

CEREBROSPINAL FLUID(CSF)

- Introduction
- Functional anatomy
- Formation, Circulation and Absorption of CSF
- Composition of CSF
- Functions of CSF
- Applied physiology/ Clinical aspects
- Blood Brain Barrier

INTRODUCTION

- Cerebrospinal fluid is a clear, colourless fluid that fills the ventricles of brain & subarachnoid space (SAS) that surrounds the brain & spinal cord.

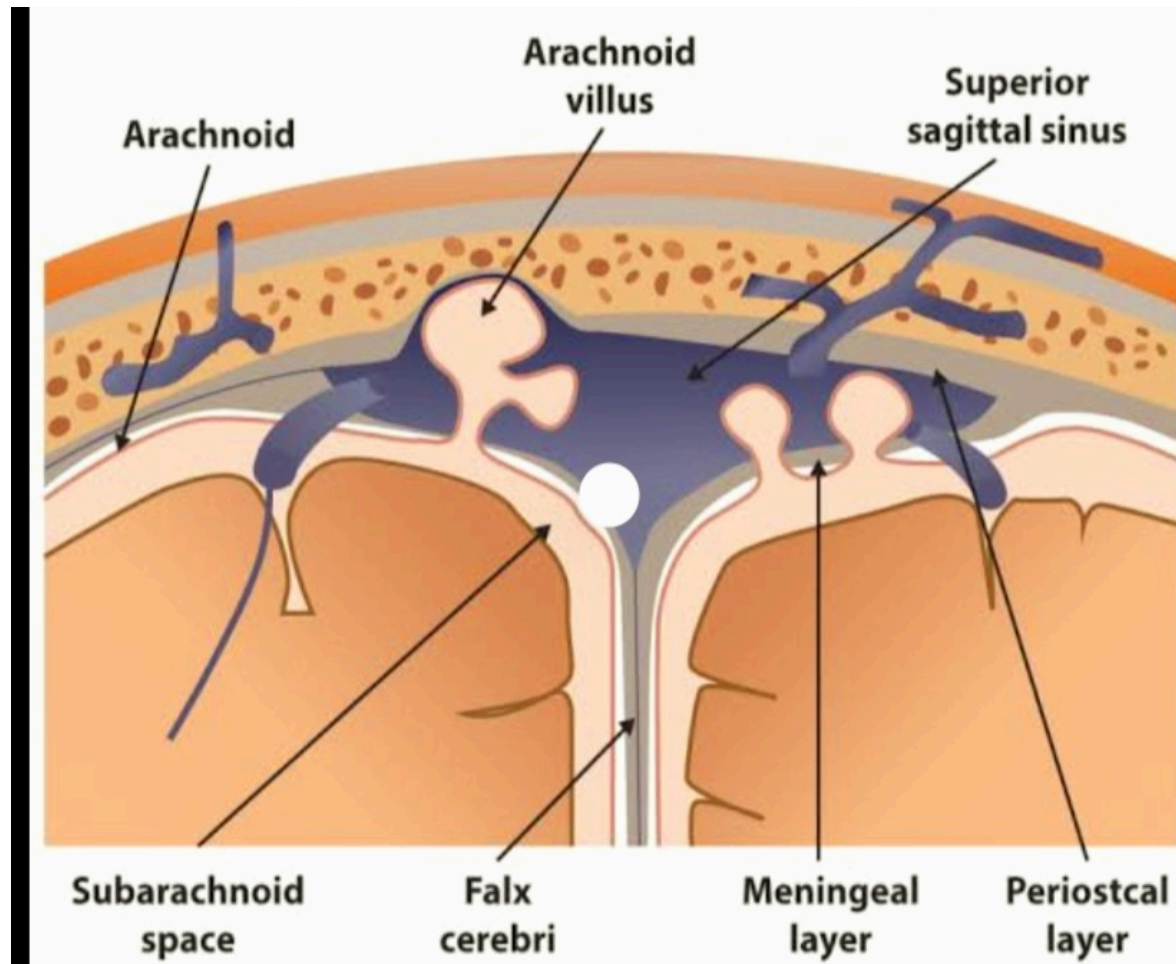
FUNCTIONAL ANATOMY

MENINGES AND SUBARACHNOID SPACE

- Brain and the spinal cord are covered by **meninges**
- The layers of meninges from inside to outside are:-
 - pia mater(close contact with brain tissue)
 - arachnoid mater and
 - dura mater

- **Subdural space** – space between arachnoid mater & dura mater
- **Subarachnoid space(SAS)** -between pia mater & arachnoid mater- filled with CSF

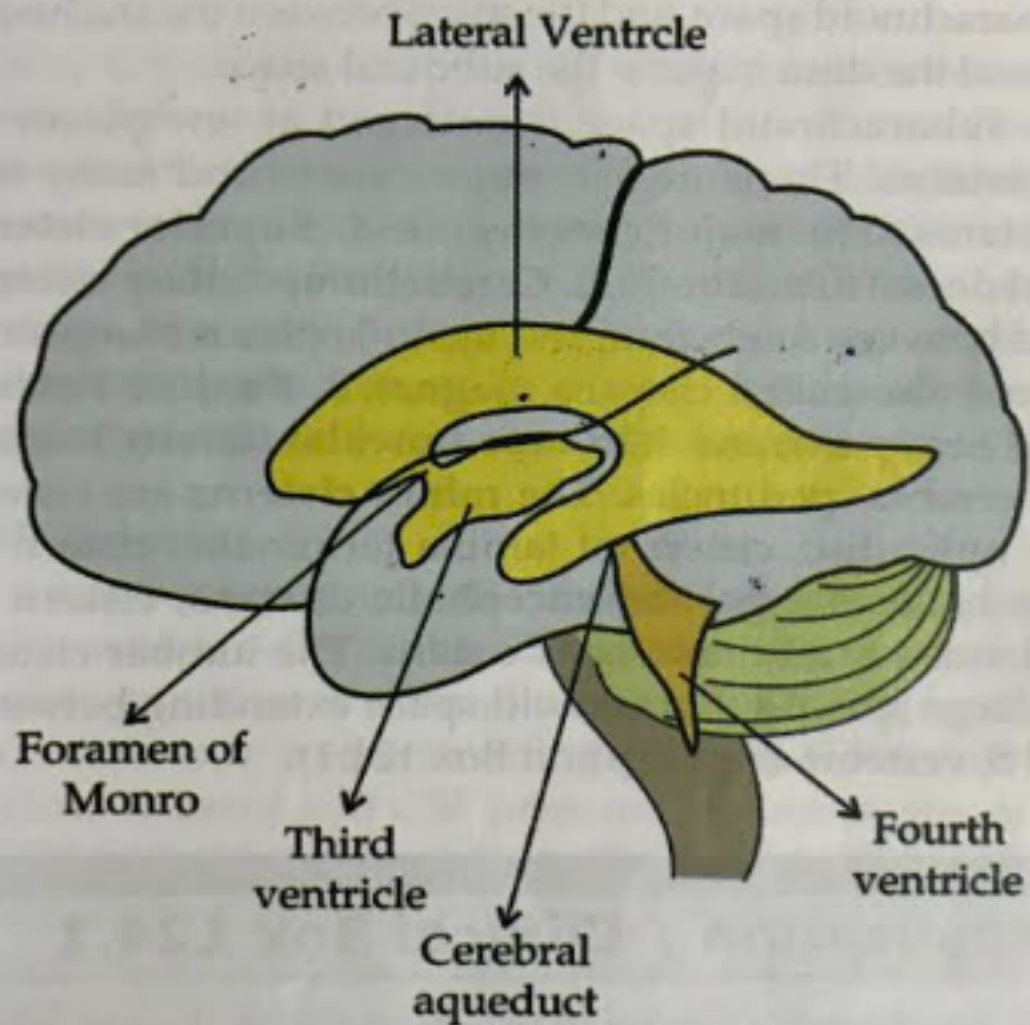
- **Arachnoid villi.**
- Collection of these villi → **arachnoid granulations**
- Subarachnoid space is enlarged at few places to form **cisterns**

