FUNCTIONAL ANATOMY OF THE SPINAL CORD AND BRAIN MENINGES  
CEREBRO-SPINAL FLUID

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1. General data and short introduction into history.
2. The spinal cord meninges – structure, topography, functions.
4. The cerebro-spinal fluid, content, production, functional role.
5. Age specific features of the meninges.
6. Examination of the meninges on alive person.
7. Innervation of the pachymeninx.
8. General data on development of the meninges.
The components of the central nervous system are covered by three coats.

1. Dura mater
2. Arachnoid mater
3. Pia mater

- Dura mater – **pachymeninx**.
- Arachnoid and pia mater – **leptomeninx**.
SHORT INTRODUCTION INTO HISTORY

- Studies regarding morphology of the meninges have been done from ancient period.
- Herophilus (340-280 b.c.) described the brain and its meninges with their derivatives such as: vascular network and venous sinuses of the dura mater with confluence of the sinuses (torcular Herophili), he named the inferior angle of the rhomboid fossa “calamus scriptorius”.
- Cl. Galenus (129-201) described the vena magna cerebri and sinus rectus, both of them were named after him.
- H. Ridley (1653-1708), english anatomist studied the meninges of the brain and venous sinuses. The venous ring located on the ventral surface of the brain around the Turkish saddle bears his name.
- The italian anatomist Antonio Pacchioni (1665-1726) studied the topography of the cerebral meninges. The tentorium cerebelli and the arachnoid granulations were named after him.
- The meninges of the brain were studied as well by J. F. Meckel (1724-1774), H. Luschka (1820-1875) and others.
Dura mater of the spinal cord is a fibrous coat, that covers outside the spinal cord.

It extends from the foramen magnum until S2 vertebrae and it is fixed by means of the **sacro-dural ligament** (Trolard).
DMSC is separated from the walls of the vertebral canal by means of the **epidural space**.

The epidural space contains fat tissue and internal vertebral venous plexus.
From the DMSC arise processes that continue with the spinal nerves sheaths.

The sheaths are fixed to the edges of the intervertebral foramina and continue into the periosteum.
On the external surface of the DMSC there are orifices for blood vessels and nerves.

The internal surface of the DMSC is smooth and shiny and it comes in contact with the arachnoid mater.

Between the outlet orifices of the spinal nerves to the internal surface of the dura mater are fixed the **denticulate ligaments**.
The DMSC consists of collagenous fibers.

a) longitudinal fibers  
b) circular fibers  
c) radiar fibers

The collagenous fibers are adapted to the basic movements of the spinal cord.
The arachnoid mater is the middle coat of the spinal meninges.

From Greek "Arachne" means spider.

The arachnoid mater has an appearance of a fine spider web.

The delicate arachnoid layer is attached to the inside of the dura mater and it surrounds the spinal cord.
The internal surface of the arachnoid mater faces the subarachnoid space.

Below the spinal cord the subarachnoid space enlarges to form the **lumbo-sacral cistern**, which inside is covered by **arachnoidea spinalis**.
Pia mater spinalis is a thin connective tissue coat, that contains blood vessels.

1. **Layers of the pia mater:**
   - Internal layer – *intima pialis*, consists of elastic and reticular fibers and it follows the relief of the spinal cord.

2. External layer – *stratum epipiale*, consists of a network of collagenous fibers, that continue with subarachnoid trabeculae.

3. Cranially the pia mater of the SC continues with the same coat of the brain.

   Caudally it becomes thin and at the level of the *filum terminale* it disappears.
From external layer of the pia mater spinalis arise denticulate ligaments, which pass along the spinal cord between the spinal nerves, starting from the first spinal nerve until the first lumbar one.

The denticulate ligaments divide the subarachnoid space into anterior and posterior parts, but they connect to each other at the level of the denticulate ligaments arches.
Dura mater of the brain (DMB) is a continuation of the similar coat of the spinal cord.

This coat differs from that of the spinal cord and consists of two layers:

1. **External – endosteal**
2. **Internal – meningeal**

- The external layer covers the inner surface of the bones of the skull and continues within their periosteum.
- The internal layer covers the brain and forms a protective coat for it.

