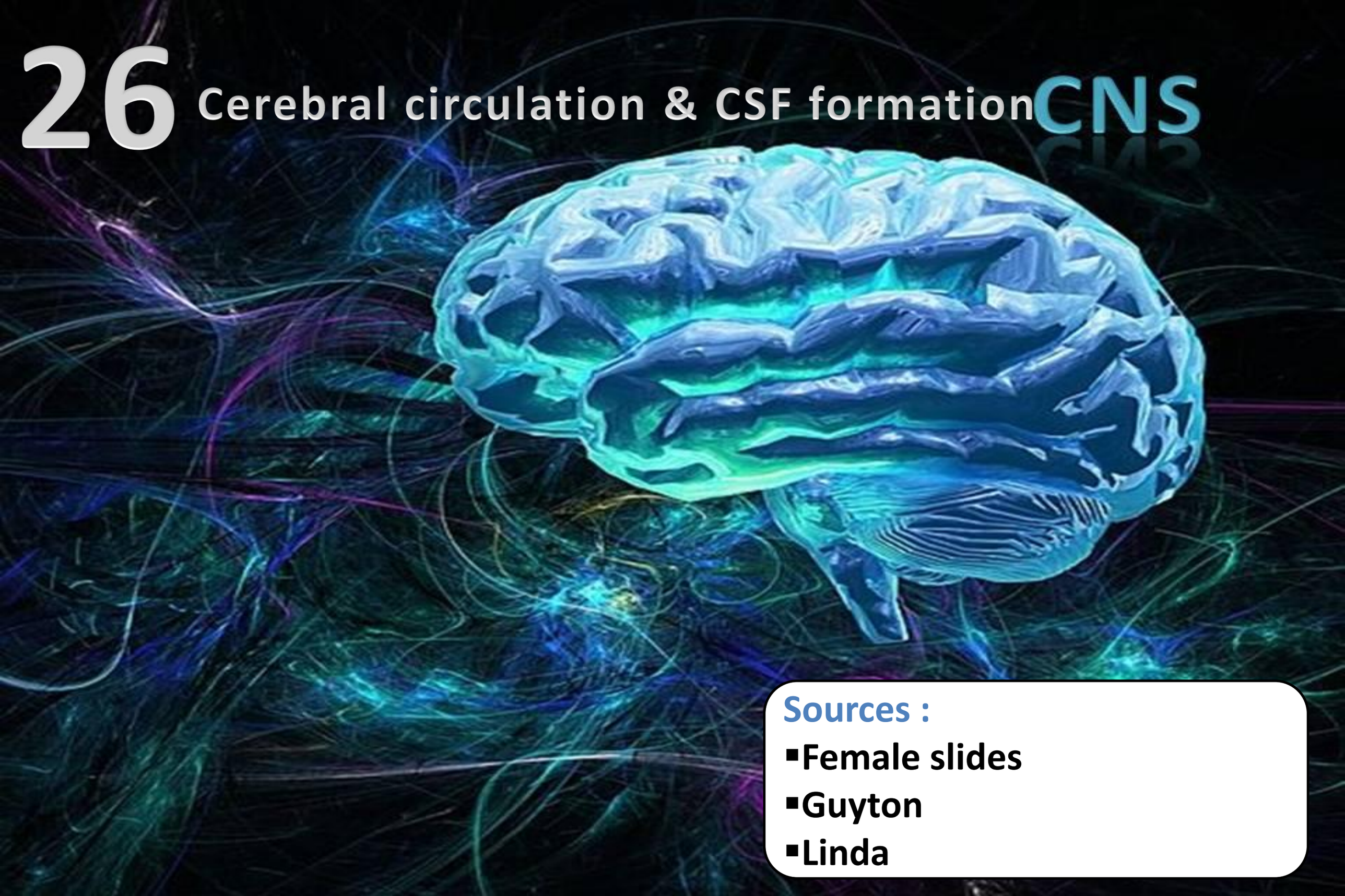
26 Cerebral circulation & CSF formation

CNS



Sources :