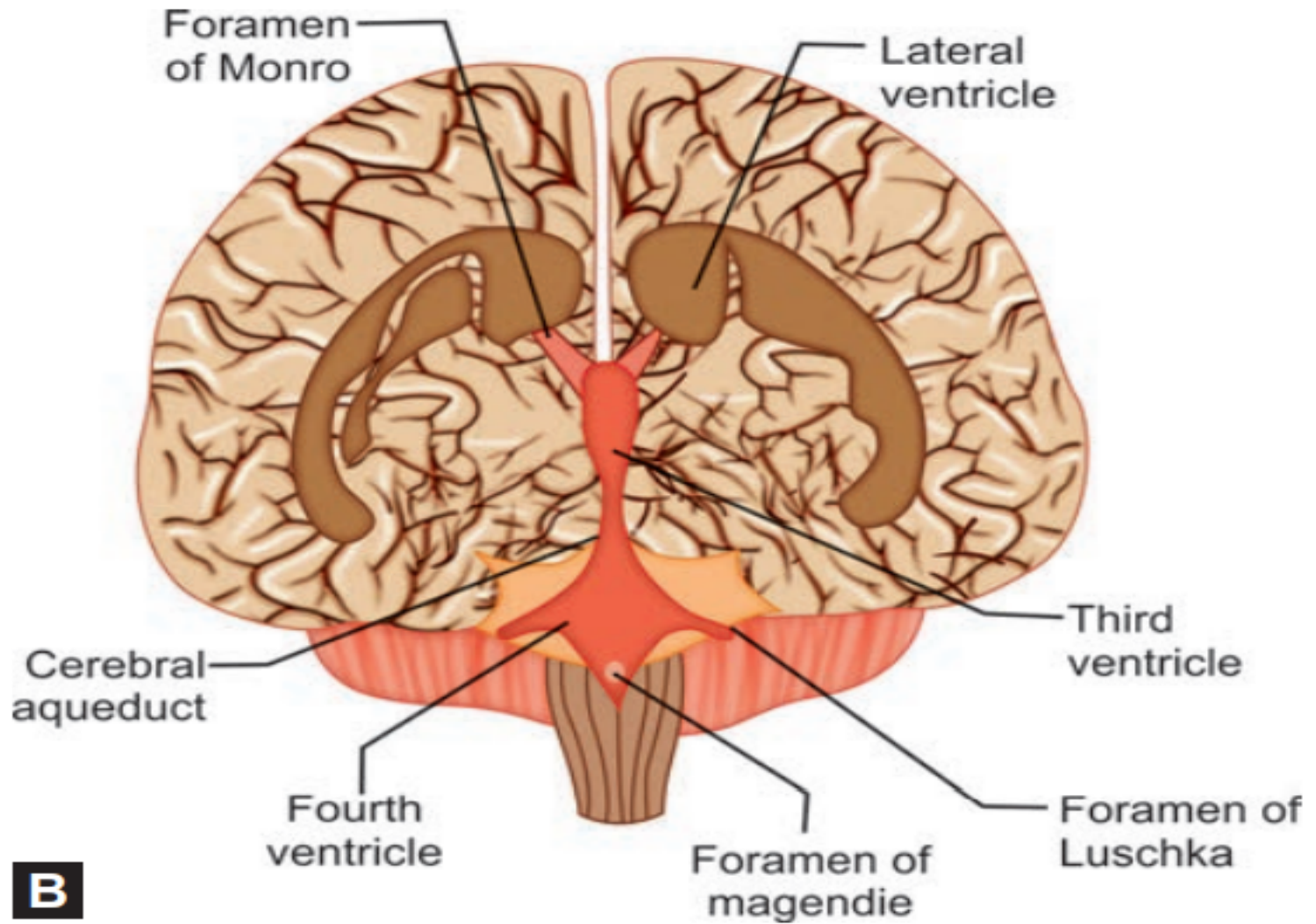


- **VENTRICULAR SYSTEM**

- These are series of interconnecting chambers within the brain
- There are 4 ventricles in brain
- 2 lateral ventricles, a third ventricle and fourth ventricle

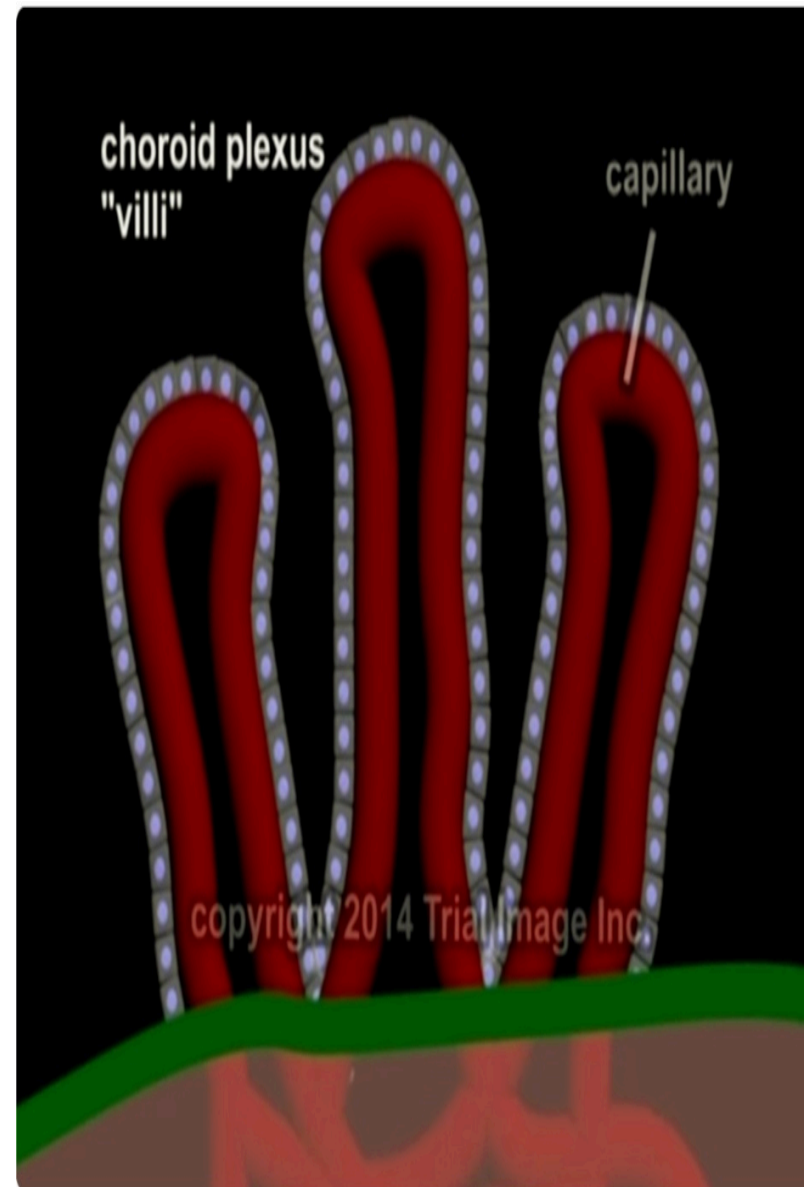
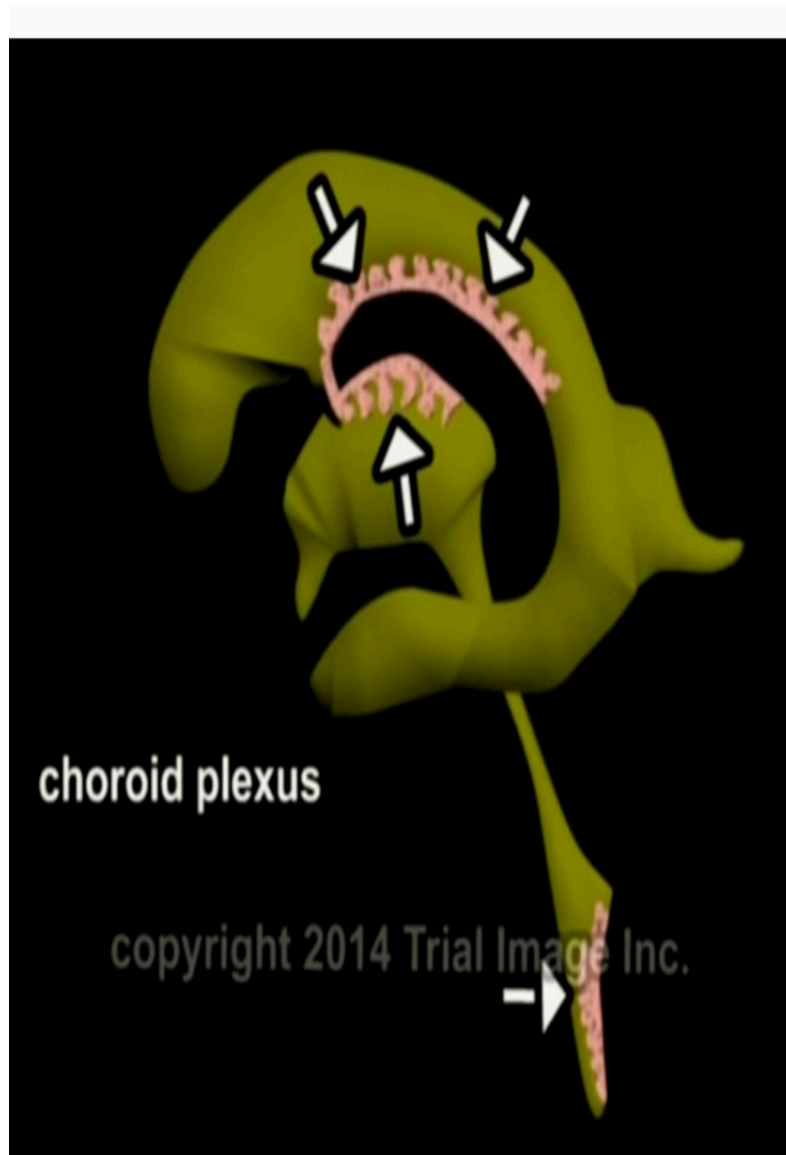
A. Lateral view





