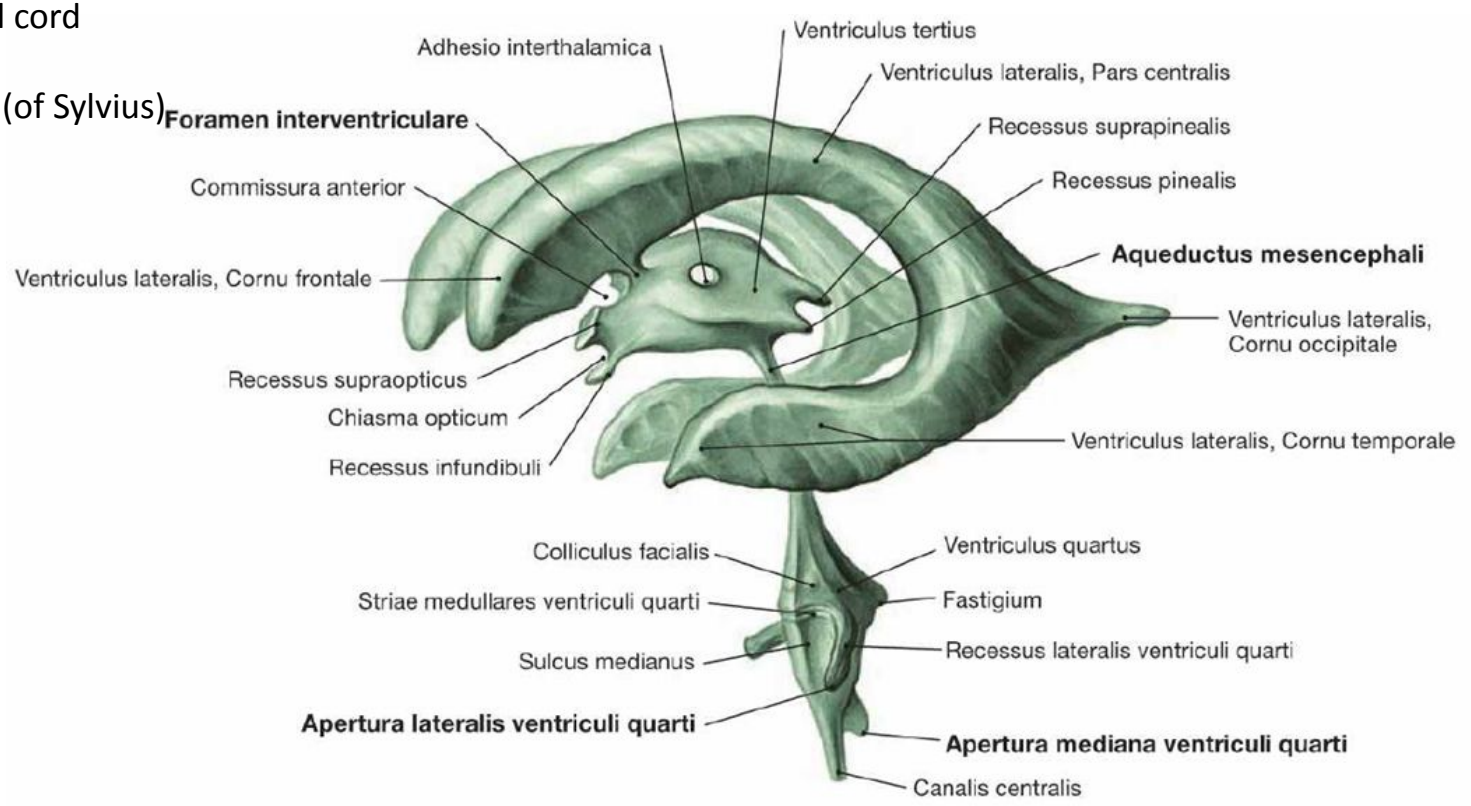
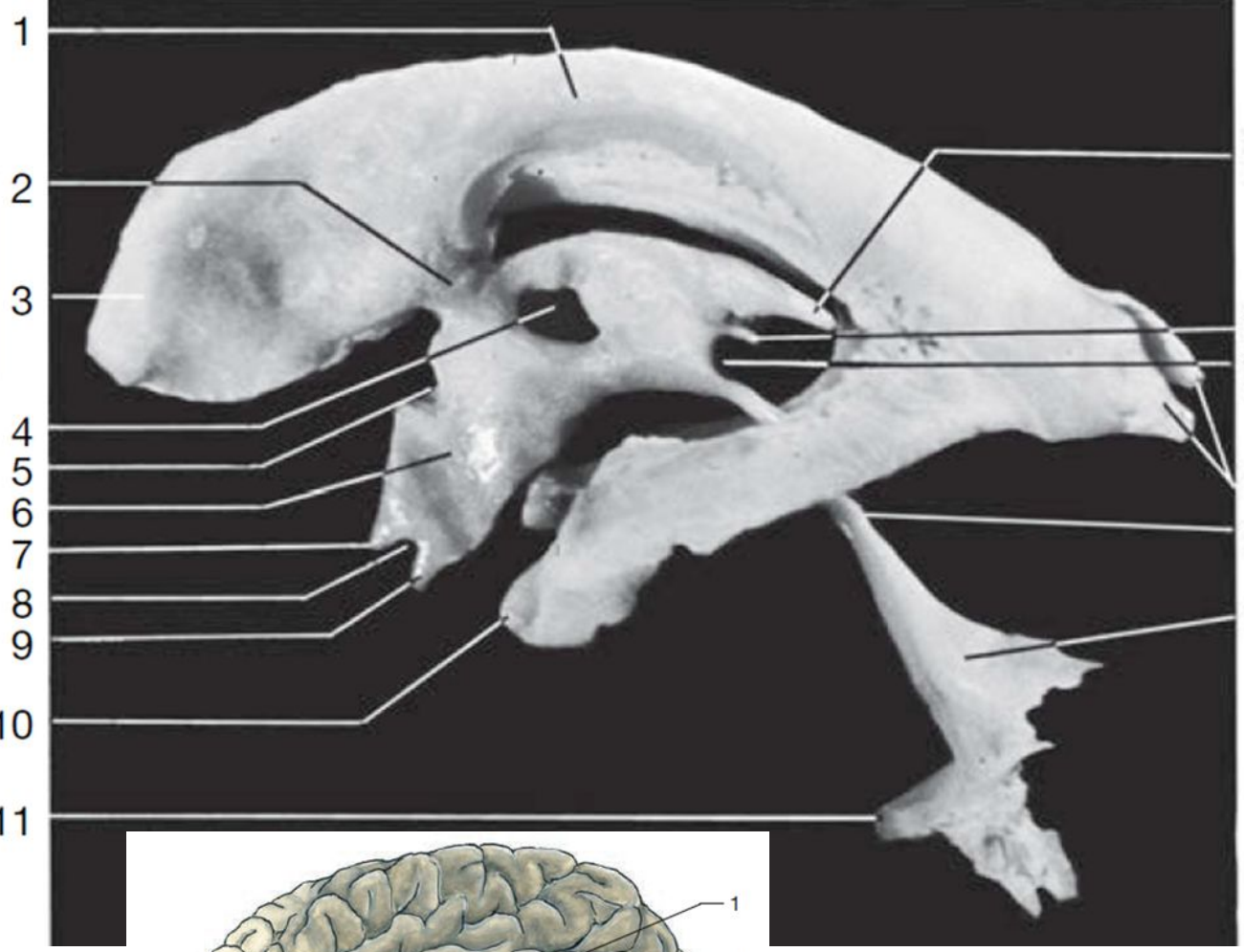
CNS VENTRICULAR SYSTEM

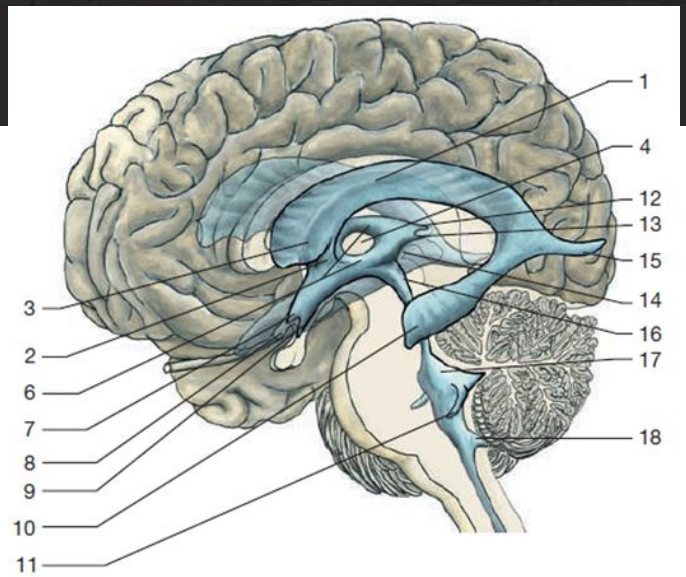
- cerebrospinal fluid
  - in the subarachnoid space of the CNS (external cerebrospinal fluid space)
  - in the cavities of the CNS (internal cerebrospinal fluid space)
  - communication between the internal and external spaces via openings in the fourth ventricle
  - originates from the choroid plexus
- the ventricles and central canal are lined by ependymal cells
  - the roof and part of the walls are formed by the choroid plexus (ependym + pia mater)
- choroid plexus
  - vascular plexuses in the choroid plexus produce cerebrospinal fluid
  - in the roof of the third and fourth cerebral ventricles
  - in the central part, in the temporal horn, and in the atrium (glomus choroideum) of the lateral ventricles