- **Female slides**
- **Guyton**
- **Linda**

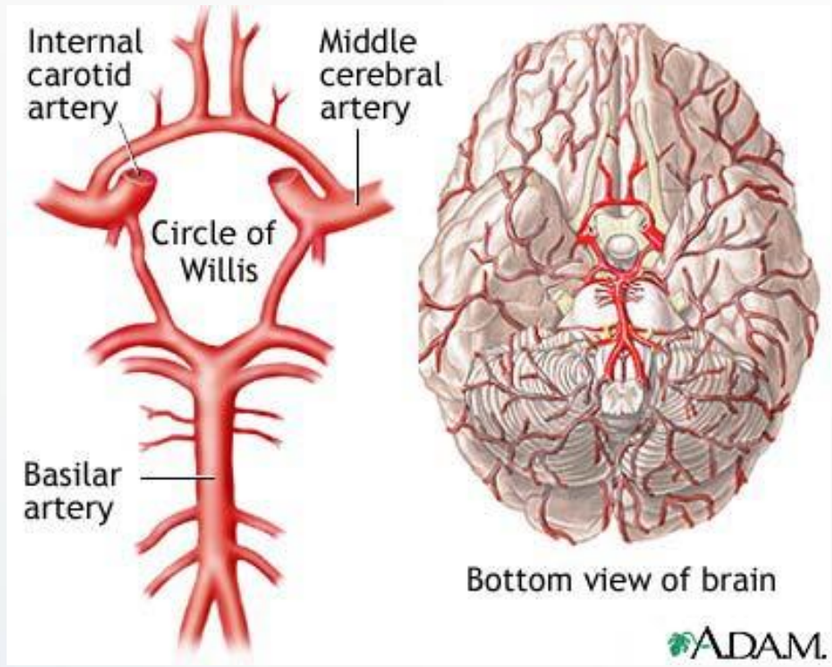
Objectives:

- ☆ Innervation of cerebral blood vessels.
- ☆ **Cerebral blood flow and factors affecting;**
  - ★ Autoregulation/metabolic .
  - ★ blood pressure.
  - ★ Intracranial pressure (ICP)
  - ★ Factors affecting cerebral blood flow: Blood gases, Neural stimuli, Humoral stimuli
- ☆ CSF formation / absorption.
- ☆ CSF functions.
- ☆ Blood brain barrier (BBB).