- The cerebral ventricles(2 lateral ventricles, 3rd and 4th ventricle) communicate with the SAS through 3 openings in the fourth ventricle:-
 - 1 opening in midline called **Foramen of Magendie**
 - 2 openings laterally called **Foramen of Luschka**

- Surface of the ventricles are lined with a thin cuboidal epithelium called **ependyma**
- **Choroid plexus** which are capillary loops covered by specialized ependymal cells are located in the ventricular system of brain



FORMATION OF CSF

- Rate of formation of CSF – 550ml/day.
- Normal CSF volume ~ 150 ml
- Normal CSF pressure : 130 mm H₂O (65 - 195 mm H₂O).

FORMATION OF CSF

SOURCE

- (i) CSF is largely formed from the choroid plexus
- (ii) Secreted by the ependymal cells
- (iii) Blood vessels of brain & spinal cord.

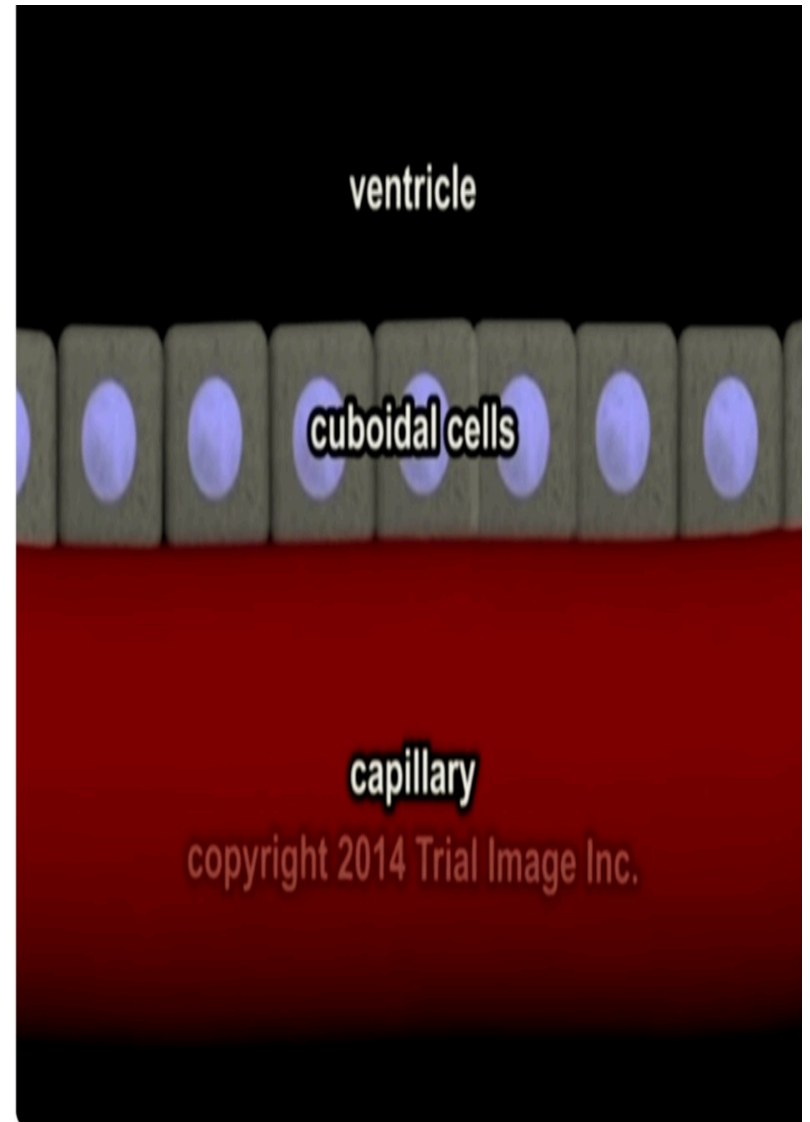
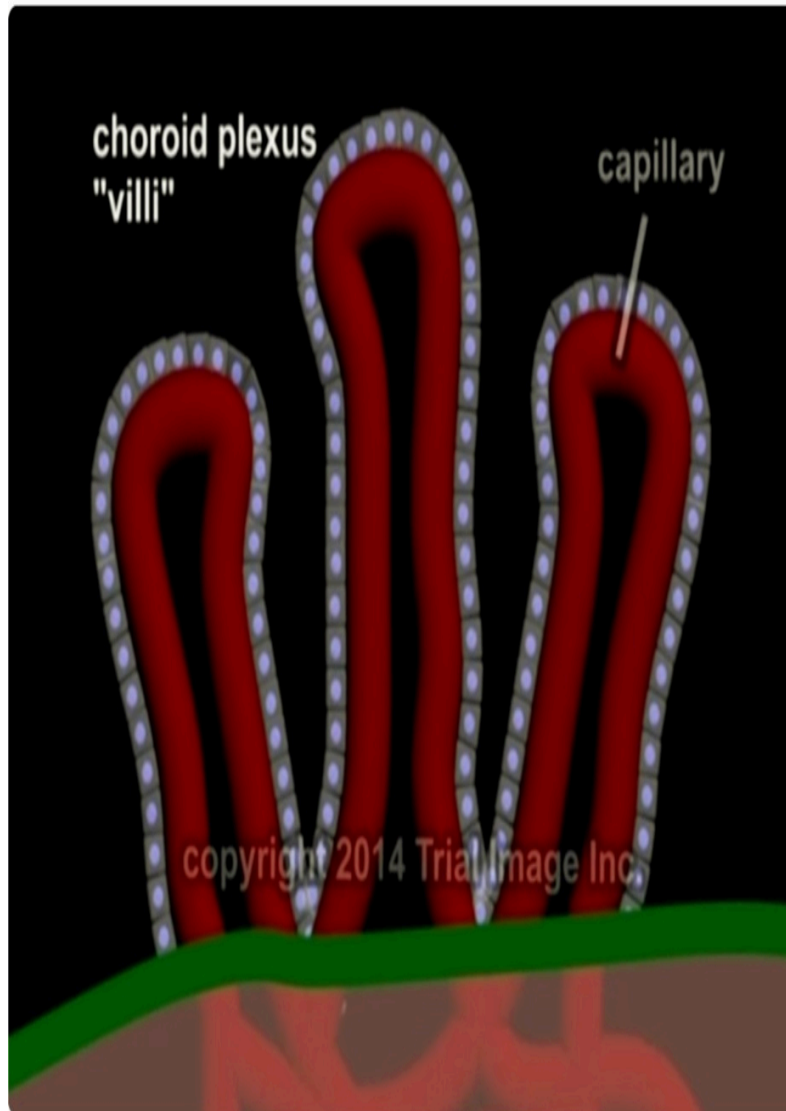
Steps of formation of CSF

