Nicolae Testemitanu State University of Medicine and Pharmacy

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

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Lecturer
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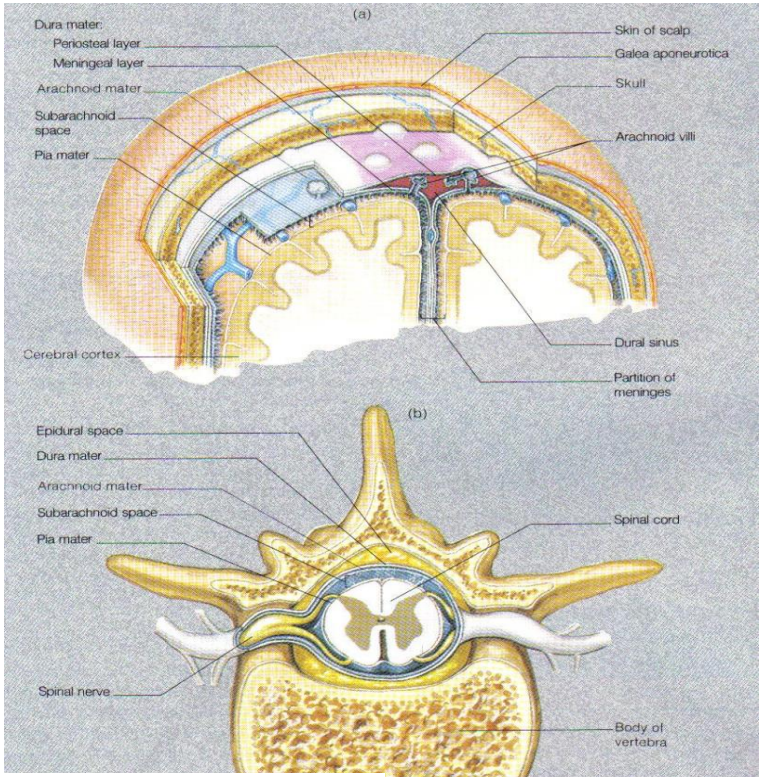
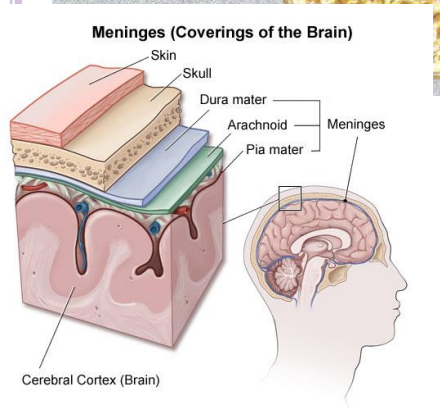
PLAN OF THE LECTURE

1. Meninges of the spinal cord – structure, topography, functions.
2. The cranial meninges – derivatives, structure, functions.
3. The cerebro-spinal fluid – content, production, functional role.
4. Age specific features of the meninges.
5. Examination of the meninges in a living anatomical model.
6. Innervation of the pachymeninx.
7. General data on development of the meninges.

GENERAL DATA





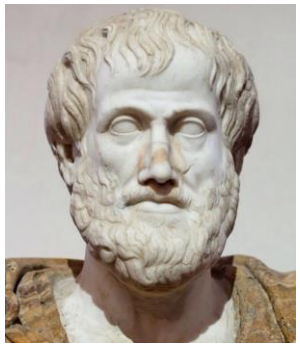
- The components of the central nervous system are covered by three coats.

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

- **Dura mater – *pachymeninx*.**
- **Arachnoidea** and **pia mater – *leptomeninx*.**

SHORT INTRODUCTION INTO HISTORY

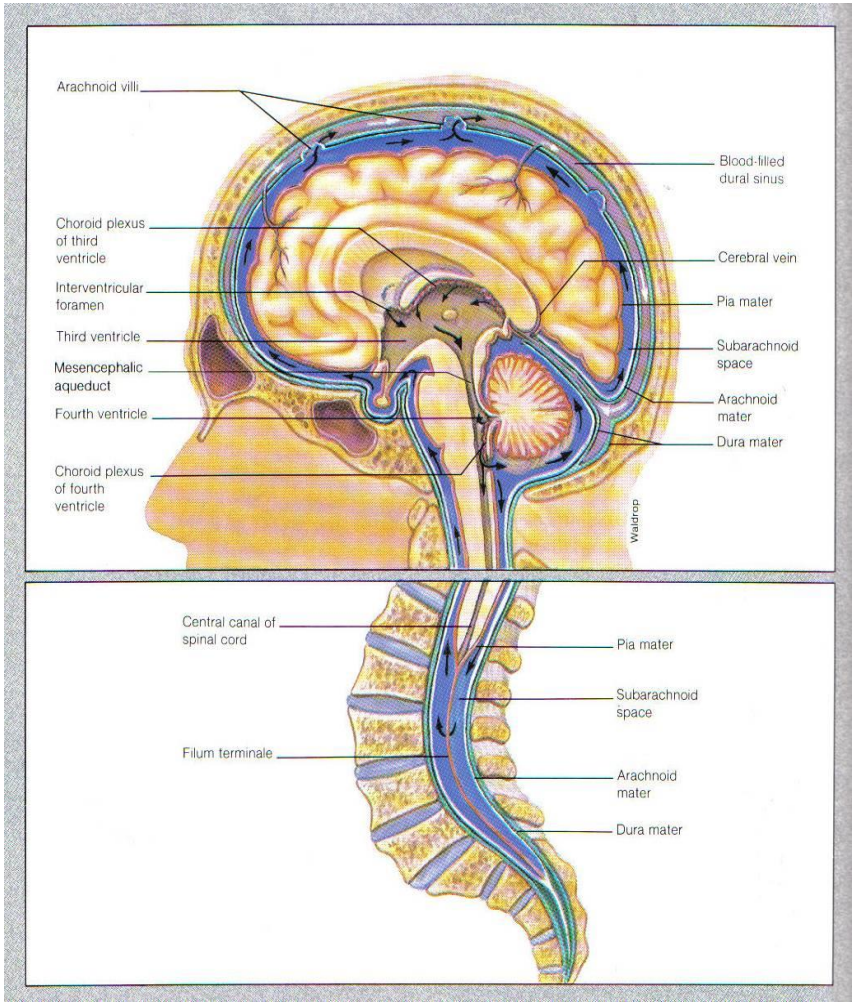
- ***Herophilos*** (335-280 b.c.) described the **brain meninges** and their derivatives: ***vascular network*** *and* ***venous sinuses*** *of the* ***dura mater*** *with* ***confluence of the sinuses,*** named after him (***torcular Herophili***).
- ***Claudius Galenus*** (131-192) described the ***vena magna cerebri*** and ***sinus rectus***, both named after him.
- ***Humphrey Ridley*** (1653-1708), an Englishman anatomist studied the meninges of the brain, venous sinuses, and arachnoid mater. 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*** was named after him, as well as the ***arachnoid granulations*** discovered in 1705.
- The meninges of the brain were studied as well by ***J. F. Meckel*** (1724-1774), ***H. Luschka*** (1820-1875) and others.



- Until 17th century it was considered that the brain is covered only by ***dura mater*** and ***pia mater***.
- ***Gerardus Blasius*** (1626–1692) was the first to describe the arachnoid mater ***(AM)*** in 1664.
- One year later ***Humphrey Ridley*** (1653–1708) described this membrane, as a separate layer investing various cerebral vessels and intracranial nerves, and he was the first to describe the concept of the subarachnoid cistern.
- In 1699 ***Frederick Ruysch*** (1638–1731) described the ***cobweb-like appearance*** of the ***AM***.
- The arachnoid membrane was noted by ***Govert Bidloo*** (1649–1713), ***John Bohn*** (1640–1718), ***Raymond Vieussens*** (1635–1715).
- The first detailed study of the ***AM*** was provided by ***Xavier Bichat*** (1771–1802) in 1802. He was the second to describe the concept of the subarachnoid cistern.
- The ***CSF*** was discovered by ***Emanuel Swedenborg*** (1688–1772) between 1741 and 1744.
- In 1822 ***François Magendie*** (1783–1855) gave the first description of the subarachnoid space.

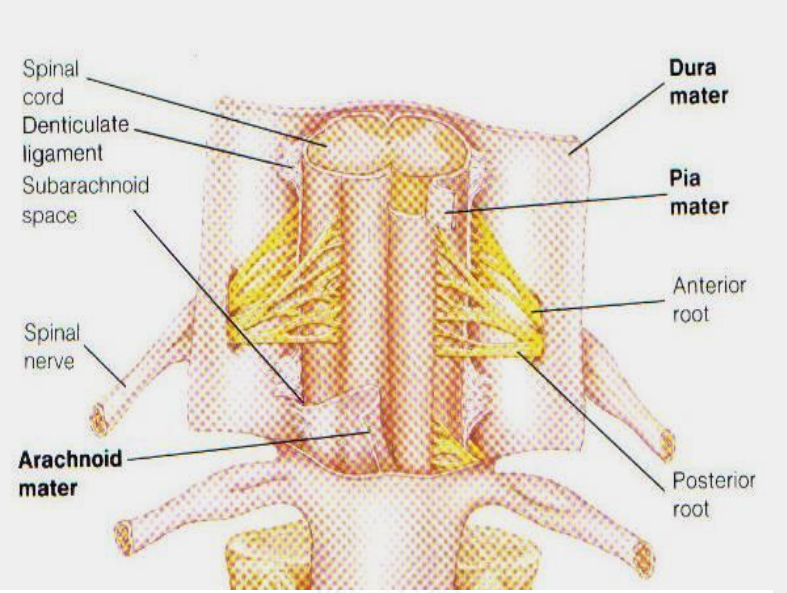
[Lü J. Arachnoid membrane: the first and probably the last piece of the roadmap. *Surg Radiol Anat*. 2015;37(2):127-138. doi:10.1007/s00276-014-1361-z].

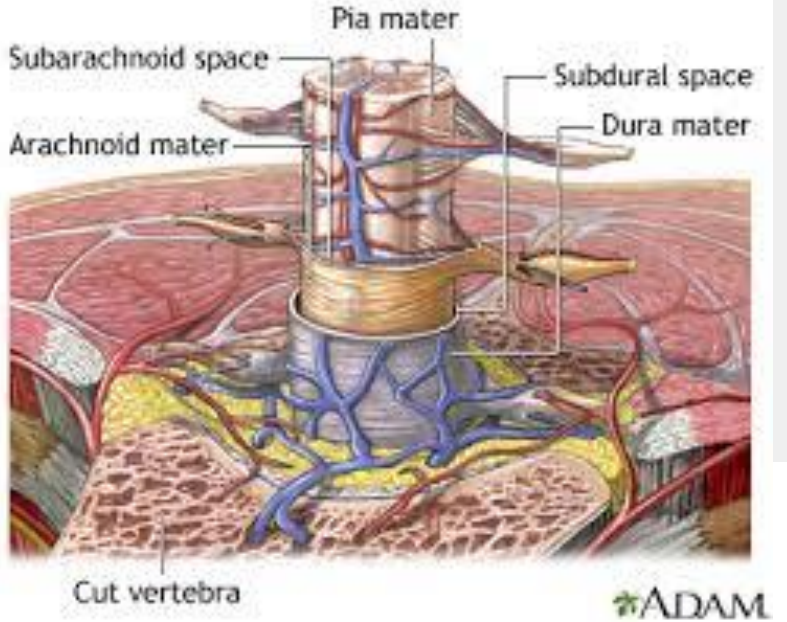
THE DURA MATER OF THE SPINAL CORD



- Dura mater of the spinal cord is a fibrous coat, that covers outside the spinal cord.
- It extends from the *foramen magnum* up to the second sacral vertebrae (S2).
- Its fixation is assured by ***sacro-dural ligament*** (***Trolard***).

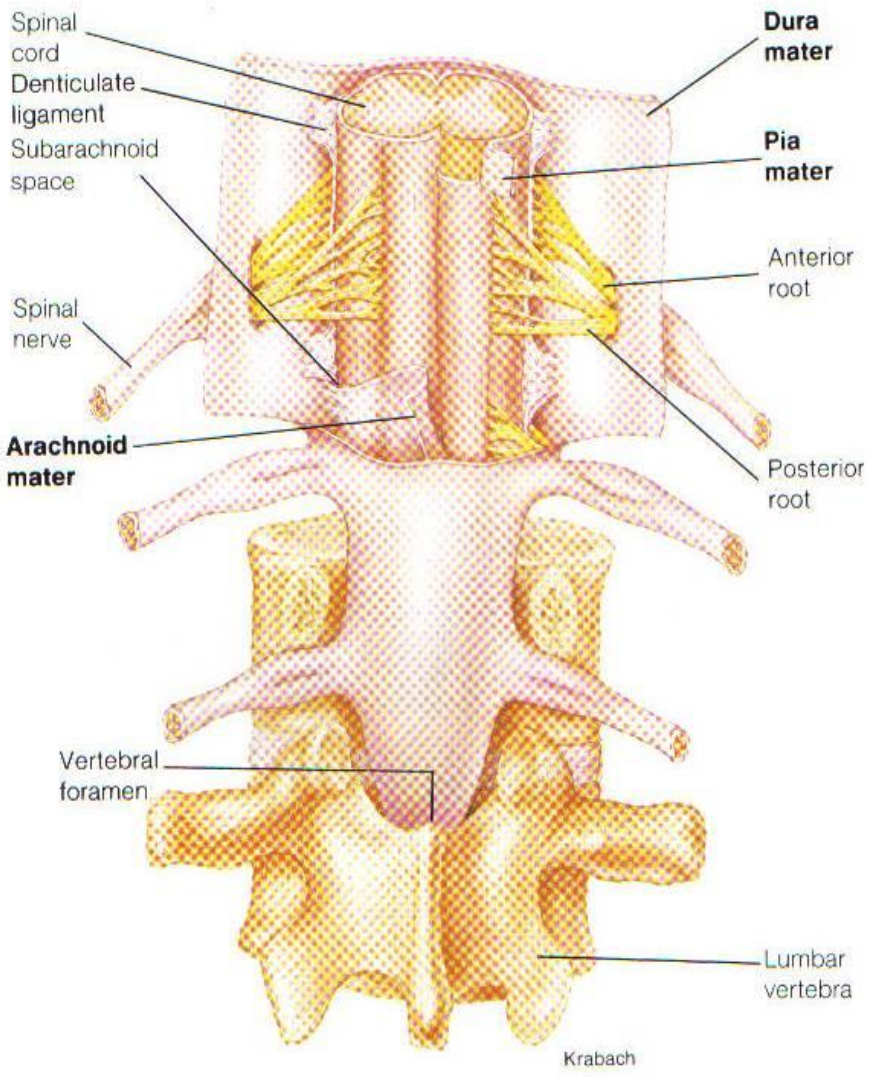
THE DURA MATER OF THE SPINAL CORD





- On the **external surface** of the dura mater of the spinal cord (DMSC) there are orifices, through which pass the blood vessels and nerves.
- The **internal surface** is smooth and shiny and it comes in contact with the arachnoid mater.
- The DMSC forms the spinal nerves sheaths.
- The sheaths are connected to the edges of the intervertebral foramina and continue into the periosteum.
- Between the outlet orifices of the spinal nerves the ***denticulate ligaments*** are distinguished.

