Telencephalon – The Anatomy and Function of the Cerebrum

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The telencephalon is made of grey matter, which is mainly the outer-lying part, and white matter, which is the inner part. Grey matter comprises the cerebral cortex (cortex cerebri) and the subcortical nuclei, which are located inside the telencephalon and are surrounded by white matter. White matter is, moreover, subcortical.

Definition

The telencephalon is the anterior division of the prosencephalon (forebrain) and comprises the cerebral hemispheres and related structures.

Embryological Development of the Telencephalon
During embryological development, the brain, spinal cord, and central nervous system develop from the neural tube, which is derived from the dorsal ectoderm. The cranial part of the neural tube forms the 3 primary cerebral vesicles.

One of these cerebral vesicles develops into the prosencephalon (forebrain). The other 2 cerebral vesicles develop into the rhombencephalon (hindbrain) and mesencephalon (midbrain). The prosencephalon separates into the diencephalon and telencephalon.

**Segmentation of the telencephalon into additional hemisphere sections**

Depending on the age of the particular part, the telencephalon is, in evolutionary terms, divided into 3 additional sections.

The oldest section is formed by the paleocortex (paleopallium), which is represented by the rhinencephalon in the adult brain. The rhinencephalon includes the olfactory bulb, olfactory tract, septum, and cortical part of the amygdala.

The archicortex (or archipallium; the older part) develops from the medial part of the embryonic brain, and in the adult brain, it forms the hippocampus containing the cornu ammonis (horn of Amun), fornix (arch), and indusium griseum (supracallosal gyrus).

The hippocampus is the biggest part of the archicortex, and it plays an important role in memory formation, especially during the transfer of information from short-term to long-term memory.

**The Papez Circuit**

This memory transfer is made possible by the Papez circuit, which consists of hippocampal afferents and efferents. The afferents of the hippocampus originate primarily in the entorhinal area, which mediates information from the olfactory bulb, amygdala, and neocortex.

More afferents reach the hippocampus via the thalamus and cingulate gyrus. The efferents leaving the hippocampus run mainly via the fornix, to end exclusively in the region of the mamillary body. Starting from the mamillary body, the Papez circuit is closed via the connection to the thalamus by means of the mammillothalamic tract (bundle of Vicq d'Azyr).
The **neocortex** (the newest part) represents the largest part of the telencephalon. It includes the **insula** and **corpus striatum** of the adult brain.

The neocortex can be divided into 50 areas, referred to as **Brodmann areas**. Specific functions are associated with each Brodmann area, as exemplified by Broca’s area and Wernicke’s area, which both represent the **language area of the brain**. **Broca’s area** is located in Brodmann areas 44 and 45, whereas, **Wernicke’s area** is located in area 22.
Histological structure of the cerebral cortex

With respect to cortical histological structure, the 2 evolutionary older parts, i.e., the paleopallium and archipallium, have a different structure compared to the neocortex. The outer layer of the neocortex consists of 6 layers, and it is also called the **isocortex**, whereas the outer layer of the paleopallium and archipallium is called the **allocortex**, and consists of 3 layers.

Two types of neurons are contained within the neocortex. One of these is represented by **non-pyramidal cells**, which are inhibited via the transmitter **GABA**, and **pyramidal cells**, which constitute the majority of neurons (85%) and are excited by the transmitters **glutamate** and **aspartate**.

The Macroscopic Structure of the Telencephalon
The telencephalon consists of 2 hemispheres, with 6 major lobes per hemisphere. The right and the left hemispheres are separated by the interhemispheric fissure, and they are connected functionally via the corpus callosum (Latin for ‘tough body’).

One hemisphere is dominant and carries out the processing for linguistic and computational activities. In addition, functions such as reading and writing are localized within this particular hemisphere. For the majority of right-handed people, the left hemisphere is the dominant one, and only for a small fraction of left-handed people is the right hemisphere dominant.

The 6 major lobes comprise the frontal lobe, parietal lobe, temporal lobe, occipital lobe, insular lobe, and limbic lobe. In addition, each hemisphere has 3 surfaces and 2 borders. The aforementioned surfaces are the medial surface, superolateral surface, and an inferior surface. The corresponding borders are the superior margin and inferolateral margin.