1. ULTRAFILTRATION OF PLASMA

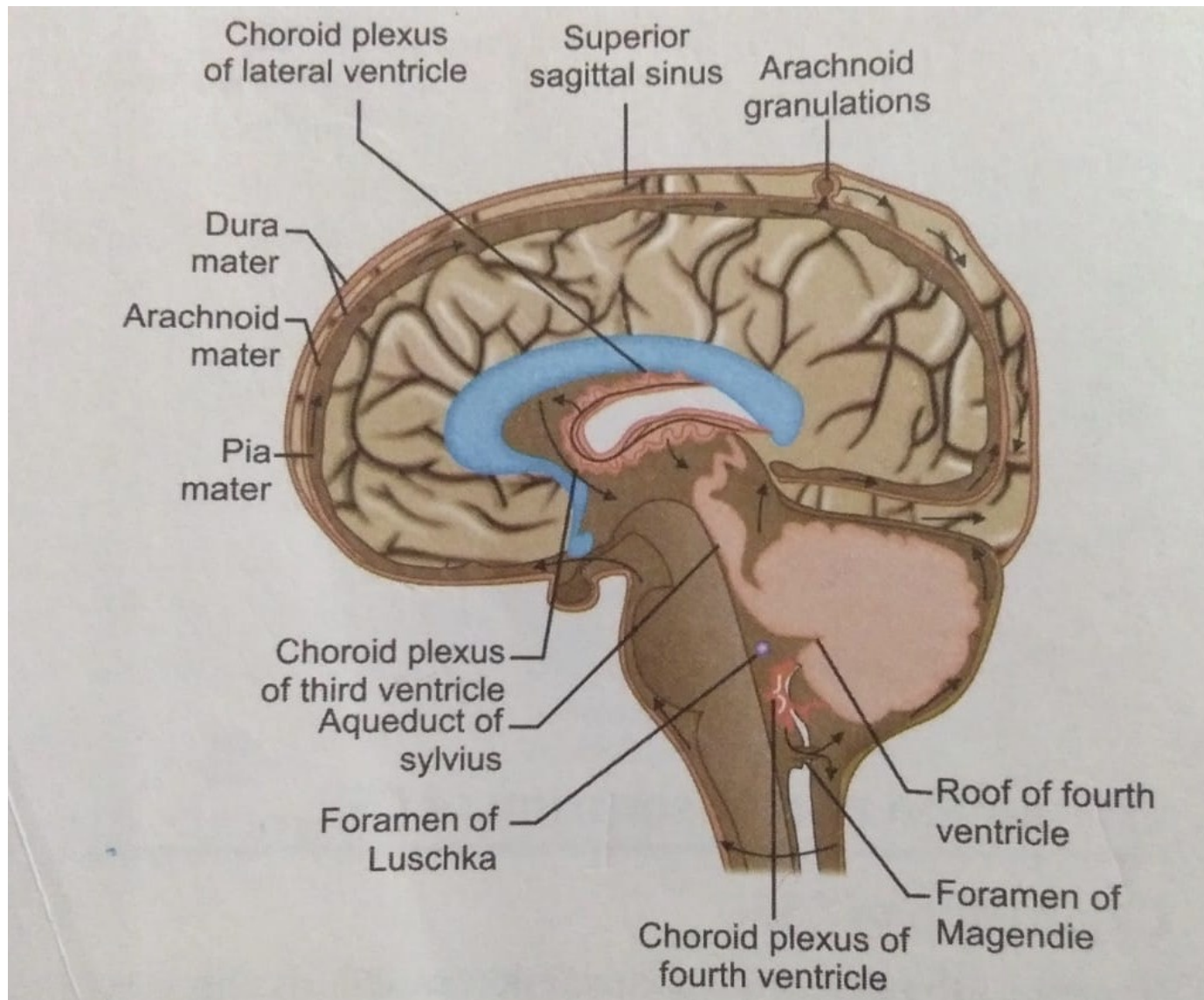
- across the endothelial cells of the fenestrated capillary wall into the ECF that surrounds the basal surface of epithelial cells of choroid plexus

2. ACTIVE SECRETION

- Choroidal epithelial cells transports ions and solutes into CSF by active secretion