THE MORPHO-FUNCTIONAL STRUCTURE OF THE DMSC



- The DMSC consists of collagenous fibers:

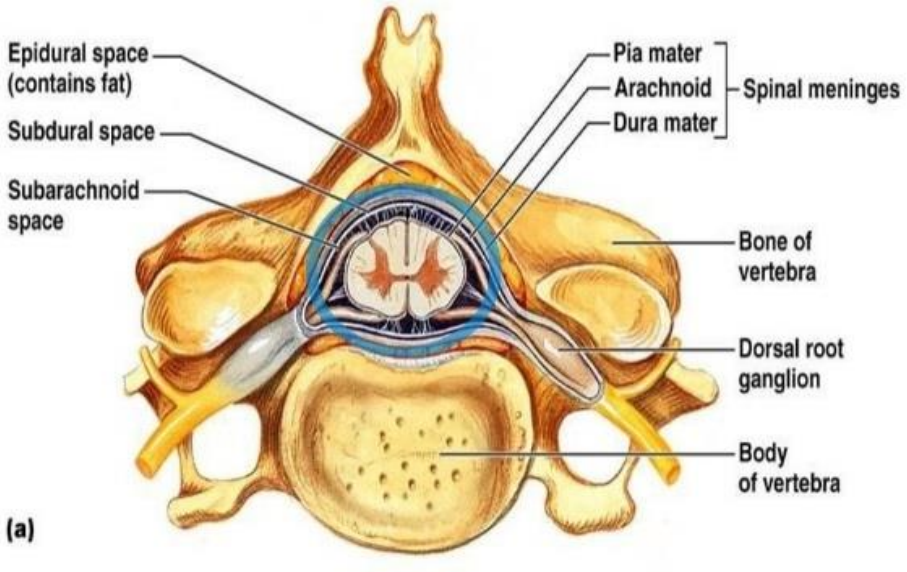
a) longitudinal

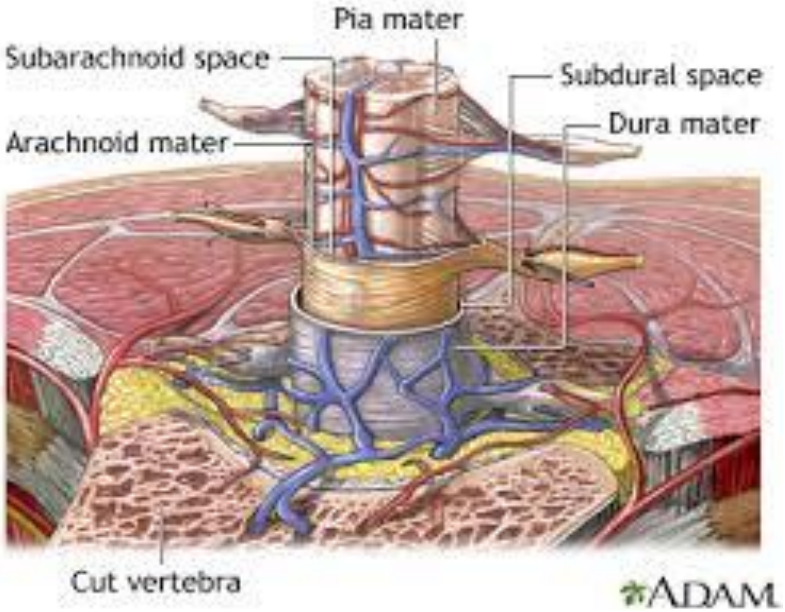
b) circular

c) radial

- The collagenous fibers are adapted to the basic movements of the spinal cord.

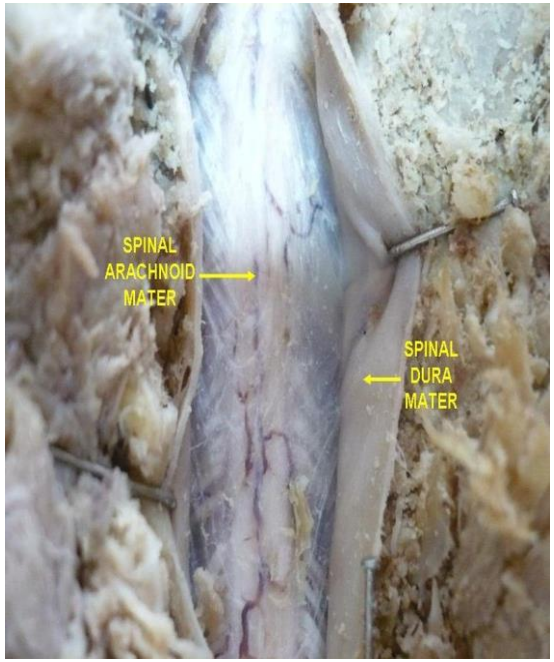
THE DURA MATER OF THE SPINAL CORD

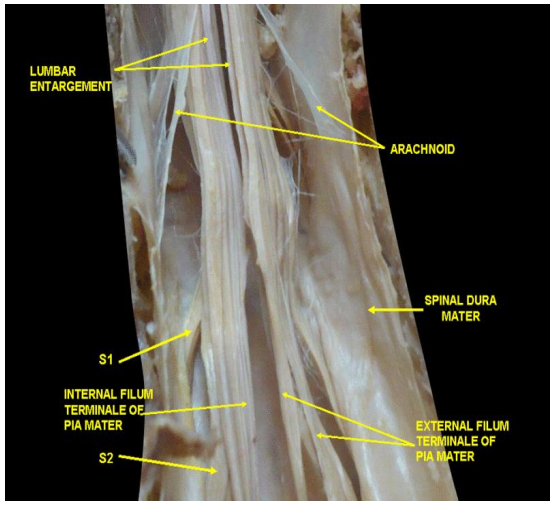




- Between the inner surface of the vertebral canal and the outer surface of the *dura mater spinalis* is located the ***epidural space***.
- The epidural space contains fat tissue and the internal vertebral venous plexus.

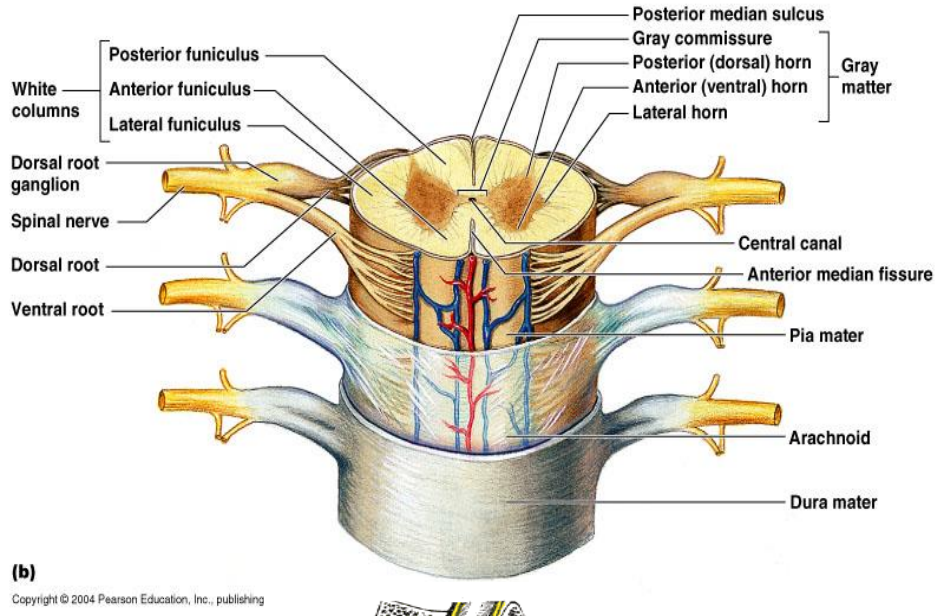
ARACHNOID MATER

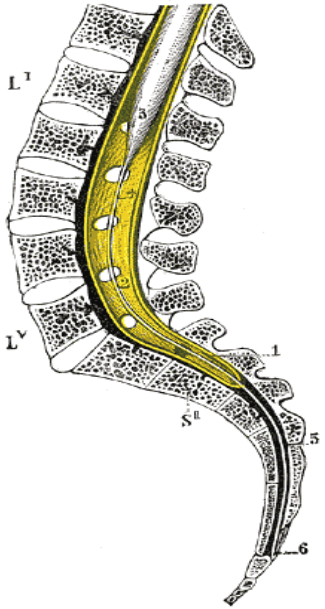




- The arachnoid mater is the middle coat of the spinal meninges.
- From Greek "Arachne" means spider.
- The arachnoid mater has an appearance of a fine spider web.
- The delicate arachnoid layer surrounds the spinal cord and it is attached to the inner surface of the dura mater.
- It is devoid of blood vessels.

PIA MATER SPINALIS





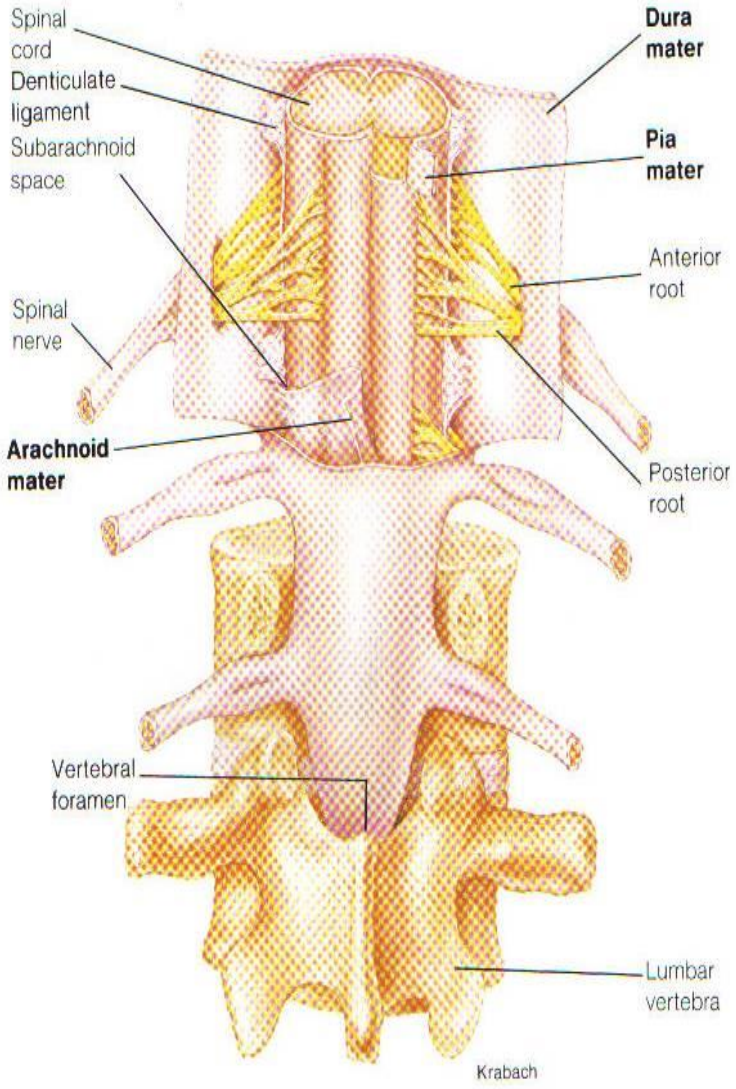
- **Pia mater spinalis** is a thin connective tissue coat, that contains blood vessels.

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

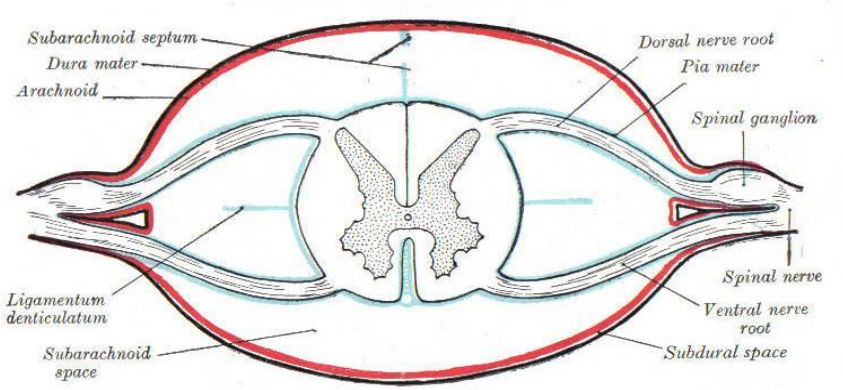
3. External layer – ***stratum epipiale***, consists of a network of collagenous fibers, that continue with subarachnoid trabeculae.

- 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.

PIA MATER SPINALIS



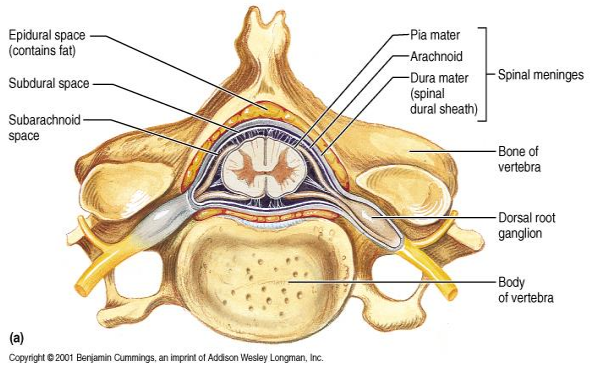
- From the external layer of the ***pia mater spinalis*** arise ***denticulate ligaments.***
- The ligaments pass along the spinal cord between the spinal nerves, from the C1 until L1.
- The *denticulate ligaments* divide patially the subarachnoid space into **anterior** and **posterior** parts.