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STRUCTURE OF THE DURA MATER OF THE BRAIN

- **External surface** is rough, contains blood vessels and connective tissue fibers and it comes in contact with the bones of the skull.

- **External surface** is smooth, shiny and lined with mesothelium.
Dura mater is fixed to the bony protrusions and edges of some anatomical structures of the inner surface of the skull, such as sutures, foramen magnum etc.
Dura mater of the brain structurally differs from the DMSC.

Specific features of the DMB:

1. It comes in contact with the bones of the skull and there is no epidural space.

2. From the inner surface of the DMB arise some processes, that divide the cavity of the skull into small compartments.

3. By its duplicature the DMB forms venous sinuses.
The processes of the DMB are lined with mesothelium and consist of connective tissue and elastic fibers.

Processes of the dura mater:
- Falx cerebri
- Falx cerebelli
- Tentorium cerebelli
- Diaphragma sellae

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COLLAGENOUS FIBERS OF THE DURA MATER OF THE BRAIN

1. They are arranged on the way of the traction forces.
2. At the level of the processes they form thick and strong bundles.
3. The fibers cross each other into different directions and continue into the parietal layer of the dura mater.
4. Functionally they increase the power of the resistance pillars of the skull.
5. They participate in formation of the walls of the venous sinuses, increasing their resistance and do not let them to collapse.
The sinuses of the dura mater are venous canals, which assure the venous drainage of the brain into the internal jugular veins.

Structural peculiarities of the sinuses:

- a) Their walls are formed by duplicature of the dura mater.
- b) They do not have valves.
- c) The sinuses communicate with each other.
CLASSIFICATION OF THE VENOUS SINUSES OF THE DURA MATER

According to their location the sinuses are divided into:

a) Sinuses of the vault of the skull
   - Superior sagittal sinus
   - Inferior sagittal sinus
   - Straight sinus, *sinus rectus*
   - Transverse sinus

b) Sinuses of the base of the skull
   - Sphenoparietal sinus
   - Cavernous sinus
   - Intercavernous sinus
   - Transverse occipital sinus (basilar)
   - Superior petrosal sinus
   - Inferior petrosal sinus
   - Petro-occipital sinus (inconstant)
   - Posterior occipital sinus (inconstant)
   - Sigmoid sinus

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THE ARACHNOID MATER OF THE BRAIN

- The arachnoidea of the brain is a thin coat devoid of blood vessels.
- It consists of collagenous and elastic fibers and of flattened elongated cells rich in nervous endings.
- The arachnoidea covers the brain outside without entering the fissures and sulci of the brain hemispheres.
  a) its **internal surface** is lined with a row of flat cells, located on the basal membrane.
  b) its **external surface** comes in contact with the dura mater and it is separated from it by a thin layer of **subdural neurothelium**.
Pia mater covers the brain mater outside.

1. Its external surface faces the subarachnoid space, and the arachnoid trabeculae are fixed on it.

2. Its internal surface follows the relief of the brain.
The pia mater consists of a basal membrane, on which are located thin connective tissue fibers and a row of mesothelial cells.

The mesothelial cells are connected to each other by means of permeable junctions, which facilitate the exchange of the macromolecules between the CSF and brain mater.
THE PIA MATER

a) It is rich in blood vessels, that supply the brain.

b) It forms vascular plexuses of the ventricles of the brain.
The subarachnoid space forms between the arachnoidea and pia mater.

In some places the subarachnoid space enlarges, and forms subarachnoid cisterns.
THE SUBARACHNOID CISTERNs

1. The cerebelo-medularis cisterna
2. Cisterna pontinae
3. Cisterna interpeduncularis
4. Cisterna chiasmatis
5. Cisterna of the lateral fossa (cisterna Sylvius)
6. Cisterna of the terminal lamina of the corpus callosum
7. Cisterna of the vena magna cerebri
8. Cisterna ambiens
9. Superior cerebellar cisternae
The arachnoidea forms some protrusions named arachnoid granulations.

They protrude into the venous sinuses and lacunae of the dura mater.
CONTENT OF THE CEREBROSPINAL FLUID (CSF)

- CSF is a transparent, colorless fluid, that forms from the blood plasma.

- Its electrolyte levels, glucose levels, and pH are very similar to those in the blood plasma, but they differ quantitatively.