CIRCULATION OF CSF



CSF from lateral ventricles



Foramen of Monro



3rd Ventricle



Aqueduct of Sylvius



Central canal of
Spinal cord ←

4th Ventricle



Foramen of Luschka & Foramen of Magendie



Sub arachnoid space around the brain and spinal cord

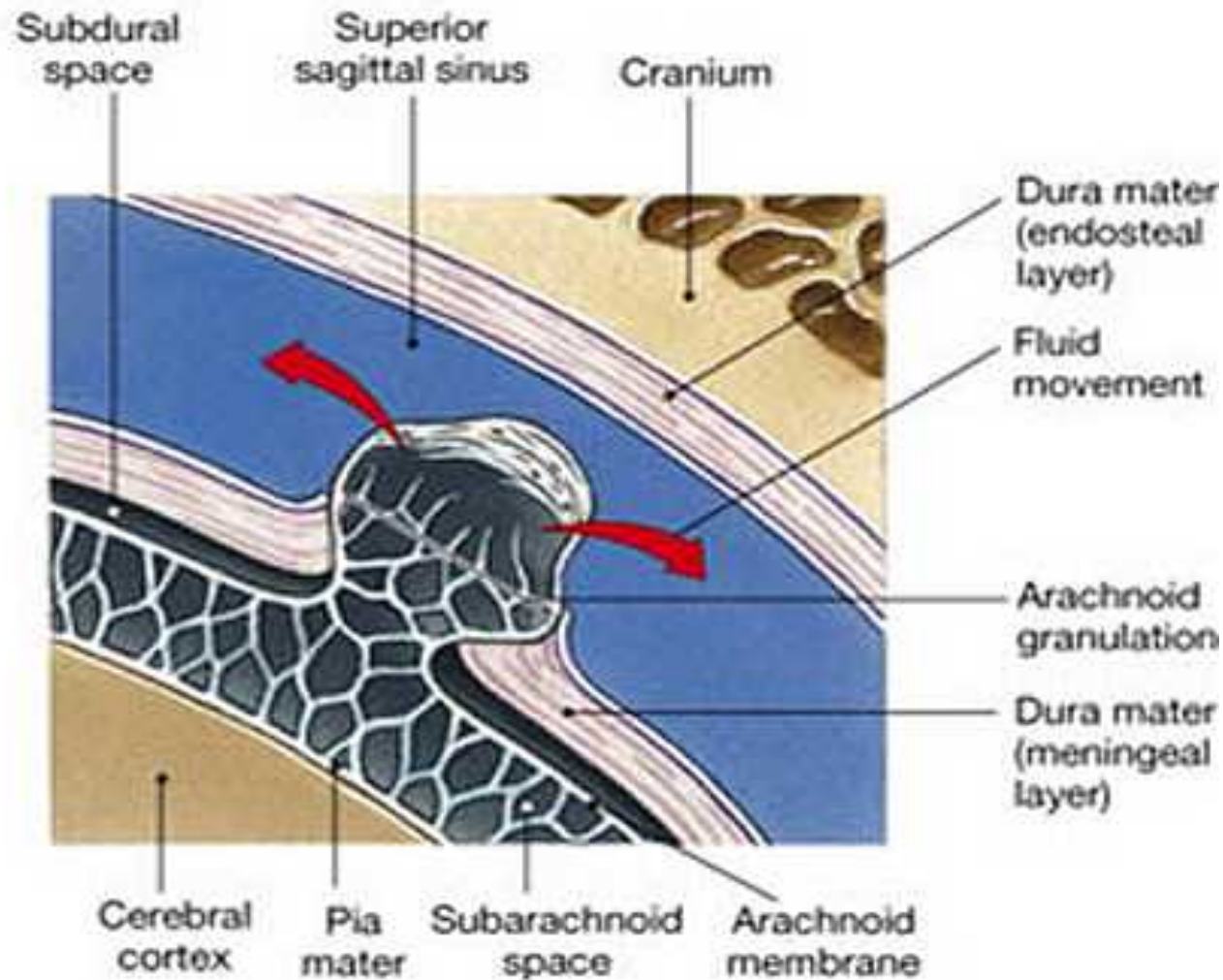
COMPOSITION OF CSF

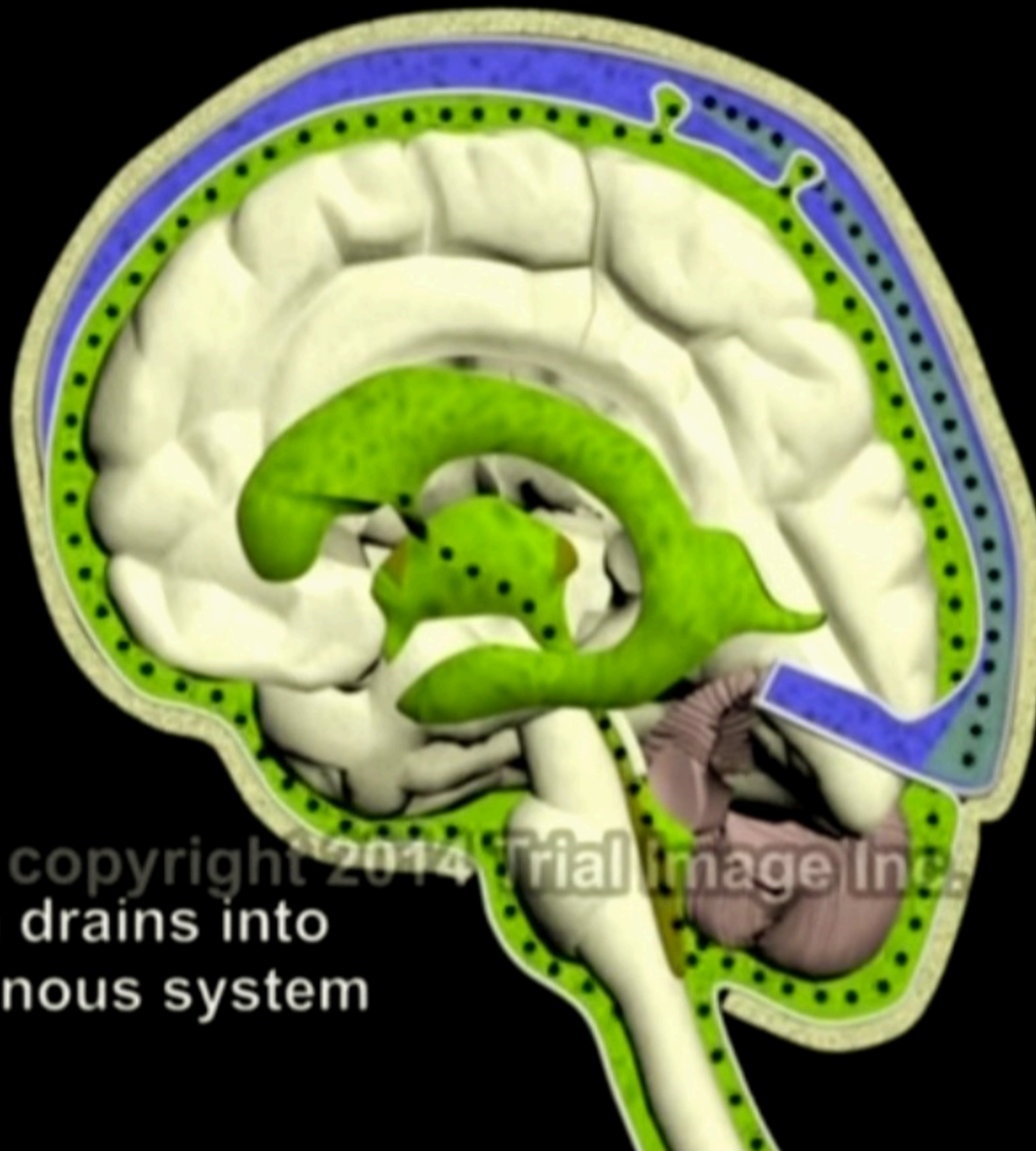
- ❖ Essentially same as that of plasma
- ❖ Clear, colourless fluid
- ❖ Specific gravity-1.007; pH- 7.3
- ❖ Almost protein free & cell free (contains < 5 lymphocytes /mm³)
- ❖ Glucose, K⁺ lower & Cl⁻ higher than that of plasma

ABSORPTION

- CSF is absorbed through **arachnoid villi** that project into the dural venous sinuses (mainly superior sagittal sinus) because:-
 - (i)Hydrostatic pressure of CSF is more than venous pressure in sinuses
 - (ii)Oncotic pressure(in plasma :-25mm Hg) is more than that of CSF(since proteins are less in CSF).

Absorption of CSF





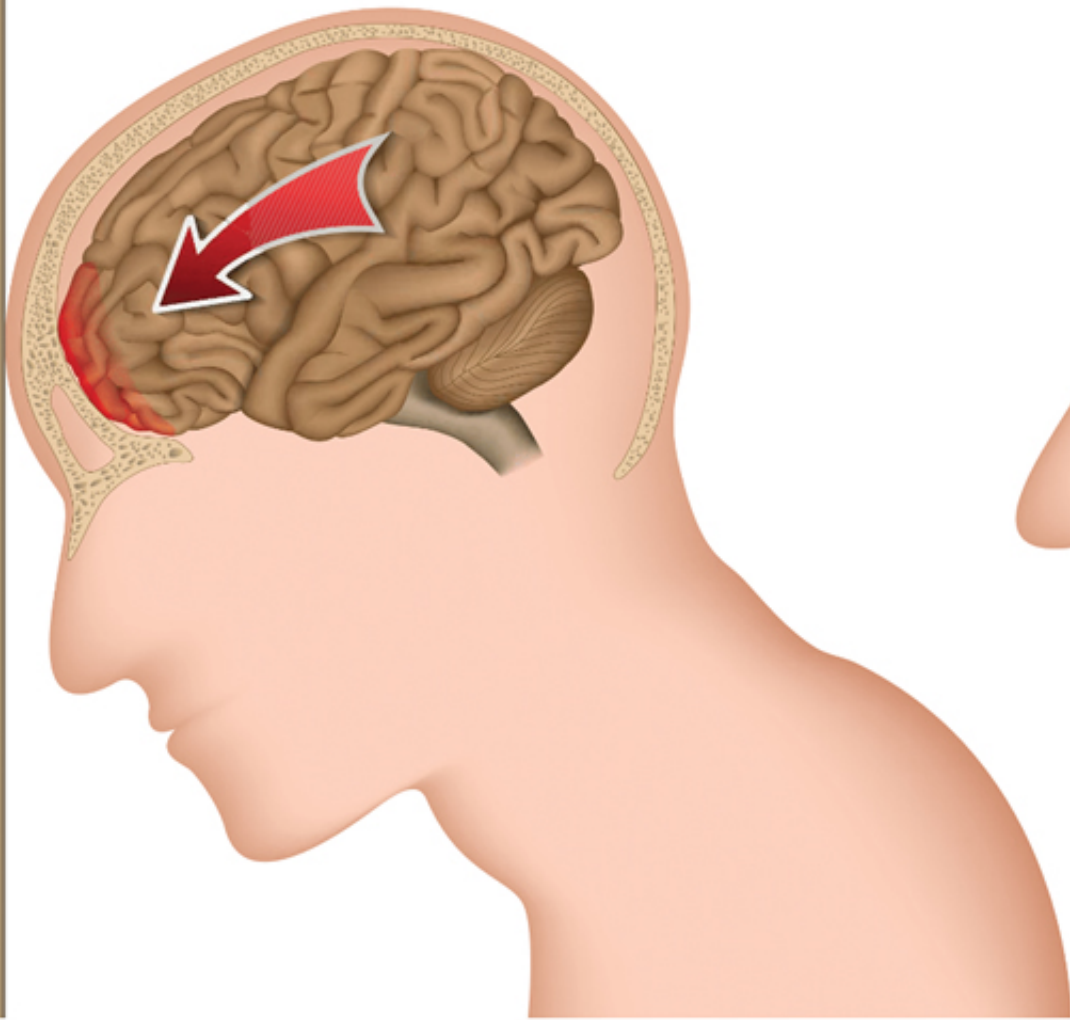
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...then drains into
the venous system