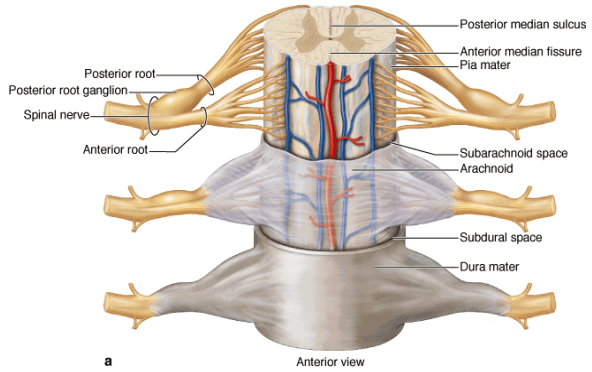


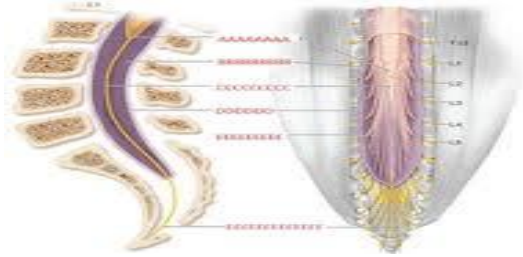
SPACES OF THE SPINAL CORD MENINGES

- ***Epidural space*** is located between the inner surface of the vertebral canal and the outer surface of the dura mater spinalis (it contains the internal vertebral venous plexus and fat tissue).
- ***Subdural space*** – between the dura mater and the arachnoid mater.
- ***Subarachnoid space*** – between the arachnoidea and pia mater (it is filled with CSF).
- Below the spinal cord the subarachnoid space enlarges to form the ***lumbo-sacral cistern***, that inside is covered by ***arachnoidea spinalis.***

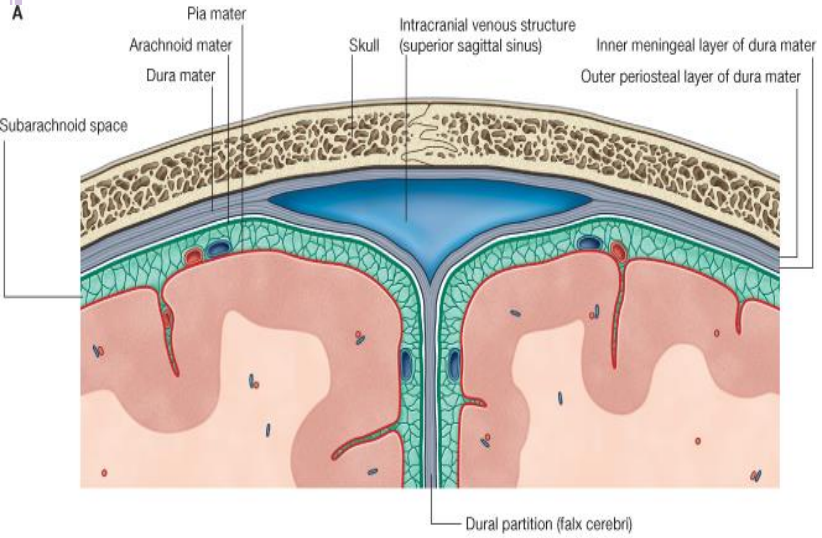
- Note: The epidural space is present only between the meninges of the spinal cord.

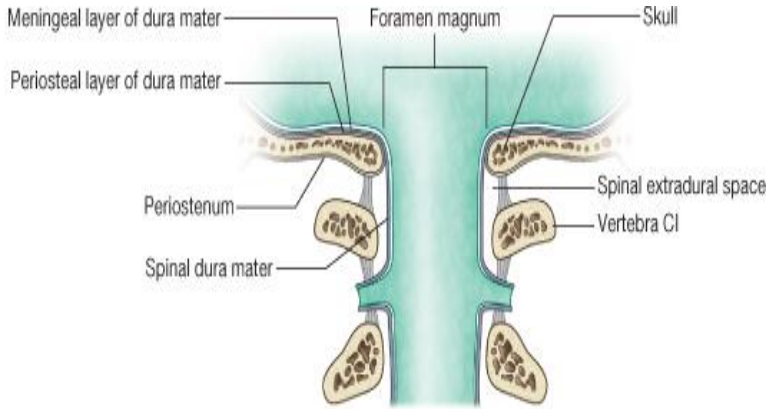






Dura mater of the brain



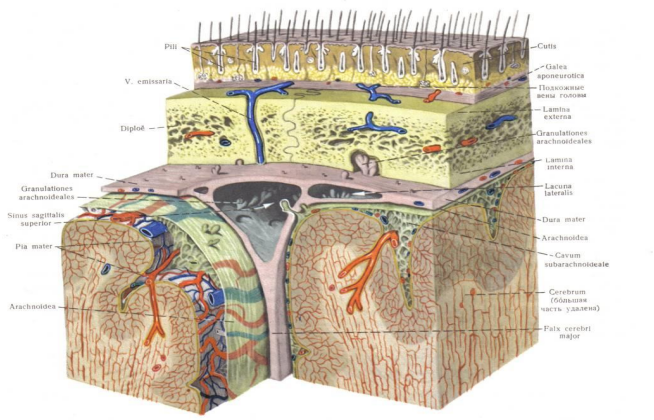


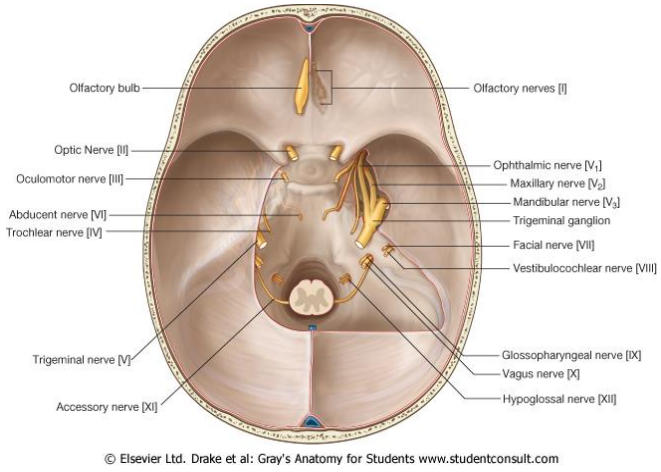
- Dura mater of the brain (DMB) is a continuation of the similar coat of the spinal cord.
- This coat differs from that of the spinal cord and consists of two layers:

1. External - endoosteal
2. Internal – meningeal

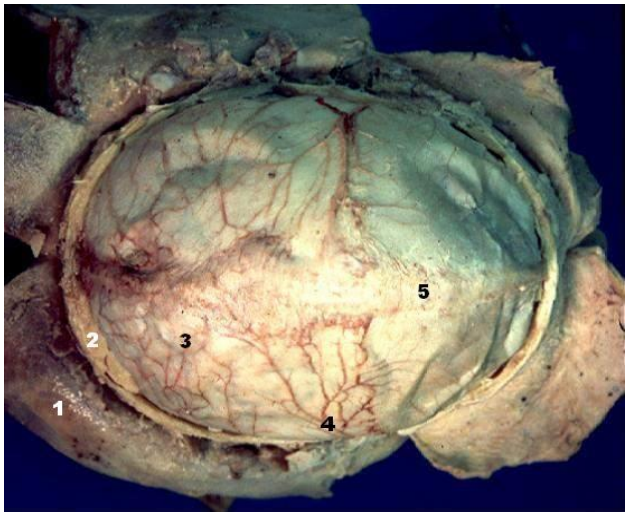
- **The external** layer covers the inner surface of the bones of the skull and continues within their periosteum.
- **The internal layer** covers the brain and forms a protective coat for it.

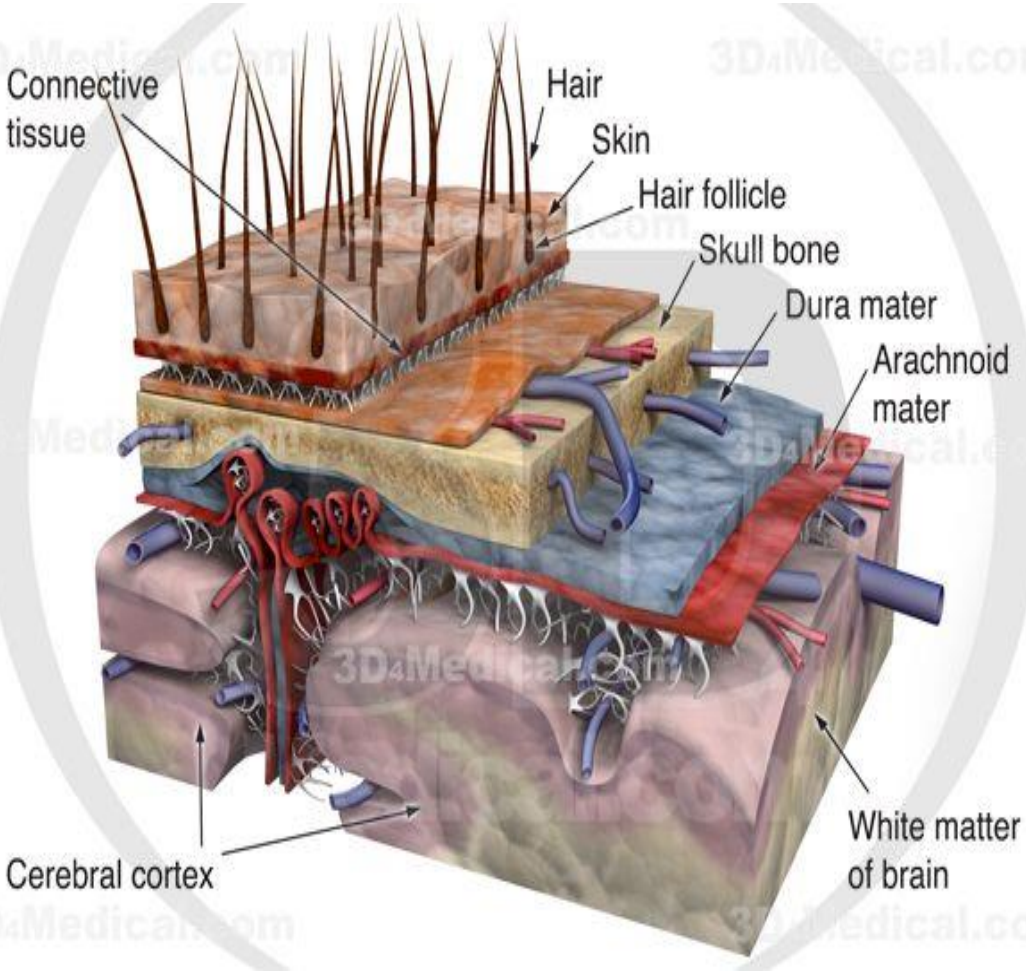
Structure of the dura mater of the brain



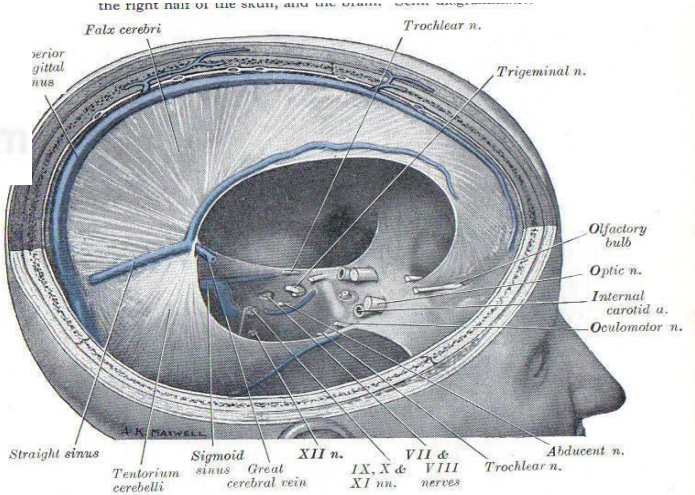


- **External surface** is rough, contains blood vessels and connective tissue fibers and it comes in contact with the bones of the skull.
- **Internal surface** is smooth, shiny and lined with mesothelium.

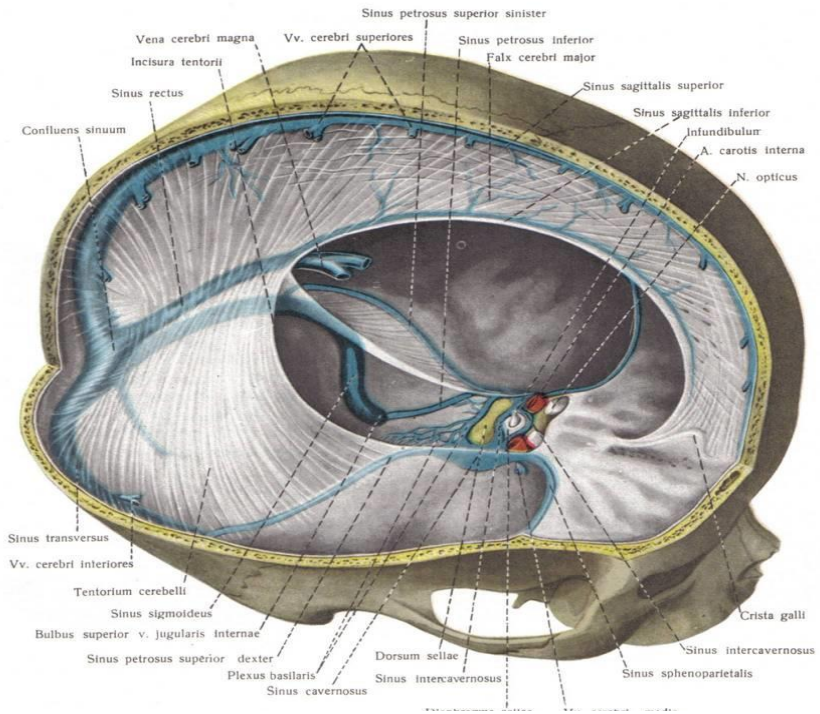


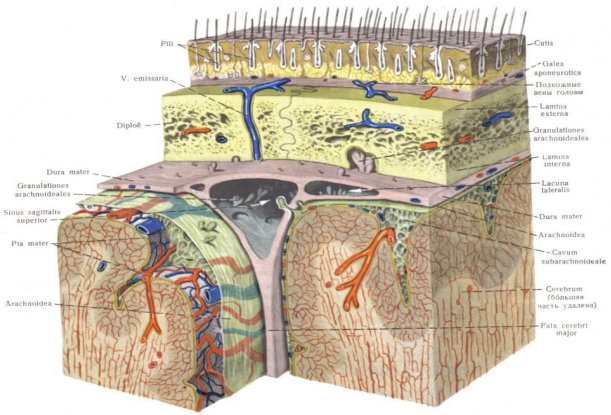


Dura mater is connected to the bony protrusions and edges of anatomical structures of the inner surface of the skull, such as sutures, foramen magnum, inclined processes of the sphenoid bone, etc.



Structural peculiarities of the dura mater of the brain





- Dura mater of the brain (DMB) structurally differs from the DMSC.
- Specific features of the DMB:

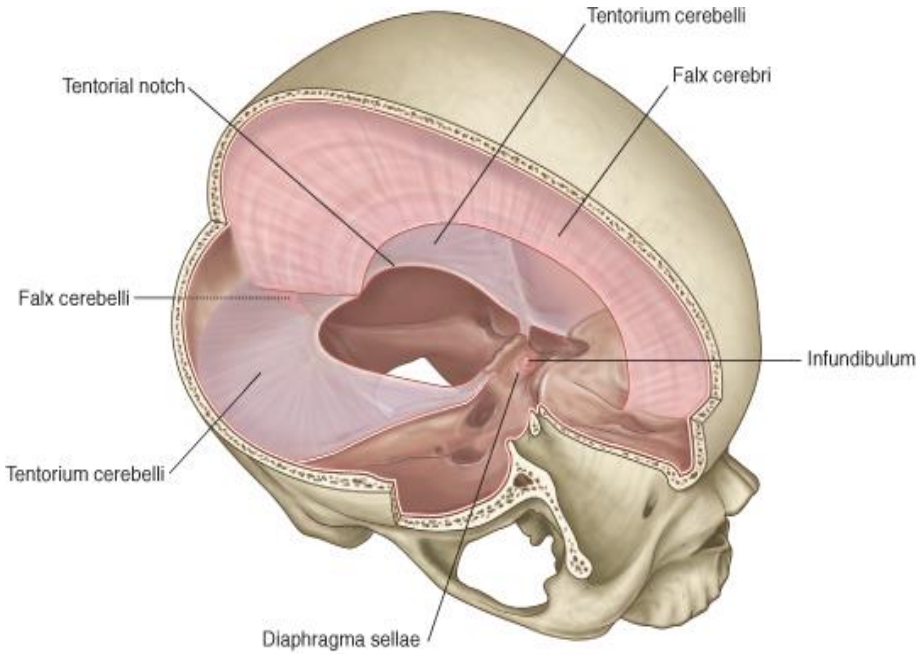
1. It comes in contact with the bones of the skull and there is no epidural space between DMB and bones of the skull.