- central canal of the spinal cord
- fourth ventricle
- mesencephalic aqueduct (of Sylvius)
- third ventricle
- lateral ventricles
- circumventricular organs





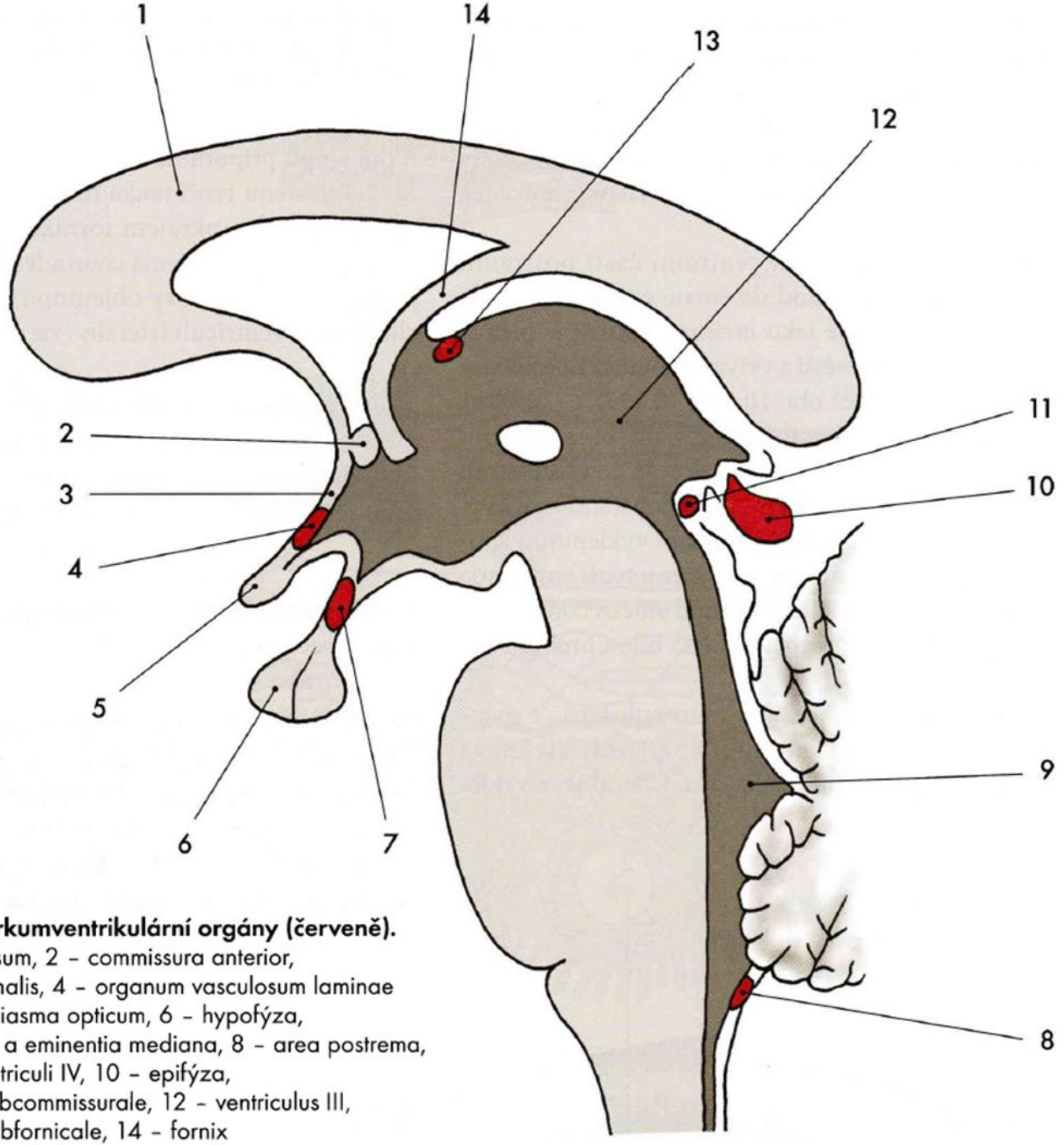
1 Central part of the lateral ventricle
2 Interventricular foramen of Monro
3 Anterior horn of the lateral ventricle
4 Site of interthalamic adhesion
5 Notch for anterior commissure
6 Third ventricle
7 Optic recess
8 Notch for optic chiasma
9 Infundibular recess
10 Inferior horn of lateral ventricle with indentation of amygdaloid body
11 Lateral recess and lateral aperture of Luschka
12 Suprapineal recess
13 Pineal recess
14 Notch for posterior commissure
15 Posterior horn of lateral ventricle
16 Cerebral aqueduct
17 Fourth ventricle
18 Median aperture of Magendie



VENTRICULAR SYSTEM

- fourth ventricle
  - between the brainstem and the cerebellum
  - floor – rhomboid fossa, laterally the peduncles; roof – superior medullary velum, cerebellum (curvature of the roof = fastigium), inferior medullary velum with openings for cerebrospinal fluid drainage (median opening = foramen of Magend, lateral openings = foramina of Luschka)
- aquaeductus mesencephali
  - connects the third and fourth ventricles, at the junction of the tectum and tegmentum
- ventriculus tertius
  - a cleft in the diencephalon
  - laterally the thalamus (interthalamic adhesion) and hypothalamus, floor – right and left halves of the hypothalamus, opposite the optic chiasm is the optic recess, opposite the pituitary gland is the infundibular recess, opposite the pineal gland are the pineal and suprapineal recesses, anteriorly the terminal lamina with the anterior commissure, roof – choroid bodies of the third ventricle (with the plexus attaching to the stria medullaris thalami)
  - foramen interventriculare
- ventriculi laterales
  - frontal horn – medially the septum pellucidum, laterally the head of the caudate nucleus, the roof of the corpus callosum
  - central part – from the interventricular foramen to the posterior margin of the thalamus, laterally the body of the caudate nucleus, the roof of the corpus callosum, medially the choroid plexus
  - atrium – choroid plexus
  - occipital horn – medially, the calcar avis (calcarine sulcus), the floor of the lateral eminence (lateral sulcus), laterally, the white matter of the hemisphere
  - temporal horn – the roof of the caudate nucleus, laterally, the lateral eminence, the floor of the hippocampus, medially, the choroid plexus
- circumverntricular organs
  - group of specialized midline structures located around the third and fourth ventricles of the brain
  - **absence of a traditional blood-brain barrier (BBB)** – a result of having fenestrated capillaries that allow for direct communication between the bloodstream, the brain parenchyma, and the cerebrospinal fluid (CSF) (Benarroch, 2011; Ganong, 2000).

CIRCUMVENTRICULAR ORGANS



Obr. 10.138. Cirkumventrikulární orgány (červeně).
1 – corpus callosum, 2 – commissura anterior,
3 – lamina terminalis, 4 – organum vasculosum laminae terminalis, 5 – chiasma opticum, 6 – hypofýza,
7 – infundibulum a eminentia mediana, 8 – area postrema,
9 – fastigium ventriculi IV, 10 – epifýza,
11 – organum subcommissurale, 12 – ventriculus III,
13 – organum subfornicale, 14 – fornix

CIRCUMVENTRICULAR ORGANS

The sources classify CVOs into two main functional groups:

- **Sensory CVOs:** These act as "windows" for the brain to monitor circulating signals. They include the **subfornical organ (SFO)**, the **organum vasculosum of the lamina terminalis (OVLT)**, and the **area postrema (AP)** (Benarroch, 2011; Kaur & Ling, 2017).
- **Secretory CVOs:** These are specialized for releasing hormones and glycoproteins into the blood or CSF. They include the **neurohypophysis (posterior pituitary)**, the **median eminence**, and the **pineal gland** (Duvernoy & Risold, 2007; Kaur & Ling, 2017).
- **Note on the Subcommissural Organ (SCO):** Although historically grouped with CVOs, the SCO is unique because its capillaries are not fenestrated, meaning it **possesses a functional blood-brain barrier** (Ganong, 2000; Duvernoy & Risold, 2007). Its primary role is the secretion of SCO-spondin to form **Reissner's fiber** in the CSF (Kaur & Ling, 2017).