❖ **Guyton** ❖ **Linda** ❖ **Explanation** ❖ slides

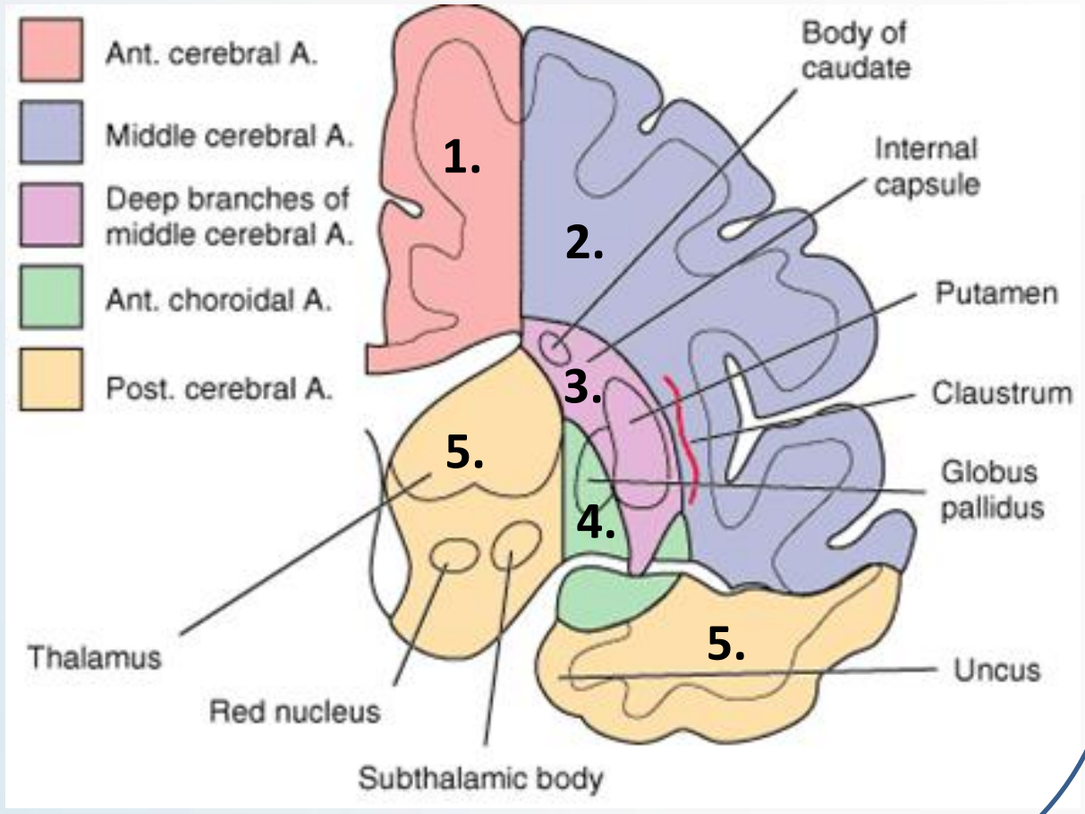
Cerebral Blood Flow

- Blood flow of the brain is supplied by **four** large arteries
  —**two carotid and two vertebral arteries**—which merge to form the *circle of Willis* at the base of the brain.



Cerebral Artery Areas

1. anterior cerebral
2. Middle cerebral
3. Penetrating branches of middle cerebral
4. anterior choroidal
5. Posterior cerebral



Innervation

Three systems of nerves innervate the cerebral blood vessels:

Sympathetic

Vasoconstriction and hypertension

- Postganglionic sympathetic neurons have their bodies in the **superior cervical ganglia**
- **Mediators :** (Norepinephrine & neuropeptide Y).
- During acute hypertension attenuate “try to prevent” increase in CBF.

Parasympathetic

Vasodilatation

- Cholinergic neuron originate in **sphenopalatine ganglia** , end on large arteries.
- **Mediators :** (Ach, VIP).

Sensory nerves

Contain mediators at the terminals such as:

- Substance P, VIP, cause **VD**
- neuropeptide Y causes **VC**
- Contribute to increase in CBF during meningitis

VD=vasodilatation
VC=vasoconstriction
VIP= Vasoactive Intestinal Peptide also found in GIT
CBF=cerebral blood flow

Cerebral blood flow

- CBF is tightly regulated to the **brain's metabolic demands**
  during mental activities : thinking ,studying , relaxing ..etc
- average must be maintained at a flow of **50ml\100g\minute** in adult humans.

- It is also depends on the **intra cranial pressure** in which :
  too much blood ➔ raise ICP ➔ compress blood vessels ➔ less blood flow
  ➔ damage delicate brain tissue **(ischemia)**

- Therefore it is important to maintain proper CBF in patients with conditions like **shock** , **stroke** and **traumatic brain injury. (**first aid is to maintain normal cerebral blood flow**).**

  ★ **Ischemia** results if CBF is below 18-20 ml\ 100 g \ minute.

  ★ **Tissue death** occurs if flow drops below 8-10 ml\ 100 g \minute.

  ★ **Hyperemia** occurs when CBF is in excess of 55-60 ml \100 g \minute.

Cerebral perfusion pressure

- **Cerebral perfusion pressure**, or **CPP**, is the net pressure of blood flow to the brain.
- Regulated by **two balanced, opposing forces**: Mean arterial pressure is the force that pushes blood into the brain, and ICP force that pushes out.

★ **CPP** can be defined as: ***CPP = MAP – ICP*** **=70-90 mmHg**

raising MAP raises CPP, but raising ICP lowers it.

(this is one reason that increasing ICP in traumatic brain injury is potentially deadly).

- CPP, is normally between 70 and 90 mmHg in an adult human, and cannot go below 70 mmHg for a sustained period without causing ischemic brain damage.
- changes in the body's overall blood pressure do not normally alter cerebral perfusion pressure drastically.
- At their most constricted condition, blood vessels create a pressure of 150 mmHg, and at their most dilated the pressure is about 60 mmHg.

When pressures are outside the range of **50 to 150** mmHg, the blood vessels' ability to autoregulate pressure is lost, and cerebral perfusion is determined by blood pressure alone. Thus, **hypotension** can result in severe cerebral ischemia in patients with conditions like brain injury, leading to a damaging process called the ischemic cascade.

Regulation of CSF

Autoregulation.

Ability of the tissues to regulate their own blood flow according to their needs.

