The brain, as well as the spinal cord, is enveloped by the meninges which, in turn, are composed of 3 layers of connective tissue. The following text gives you an overview of the structure of the individual meninges.
From the outside to the inside, one distinguishes between the **dura mater** (= outermost layer), the **arachnoid mater**, and the **pia mater**. The arachnoid and cranial pia mater together form the leptomeninges (soft meninx) and originate from 1 single layer. Opposite them, there is the dura mater (hard meninx), which is also referred to as pachymeninx (pachyderm = thick-skinned). The meninges, in combination with the subarachnoid space filled with cerebrospinal fluid, and the calvaria, protect the brain from concussions and blows, for instance.

**Dura Mater**

**Structure of the dura mater**
The dura mater consists of firm, collagenous connective tissue organized in 2 layers known as:

- The superficial layer is known as the periosteal (*stratum periosstale*). This layer serves as the inner layer of the skull (endocranium).
- Inner meningeal layer (*stratum meningeale*). This is known as the true dura mater. The dura surface in association with the skull (as opposed to the spinal cord), the periosteal section is tightly grown, together with the periosteum of the calvaria. When it covers the spinal cord, it is known as the *thecal sac*.

Exception is the places in which the venae emissariae runs through the dura mater (see figure). The above-mentioned veins then flow into the venous blood vessels of the brain (*dural venous sinuses*) which are located between the 2 layers of the dura mater.

Aside from the venae emissariae, the **bridging veins** which run between the arachnoid mater and the meningeal layer of the dura mater flow into the dural venous sinuses as well. Injury of these bridging veins results in subdural bleeding. Due to the tight connection between the dura mater and the arachnoid mater, a true subdural space usually does not exist. However, subdural bleeding may cause the neurothelium of the arachnoid mater (see below) to detach from the dura mater, creating an artificial subdural space.

**Please note:** Epidural space exists in the vertebral canal, but not in the brain.

**Septa of the dura mater**

In some places, the dura mater extends into the depths of the brain and thereby forms the septa or **duplications of the meningeal layer of the dura**. Overall, 4 septa of the dura mater are identified.

**Falx cerebri:** It is the largest septum which is sickle-shaped and runs through the fissure longitudinalis cerebri, and separates the 2 brain hemispheres from another. The falx cerebri originates in the crista galli of the ethmoid bone. It separates the 2 cerebral...
hemispheres.

The falx cerebelli/cerebellar falx: It is a vertical dural fold that lies inferior to the cerebellar tentorium in the posterior cranial fossa separating the cerebellar hemispheres.

The tentorium cerebelli (tentorium = time), separates the occipital lobe of the brain from the cerebellum. Also, with the aid of the tentorium cerebelli, one differentiates between the supratentorial telencephalon and the infratentorial cerebellum. It has an opening, the so-called tentorial incisura, for the brain stem to pass through.

The diaphragma sellae. It covers the sella turcica and has a small opening for the pituitary stalk and hypophyseal veins to pass through.

Blood supply of the dura mater

The blood supply of the dura mater, along with the supply of the periosteum and the neighboring cranial bones comes from 3 arteries. The main supply comes from the middle meningeal artery, which is a branch of the maxillary artery. The 2 other supply arteries, the anterior and posterior meningeal arteries, play a minor role from a clinical point of view.

In traumatic brain injury cases, the middle meningeal artery may tear, possibly resulting in epidural bleeding, whereby this epidural space normally does not exist due to the tight connection between the dura mater and the periosteum.
Innervation of the dura mater

The innervation of the dura mater occurs via the cranial nerves V (trigeminal nerve), IX (glossopharyngeal nerve) and X (vagus nerve), as well as via the 1st 2 branches of the cervical nerves. In cases of meningitis, these sensitive nerves are irritated, resulting in headaches and reflective stiffness of the neck. Furthermore, to relax the meninges as much as possible, the head is held in a certain way which is supposed to relax, but rather leads to a hyperextension of the head. In contrast to the dura mater, the brain is not sensibly innervated, and therefore insensitive to pain.

Please note: Headaches always emanate from the meninges since the brain itself is not sensibly innervated.

Diseases of the dura mater

As the dura mater is made up of firm collagenous connective tissue, space demanding processes such as bleeding or tumors in the cranial fossa may lead to incarcerations in the area of the septa. Here, one differentiates between axial and lateral incarceration.