CVOs are essential for integrating autonomic, endocrine, and immune responses:

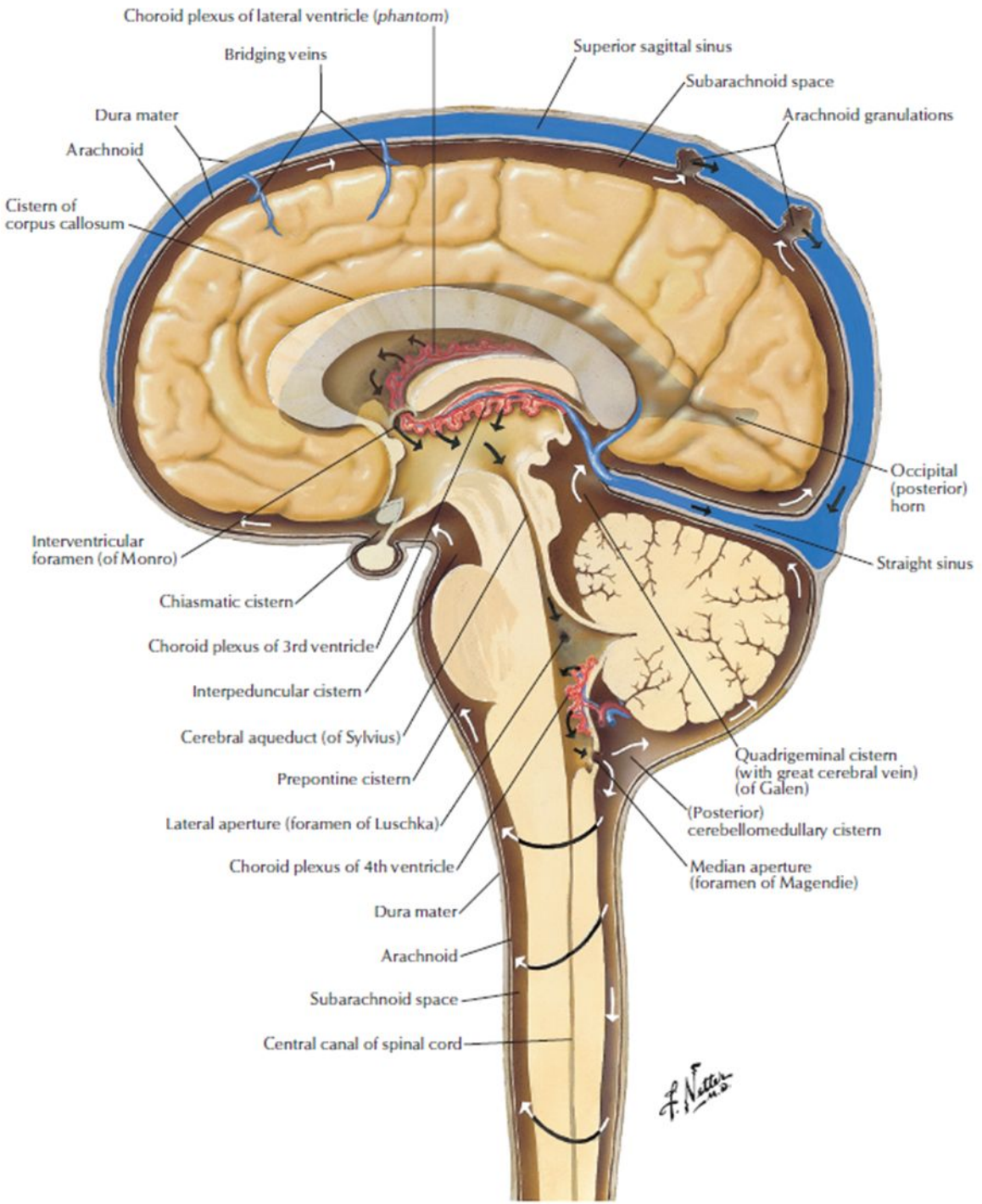
- **Fluid and Sodium Balance:** The SFO and OVLT are primary centers for **thirst and osmoregulation** (Benarroch, 2011). They respond to serum osmolarity and circulating **angiotensin II** via specific AT1 receptors to trigger salt appetite and the release of vasopressin (Benarroch, 2011; Kaur & Ling, 2017).
- **Cardiovascular Regulation:** The SFO and AP help regulate blood pressure. For instance, activation of the AP by angiotensin II can reset the baroreflex to a higher blood pressure level (Benarroch, 2011).
- **Energy Metabolism:** Sensory CVOs detect humoral **satiety signals**, such as glucose, leptin, amylin, and ghrelin, to regulate food intake (Kaur & Ling, 2017).
- **Vomiting Reflex:** The area postrema serves as a **chemoreceptor trigger zone**, detecting toxins in the blood and triggering the emetic reflex (Kaur & Ling, 2017).
- **Immune Monitoring:** CVOs monitor systemic inflammation. Interleukin-6 and other cytokines can act on the OVLT to induce the **febrile response (fever)** (Benarroch, 2011).

Clinical and Evolutionary Insights

- **Neuromyelitis Optica (NMO):** This autoimmune disease targets **aquaporin-4 (AQP4)** channels, which are highly concentrated in CVO astrocytes (Benarroch, 2011). Involvement of the area postrema in NMO often results in **intractable nausea and vomiting** (Benarroch, 2011; Kiecker, 2018).
- **Pathogen Entry:** Because they lack a BBB, CVOs are potential **entry points for microorganisms** (like *Trypanosoma brucei*), prion proteins, and autoantibodies into the central nervous system (Benarroch, 2011).
- **Developmental Origins:** Current research indicates that CVOs are a heterogeneous group that likely **emerged independently in evolution** (homoplasy) rather than from a shared genetic origin (Kiecker, 2018). While they share traits like specialized glia called **tanycytes**, no single "master regulator" gene has been found for all CVOs (Kiecker, 2018).

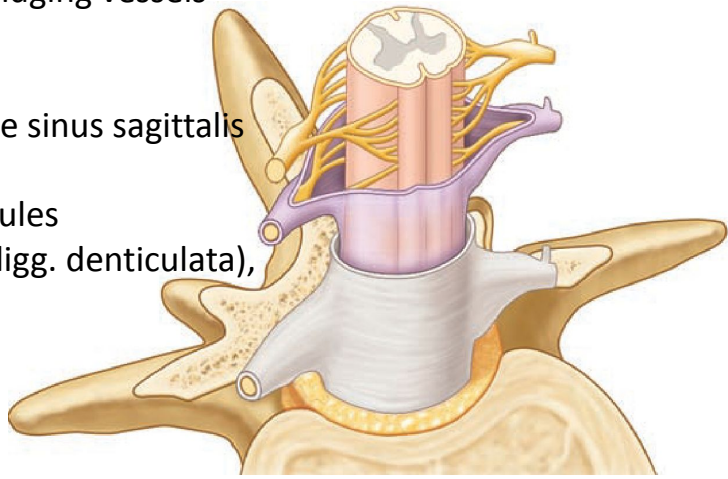
Benarroch, E. E. (2011). Circumventricular organs: Receptive and homeostatic functions and clinical implications. *Neurology*, 77(12), 1198-1204.
Duvernoy, H. M., & Risold, P. Y. (2007). The circumventricular organs: An atlas of comparative anatomy and vascularization. *Brain Research Reviews*, 56(1), 119-147.
Ganong, W. F. (2000). Circumventricular organs: Definition and role in the regulation of endocrine and autonomic function. *Clinical and Experimental Pharmacology and Physiology*, 27(5-6), 422-427.
Kaur, C., & Ling, E. A. (2017). The circumventricular organs. *Histology and Histopathology*, 32, 879-892.
Kiecker, C. (2018). The origins of the circumventricular organs. *Journal of Anatomy*, 232(4), 540-553.