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.

DERIVATIVES OF THE DURA MATER OF THE BRAIN

The processes of the DMB are lined with mesothelium and consist of connective tissue and elastic fibers.

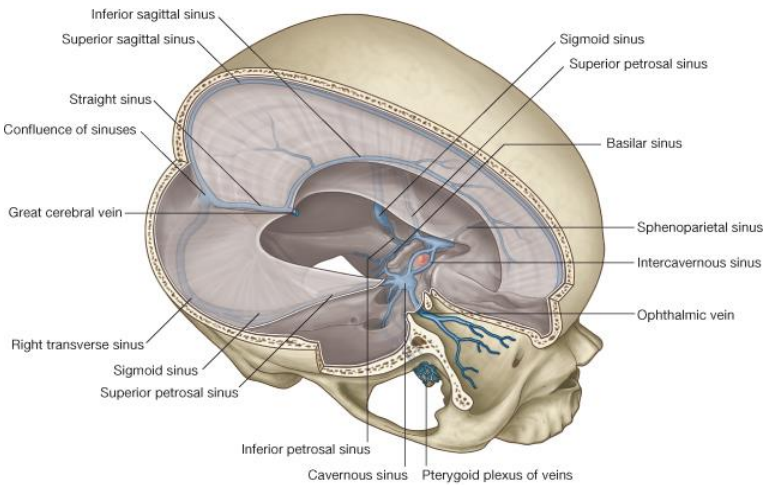


Processes of the dura mater:

- ***Falx cerebri***
- ***Falx cerebelli***
- ***Tentorium cerebelli***
- ***Diaphragma sellae (sellar diaphragm).***

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 in different directions and continue into the endoosteal 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 prevent their collapse.



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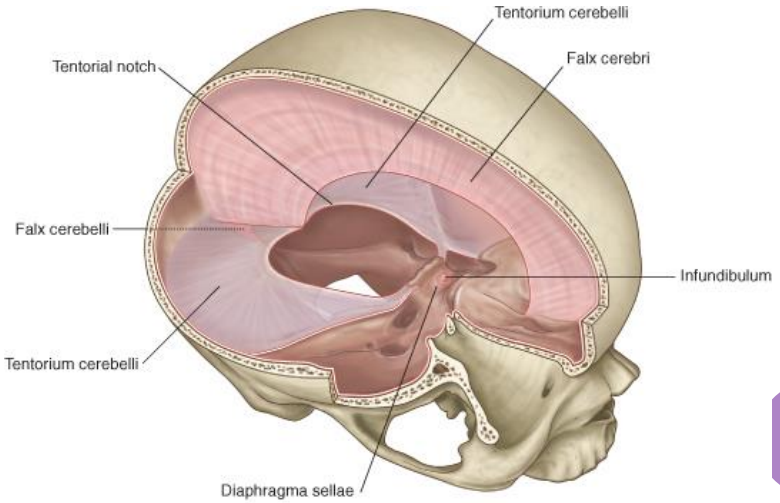

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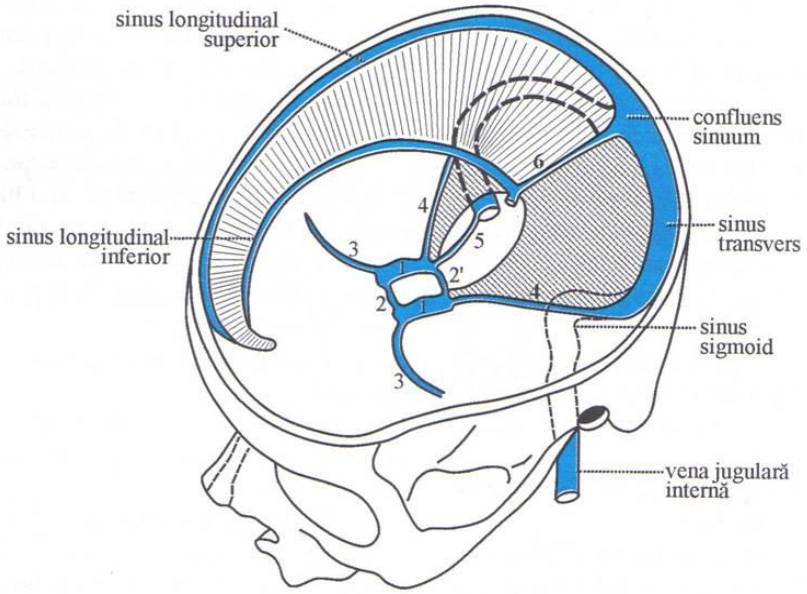
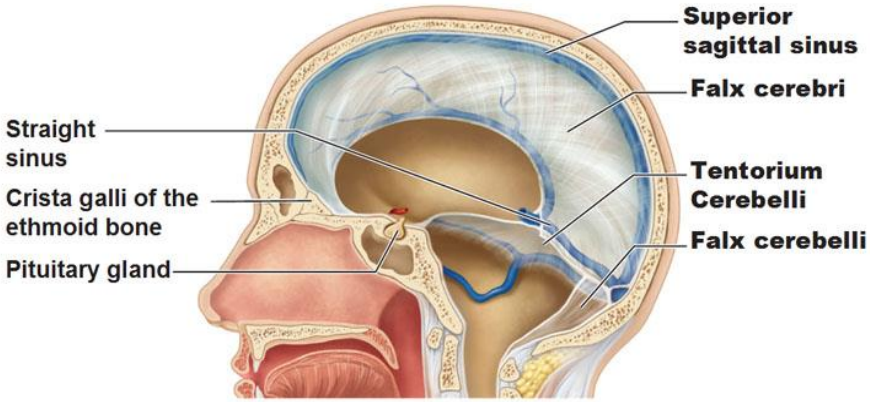
Sinuses of the Dura Mater



The Dura Mater and Dural Sinuses



(a) Midsagittal view

- 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.

CCLASSIFICATION OF THE DURA MATER VENOUS SINUSES

- According to their location the sinuses are divided into:

a) Sinuses of the vault of the skull

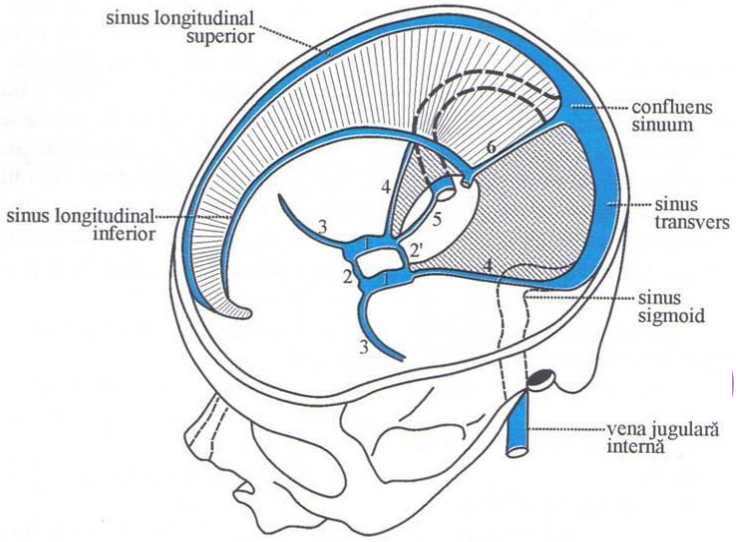
b) Sinuses of the base o the skull

Sinuses of the vault of the skull

1. Superior sagittal sinus
2. Inferior sagittal sinus
3. Straight sinus, sinus rectus
4. Transverse sinus

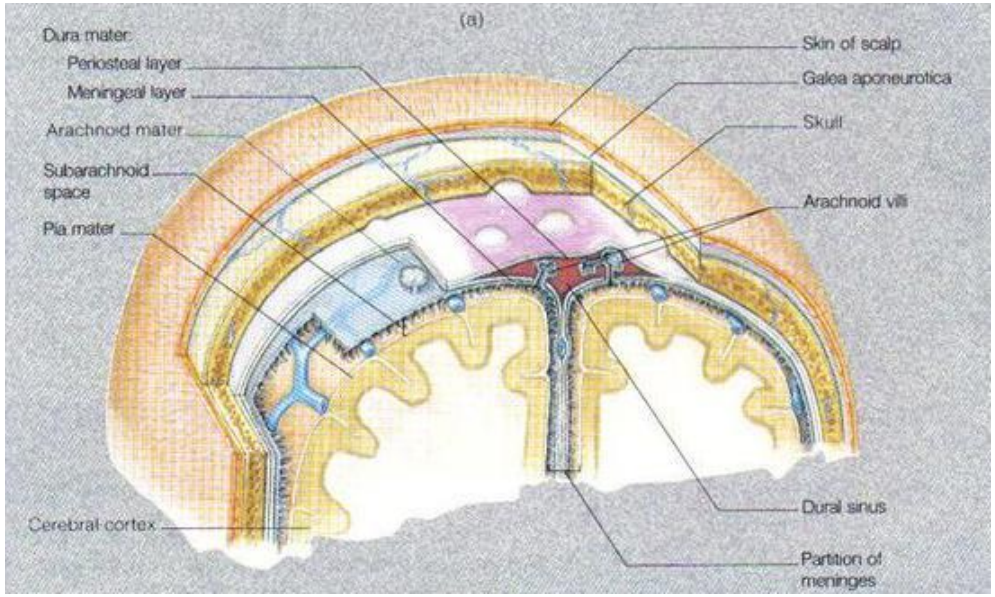
Sinuses of the base of the skull

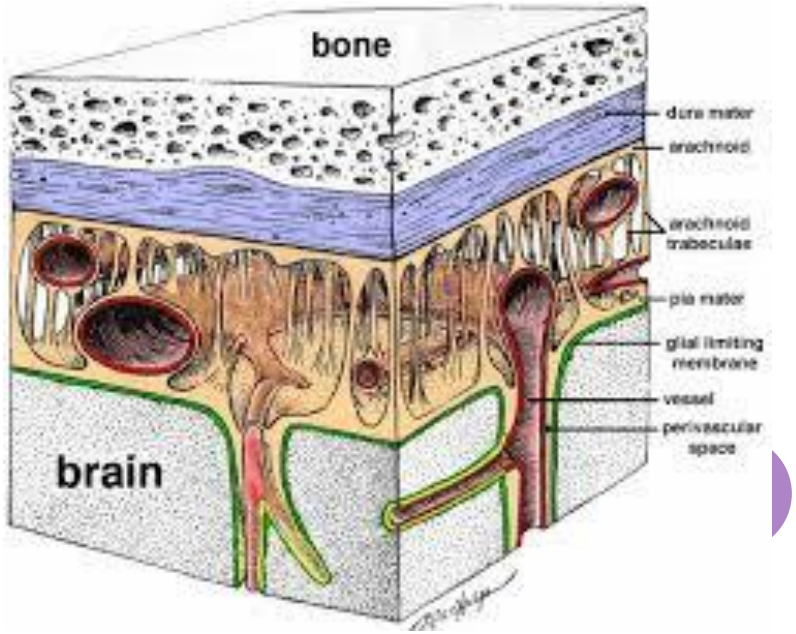
1. Sphenoparietal sinus
2. Cavernous sinus
3. Intercavernous sinus
4. Transverse occipital sinus (basilar)
5. Superior petrosal sinus
6. Inferior petrosal sinus
7. Petro-occipital sinus (inconstant)
8. Posterior occipital sinus (inconstant)
9. Sigmoid sinus



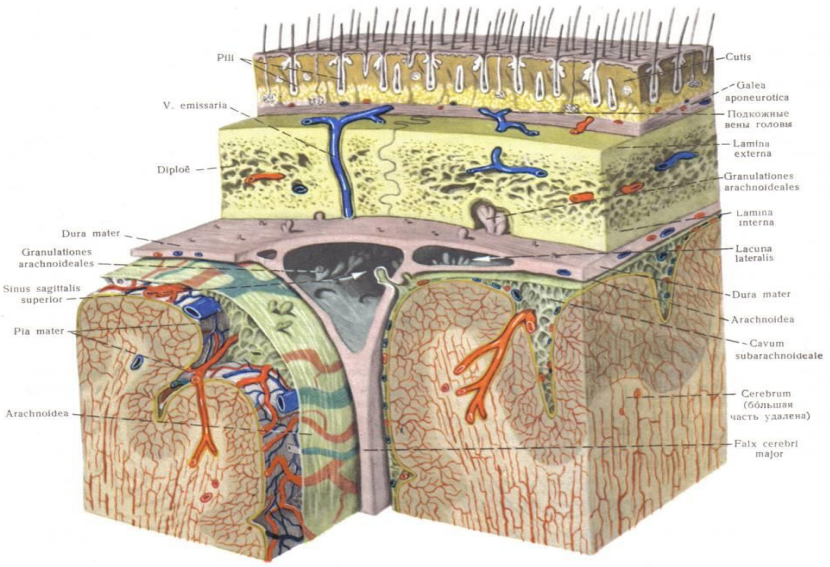
THE ARACHNOID MATER OF THE BRAIN

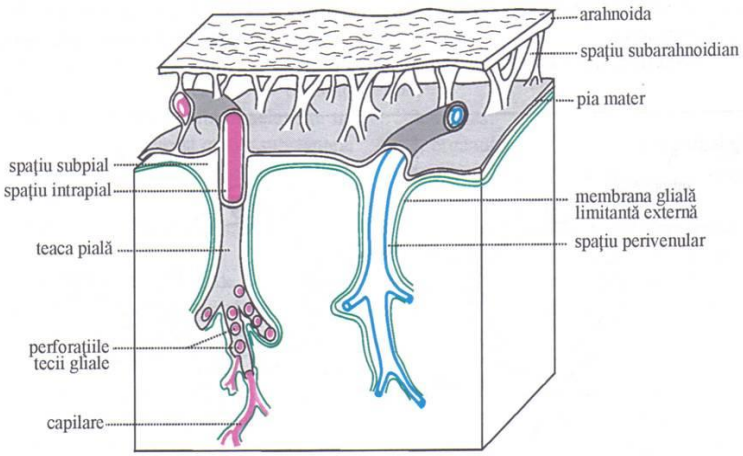
- The arachnoidea of the brain is a thin coat devoid of blood vessels.
- It consists of collagenous and elastic fibers and of flattened elongated cells rich in nerve endings.
- The arachnoidea covers the brain outside without entering the fissures and grooves of the brain hemispheres.
  a) ***its internal 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 *subdural space*.