The axial incarceration represents symmetrical incarceration due to a process that takes place equally in both hemispheres (i.e. cerebral edema). In the case of upper axial incarceration, the 2 middle and lower parts of the temporal lobe are pressed through the slit of the tentorium cerebelli and, as a consequence, apply pressure on the midbrain (mesencephalon).

In cases of lower axial incarceration, a displacement of the cerebellar tonsils through the foramen magnum, and thus, compression of the brainstem takes place.

On the other hand, there is the lateral incarceration which happens in cases of unilateral, space demanding processes (i.e. brain tumor and bleeding). In this case, a displacement of the crura cerebri to the opposite side takes place due to an ipsilateral herniation of the temporal lobe in the area of the tentorium cerebelli. As a result, the pyramidal tract is damaged before it crosses over to the contralateral side, meaning the muscles of the opposite side are affected.
**Arachnoid Mater**

The arachnoid mater represents the **middle layer of the meninges** and consists of a fine layer of connective tissue. The part of the arachnoid mater that borders the dura mater is made up of multiple layers of flat cells (**meningeal cells**). These layers are defined as the **neurothelium since the membrane is a derivative of the neural crest mesoectoderm of the embryo**. There, the meningeal cells are closely connected via tight junctions and form a barrier between the dura mater and the subarachnoid space (blood-cerebrospinal fluid barrier).

It is closely associated with dura mater superiorly and the inner surface covers the brain (arachnoidea encephali) and spinal cord (arachnoidea spinalis). The part covering the brain cavity does not form folds like the dura mater apart from the region of the longitudinal fissure. The part covering the spinal canal continues until the level of S2 where it ends as the filum terminale attached to the coccygeal end of the spinal column.

**Clinical:** Originating from cells of the arachnoid mater, the so-called meningioma may occur. The latter is slowly growing, usually benign brain tumors, which are among the most frequent tumors in the brain.

**Subarachnoid Space (Spatium Subarachnoideum)**

The border of the subarachnoid space is formed by the outer arachnoid mater and the inner pia mater. Within the subarachnoid space, there are numerous connective tissue **trabeculae**, which are also covered by meningeal cells.

Furthermore, the subarachnoid space contains the **cerebrospinal fluid**, which is produced in the area of the choroid plexus (roof of the 3rd and 4th ventricles, the wall of...
the lateral ventricles) and therefore forms the outer cerebrospinal fluid space.

The cerebrospinal fluid finds its way through 3 openings in the roof of the 4th ventricle into the subarachnoid space, and from there via the arachnoid villi into the venous vascular system. The arachnoid villi (granulationes arachnoidea Pacchioni) represent bulges of the arachnoid mater, with parts of the subarachnoid space into the lumen of the dural venous sinuses. They serve to reabsorb the cerebrospinal fluid into the blood.

As the arachnoid mater has the calvaria as its border, as opposed to the pia mater which rests against the surface of the brain, it leads to expansions of the subarachnoid space where there is a deviation from the skull’s inner surface to the brain’s surface. These expansions are called cisterns (subarachnoid cisterns).

In this context, the most important cistern is the cerebellomedullary cistern (cisterna cerebellomedullaris), which is located between the cerebellum and the medulla oblongata. This cistern may be used via a suboccipital puncture to extract cerebrospinal fluid for clinical diagnostics.

However, in the daily clinical routine, the lumbar cistern, located in the lower lumbar area, is by far used more often to capture cerebrospinal fluid (lumbar puncture) as there are fewer complications expected than with a suboccipital puncture. Additional cisterns are, among others, the cistern of the lateral cerebral fossa, the ambient cistern, and the interpeduncular cistern.

Cranial Pia Mater

The cranial pia mater rests directly on the gyri of the brain and continues into the respective sulci. The Virchow-Robin Space, which is located between the cranial pia mater and the membrana limitans externa of the brain, separates the pia mater from the brain. The cranial pia mater consists of a thin layer of connective tissue cells (meningeal cells) which brings about a shimmering appearance of the brain’s surface.

The cranial pia mater is very vessel-rich and forms the outermost layer of blood vessels, which enter or exit the central nervous system, respectively, and eventually enter into it along with them. Together with the arachnoid mater, the pia mater forms the border of the subarachnoid space (see above).

The arachnoid mater, the cranial pia mater, as well as the subarachnoid space, continue as arachnoid mater and pia mater spinalis in the vertebral canal.
References


Hughes, D., La Trobe University, & La Trobe University. (2014). The meninges.

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