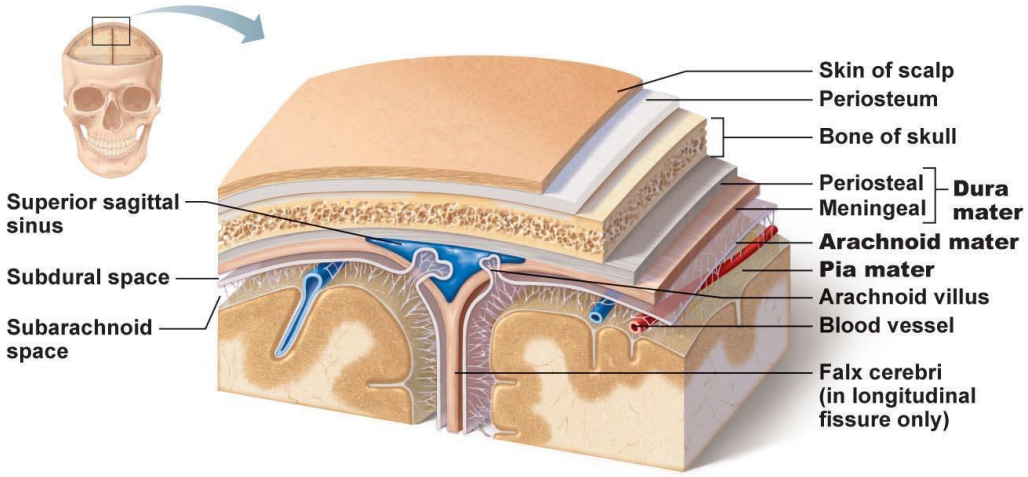
LIQUOR CIRCULATION



MENINGES

- dura mater cranialis/spinalis
  - endosteal/endorhachis
  - sinus durae matris + cavitas tirgeminalis/spatium epidurale (adipose connective tissue + plexus venosi vertebrales interni anteriores et posteriores)
  - meningeal/saccus durae matirs
- spatium subdurale
  - It results from the accumulation of blood following the rupture of bridging vessels (most commonly superficial veins into the dural sinuses)
- arachnoidea
  - granulationes arachnoideae (Pacchini) protruding to the lumen of the sinus sagittalis superior
- spatium subarachnoideum (external cerebrospinal fluid space) with trabecules
  - cisterny/dorsal (dorsal septum septum – septum posticum), lateral (ligg. denticulata), ventral section
- pia mater
  - adheres firmly to brain/spinal cord tissue





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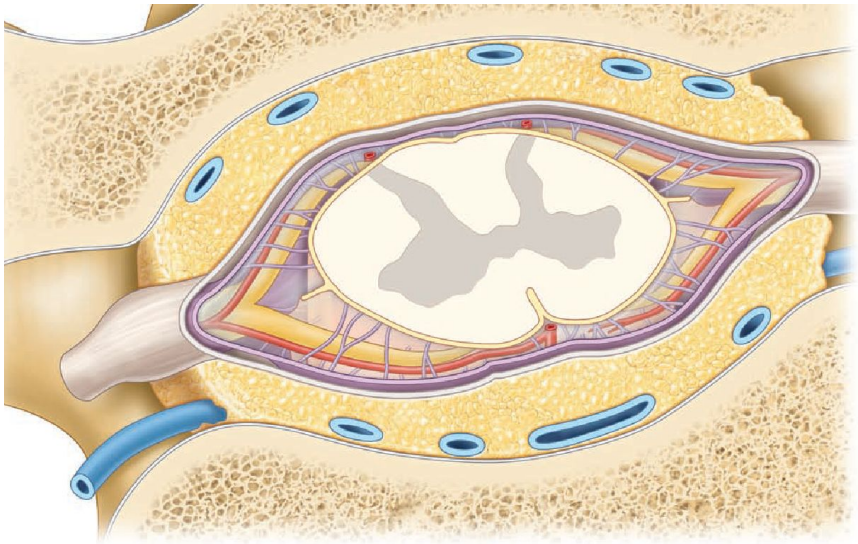
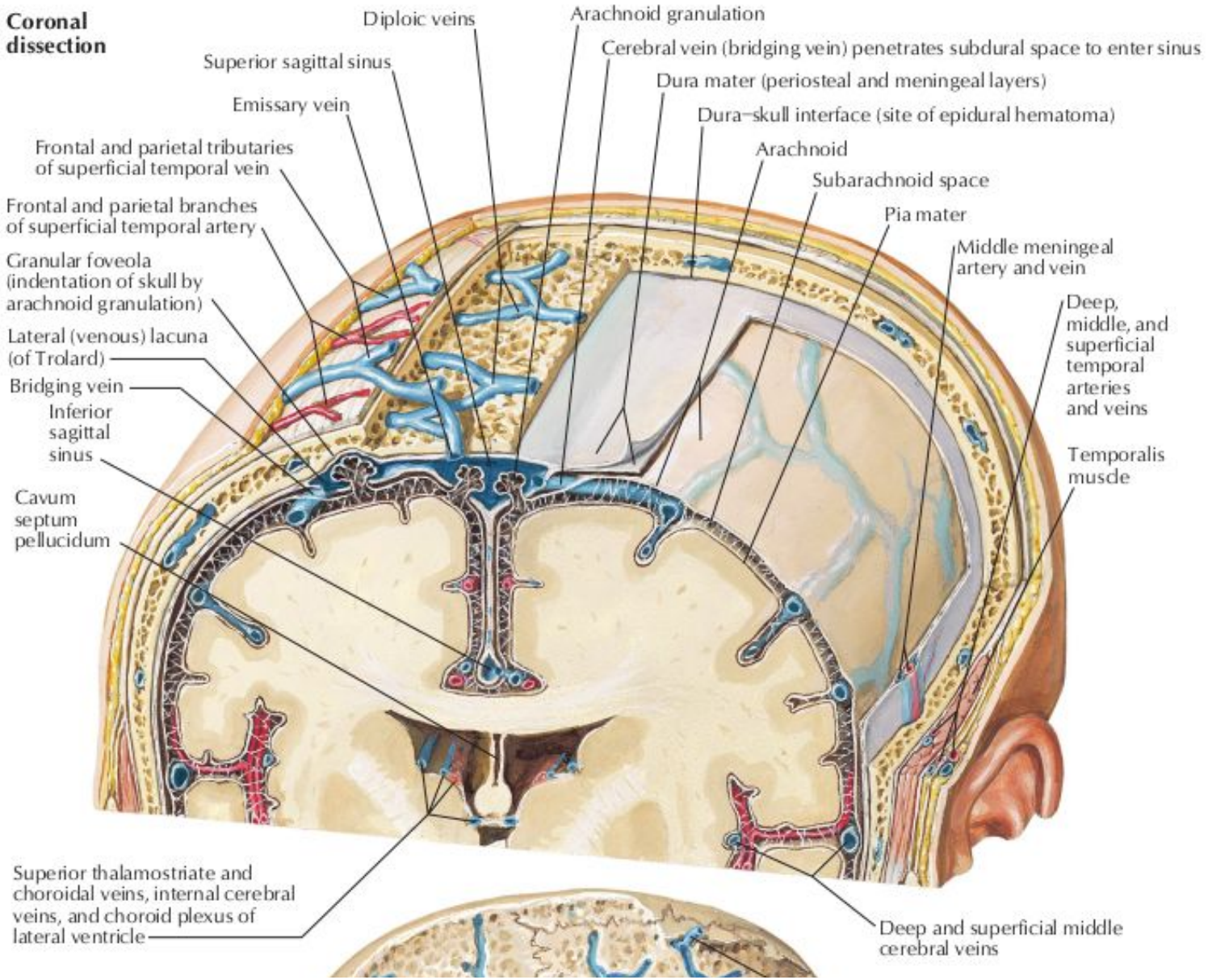
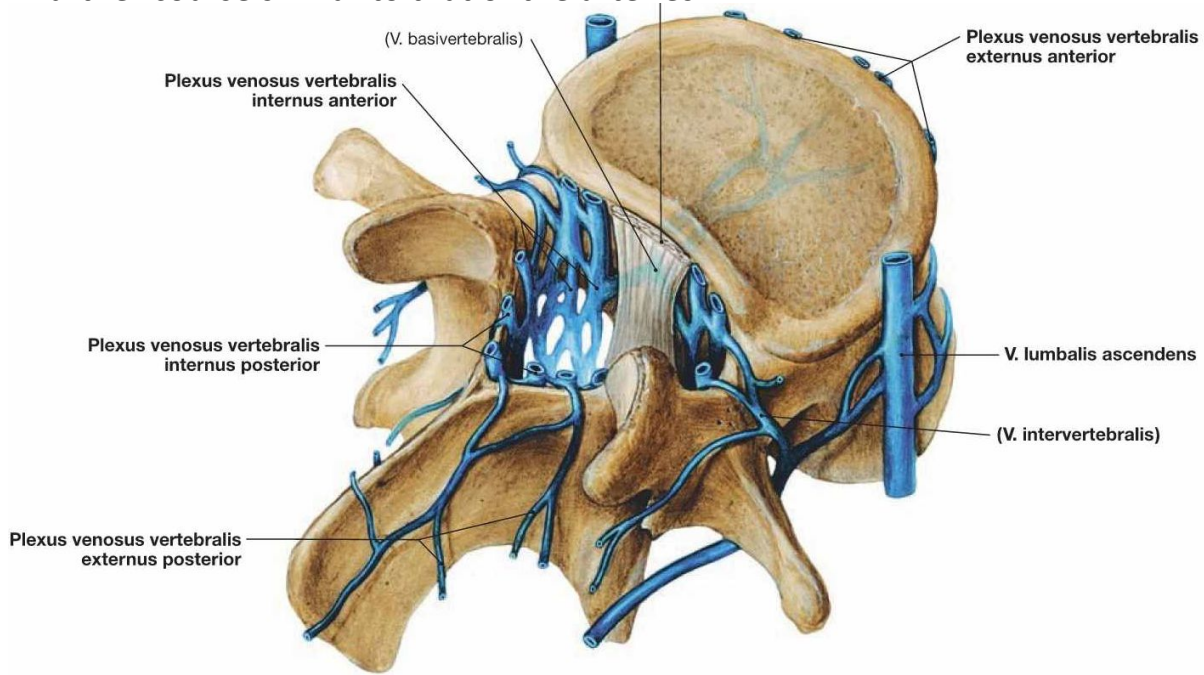


