Neurology

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, a division of forebrain) and comprises of cerebral hemispheres and related structures.

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

One of these cerebral vesicles develops the prosencephalon (the forebrain). The other two cerebral vesicles develop the rhombencephalon (the hindbrain) and the mesencephalon (the midbrain). The prosencephalon separates into the diencephalon and the 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 three further sections. The oldest section is formed by the palaeocortex, which is represented by the rhinencephalon in the adult brain. The rhinencephalon includes the bulbus olfactorius, the tractus olfactorius, the septum and the cortical part of the amygdala.

The arch cortex (the more ancient 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), the fornix (arch) and the indusium griseum ("grey veil").

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 regio entorhinalis, which mediates information from the olfactory bulb, the amygdala and the neocortex.

More afferents reach the hippocampus via the thalamus and the gyrus cinguli. The efferents leaving the hippocampus run mainly via the fornix, to end exclusively in the region of the corpora mamillaria. Starting from the corpora mamillaria, the Papez circuit is closed via the connection to the thalamus by means of the fasciculus mamillothalamicus (the bundle of Vicq d’Azyr).
The neocortex (the newest part) represents the largest part of the telencephalon. It includes the insula and the 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 of them, as exemplified by Broca’s area and Wernicke’s area, which both represent the language area of the brain. Broca’s area is composed of Brodmann areas 44 and 45, whereas the Wernicke’s area is located in area 22.
The histological structure of the cerebral cortex

With respect to cortical histological structure, the two evolutionary older parts, i.e., the paleopallium and archipallium, have a different structure to the neocortex. The outer layer of the neocortex consists of six layers, and it is also called the isocortex, whereas the outer layer of the paleopallium and the archipallium is called the allocortex, and it consists of three 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 two **hemispheres**, with six major lobes per hemisphere. The right and the left hemispheres are separated by the **fissura longitudinalis cerebri** (interhemispheric fissure), and they are connected functionally via the **corpus callosum** (Latin for “tough body”).

One hemisphere constitutes the **dominant hemisphere**. This hemisphere 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 dominant is the right hemisphere.

The six major lobes comprise the **frontal lobe**, the **parietal lobe**, the **temporal lobe**, the **occipital lobe**, the **insular lobe** and the **limbic lobe**. In addition, each hemisphere has three surfaces (facies) and two borders (margo). The aforementioned facies are: the **facies medialis**, the **facies superolateralis** and the **facies inferior**. The corresponding borders are: the **margo superior** (margo superior cerebri) and the **margo inferolateralis**.

Taking a view from the outside, the lobes are separated from each other by the so-called primary sulci (sulci cerebri). These comprise the **sulcus centralis** (sulcus of Rolando) between the parietal and the frontal lobe; the **sulcus lateralis** between the temporal, frontal and parietal lobe; and the **sulcus parietooccipitalis** between the parietal and the occipital lobe.

The **sulcus calcarinus** also belongs to the primary sulci, and it divides the occipital lobe into an upper and a lower portion.
In addition to the primary sulci, there are also the secondary and tertiary sulci, with the secondary sulci further subdividing each lobe. The tertiary sulci have their origin here, and depart from this point.

Not only the sulci cerebri, but also the brain convolutions (gyri cerebri) expand the surface of the brain enjoying increased surface area. These convolutions are exemplified by the gyrus praecentralis and the gyrus postcentralis, 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 gyri frontales superior and medius, the gyrus frontalis inferior and the gyrus praecentralis are differentiated with reference to the gyri.

**The function of the gyri frontales superior et medius**

The so-called frontal association cortex is localized within the area of the gyri frontales superior and medius. Frontal association cortex is comprised of prefrontal cortex and motor-related areas except for primary motor cortex. 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 **effective state**. Among other things, this can lead to uninhibited, suspicious and irascible behavior, and also to an exaggerated jocularity on the part of the patient.

**Please note:** Association fields are not associated with any particular area of the cortex, nor do they receive any information from the thalamus.