Depends on metabolic demands.

↓pressure ➔ **VD** , ↑pressure ➔ **VC**

Mediators : Nitric oxide & adenosine

Neural stimuli

Under normal conditions **sympathetic** has little effect.

During acute hypertension, a decrease in CBF occurs.

Humoral stimuli

affect constriction and dilation even in the absence of autoregulation:

↑CO_2 ➔**VD**

↑O_2 ➔ **VC**

Hypoxia: ↓ O_2 ➔ **VD**

Low pH ➔ **VD**

Hypoxia/ Hypercapnia.

Endothelium mediated vasodilation

is impaired by hypertension.

Effect of ICP changes on systemic blood pressure;

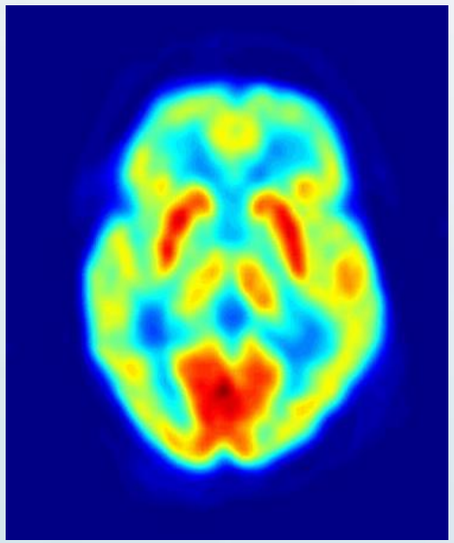
Example :patients with brain tumor , have high ICP which compress the blood vessels and leads to decrease CBF “ischemia” .. This stimuli some of the brain centers (cardiovascular center) which sends significant sympathetic impulses to make strong vasoconstriction of cerebral blood vessels and that’s make MAP higher than ICP ➔ try to raise cerebral blood flow

Cushing reflex:

If ICP > 33 mmHg over a short period of time, CBF will drop markedly, leading to ischemia of vasomotor area. Then blood pressure rises.

Vasoconstriction	Vasodilatation
Sympathetic innervation	Parasympathetic innervation
↑pressure	↓pressure
↑O_2	↑CO_2
	↓O_2
	Hypoxia
	Acidosis , Low pH ,↑H+

Measuring cerebral blood flow



Average cerebral blood flow = 756 ml/min =3* choronary blood flow.

- Functional imaging resonance.
- Positron emission tomography.

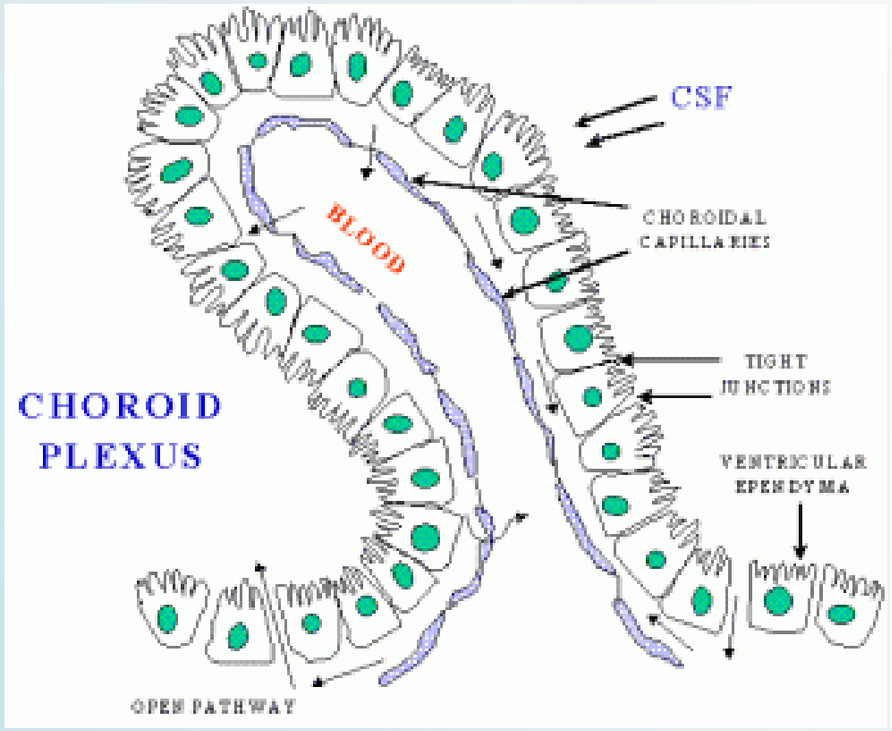
Both be used to measure CBF. These techniques are also used to measure regional CBF (rCBF) within a specific brain region.