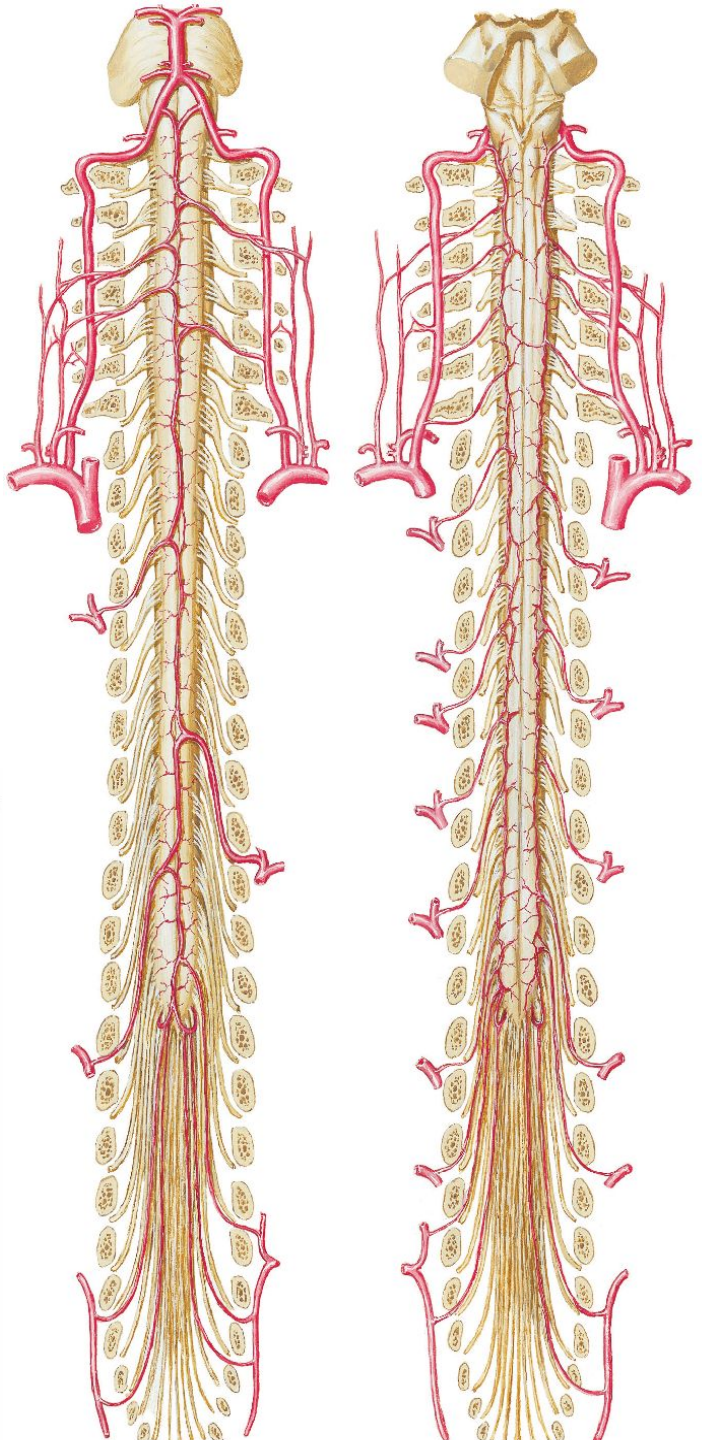

Coronal dissection
Diploic veins
Arachnoid granulation
Cerebral vein (bridging vein) penetrates subdural space to enter sinus
Superior sagittal sinus
Dura mater (periosteal and meningeal layers)
Emissary vein
Dura–skull interface (site of epidural hematoma)
Frontal and parietal tributaries of superficial temporal vein
Arachnoid
Subarachnoid space
Frontal and parietal branches of superficial temporal artery
Pia mater
Middle meningeal artery and vein
Granular foveola (indentation of skull by arachnoid granulation)
Deep, middle, and superficial temporal arteries and veins
Lateral (venous) lacuna (of Trolard)
Bridging vein
Inferior sagittal sinus
Temporalis muscle
Cavum septum pellucidum
Superior thalamostriate and choroidal veins, internal cerebral veins, and choroid plexus of lateral ventricle
Deep and superficial middle cerebral veins

BLOOD SUPPLY TO THE SPINAL CORD

- spinal arteries from the vertebral artery
  - run vertically
  - anterior (in the anterior median fissure)
  - two posterior (near the posterior spinal roots)
- segmental spinal arteries (radicular arteries) from the vertebral artery, ascending cervical artery, deep cervical artery, intercostal arteries, lumbar arteries, iliolumbar artery, and lateral sacral arteries
  - through the intervertebral foramen, through the spinal dura mater; they divide into anterior and posterior radicular arteries
  - form 4 to 9 functionally significant connections with vertical vessels (the largest being the a. spinalis magna Adamkiewiczi)

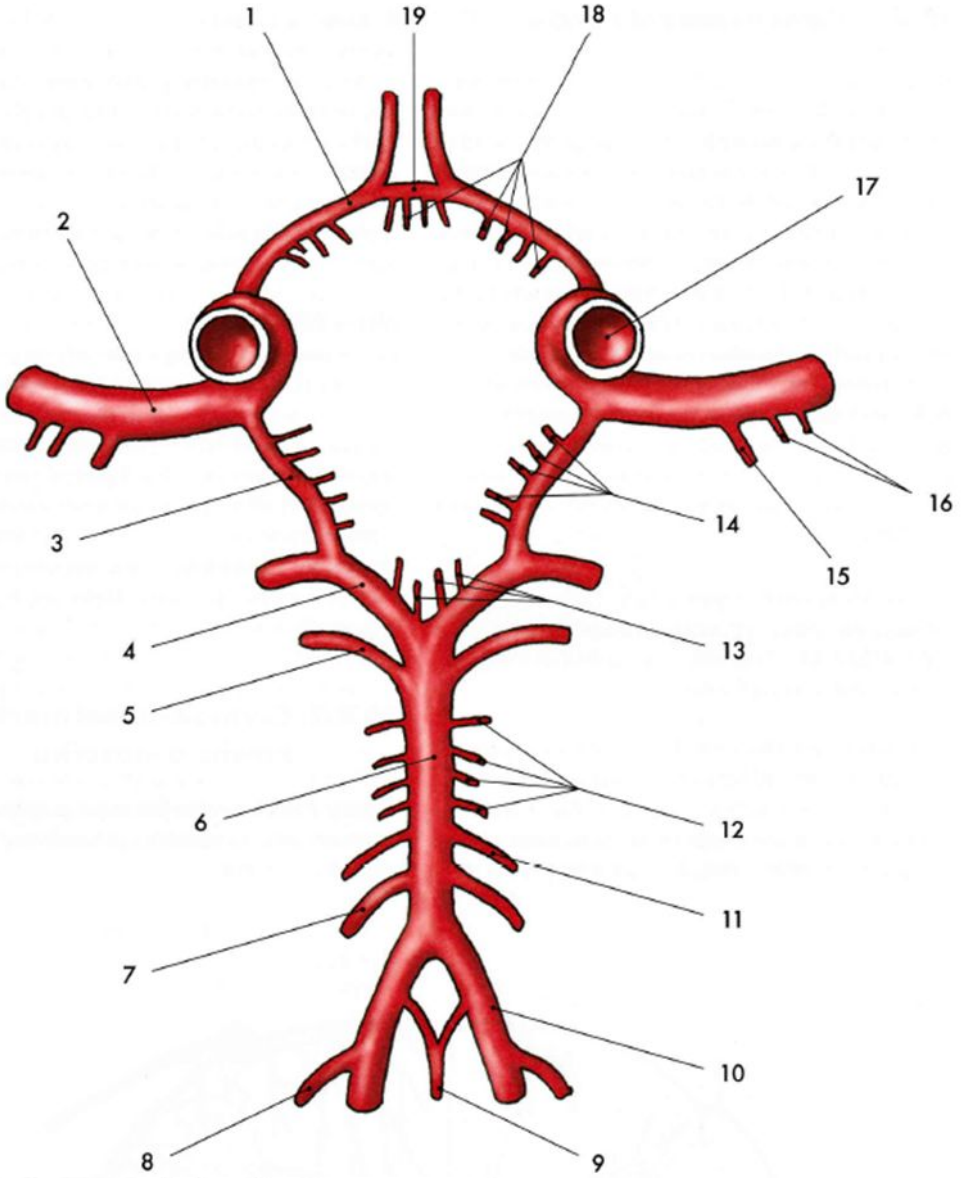
- veins from the pia mater to the epidural plexuses (plexus venosus vertebralis interni), from there to the p. v. v. externi
- further course similar to that of the arteries