PIA MATER OF THE BRAIN



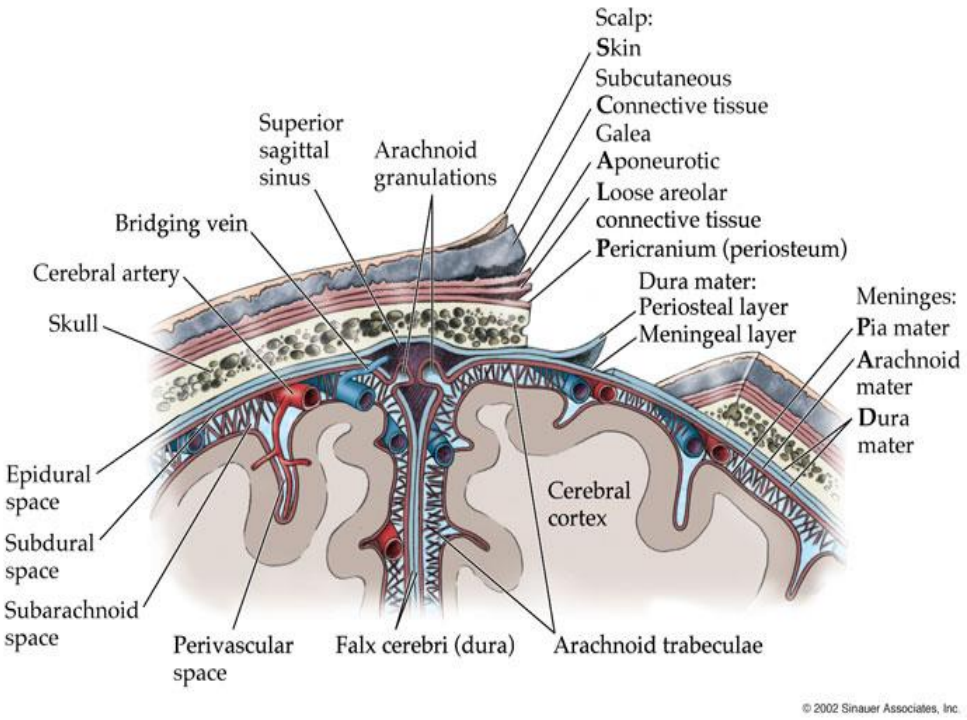


- Pia mater covers the brain mater outside.

1. **Its external surface** faces the subarachnoid space, and the arachnoid trabeculae are connected to it.

2. **Its internal surface** follows the relief of the brain.

STRUCTURE OF THE PIA MATER

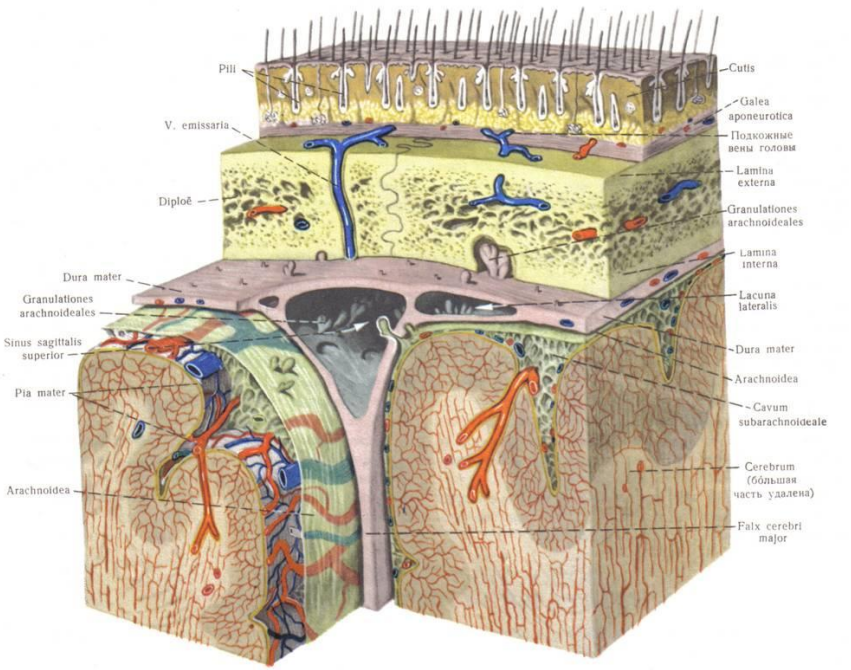


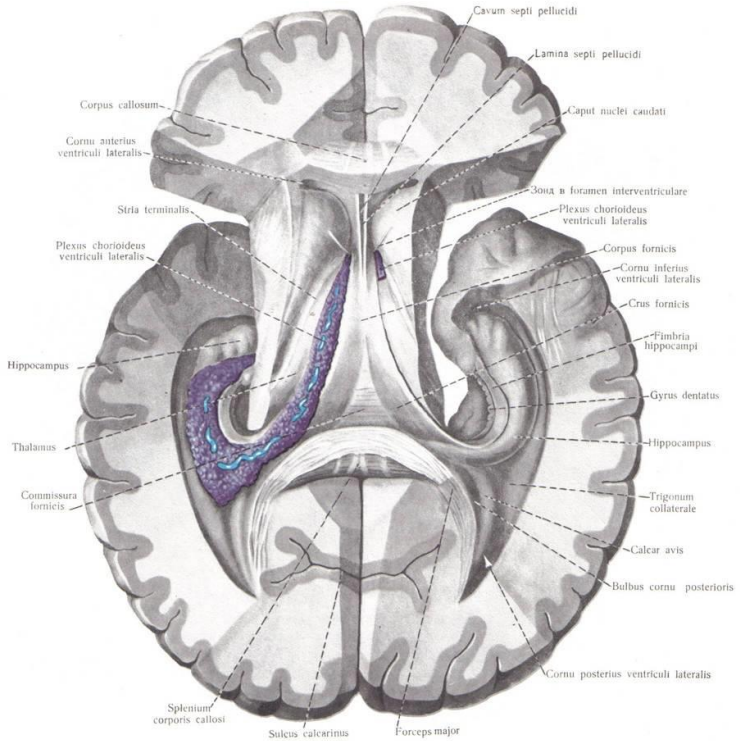
- The pia mater consists of a ***basement membrane***, on which are located thin connective tissue fibers and a row of ***mesothelial cells.***

- 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

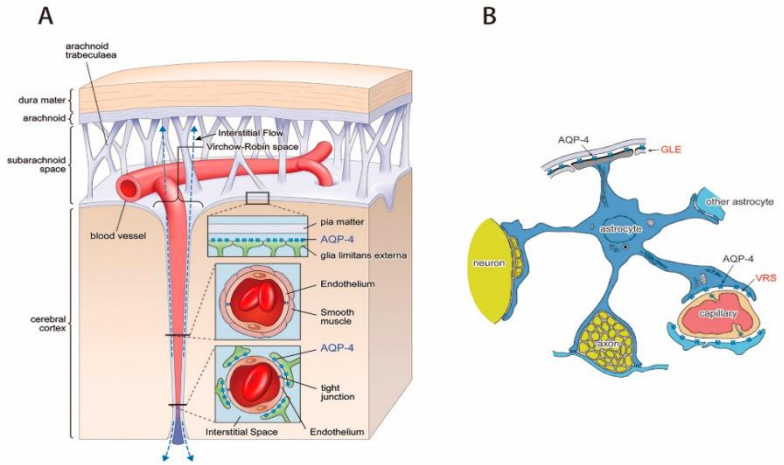
a) It is rich in blood vessels, that assure the vascularisation of the brain.
б) It forms vascular plexuses of the ventricles of the brain.





SPECIFIC FEATURES OF THE PIA MATER

- It enters the grooves and fissures of the brain.
- Participates in formation of the choroid plexus together with blood vessels.
- It delimits the perivascular and pericellular ***Virchow-Robin space***.
- The Virchow-Robin space is an immunological space between a blood vessel (artery/vein, but not capillaries), and the pia mater that can be expanded by leukocytes.
- The space is formed when pia mater dive deep into the brain together with large vessels.
- ***Virchow-Robin space*** is extremely small and it can usually only be seen on MRI image.



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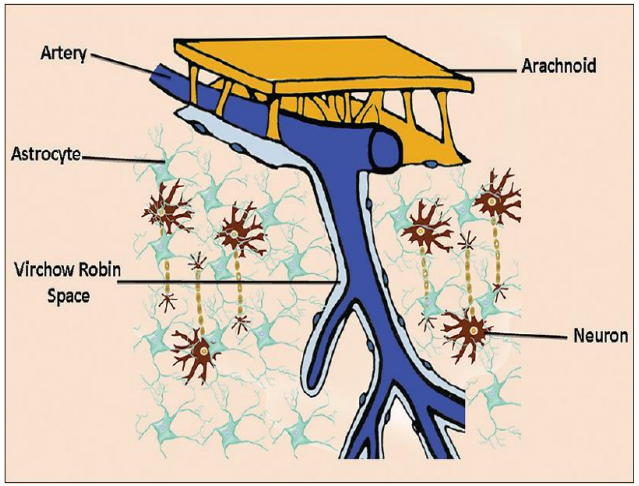
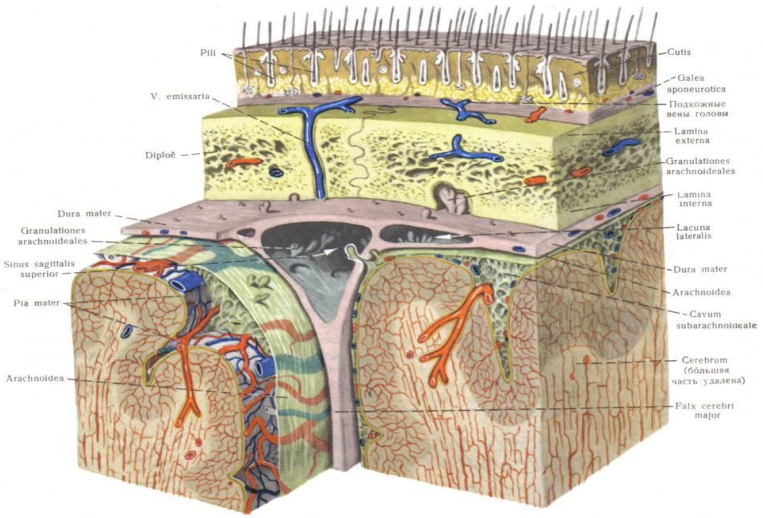
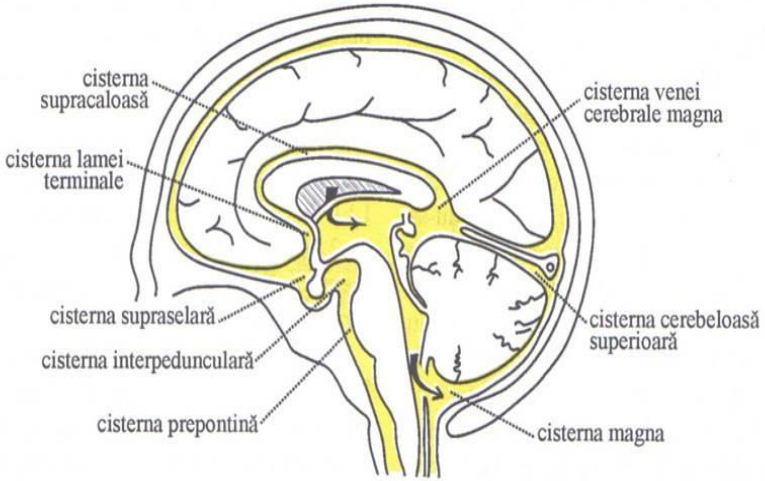


Subarachnoid space

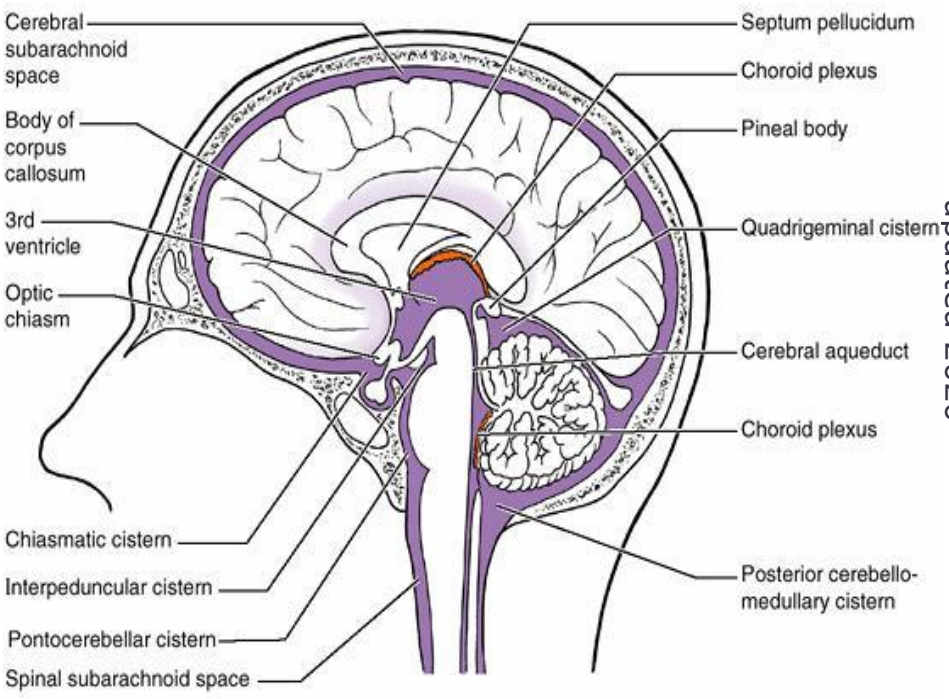




- The *subarachnoid space* forms between the ***arachnoidea*** and ***pia mater.***
- In some places the subarachnoid space enlarges, and forms ***subarachnoid cisterns***.