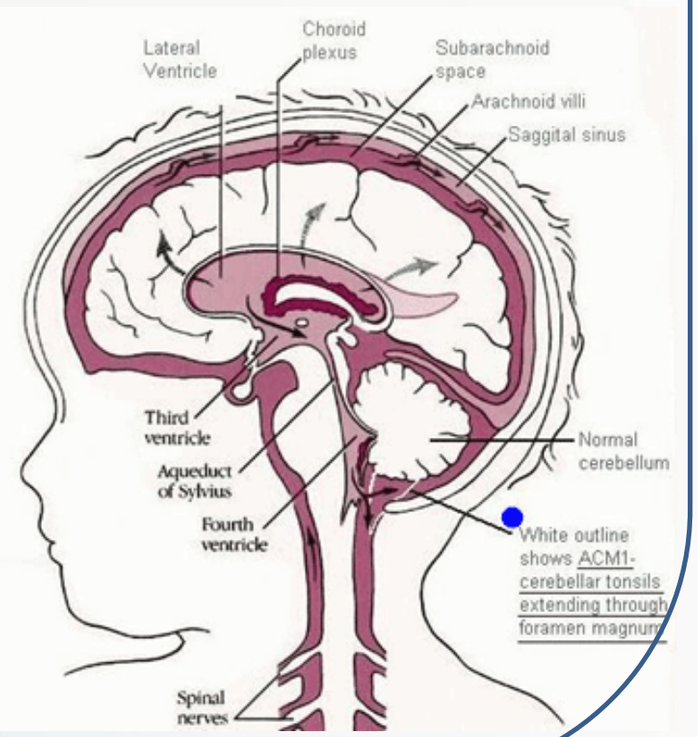
❖ **CSF is formed in:**

1. Choroid plexus.
2. Around blood vessels.
3. Along ventricular walls.

❖ **CSF is absorbed by:**

Arachnoid villi





Cerebrospinal Fluid (CSF)

- It is the extracellular fluid of the brain , fills ventricles and subarachnoid space.
- Volume = 150 ml
- Rate of production =550 ml/d, so it turns 3.7 times/day.
- Lumbar CSF pressure = 70-180 mm CSF
- Absorption of CSF occurs by bulk flow is proportionate to CSF pressure.
- At pressure of **112** mm (normal average): filtration and absorption are equal.
- Below pressure of **68** mm CSF, absorption stops.

- Hydrocephalus: a condition in which fluid accumulates in the brain, typically in young children, enlarging the head and sometimes causing brain damage.

1. **External hydrocephallus:** Large amounts of CSF accumulates when the reabsorptive capacity of arachnoid villi decreases.
2. **Internal hydrocephallus:** occurs when foramina of Luschka & Magendie are blocked or obstruction within ventricular system, resulting in distention of the ventricles.

Composition of the (CSF)

❖ The composition of CSF is essentially the same as brain ECF

Substance	CSF	Plasma	
Na+	147	150	Same
K+	2.9	4.6	CSF higher
HCO3-	25	24.8	same
PCO2	50	39.5	CSF slightly higher
pH	7.33	7.4	Same
Osmolality	289	289	Same ***
glucose	64	100	Plasma higher **