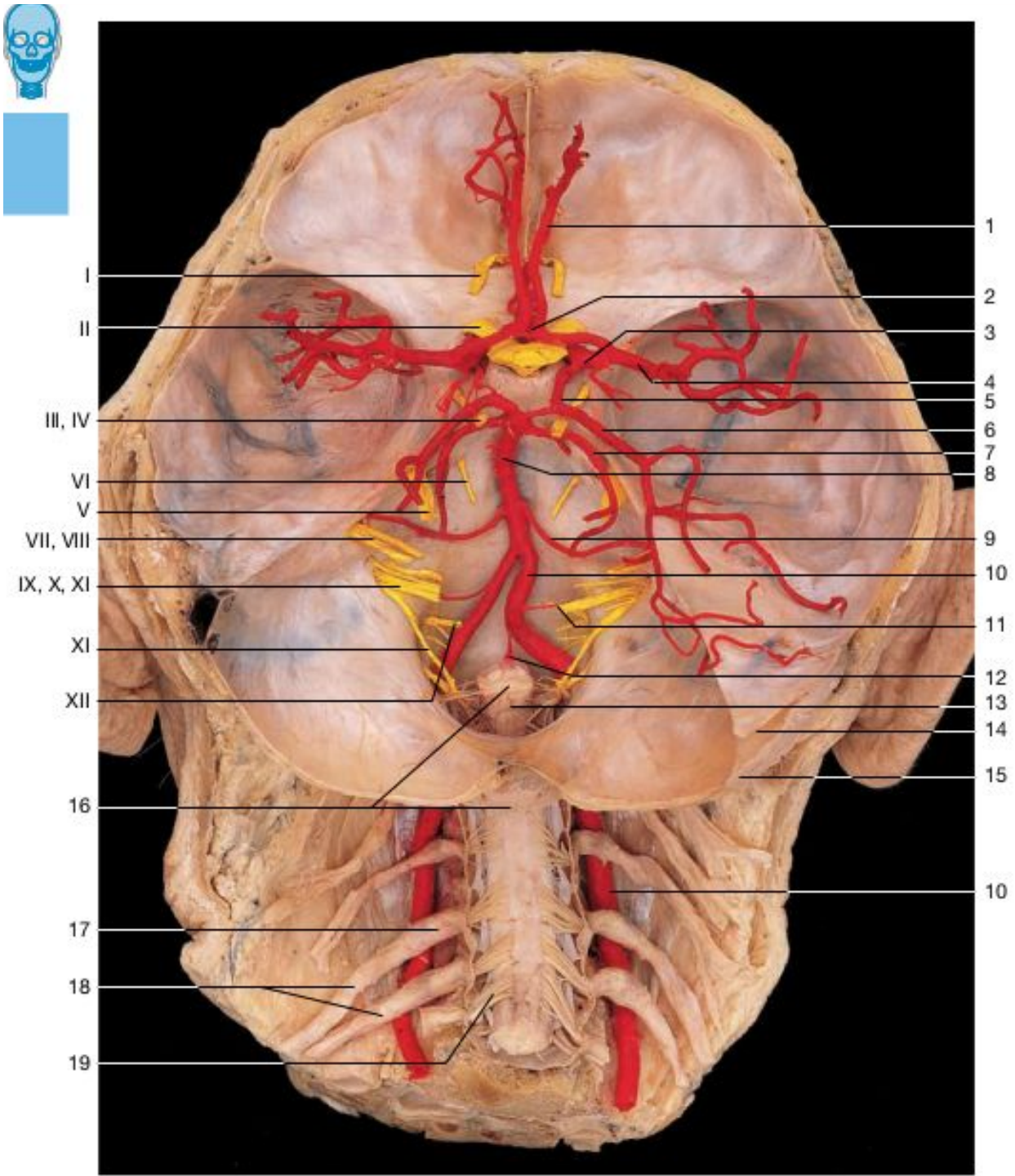


BLOOD SUPPLY TO THE BRAINSTAM, CEREBELLUM, AND CEREBRUM

- a. carotis interna
  - a. hypophysialis inferior
  - pro ggl. n. V.
  - a. cerebri anterior – a. communicans anterior
  - a. cerebri media
  - a. communicans posterior
- aa. vertebrales – a. basilaris
  - aa. medullares
  - aa. pontini
  - aa. cerebelli
  - aa. mesencephalicae
  - a. cerebri posterior – a. communicans posterior
- circulus arteriosus cerebri (Willisi)

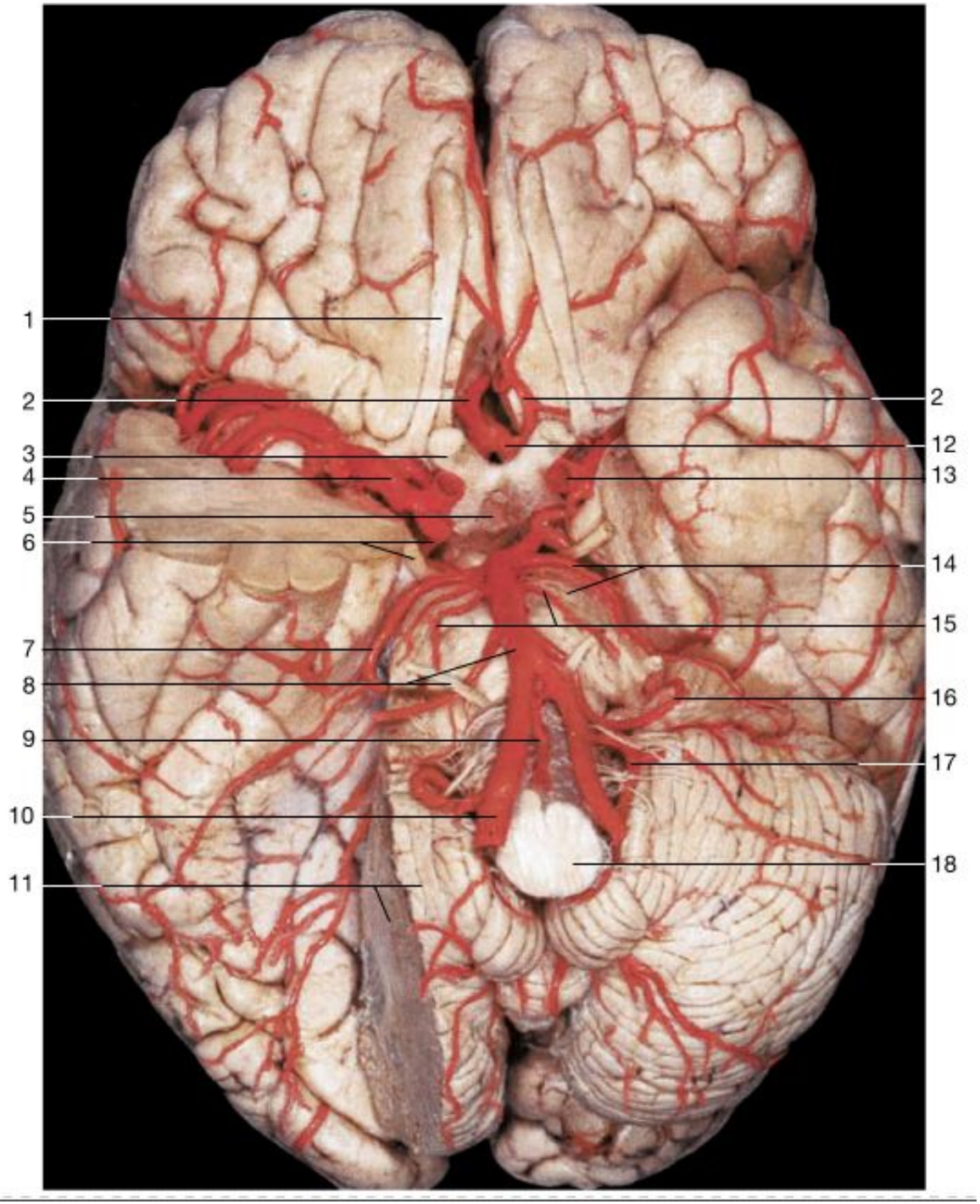


Obr. 10.145. Circulus arteriosus cerebri (Willisi). 1 – a. cerebri anterior, 2 – a. cerebri media, 3 – a. communicans posterior, 4 – a. cerebri posterior, 5 – a. cerebelli superior, 6 – a. basilaris, 7 – a. cerebelli inferior anterior, 8 – a. cerebelli inferior posterior, 9 – a. spinalis anterior, 10 – a. vertebralis, 11 – a. labyrinthi, 12 – aa. pontis et aa. mesencephalicae, 13 – aa. centrales posteromediales, 14 – aa. centrales posterolaterales, 15 – a. choroidea anterior, 16 – aa. centrales anterolaterales, 17 – a. carotis interna, 18 – aa. centrales anteromediales, 19 – a. communicans anterior