FUNCTIONS OF CSF

(1)Protective function(major function)

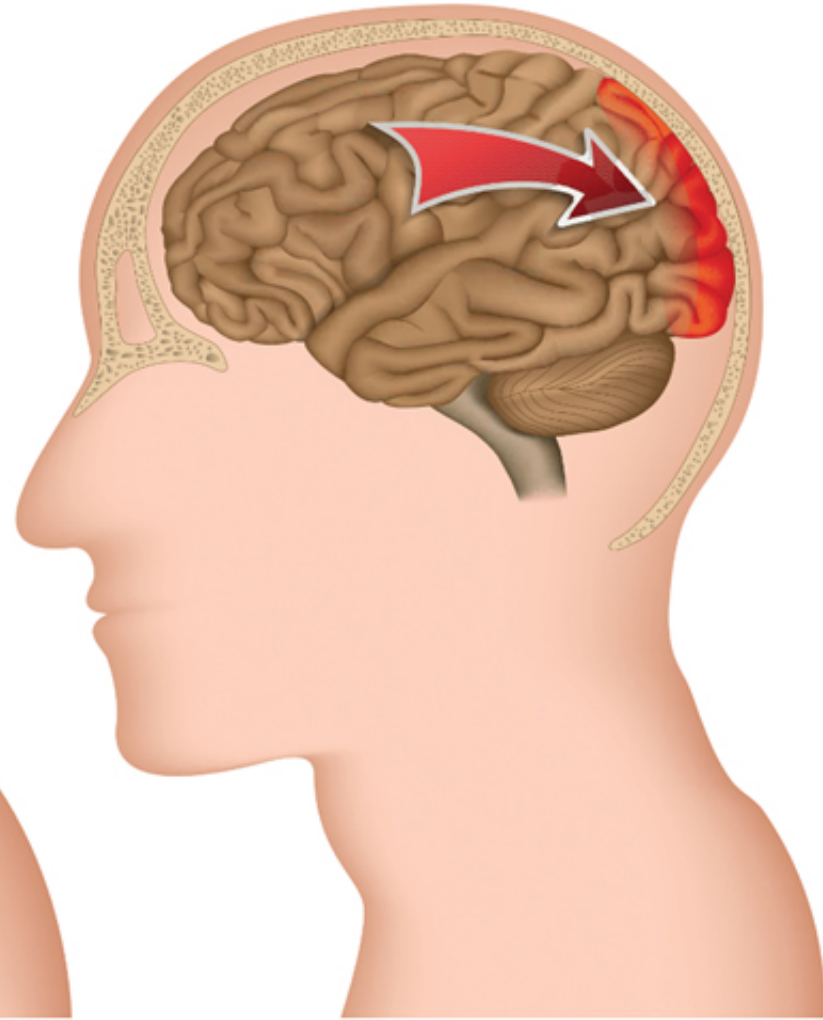
- For brain & spinal cord
- Mechanical cushion for the brain
- Brain weighs about 1400g in air but in its water bath of CSF, it weighs only 50 g due to the effect of buoyancy

- When a blow to the head is extremely severe, it may not damage the brain on the side of the head where the blow is struck but on the opposite side
- This phenomenon is called **contrecoup injury**



1. Primary Impact - Coup

The brain strikes the skull on the side of impact.



2. Secondary Impact -
Contrecoup Impact posterior
area of skull.

(2) It serves as a fluid buffer thereby providing optimum environment for neurons.

(3) Act as a reservoir & regulates the contents of the cranium

So , at any moment if blood volume of brain increases → then CSF drains away

- if brain's blood volume shrinks, more CSF is retained
- Thus, CSF keeps the total volume of cranial content constant

MONRO – KELLIE DOCTRINE

- As brain tissue and CSF is essentially incompressible, the volume of blood, CSF and brain in the cranium at any time must be relatively constant

(4) Role in homeostasis

- CSF is indirectly involved in the regulation of respiration, BP, water intake & visceral function
- Changes in blood pO_2 , pCO_2 & pH sensed by chemo sensitive respiratory neurons & central chemoreceptors via CSF

(5) Transports hormones & hormone releasing factors.

(6) CSF serves as a medium for nutritional exchange in CNS

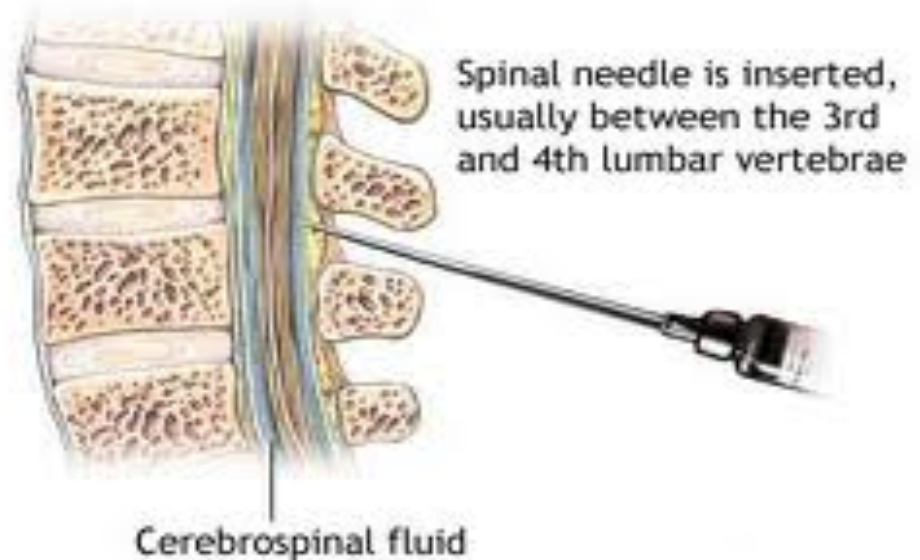
(7) CSF serves the function of Lymphatic system in CNS

APPLIED PHYSIOLOGY

- Lumbar puncture
- Hydrocephalus

LUMBAR PUNCTURE(LP) OR SPINAL TAP

- **DEFINITION:** Insertion of a spinal needle into the subarachnoid space between lumbar spinous processes for collection of CSF which can be either for therapeutic or diagnostic purpose





SITE

- In adults, LP is done between L3 & L4 vertebrae because:-

the spinal cord terminates at the lower border of L1 vertebrae; → So the inserted needle doesn't cause trauma to the spinal cord

INDICATIONS OF LP :-

(A)Diagnostic:

- Meningitis
- Encephalitis
- Subarachnoid Hemorrhage
- Brain tumour
- Brain abscess
- Spinal cord tumour

CSF EXAMINATION

CONDITIONS	APPEARANCE	CELLS	GLUCOSE	PROTEIN	ORGANISM
NORMAL	CLEAR	LYMPHOCYTE < 5 /mm ³	2/3 RD OF PLASMA GLUCOSE LEVEL	20-40mg%	NIL
PYOGENIC MENINGITIS	TURBID	POLYMORPHS MORE	< 2/3 RD OF PLASMA GLUCOSE LEVEL (40mg%)	1-5gm%	PRESENT
TUBERCULAR MENINGITIS	CLEAR/YELLOW) COBWEB FORMATION	LYMPHOCYTES MORE	< 2/3 RD OF PLASMA GLUCOSE LEVEL	1-5gm%	ACID FAST BACILLI PRESENT IN COBWEB
VIRAL MENINGITIS	CLEAR	MODERATE INCREASE IN LYMPHOCYTES	NORMAL	NORMAL / RAISED	NIL
MALIGNANCY	CLEAR	LYMPHOCYTES 0-100	LOW	NORMAL / ELEVATED	NIL