- The water, Na, HCO3, and creatinine have almost the same concentration in both fluids.

- Content of glucose, proteins, urea, uric acid, K, Ca and pH is lower in the CSP, than in the blood plasma.

- The Mg and chlorine compounds have a higher concentration in the blood plasma then in the CSF.
THE CEREBROSPINAL FLUID

- Under the normal conditions, the CSF contains from 1 to 5 blood formative elements in 1 mm$^3$ (usually lymphocytes).

- Total amount of CSF in an adult is about 140 ml.

- About 0.35 ml/min of CSF is produced.

- During 24 hours is produced about 400 to 500 ml of CSF.

- Every 6 hours the CSF is renewed.
ORIGIN OF THE CSF

- About 60-70% of the total amount of the CSF is produced by the choroid plexuses of the ventricles of the brain.

- The remaining 30-40% of CSF is of extraplexual origin.
Some components of the CSF pass from the blood plasma by diffusion (e.g. water).

By active mechanisms, from the blood plasma are transported the most amount of ions.
THE COMPARTMENTS OF THE CNS CONTAINING CSF

- **Internal spaces** - the ventricular compartment.
- **External spaces** – subarachnoid compartment.
- Both spaces communicate at the level of the fourth ventricle of the brain.
CIRCULATION OF THE CSF

- From the lateral ventricle through the interventricular orifices the fluid enters the third ventricle.
- From the third ventricle through the aqueduct of the brain it passes into the fourth ventricle.
- From the fourth ventricle through its lateral and median appertures the CSF is transported into the subarachnoid space and then it is drained into the sinuses of the dura mater.
From the cerebello-medullary cistern the CSF runs into two directions:

1. Towards the subarachnoid space of the spinal cord.
2. Towards the subarachnoid space of the brain and then into the venous sinuses.
FACTORS THAT INFLUENCE THE FLOW OF THE CSF

1. Pulsation of the arteries
2. Breathing
3. Physical effort
4. Pressure
5. Cough
DRAINAGE OF THE CSF

- Secretion and drainage of the CSF occurs permanently.
- The total amount of fluid is constant.
- Its drainage occurs by means of:
  - Venous way
  - By mean of secondary ways.
THE VENOUS WAY OF DRAINAGE

1. Reabsorption of the CSF.

2. Through the granulations of the arachnoidea.

3. CSF is transported by the neurothelial cells, that discharge it into the venous blood.
SECONDARY WAYS OF CSF DRAINAGE

- Reabsorption of the CSF along the nervous sheath of the spinal and cranial nerves.
- Reabsorption at the level of the cortex capillaries.
- Reabsorption at the level of the ventricular ependyma.
ROLE OF THE CSF

MECHANICAL FUNCTION

BIOLOGICAL FUNCTION

EXCRETORY FUNCTION
MECHANICAL FUNCTION OF THE CSF

a) The brain being bathed by CSF “in situ” weight about 50gr, instead of real weight 1400gr.

b) The brain is fixed by means of blood vessels, nerves and trabecules of the subarachnoid space.

c) The CSF protects the brain.

d) It has an amortization role and protects the brain of arterial pulsation.
BIOLOGICAL FUNCTION

1. Trophyc function
2. Immunological function
3. CSF secrets neurohormones and neuromodullators
4. CSF maintains the homeostasis
EXCRETORY FUNCTION

Through the CSF are removed the:
- Products of brain catabolism: CO2, holin;
- Immunoglobulins and albumins;
- Some drugs such as antibiotics and sulphanialamides;
- Cells elements, which accidently enter the CSF.
**BARRIERS**

1. Hemato – encephalic barrier
2. Blood – CSF barrier
3. Brain – blood barrier
The blood brain barrier was discovered by the German scientist Paul Ehrlich who observed that intravenous injection of dyes into the body stained almost all organs except the brain.

He believed that this was because the brain just didn't take up the dyes.

Then in an experiment in 1913, Edwin Goldmann, who was one of Ehrlich's students, injected dye directly into the spinal fluid and observed that the brain did stain, but the rest of the body's organs did not.

In 1921 the neurophysiologist Lina Stern came up with the concept of the blood-brain barrier.