1 Anterior cerebral artery
2 Anterior communicating artery
3 Internal carotid artery
4 Medial cerebral artery
5 Posterior communicating artery
6 Posterior cerebral artery
7 Superior cerebellar artery
8 Basilar artery
9 Anterior inferior cerebellar artery with artery of the labyrinth
10 Vertebral artery
11 Posterior inferior cerebellar artery
12 Anterior spinal artery
13 Pia mater of spinal cord
14 Cerebellar tentorium
15 Dura mater of the cranial cavity
16 Spinal cord
17 Spinal ganglion
18 Spinal nerves (C_3, C_4)
19 Posterior root filaments (fila radicularia post.)
20 Ophthalmic artery (within the orbit)
21 Internal carotid artery (within carotid canal)

I = Olfactory tract
II = Optic nerve
III = Oculomotor nerve
IV = Trochlear nerve
V = Trigeminal nerve
VI = Abducent nerve
VII = Facial nerve
VIII = Vestibulocochlear nerve
IX = Glossopharyngeal nerve
X = Vagus nerve
XI = Accessory nerve
XII = Hypoglossus nerve



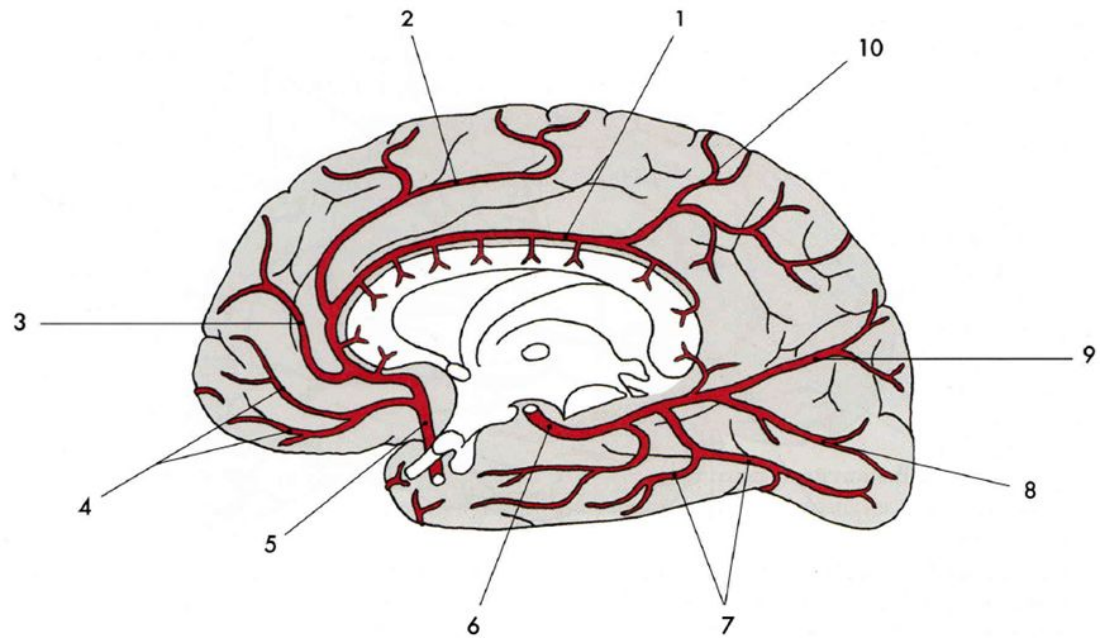
1 Olfactory tract
2 Anterior cerebral artery
3 Optic nerve (n. II)
4 Middle cerebral artery
5 Infundibulum
6 Oculomotor nerve (n. III) and posterior communicating artery
7 Posterior cerebral artery
8 Basilar artery and abducent nerve (n. VI)
9 Anterior spinal artery
10 Vertebral artery
11 Cerebellum
12 Anterior communicating artery
13 Internal carotid artery
14 Superior cerebellar artery and pons
15 Labyrinthine arteries
16 Inferior anterior cerebellar artery
17 Inferior posterior cerebellar artery
18 Medulla oblongata

CORTICAL, CENTRAL, AND CHOROIDAL ARTERIES

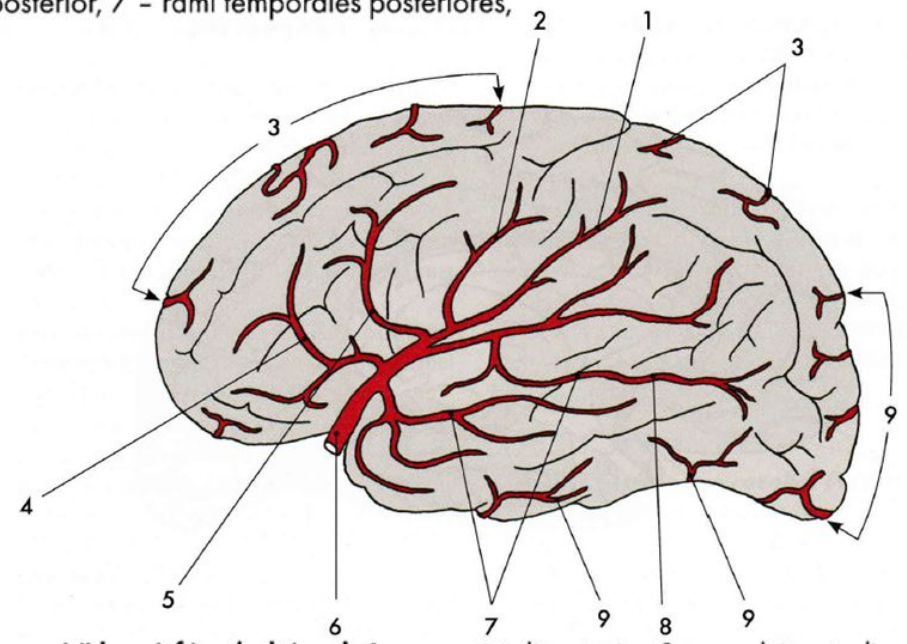
- anterior cerebral artery
  - runs around the genua of the corpus callosum and along the superior surface of the corpus callosum
  - occlusion causes contralateral hemiplegia affecting primarily the lower limb
- middle cerebral artery
  - runs laterally to the base of the insula; branches extend to the convexity of the hemisphere
  - occlusion causes contralateral hemiplegia affecting primarily the upper limb, facial muscles, and contralateral sensory disturbances
- posterior cerebral artery
  - around the cerebral peduncle to the medial surface of the temporal and occipital lobes
  - occlusion leads to visual impairment in the contralateral visual field
- central (basal) arteries
  - anteromedial, anterolateral, posteromedial, posterolateral
- choroidal arteries
  - anterior (from internal carotid), posterior (from posterior cerebral)

On the medial surface of the hemisphere, it gives off branches to the orbital surface of the frontal lobe (the superior frontal gyrus), to the paracentral and postcentral gyri (motor and sensory areas for the lower limb—the callosomarginal artery), and branches to the cingulate gyrus and precuneus (the pericallosal artery).

The insular arteries supply the insular cortex, the external capsule, the claustrum, and the extreme capsule.
On the convexity, it supplies the middle and inferior frontal gyri, the lower three-quarters of the precentral and postcentral gyri, most of the parietal lobe, the superior and middle temporal gyri, and the temporal pole.



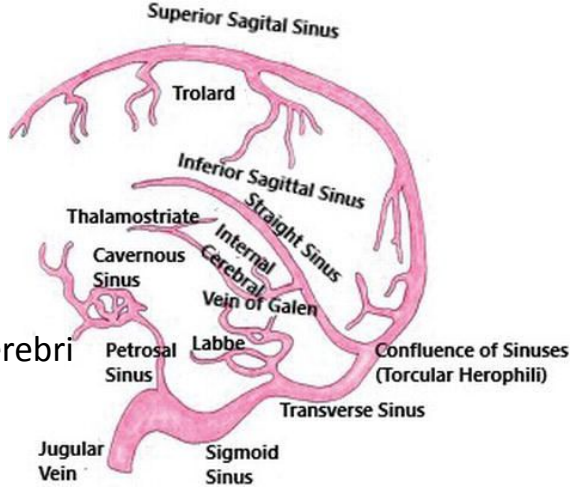
Obr. 10.148. Arteria cerebri anterior a arteria cerebri posterior (schéma). 1 – a. pericallosa, 2 – a. callosomarginalis, 3 – rami frontopolares, 4 – rami orbitales, 5 – a. cerebri anterior, 6 – a. cerebri posterior, 7 – rami temporales posteriores, 8 – a. calcarina, 9 – a. parietooccipitalis, 10 – rami paracentrales