(B)To measure CSF pressure

- During LP, if the needle is connected to a manometer, it records CSF pressure
- Normal value of Lumbar CSF pressure in lateral lying position: 130 mm H₂O

(C)Therapeutic:

- To decrease CSF pressure
- To administer drugs into subarachnoid space so that these drugs will act quickly & effectively on brain tissue
- Used to deliver anaesthetic drugs in spinal anaesthesia

HYDROCEPHALUS

- DEFINITION: Increase in volume of CSF resulting in enlargement of cerebral ventricles
- TYPES:
 - Non- communicating/ Internal Hydrocephalus
 - Communicating/ External Hydrocephalus

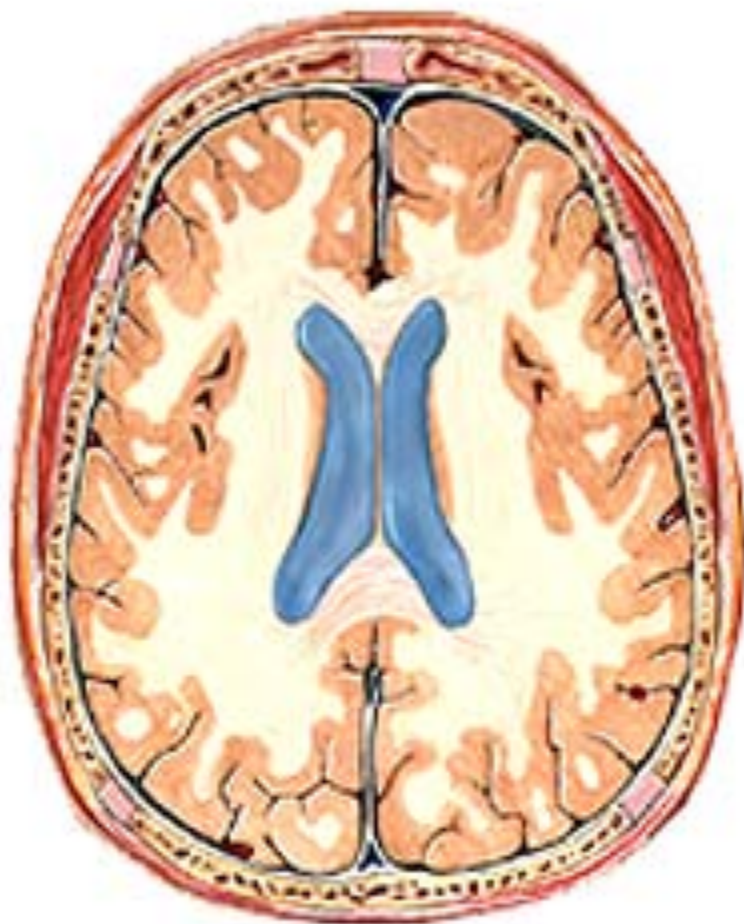
Non-Communicating hydrocephalus

- Obstruction is in any of the foramens that drains CSF
- Fluid formed in the choroid plexus will accumulate in the ventricles & their volumes increases greatly

Communicating hydrocephalus

- Causes :-
 - rate of CSF formation is more than rate of its absorption (over development of choroid plexuses)
 - decrease absorptive capacity of arachnoid villi

Normal



Hydrocephalic

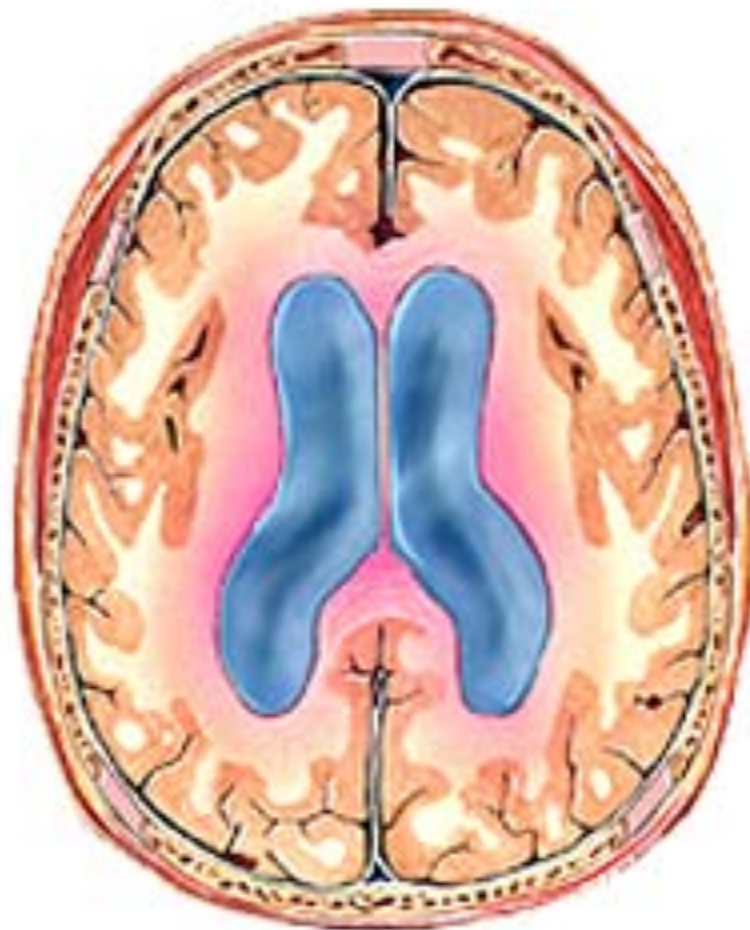
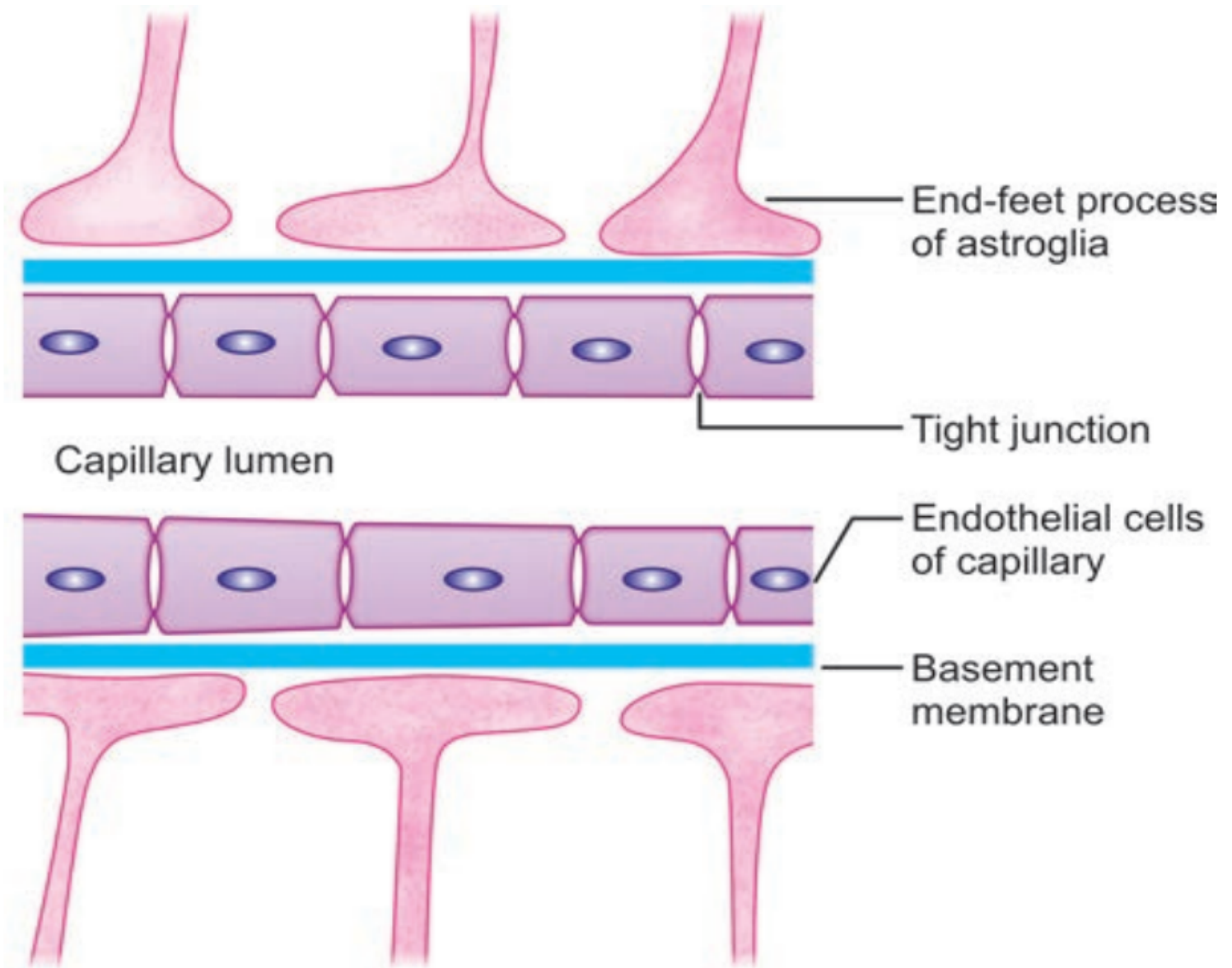