**The function of the gyrus frontalis inferior**

The gyrus frontalis inferior can be subdivided into further sections. The following are differentiated: the **pars orbitalis**, the **pars opercularis** and the **pars triangularis**. Within Brodmann area **44**, **Broca’s center** is located within the Gyrus frontalis inferior, which is counted among the language centers, in addition to Wernicke’s area. The two language centers are dealt with in the separate article “Telencephalon – Language Centers, Structure of the Limbic System and Basal Ganglia”.

**The function of the gyrus frontalis medius**

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 gyrus frontalis medius. 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 **colliculi superiors**. These cranial nerves are responsible for the innervation of the **eye muscle nuclei**.

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

The motor cortex itself receives afferents from the region of the **thalamus** (ncl. ventralis anterolateralis) and from the **gyrus postcentralis** (see basal ganglia loop).

The **premotor cortex** and the **supplementary motor cortex** have comparable afferents. The efferents go from the premotor cortex to the cerebellum via the **tractus frontopontinus**, 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, two factors are of particular importance. Firstly, there is the fact that up to 80 % of the pyramidal tract crosses (**decussatio pyramidalis**) to the opposite side at the level of the **medulla oblongata**, and secondly, there is the fact that the respective body parts are somatotopically organized within the area of the gyrus precentralis. 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
two 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.

An injury in the area of the parasagittal cortical zone, which is supplied by the a. cerebri anterior, leads to a spastic paralysis of the legs, for example.

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

The function of the gyrus postcentralis

The gyrus postcentralis includes the somatosensory cortex, where the sensory afferents (the 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 nucleus ventralis posteromedialis and the nucleus ventralis posterolaterales of the thalamus.

Originating from the somatosensory cortex, the efferent fibers pass to the secondary somatosensory cortex and the motor cortex (gyrus praecentralis).

The fibers within the region of the gyrus postcentralis are somatotopically organized, correspondent to the fibers of the gyrus praecentralis, 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, have been apportioned only a relatively small region.

The function of the secondary somatosensory cortex

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

The 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 gyrus angularis and the gyrus supramarginalis of the parietal lobe.

The gyrus angularis (area 39), which winds itself around the end of the sulcus temporalis superior in an arc-like fashion, mediates between the secondary auditory cortex and the secondary visual vortex. 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. Lesion to this area results in loss of memory related to distribution or physical arrangement of body parts, patient may be unaware of one half of the body unless reminded. He may have an illusion of his absence and may be convinced of this idea. He may be unable to explain and follow his familiar routes, may neglect particular side of home, and may make mistake the side while turning.

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

Review Questions

The answers are below the references.

1. Which statement about the telencephalon is not true?
   A. The telencephalon is divided into the paleocortex, the archicortex, and the neocortex, in evolutionary terms.
   B. The paleocortex represents the oldest part of the telencephalon.
   C. The neocortex can be histologically divided into six layers.
   D. The archicortex has three layers.
   E. The telencephalon develops from the prosencephalon, together with the rhombencephalon.

2. Which statement about the frontal lobe is not true?
   A. The gyrus praecentralis is a part of the frontal lobe.
   B. Brodmann area 8
   C. Broca’s area is found in the region of the gyrus frontalis inferior.
   D. Wernicke’s area is found in the region of the gyrus frontalis medius.
   E. When the frontal lobe is damaged, it can lead to changes in the affective state.

3. Which statement about the parietal lobe is true?
   A. This is where the motor cortex is found.
   B. The gyrus angularis is located behind the sulcus centralis.
   C. The primary and the secondary somatosensory cortex are found within the parietal lobe.
   D. The gyrus postcentralis correlates to Brodmann area 22.
   E. In contrast to the motor system, there is no somatotopic segmentation within the somatosensory cortex.

References


Anatomy, 29-84. doi:10.1007/978-3-540-49468-3_2

Correct Answers: 1E, 2D, 3C

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