THE SUBARACHNOID CISTERNS

1. Posterior cerebellomedulary cistern; Cisterna magna
2. Lateral cerebellomedulary cistern;
3. Cistern of lateral cerebral fossa *(of Sylvius)*
4. Chiasmatic cistern
5. Interpeduncular cistern
6. Cisterna ambiens, Ambient cistern
7. Pericallosal cistern
8. Pontocerebellar cistern
9. Cisterna of lamina terminalis
10. Quadrigeminal cistern, Cistern of great cerebral vein



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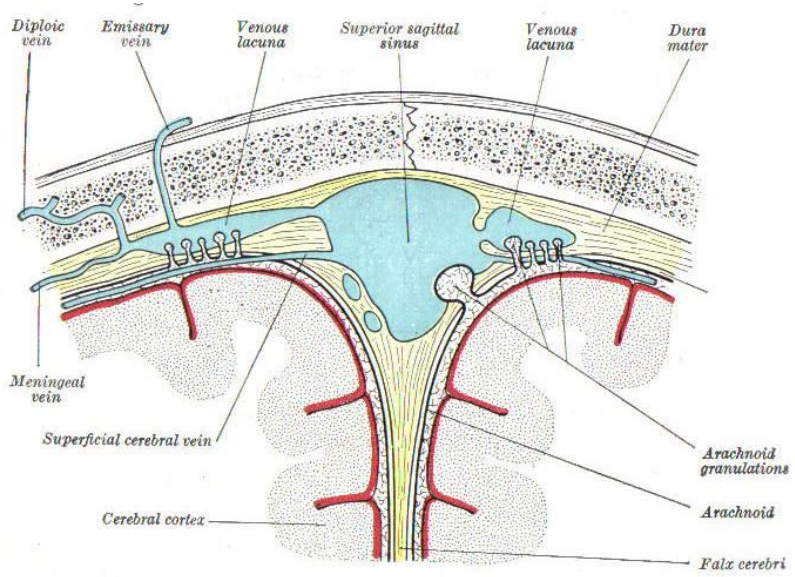
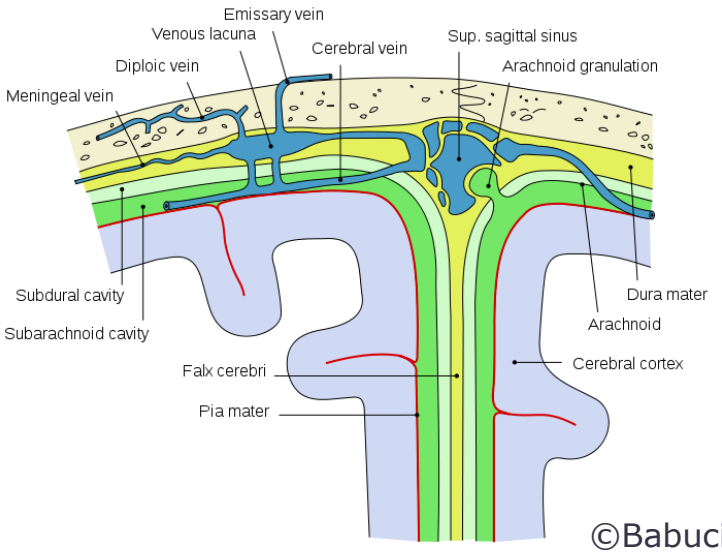
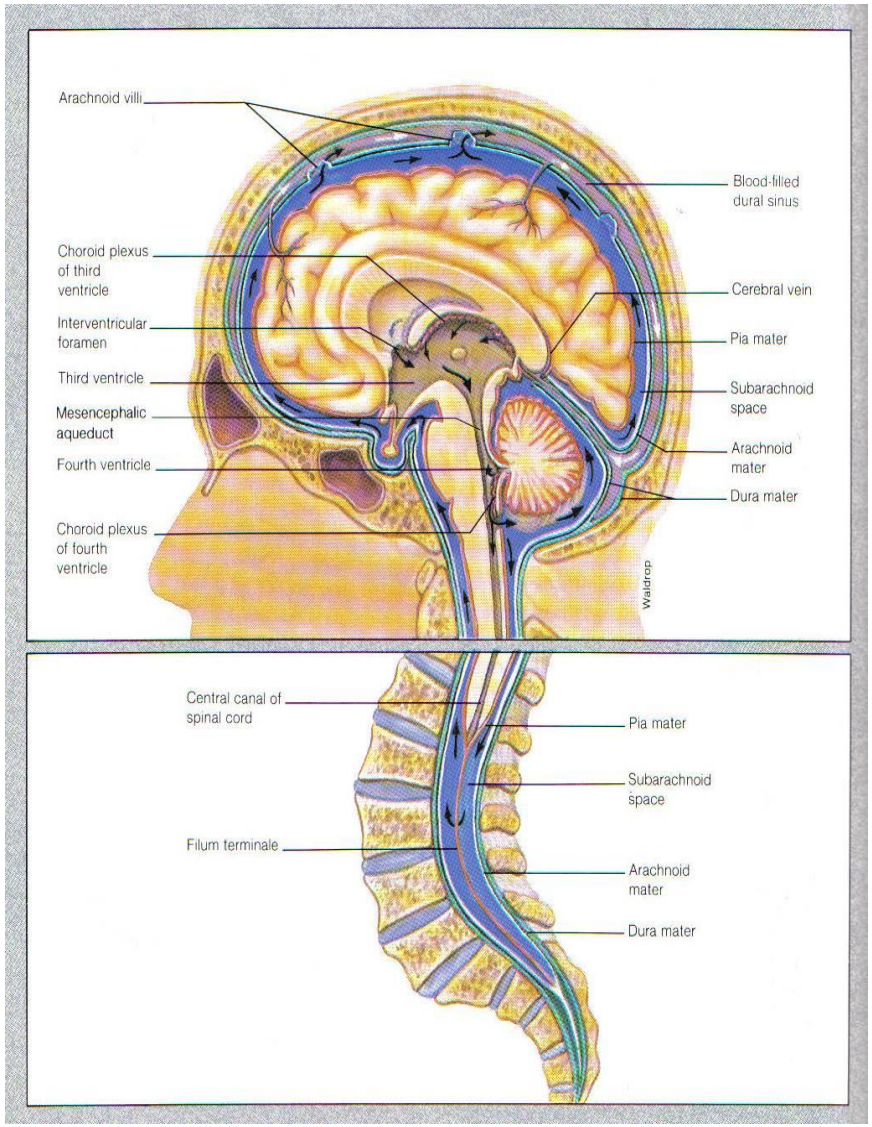
Granulations of the arachnoidea





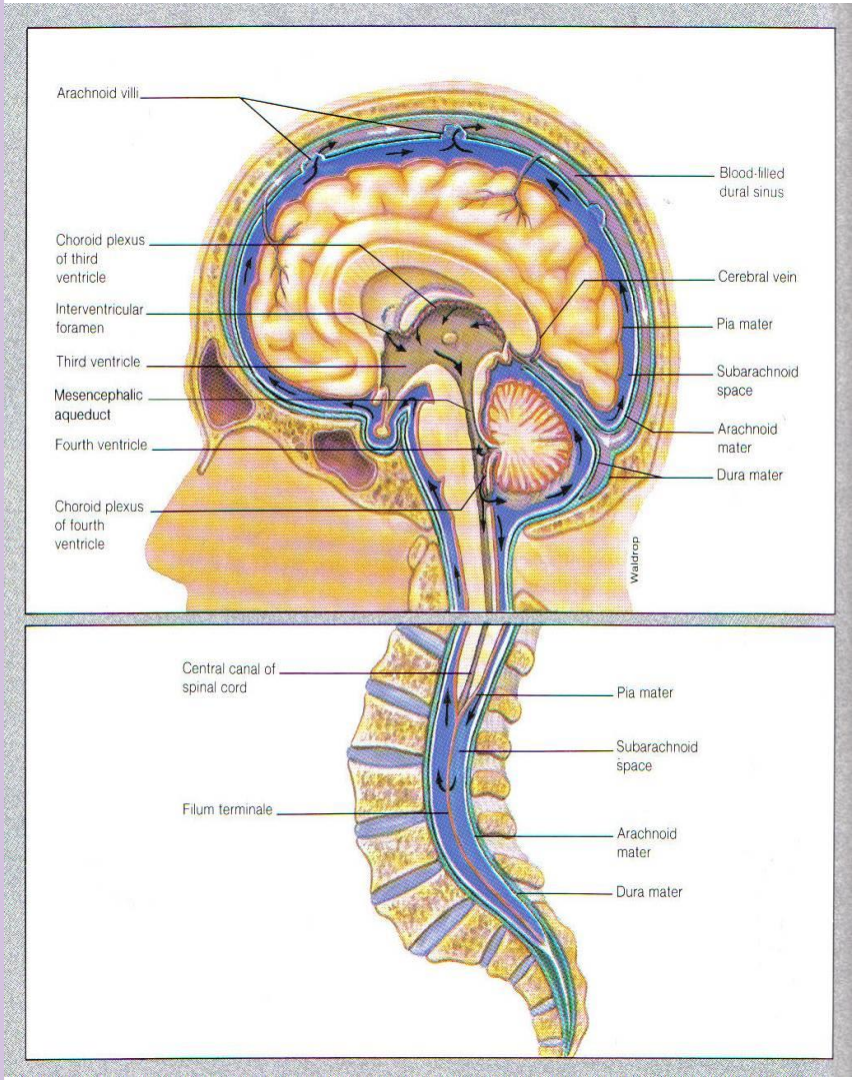
- The arachnoidea form some protrusions named ***arachnoid granulations (Pacchionian granulations).***
- They protrude into the venous sinuses and lacunae of the dura mater.

Content of the cerebro-spinal fluid (CSF)



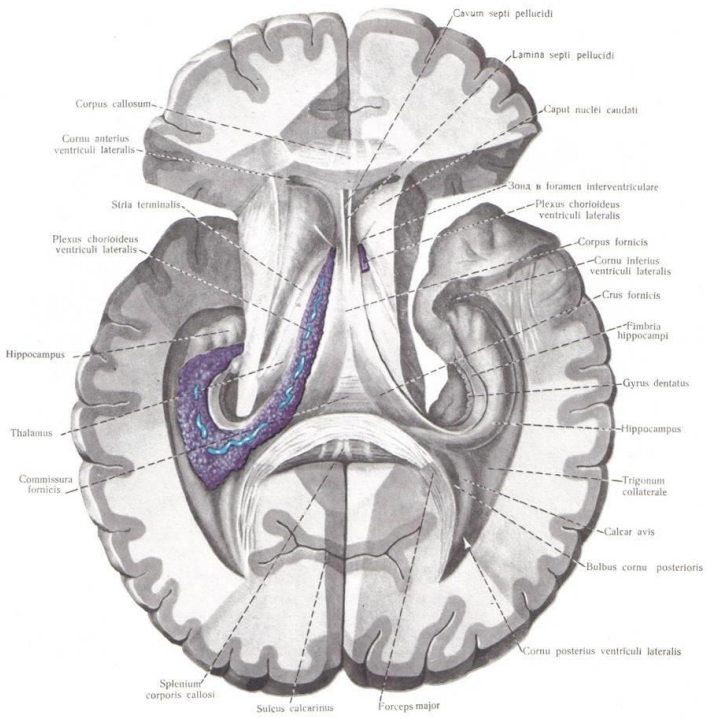
- CSF is a transparent, colorless fluid, that forms from the blood plasma.
- Its electrolyte levels, glucose levels, and pH are very similar to those in the blood plasma, but they differ quantitatively.
- The water, Na, HCO3, and creatinine have almost similar concentration in both fluids.
- Content of glucose, proteins, urea, uric acid K, Ca и pH their content in the CSP is lower, than in the blood plasma.
- The Mg and chlorine compounds have a higher concentration in the CSF, than in the blood plasma.

THE CEREBRO-SPINAL FLUID



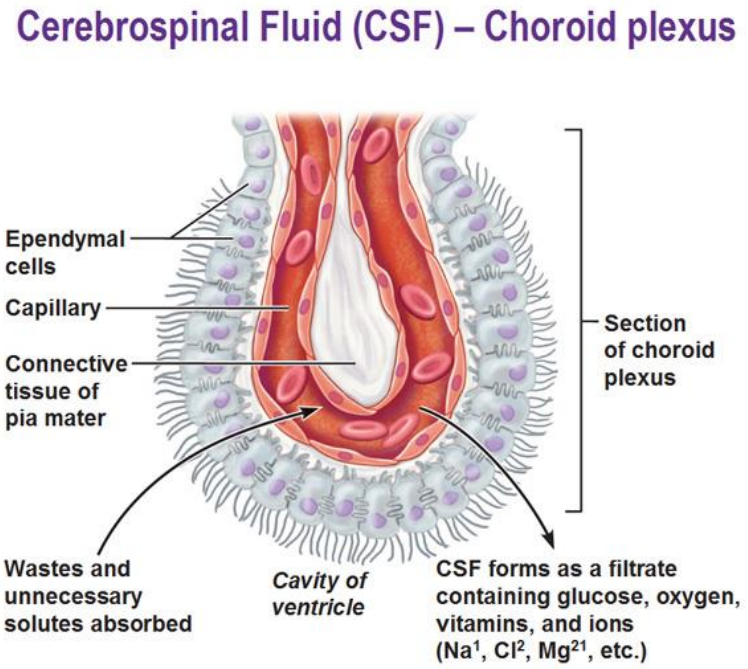
- Under the normal conditions the CSF contains from 1 to 5 blood formative elements in 1 mm^3 (usually lymphocytes).
- Total amount of CSF in an adult is about 140 ml.
- About 0,35 ml/min of CSF is produced.
- During 24 hours is produced about 400 to 500 ml of CSF.
- Every 6 hours the CSF is renewed.
- The CSF should not contain blood.

Origin of the CSF



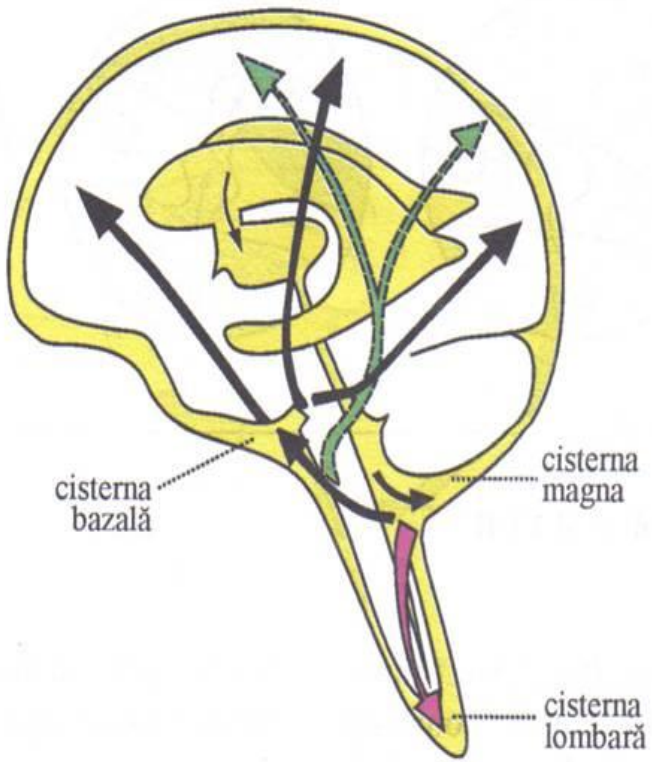
- About 60-70% of the total amount of the CSF is produced by the choroid plexuses of the ventricles of the brain.
- The remaining 30-40% of CSF is of extraplexual origin.