Figure 12.25 Hydrocephalus in a newborn.



BLOOD BRAIN BARRIER(BBB)

- Special barrier that exists between the blood and brain tissue
- BLOOD BRAIN BARRIER is formed by:-
 - endothelium of capillaries of the brain, cells are joined by tight junctions
 - basement membrane
 - foot processes of astrocytes



BLOOD-CSF BARRIER

- Barrier Between blood & CSF
- Resides in the choroid tissue
- The capillaries in the choroid plexus also have tight junctions between the endothelial cells

BLOOD-CSF AND BLOOD-BRAIN BARRIERS are:-

- 1) highly permeable to water, CO_2 , O_2 & most lipid soluble substances such as alcohol and anaesthetics
- 2) slightly permeable to electrolytes such as Na^+ , Cl^- , H^+ , Mg^{2+} , HCO_3^- , K^+ ,
- 3) totally impermeable to plasma proteins and non-lipid soluble large organic molecules

Clinical importance

(1) Kernicterus

- BBB is not fully developed during infancy and early childhood
- In conditions of hyperbilirubinemia in infancy (eg: hemolytic disease of newborn), bilirubin enters the brain and gets deposited in basal ganglia

2) L-dopa which crosses BBB is used in treatment for Parkinsonism

(3) BBB breaks down in the areas of irradiation, infection or brain tumours.

(4) As BBB breaks down in the regions of infections/injury, antibiotics that do not cross BBB in normal individuals penetrate brain tissue easily in patients with infection

(5) IV injection of hypertonic fluid → shrinkage of endothelial cells → makes tight junctions between endothelial cells leaky/less tight

Functions of BBB

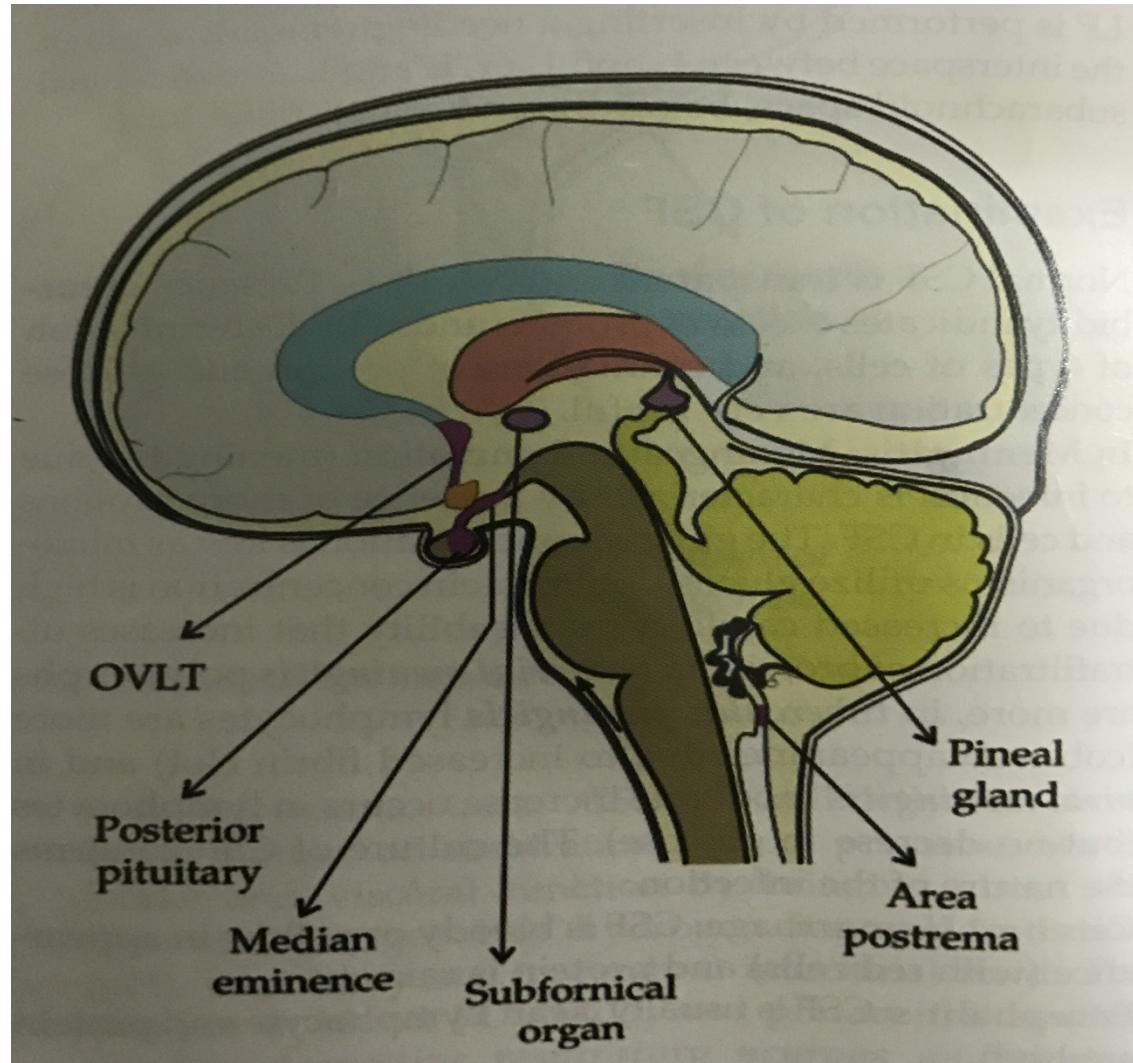
1. BBB protects the sensitivity of the cortical neurons to ionic changes with fluid bathing them
 - This helps to maintain constancy of environment i.e. conc. of K^+ , Ca^{2+} , Mg^{2+} , H^+ and other ions in the CNS
2. Protects brain from endogenous & exogenous toxins in the blood

3. Prevents escape of neurotransmitters into general circulation
4. Disruption of BBB helps in identifying location & extension of lesions in brain
5. BBB influences drug permeability into the brain

CIRCUMVENTRICULAR ORGANS

- Areas outside BBB

CIRCUMVENTRICULAR ORGANS



- **Subfornical organ**
- **Organum Vasculosum of Lamina Terminalis (OVLT)**
- **Area postrema (in medulla)**
- **Posterior pituitary & median eminence of Hypothalamus**
- **Pineal gland**