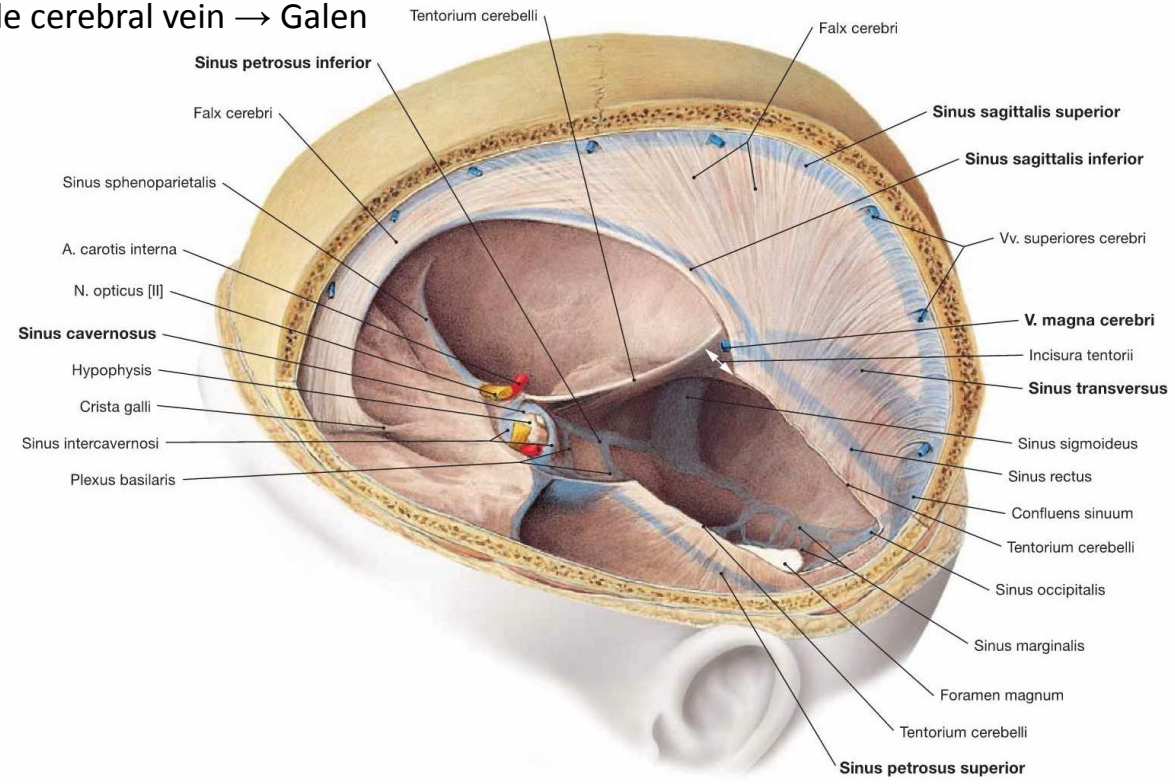


Obr. 10.150. Větvení a. cerebri media na konvexitě hemisféry (schéma). 1 – a. parietalis anterior, 2 – a. sulci centralis, 3 – větve z a. cerebri anterior přesahující na konvexitu hemisféry, 4 – a. frontobasalis, 5 – a. prefrontalis, 6 – a. cerebri media, 7 – aa. temporales, 8 – a. gyri angularis, 9 – větve a. cerebri posterior přesahující na konvexitu hemisféry

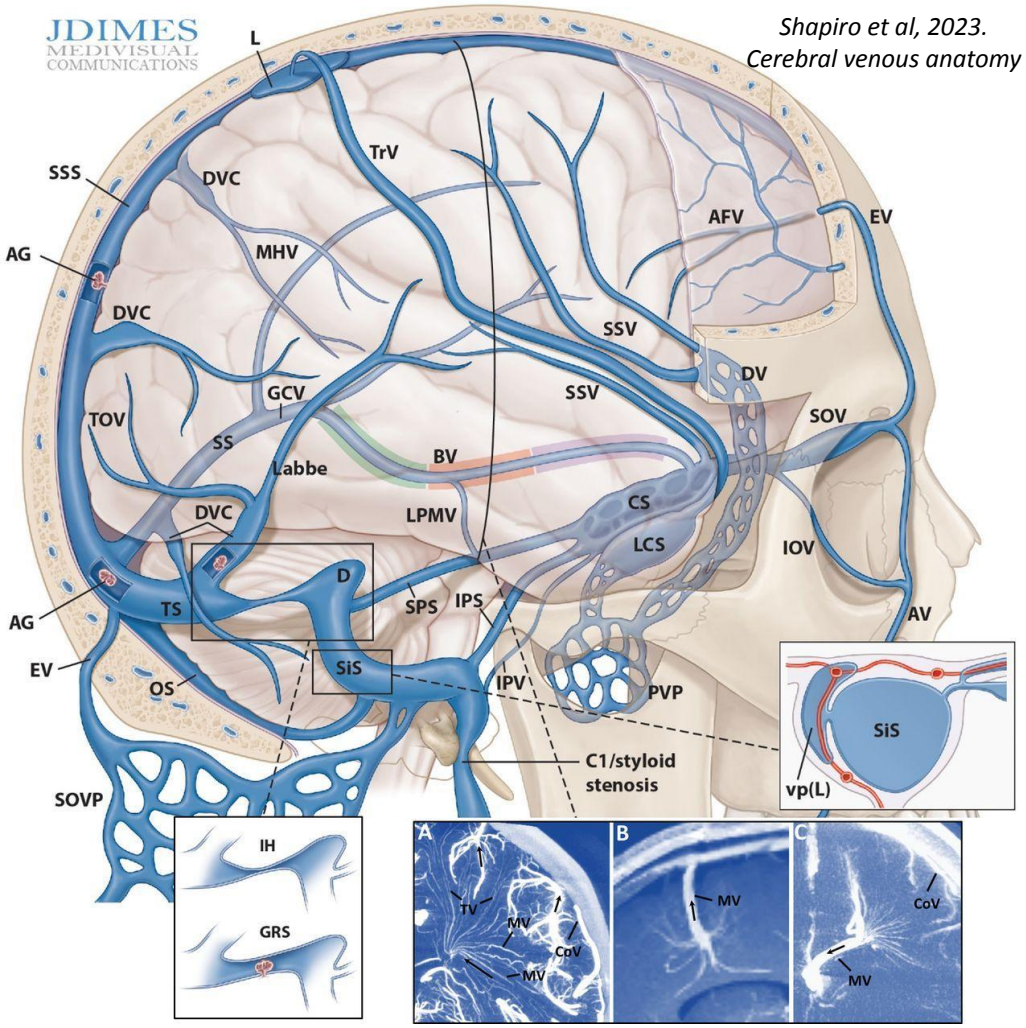
CEREBRAL VEINS

- superficial
  - small branches extending from the cortex and subcortical white matter, forming pial plexuses; from there, veins drain into the sinus durae matris
  - superior cerebral veins – Trolard's vein (superior anastomotic vein) – connects the superior sagittal sinus with the middle cerebral vein, runs in the postcentral sulcus
  - vv. cerebri medii – Labbé's vein (v. anastomotica inf.) – connects the v. media spfc. cerebri to the sinus transversus
  - v. cerebri media profunda
  - vv. cerebri inferiores
- deep
  - internal cerebral vv. – beneath the splenium of the corpus callosum into the great cerebral vein (Galen) → straight sinus
  - in the region of the anterior perforating substance, the basilar vein (Rosenthal) is formed by the confluence of the anterior cerebral vein and the deep middle cerebral vein → Galen
  - sinus of the dura mater





V. INTERNAL JUGULAR – INTRACRANIAL TRIBUTARIES



Shapiro et al, 2023. Cerebral venous anatomy

FV, anterior frontal vein;
AG, arachnoid granulation;
AV, angular vein;
BV, basal vein, with its three functional segments (telencephalic=purple; mesencephalic=red; galenic=green)
CoV, cortical vein;
CS, cavernous sinus;
D, diverticulum;
DV, diploic vein;
DVC, dural venous channel;
EV, emissary vein;
GCV, Galen;
GRS, granulation-related stenosis;
IH, intracranial hypertension- related stenosis;
IOV, inferior ophthalmic vein;
iPS, inferior petrosal sinus;
IPV, inferior petroclival vein;
L, venous lake;
LCS, laterocavernous sinus;
LPMV, lateral (anastomotic) pontomesencephalic vein
MHV, medial hemispheric vein;
MV, medullary veins;
OS, occipital sinus;
PVP, pterygopalatine venous plexus;
SiS, sigmoid sinus;
SOV, superior ophthalmic vein;
SOVP, suboccipital venous plexus;
SPS, superior petrosal sinus;
SS, straight sinus;
SSS, superior sagittal sinus;
SSV, superficial sylvian (superficial middle cerebral) veins;
TOV, temporo-occipital veins;
TrV, Trolard vein;
TS, transverse sinus;
TV, transmedullary (transcerebral) veins;
vp(L), venous pouch (Lake).

Inserts
A, normal anatomy;
B, superficially-draining developmental venous anomaly (DVA);
C, deep-draining DVA.