THE MECHANISM OF CSF SECRETION



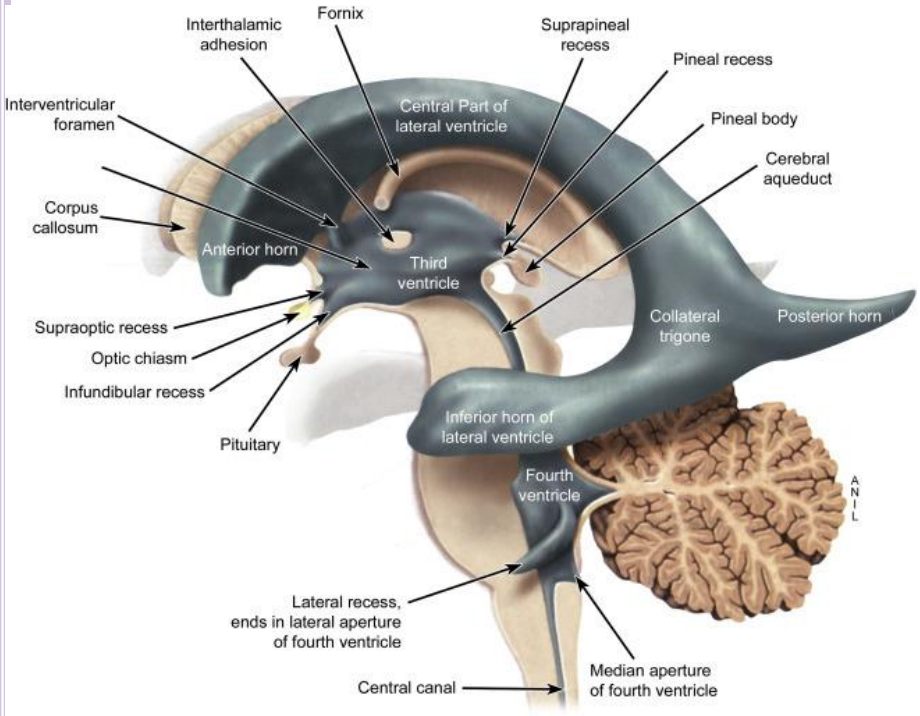
- Some components of the CSF pass from the blood plasma by diffusion method (water).
- By active mechanisms, from the blood plasma are transported the most amount of ions.

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



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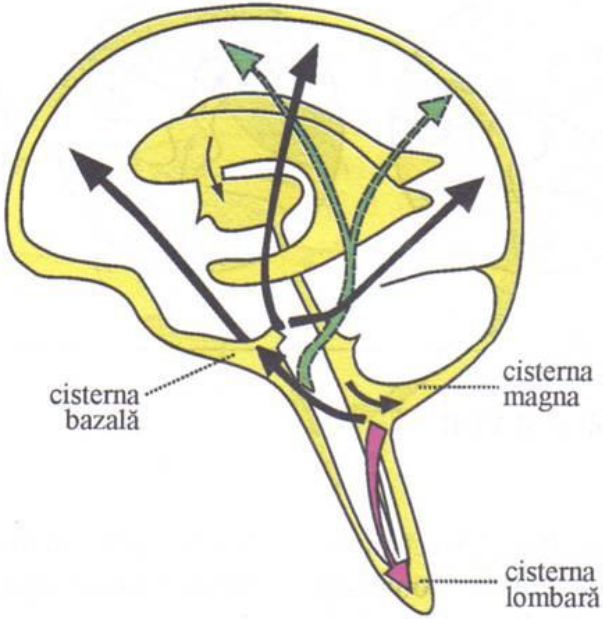
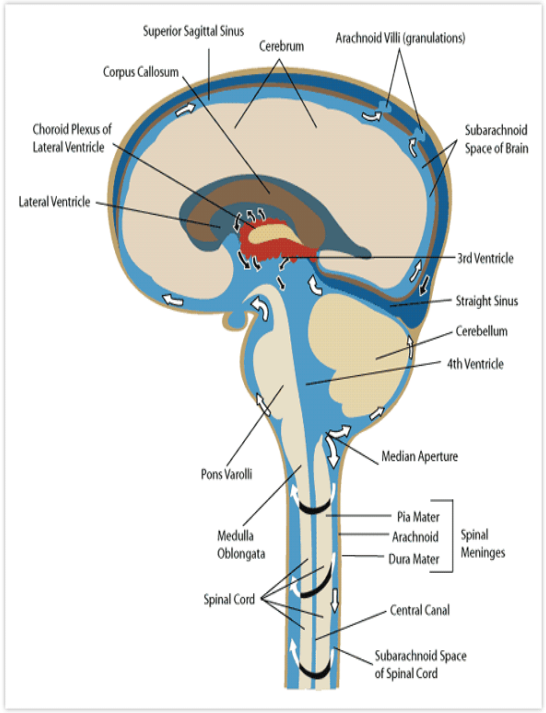
- **From the lateral ventricle** (through the interventricular orifices the fluid enters the third ventricle.
- **From the third ventricle** through the aqueduct of the brain it passes into the fourth ventricle.
- **From the fourth ventricle** through the lateral and median appertures the CSF is transported into the subarachnoid space and then it is drained into the sinuses of the dura mater.

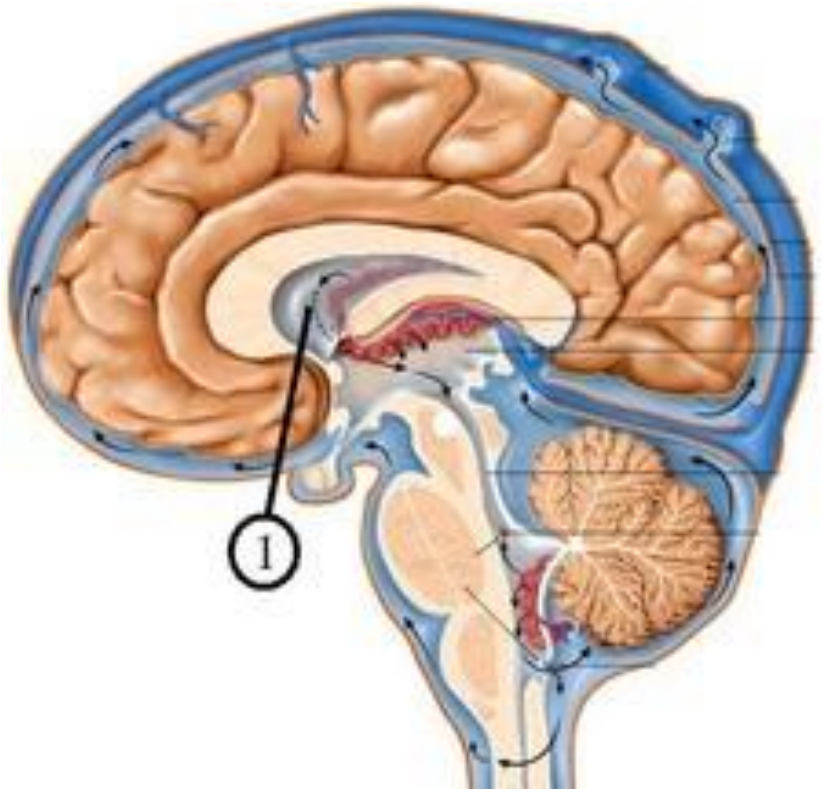




From the cerebello-medullary cistern the CSF runs into two directions:

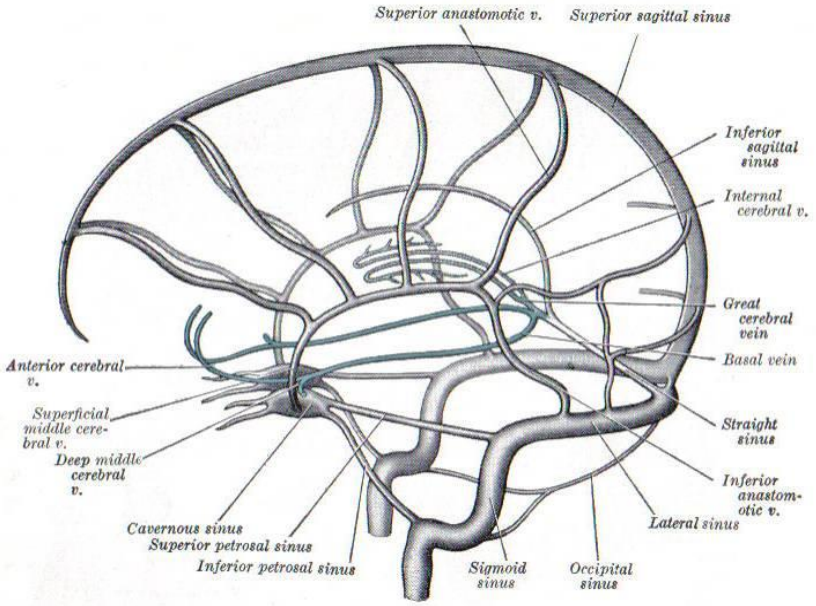
1. Towards the subarachnoid space of the spinal cord.
2. Towards the subarachnoid space of the brain and then into the venous sinuses.

FACTORS THAT INFLUENCE THE CIRCULATION OF THE CSF



1. Pulsation of the arteries
2. Breathing
3. Physical effort
4. Pressure
5. Cough

Drainage of the CSF

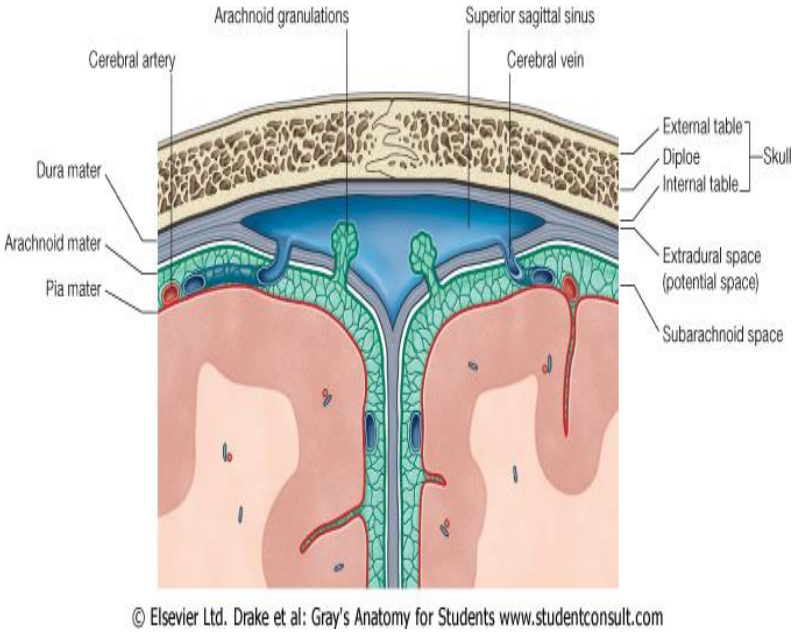


- Secretion and drainage of the CSF occurs permanently.
- The total amount of fluid is constant.
- Its drainage occurs:

a) by means of venous way;

b) by secondary ways.

THE VENOUS WAY OF DRAINAGE



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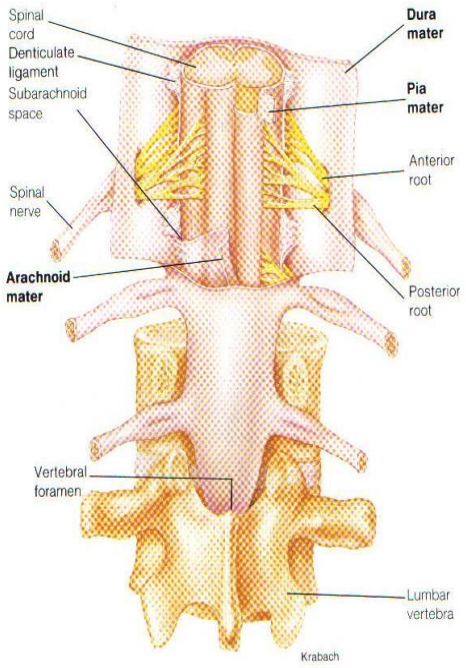
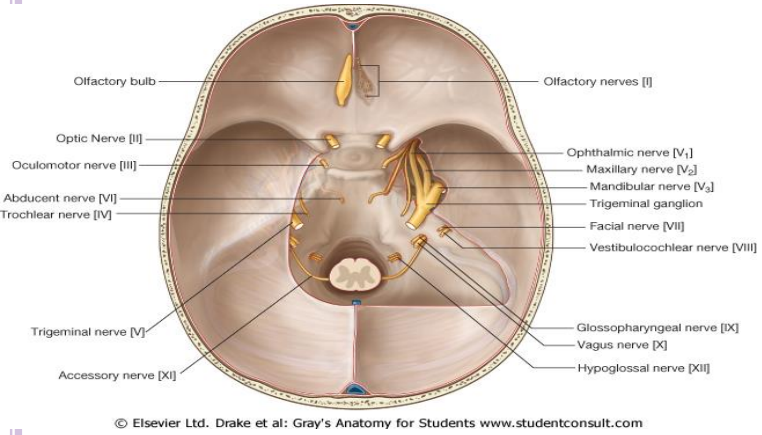
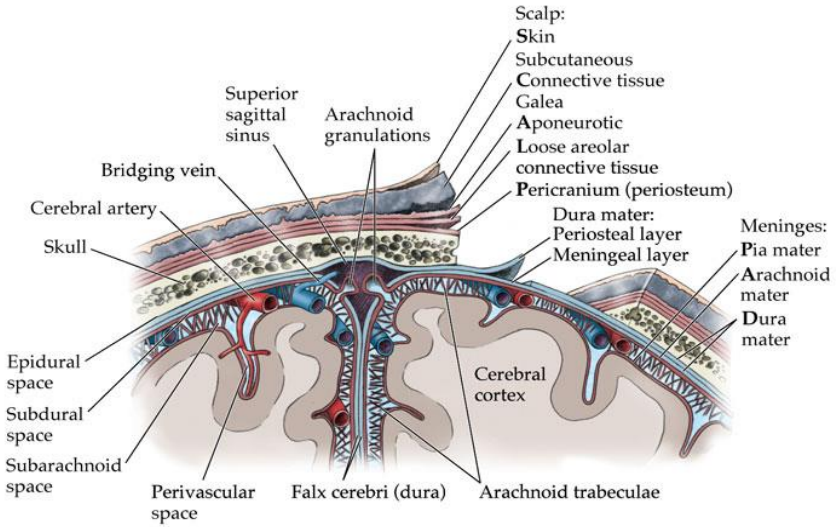
1. Reabsoption of the CSF.
2. Through the granulations of the arachnoidea.
3. CSF is transported by the neurothelial cells, that discharge it into the venous blood.

SECONDARY WAYS OF DRAINAGE OF THE CSF



- Reabsoption of the CSF along the nervous sheath of the spinal and cranial nerves.
- Reabsoption at the level of the cortex capillaries.
- Reabsoption 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 50 gr, instead of real weight 1400 gr.

b) Fixation of the brain is assured by the blood vessels, nerves and trabeculae 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.