Taking a view from the outside, the lobes are separated from each other by the primary sulci (cerebral sulci). These comprise the central sulcus (sulcus of Rolando) between the parietal and frontal lobes; the lateral sulcus between the temporal, frontal, and parietal lobes; and the parietooccipital sulcus between the parietal and occipital lobes.

The calcarine sulcus also belongs to the primary sulci and divides the occipital lobe into an upper and a lower portion.

In addition to the primary sulci, there are also secondary and tertiary sulci, with the secondary sulci further subdividing each lobe. The tertiary sulci are responsible for the
individual sulci of the cortex, develop after birth, and are influenced by non-genetic factors.

Not only the cerebral sulci but also the brain convolutions (cerebral gyri) expand the surface area of the brain. These convolutions are exemplified by the precentral gyrus and the postcentral gyrus, which are discussed below.

Structure of the Frontal Lobe

Various functional centers are found in the frontal lobe area. They can be attributed to particular areas of the cortex and particular gyri. The superior and middle frontal gyri, the inferior frontal gyrus, and the precentral gyrus are differentiated with reference to the gyri.

The function of the superior and middle frontal gyri

The frontal association cortex is localized within the area of the superior and middle frontal gyri. The frontal association cortex consists of the prefrontal cortex and motor-related areas except for the primary motor cortex. The prefrontal cortex is associated with the processing of a variety of information received from different lobes and this information is passed to the primary motor cortex. It regulates the behavior in response to the changing environment. Cognitive signals are passed to the motor areas. Based on the Brodmann areas, the frontal association cortex is within areas 9-11. The processing associated with higher mental abilities, such as planned actions, is carried out within the association cortex.

Symptomatology associated with an injury in the area of the frontal association cortex

An injury in this area results in deficits in the planning of actions, among other things. Moreover, it can result in general drive disorders that present as impaired thinking.
capacity and impaired concentration levels, as well as a reduction in spontaneous movements.

Lesions predominantly situated in the orbital part of the frontal lobe (area 11) mainly result in impairment of the affective state. Among other things, this can lead to uninhibited, suspicious, and irascible behavior, and also too exaggerated jocularity on the part of the patient.

Please note: Association fields are not associated with any particular area of the cortex and do not receive any information from the thalamus.

**Function of the inferior frontal gyrus**

![Image: Gyrus frontalis inferior. By Gray, vectorized by Mysid, colored by was_a_bee, License: Public domain](image)

The inferior frontal gyrus can be subdivided into further sections as follows: pars orbitalis, pars opercularis, and pars triangularis.

Within Brodmann area 44, Broca’s center is located within the inferior frontal gyrus, which is counted among the language centers, in addition to Wernicke’s area. The 2 language centers are dealt with in the separate article ‘Telencephalon – Language Centers, Structure of the Limbic System, and Basal Ganglia’.

**The function of the middle frontal gyrus**

Another center, which is located in the frontal lobe, is the frontal eye field. This is equivalent to Brodmann area 8 and is located within the middle frontal gyrus. Its function is to control voluntary eye movements.

To this end, it receives afferents from the primary and secondary visual cortex and provides efferents to the brain muscle nuclei of the cranial nerves III, IV and VI, via the superior colliculus. These cranial nerves are responsible for the innervation of the eye muscle nuclei.
The function of the precentral gyrus

The precentral gyrus, premotor cortex (area 6), and supplementary motor cortex (area 6) are associated with the motor system. The primary somatomotor cortex (area 4) is situated in the area of the precentral gyrus, which is located in front of the central sulcus. Originating here, the pyramidal tract continues to the respective body parts as an efferent.

The motor cortex itself receives afferents from the region of the thalamus (ventral lateral nucleus) and from the postcentral gyrus (see basal ganglia loop).

The premotor cortex and supplementary motor cortex have comparable afferents. The efferents go from the premotor cortex to the cerebellum via the frontopontine tract, and the cerebellum then projects back into the primary motor cortex. This creates a type of control mechanism that allows fine regulation of movements.

Motion sequences, on the other hand, are stored and planned within the supplementary motor area.

