection fibers.

<u>Association fibers:</u>

Those are fibers that originate from cerebral cortex & terminate in the cerebral cortex of the same side. They connect different parts of one cerebral hemisphere. Association fibers are arranged into bundles, which are of 2 types:

- Short association (arcuate) fibers: those are arching nerve fibers that connect 2 adjacent areas (gyri) in the cerebral cortex, within a lobe or in 2 adjacent lobes.
- Long association fibers: those are longer bundles of fibers that connect remote areas in the same hemisphere, eg: the frontal & parietal lobes, etc. Specific bundles are recognized belonging to this type, including:
  1. **Superior longitudinal fasciculus**: connecting the frontal lobe with the parietal, occipital, & temporal lobes.
  2. **Inferior longitudinal fasciculus**: connecting the temporal lobe with the occipital lobe.
  3. **The cingulum**: a curved bundle deep to the cingulate & parahippocampal gyri. It connects some parts of the limbic system with each other, & with the temporal lobe.

4. **Perpendicular fasciculus**: connecting the lateral & medial surfaces of the occipital lobe to the inferior surface of it.
5. **Uncinate fasciculus**: a hook-like bundles connecting the orbital surface & Broca's area of the frontal lobe to the anterior part of the temporal lobe.

Commissural fibers:

Those are fibers that cross the midline, connecting the right & left cerebral cortices to each other. In the cerebrum, commissural fibers are confined to distinct structures, which are:

1. **Corpus callosum**: this is by far the largest collection of commissural fibers in the brain, & the main structure holding the 2 hemispheres together. In mid-sagittal section, corpus callosum appears as a 10 cm long mass of white matter extending anteroposteriorly above the septum pellucidum. Corpus callosum consists of the following parts:
   a. **Rostrum**: a wedge-shaped part that forms the anterior wall of the anterior horns of lateral ventricles. Inferiorly, it tappers to be continuous with the lamina terminalis (the anterior wall of 3rd ventricle). Anterosuperiorly, it joins the genu of corpus callosum. The rostrum contains fibers connecting the orbital surfaces of the frontal lobes.
   b. **Genu**: the anterior angulated part of corpus callosum. Fibers in the genu curve forward, as the forceps minor, to connect the lateral and medial surfaces of the frontal lobes.
   c. **Body**: the largest part, extending backwards from the genu forming the roof of the anterior horn & body of lateral ventricle. It contains fibers that pass laterally, intersecting with the fibers of the corona radiata to connect wide cortical areas of the hemispheres (mainly frontal & parietal lobes). Fibers in the posterior part of the body (with fibers from the splenium) spread laterally forming the roof & lateral wall of the posterior horn, & the lateral wall of the inferior horn, of lateral ventricle. Those fibers form the "tapetum".
   d. **Splenium (head)**: this is the posterior end & the thickest part of corpus callosum. Its anterior fibers form the tapetum with fibers of the body. The most posterior fibers of the splenium curve back into the occipital lobes as the forceps major.
2. **Anterior commissure**: a small compact bundle of commissural fibers that is embedded in the lamina terminalis, forming part of the anterior wall of the 3rd ventricle. As they spread laterally, its fibers divide into an anterior bundle (connecting the anterior perforated substance & olfactory tract), & a larger posterior bundles that fans out into the anterior part of the temporal lobe, including the parahippocampal gyrus.
3. **Posterior commissure**: The posterior commissure is located in the posterior wall of 3rd ventricle, just above the opening of the cerebral aqueduct. It forms the inferior lamina or stalk of the pineal gland. It connects the language processing centers of both cerebral hemispheres. It is closely related in function to the splenium of the corpus callosum, and injury to it may lead to disorders such as alexia. It is an important part of the epithalamus.
4. **Habenular commissure**: The superior lamina or stalk of the pineal body is called the habenular commissure. it connects the habenular nuclei of the two cerebral hemispheres. Thus it is also a vital part of the epithalamus.
5. **Commissure of the fornix** (the hippocampal commissure): a bundle of fibers interconnecting the hippocampi of the two cerebral hemispheres. More specifically, this commissure connects a part of the fornix called the crus on both sides of the midline.

Projection fibers:

Projection fibers connect the cerebral cortex with lower levels in the brain and spinal cord. So, they represent the afferent & efferent tracts connecting the cerebral cortex to the lower brain & spinal cord centers. Note the following:

- Cerebral projection fibers are aggregated in a large, fan-shaped bundle called the "corona radiata". Its fibers are connected to all of the cerebral cortex.
- Fibers of corona radiata aggregate & pass medial to the lentiform nucleus, where they become the "internal capsule". In the horizontal sections, the internal capsule appears as an angulated band with anterior limb, genu, & posterior limb.
- The anterior limb of internal capsule lies between the head of caudate nucleus & the lentiform nucleus. It is divided into 3 parallel zones: outer, inner, & middle zones. The outer & the inner zones are efferent (corticofugal fibers) that pass from the frontal lobe to the thalamus & pontine nuclei, while the middle zone is afferent fibers from the thalamus.

- The genu of internal capsule lies medial to the tip of lentiform nucleus. It contains the corticonuclear & the upper corticospinal fibers (of the head & neck).
- The posterior limb of internal capsule lies between the thalamus & the lentiform nucleus. It has medial & lateral zones. The medial zone is made of the afferent thalamocortical fibers passing to the postcentral gyrus (somatosensory). The lateral zone is made of corticofugal fibers, with the following bundles embedded in it (anterior to posterior): corticospinal fibers for the upper limb, corticospinal fibers for the trunk, cortico-rubral fibers, & corticospinal fibers for the lower limbs.
- Retrolenticular part of internal capsule: fibers that are located beyond the posterior border of lentiform nucleus. They include: parietopontine, occipitopontine and occipitotectal fibres. It also includes the optic radiation (from the lateral geniculate body to the visual cortex in the occipital lobe.) and interconnections between the pulvinar & the occipital and parietal lobes.
- Sublenticular part of the internal capsule: fibers that pass inferior to the lentiform nucleus, they contain temporopontine and some parietopontine fibres, in addition to the acoustic (auditory) radiation from the medial geniculate body to the auditory cortex in the temporal lobe.
- Below the level of lentiform nucleus, the internal capsule continues as the cerebral peduncle.

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