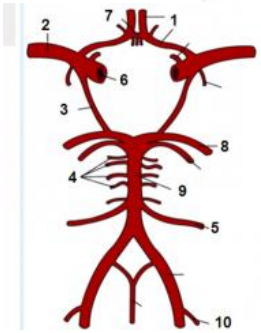
EXCRETORY FUNCTION

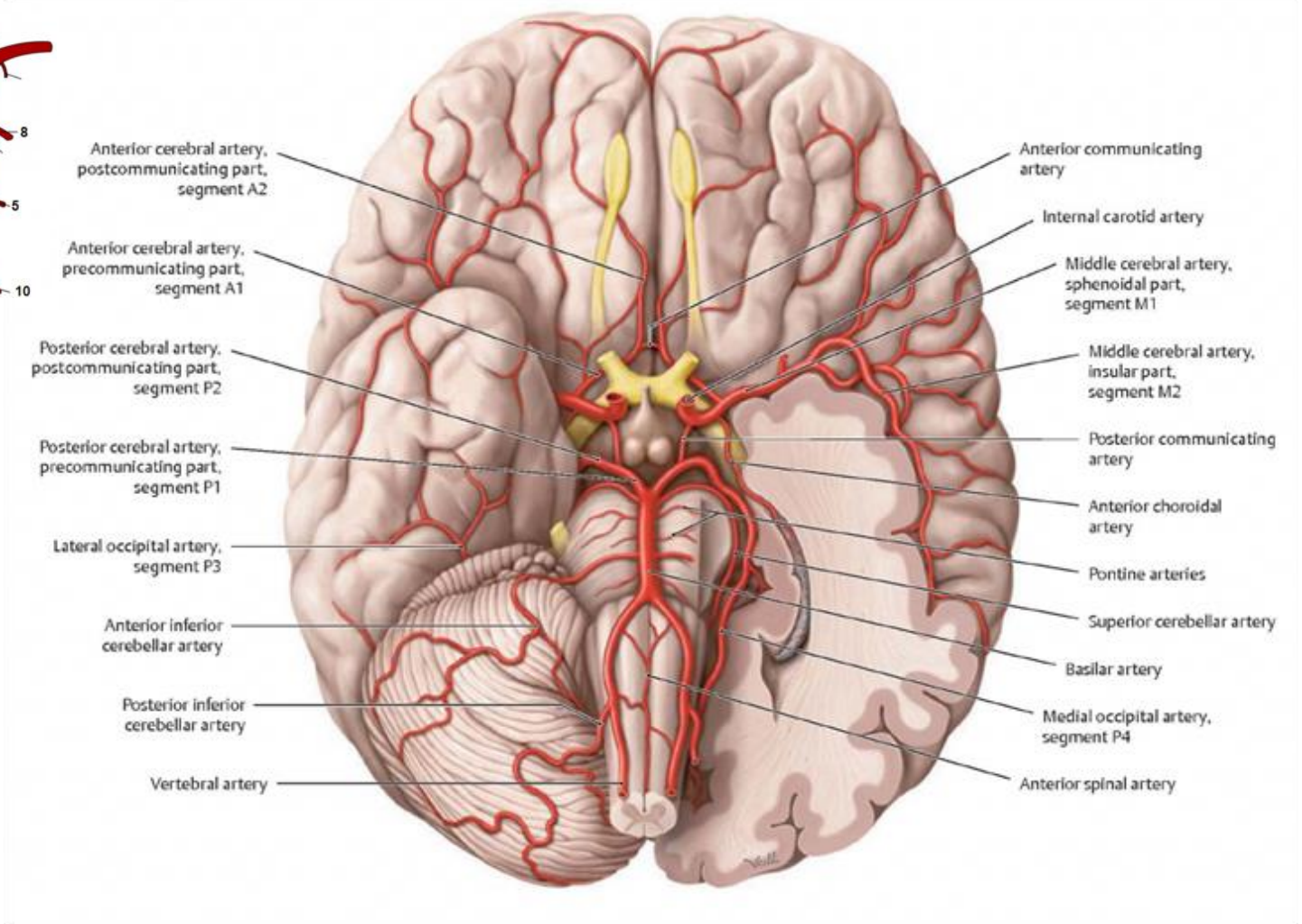
Through the CSF are removed the:

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

BLOOD SUPPLY OF THE BRAIN

Circulus arteriosus Willis and Zacharcenko





Barriers

- Blood – Brain barrier
- Blood – CSF barrier
- Brain – blood barrier

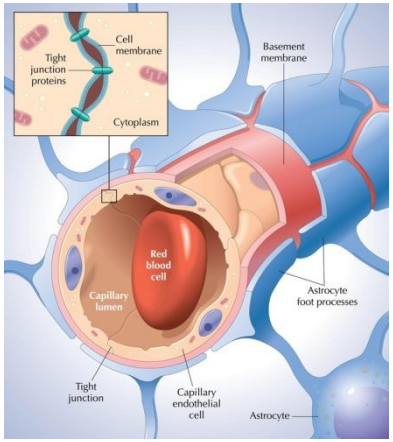
THE BLOOD–BRAIN BARRIER

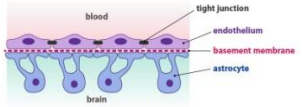
- The blood–brain barrier, or haematoencephalic barrier forms along the capillaries of the brain on the external surface of which are placed the astrocyte foot processes.
- The wall of the capillaries consists of a basement membrane lined with endothelial cells.
- Peculiarities of the endothelial cells:

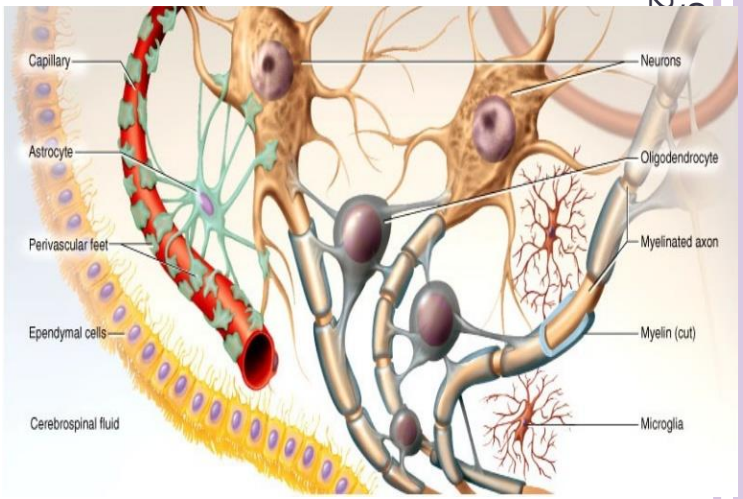
a) there are tight junctions around the capillaries with an extremely high electrical resistivity.

b) presence of big amount of mitochondria, without pinocytosis *vesicles* (a relative lack of transcytotic vesicular transport).

c) the endothelial cells actively transport across the barrier metabolic products such as glucose with specific proteins, insulin, amino acids, oxygen, and anaesthetic drugs (lipid soluble).







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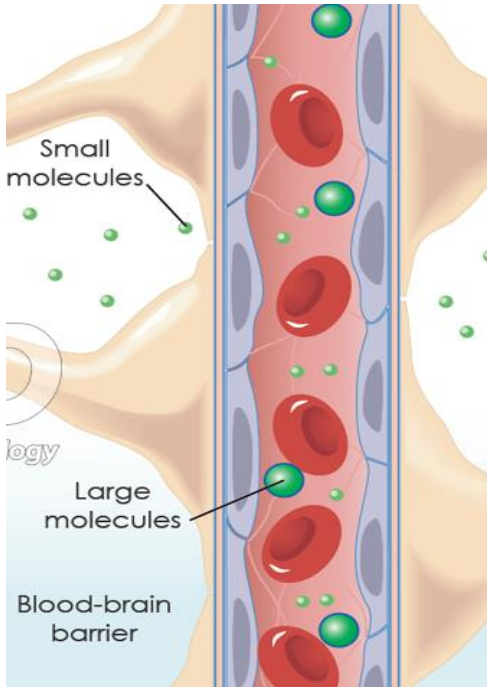
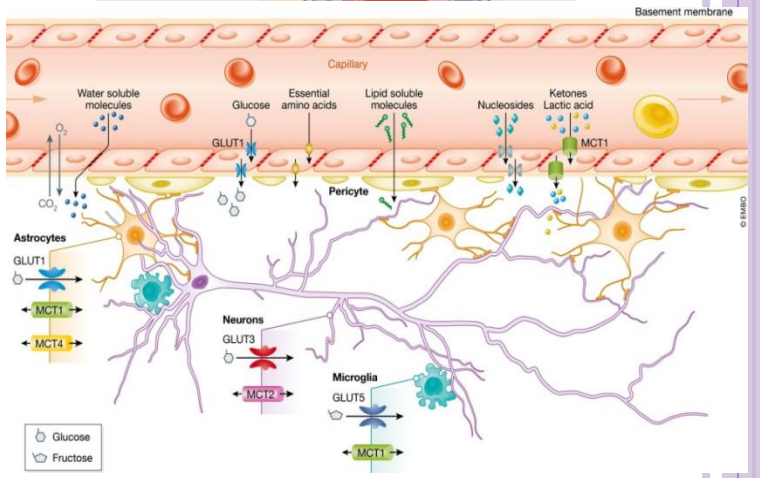
THE BLOOD-BRAIN BARRIER

- The **blood–brain barrier** (**BBB**) is a highly selective permeability barrier.
- It 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 HEB 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.

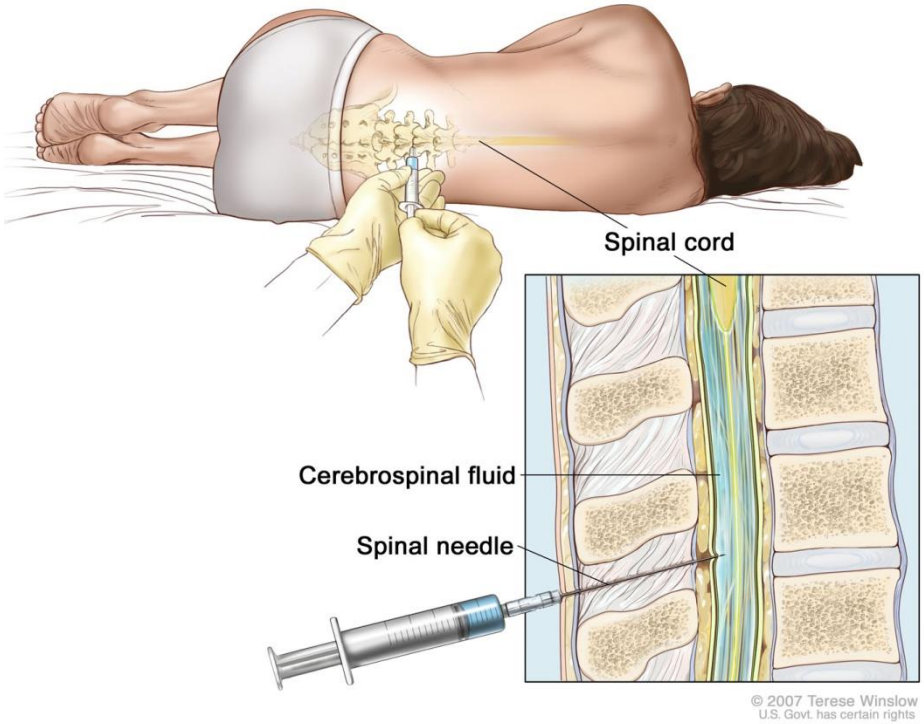




Methods of examination of the spinal cord and cranial meninges

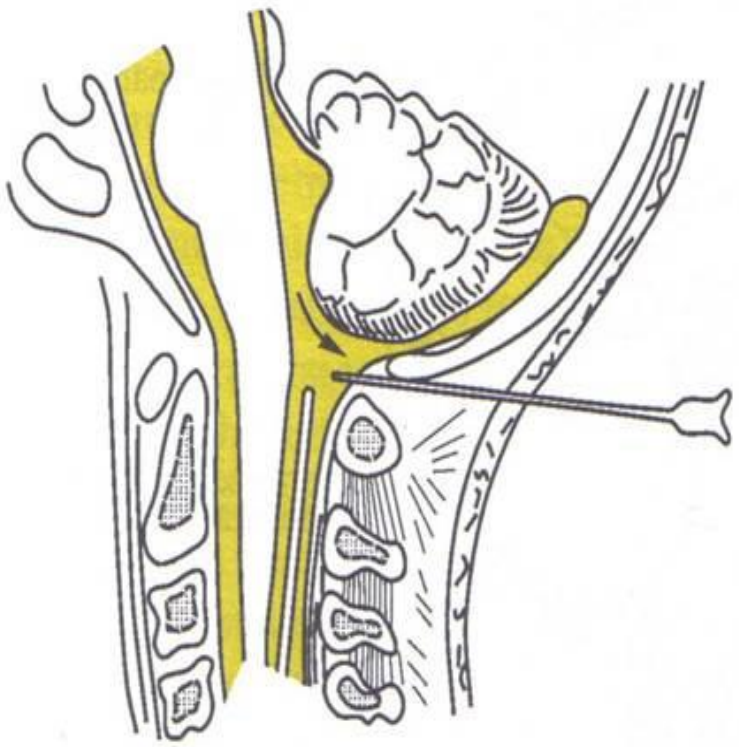
- Lumbar puncture.
- Puncture of the cerebello-medullary cistern
- Ventriculography with contrast medium (radioactive sodium).
- Secretion into the subarachnoid space of colloidal fluid that contains radioactive gold.
- Pneumoencephalography.
- CT and MRI.

Lumbar puncture



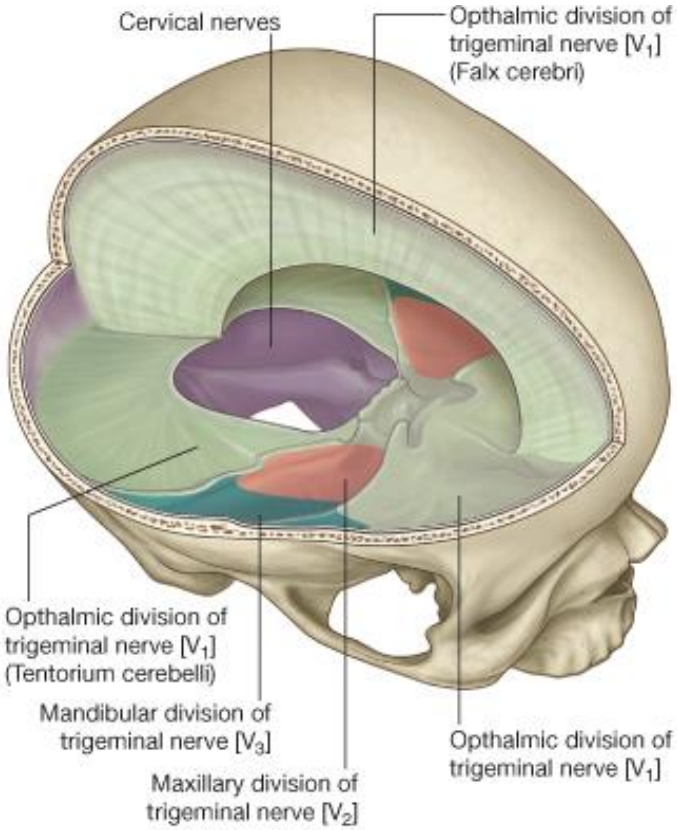
- Between the L3 and L4 vertebrae.

PUNCTURE OF THE CEREBELLO-MEDULLARY CISTERN



Between the occipital bone and edges of the posterior arch of the atlas.

INNERVATION OF THE DMB



- Sensory innervation is assured by the meningeal branches of the:
  1. Trigeminal nerve;
  2. Vagus nerve,
  3. First spinal nerve.

- ***B. Z. Perlin's*** research proved that the hypoglossal nerve, the accessory and especially the superior cervical spinal nerves as well supply sensory branches to the dura mater of the brain.

- B. Z. Perlin –was the Head of the Human Anatomy Department (1959-1987).

Development of the meninges

- **The dura mater** develops from the mesenchyma, which surrounds the primary nervous tube.

- The **arachnoidea** and **pia mater** are of ectodermal origin and develop from the neural crest.

AGE PECULIARITIES OF THE DURA MATER

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

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

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