Clinical symptoms associated with injury to the pyramidal tract

In tracing the symptoms associated with damage to the pyramidal tract, 2 factors are particularly important. Firstly, there is the fact that up to 80% of the pyramidal tract crosses (pyramidal decussation) to the opposite side at the level of the medulla oblongata, and secondly, the respective body parts are somatotopically organized within the area of the precentral gyrus. This somatotopic division may be illustrated by means of the motor homunculus.

Contingent on the fact that within the area of the medulla oblongata 80% of the fibers of the pyramidal tract cross to the opposite side (the remaining parts constitute 20%), central damage to the pyramidal tract results in motor deficits on the contralateral side of the body.

These motor deficits present as paresis, whereby damage to the pyramidal tract, i.e., the
1st motor neuron, takes the form of spastic paralysis. The initial presentation is flaccid paralysis, due to ‘spinal shock’. The spastic paralysis usually forms within a time frame of 3–4 weeks.

A permanent flaccid paralysis arises when the 2nd motor neuron is damaged. These 2 forms of paresis can be distinguished on the basis of clinical parameters.

Spastic paralysis manifests clinically in terms of exaggerated proprioceptive reflexes and attenuated or missing polysynaptic reflexes, for example, in addition to other existing pathological reflexes. The Babinski sign is one example of a pathological reflex, expressed as dorsiflexion of the big toe when the lateral plantar surface is rubbed. The remaining toes stay in their original position or spread out into a fan-shape position.

Flaccid or peripheral paralysis is characterized by an absence of tendon reflexes, whereas, in contrast, the polysynaptic reflexes are not usually affected. Pathological reflexes do not occur in a peripheral paresis, either. In addition, flaccid paralysis leads to neurogenic atrophy of the muscles. The muscles are usually not affected in spastic paralysis as a result of the increased muscle tone. Spastic paralysis-related immobilization can also lead to light muscle atrophy. The homunculus can be used to draw further conclusions about the respective central location of the impairment.

For example, an injury in the area of the parasagittal cortical zone, which is supplied by the anterior cerebral artery, leads to a spastic paralysis of the legs.

Structure of the Parietal Lobe
The postcentral gyrus, secondary somatosensory cortex, and parietal association cortex are localized within the parietal lobe.

**Function of the postcentral gyrus**

The postcentral gyrus includes the **somatosensory** cortex, where the sensory afferents (sense of pain, touch, and temperature) from the periphery are processed. These afferents reach the somatosensory cortex, with the thalamus acting as a filter (a ‘gateway to the mind’) – primarily via the **ventral posteromedial nucleus** and the **ventral posterolateral nucleus** of the thalamus.

Originating from the somatosensory cortex, the efferent fibers pass to the **secondary somatosensory** cortex and the **motor cortex** (precentral gyrus).
The fibers within the region of the postcentral gyrus are somatotopically organized, and correspond with the fibers of the precentral gyrus so that a sensory homunculus is also found beside the motor homunculus.

The homunculus illustrates how individual regions have stronger or weaker sensory innervation, regardless of their anatomical size. For example, the hands and the tongue possess a relatively large region of innervation in the homunculus, whereas the thighs, for example, only have a relatively small region.

**Function of the secondary somatosensory cortex**

Information coming from the somatosensory cortex is interpreted or classified within the secondary somatosensory cortex (areas 5 and 7).

**Function of the parietal association cortex**

In addition to the frontal association cortex (see above), there is also a parietal association cortex, which is composed of the angular gyrus and supramarginal gyrus of the parietal lobe.
The angular gyrus (area 39), which winds itself around the end of the superior temporal sulcus in an arc-like fashion, mediates between the secondary auditory cortex and secondary visual cortex. This explains the importance of the parietal association cortex with respect to functions such as reading or writing.

The parietal association cortex is associated with the processing of spatial events. A lesion in this area results in loss of memory related to the distribution or physical arrangement of body parts. Patients may be unaware of one half of the body unless reminded. Further, they may have an illusion of their absence and may be convinced of this idea. They may also be unable to explain and follow familiar routes, may neglect a particular side of their home, and may mistakenly turn to the wrong side when asked.

The supramarginal gyrus (area 40) is situated at the end of the lateral sulcus and surrounds it.

References


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