She had been puzzled by the fact that medicines and serums injected into the body did not reach the brain, and came to the conclusion that there must be a special filter to protect the organ and she named it the "hematoencephalic barrier."
The blood–brain barrier forms along the capillaries of the brain on the external surface of which are placed the astrocytic feet.

The wall of the capillaries consists of a basement membrane lined with endothelial cells.

Peculiarities of the endothelial cells:

- there are tight junctions around the capillaries with an extremely high electrical resistivity.
- presence of big amount of mitochondria, without pinocytosis vesicles (a relative lack of transcytotic vesicular transport).
- the endothelial cells actively transport metabolic products such as glucose across the barrier with specific proteins, insulin, amino acids, oxygen, and anaesthetic drugs (lipid soluble), because the cells of the blood brain barrier have a phospholipid bilayer.
The blood–brain barrier (BBB) is a highly selective permeability barrier that separates the circulating blood from the brain extracellular fluid.

The blood–brain barrier allows the passage of water, some gases and lipid-soluble molecules by passive diffusion.

It assures the selective transport of molecules such as glucose and amino acids that are crucial to neural function.

The BBB may prevent the entry of lipophilic, potential neurotoxins.

A small number of regions in the brain, including the circumventricular organs, do not have a blood–brain barrier.

Proteins circulating in the blood enter most tissues of the body except those of the brain, spinal cord or peripheral nerves.

This concept of a blood–brain named hematoencephalic barrier applies to many substances some are actively transported across the blood–brain barrier, others are actively excluded.
**THE FUNCTIONAL ROLE OF THE BBB**

The blood brain barrier (BBB) carries out three vital functions:

- Protect the brain from foreign substances that might damage it;
- Maintain a constant environment for the brain;
- Protect the brain from the harmful effects of some hormones.

Nicotine and alcohol easily dissolve in lipids and their effects can be felt very soon after they've entered the bloodstream.

On the BBB depends the psychical activity, memory, mood and liability to different diseases.
THE FUNCTIONAL ROLE OF THE BBB

- The blood brain barrier provides an excellent block to bacteria and infections of the brain are rare.
- It must be taken into consideration that inflammation increases blood brain barrier permeability.
- The BBB functions so well that it make some diseases of the brain, such as malignant tumors, very difficult to treat.
METHODS OF EXAMINATION OF THE MENINGES

- Lumbar puncture.
- Puncture of the cerebello-medullary cistern.
- Ventriculography with contrast medium (radioactive sodium).
- Secretion into the subarachnoid space of colloidal fluid that contains radioactive gold.
- Pneumoencephalography.
- CT and MRI.
LUMBAR PUNCTURE

- Between the L3 and L4 vertebrae.
PUNCTURE OF THE CEREBELLO-MEDULLARY CISTERNS

- Between the occipital bone and edges of the posterior arch of the atlas.
Sensory innervation is assured by the meningeal branches of the:

1. Trigeminal nerve (each branch of the trigeminal before leaving the skull gives off a meningeal branch).
2. Vagus nerve.
3. According to Perlin B. Z. the hypoglossal nerve, accessory and the upper cervical spinal nerves as well supply the meninges of the brain.
DEVELOPMENT OF THE MENINGES

- At the end of the 1st – beginning of the 2nd month of the intrauterine life around the spinal and cephalic portion of the neural tube from the mesenchyme of the somites appears some embryonic connective tissue, that surrounds the neural tube.

- During the 7th and 8th weeks of embryonic development the tissue surrounding the neural tube differentiates into two layers: the external and internal one.

- The outer layer becomes more dense and give rise to the pachymeninx.

- From the inner layer after its differentiation will develop the arachnoid and pia mater. Embryologically they develop from the mesenchyme migrated from the ganglionic crests, so-called ectomesenchyme.

- The arachnoid and pia mater (leptomeninx) have a common embryological origin and are connected functionally, that is why usually they are involved together in various pathological processes.
AGE PECULIARITIES OF THE MENINGES

- Connection of the dura mater with bones of the skull depends on age and it is stronger during childhood and in old people.

- In old people increases the number of the arachnoid granulations from 200-300 to 400-600 and their hypertrophy is accoutered.