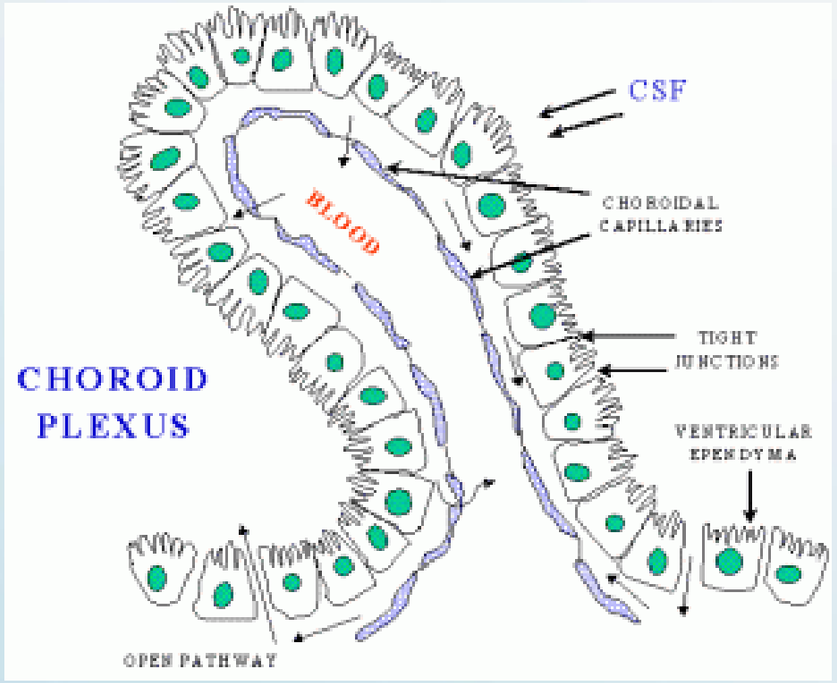
*** it has to be the same .. Why ? Cause osmolality control the movement of fluids in & out the cell . any difference will harm the brain.

** the less glucose the brain have , the more sensitivity of hypoglycemia it will have

Functions of the (CSF)

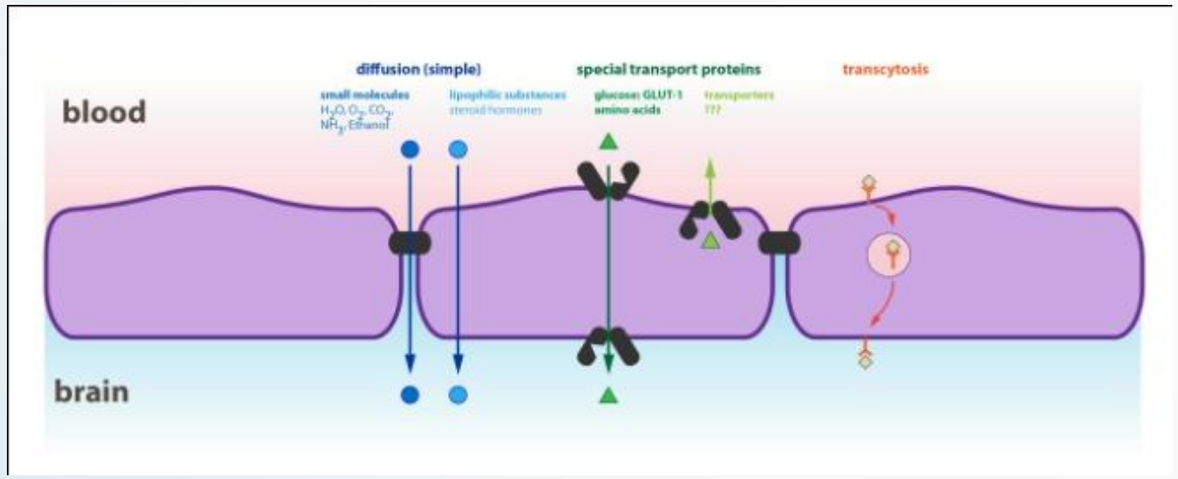
1. Protective function & making brain suspended effectively
2. Facilitation of pulsatile cerebral blood flow
3. Distribution of essential substances
4. Wash away waste products
5. Cardiovascular dynamics are also affected by CSF pressure

Features of cerebral vessels



Choroid plexus:

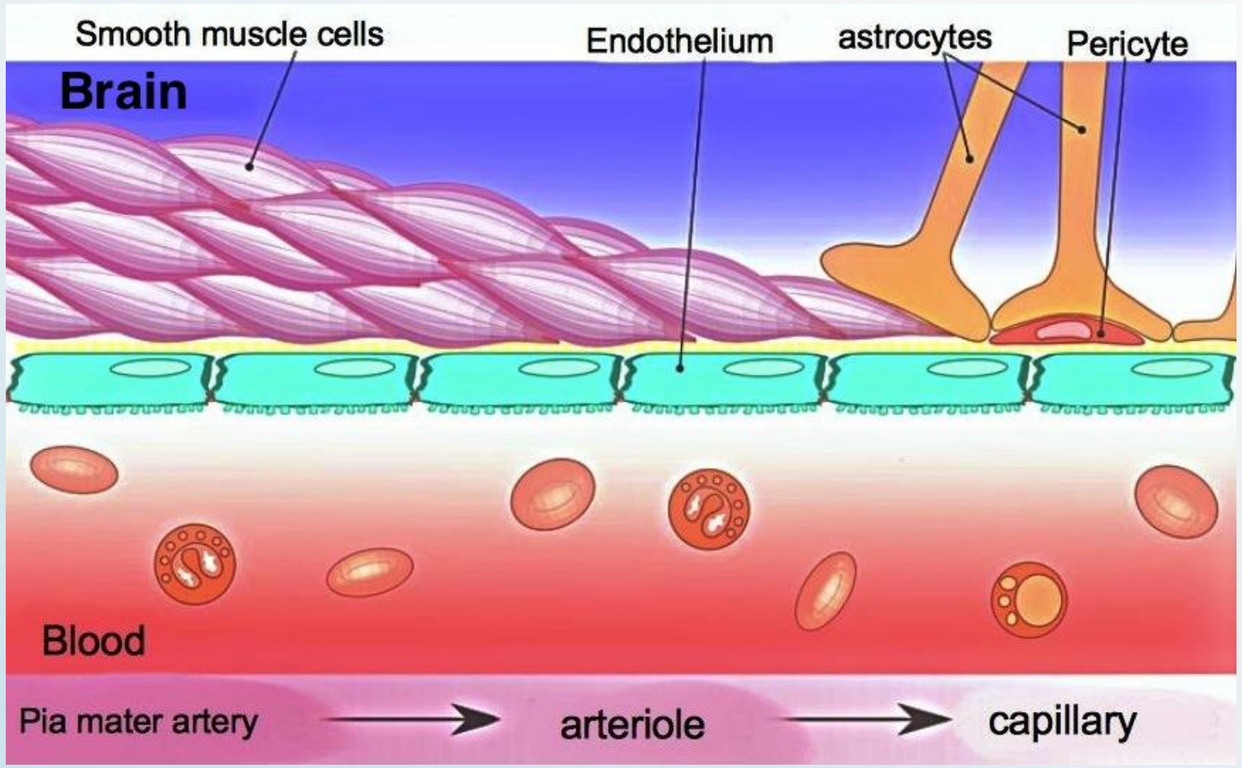
Gaps are present between endothelial cells of the capillary wall, while choroid epithelial cells that separate them from CSF are connected by tight junctions.



Capillaries in the brain substance :

are **non-fenestrated** and there are tight junctions between endothelial cells to limit passage of substances through the junctions.

Blood Brain Barrier



- It is formed by the tight junctions between capillary endothelial cells of the brain and between epithelial cells in the choroid plexus.
- This effectively prevents proteins from entering the brain in adults and slow the penetration of smaller molecules.

Functions of BBB

- Maintanins the constancy of the environment of the neurons in the CNS.
- Protection of the brain from endogenous and exogenous toxins.
- Prevent escape of the neurotransmitters into the general circulation.

Development of BBB

- Premature infants with **hyperbilirubinemia**, free bilirubin pass BBB, and may stain basal ganglia causing damage (Kernicterus).

Penetration of substances into the brain :

- **Molecules pass easily:** H2O, CO2, O2, lipid-soluble free forms of steroid hormones, anesthetics drugs .
- **Molecules not pass:** proteins, polypeptides.
- **Slow penetration:** H+, HCO3-
- **Glucose :** its passive penetration is slow, but is transported across brain capillaries by **GLUT1**

Clinical implications :

- Some drugs penetrate BBB with difficulty e.g. antibiotics and dopamine.
- BBB breaks down in areas of infection, injury, tumors, sudden increase in blood pressure, and I.V injection of hypertonic fluids.
- Injection of radiolabeled materials help diagnose tumors as BBB is broken down at tumor site because of increased vascularity by abnormal vessels.

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CNS Block