Cerebrospinal Fluid (CSF)

INTRODUCTION

Cerebrospinal fluid (CSF) is the clear, colorless and transparent fluid that circulates through **ventricles** of brain, **subarachnoid space** and **central canal** of spinal cord. It is a part of extracellular fluid (ECF).

PROPERTIES AND COMPOSITION OF CEREBROSPINAL FLUID

Properties

Volume	:	150 mL (100 mL to 200 mL)
Rate of formation	:	0.3 mL per minute
Specific gravity	:	1.005
Reaction	:	Alkaline.

Composition

Composition of CSF is given in Figure 163.1. Since CSF is a part of ECF, it contains more amount of sodium than potassium. CSF also contains some lymphocytes. CSF secreted by ventricle does not contain any cell. Lymphocytes are added when CSF flows in the spinal cord.

FORMATION OF CEREBROSPINAL FLUID

SITE OF FORMATION

CSF is formed by **choroid plexuses,** situated within the ventricles. Choroid plexuses are tuft of capillary projections present inside the ventricles and are covered by pia mater and ependymal covering. A large amount of CSF is formed in the lateral ventricles.

MECHANISM OF FORMATION

CSF is formed by the process of **secretion** that involves **active transport mechanism.** Formation of CSF does not involve ultrafiltration or dialysis.

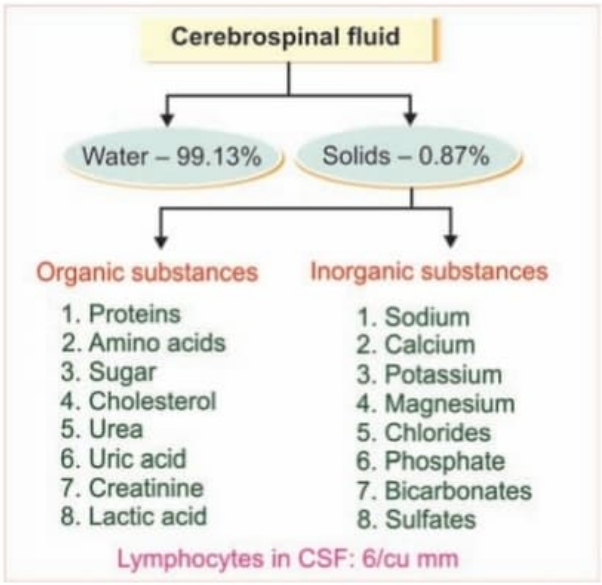

FIGURE 163.1: Composition of cerebrospinal fluid

■ SUBSTANCES AFFECTING THE FORMATION OF CSF

1. Pilocarpine, ether and extracts of pituitary gland stimulate the secretion of CSF by stimulating choroid plexus
2. Injection of isotonic saline also stimulates CSF formation
3. Injection of hypotonic saline causes greater rise in capillary pressure and intracranial pressure and fall in osmotic pressure, leading to increase in CSF formation
4. Hypertonic saline decreases CSF formation and decreases the CSF pressure. The increased intracranial pressure is reduced by injection of 30% to 35% of sodium chloride or 50% sucrose.

■ CIRCULATION OF CEREBROSPINAL FLUID

Major quantity of CSF is formed in **lateral ventricles** and enters third ventricle by passing through **foramen of Monro** (Figs. 163.2 and 163.3). From here, it passes to **fourth ventricle** through **aqueductus Sylvius.** From fourth ventricle, CSF enters the **cisterna magna** and **cisterna lateralis** through **foramen of Magendie** (central opening) and **foramen of Luschka** (lateral opening).

From cisterna magna and cisterna lateralis, CSF circulates through **subarachnoid space** over spinal cord and cerebral hemispheres. It also flows into **central canal** of spinal cord.

■ ABSORPTION OF CEREBROSPINAL FLUID

CSF is mostly absorbed by the **arachnoid villi** into **dural sinuses** and **spinal veins.** Small amount is absorbed along the **perineural spaces** into **cervical lymphatics** and into the **perivascular spaces.**

The mechanism of absorption is by filtration due to pressure gradient between hydrostatic pressure in the subarachnoid space fluid and the pressure that exists in the dural sinus blood. Colloidal substances pass slowly and crystalloids are absorbed rapidly.

Normally, about 500 mL of CSF is formed everyday and an equal amount is absorbed.

■ PRESSURE EXERTED BY CEREBROSPINAL FLUID

Pressure exerted by CSF in man varies in different position, viz.

Lateral recumbent position	:	10 to 18 cm of H_2O
Lying position	:	13 cm of H_2O
Sitting position	:	30 cm of H_2O

Certain events like coughing and crying increase the pressure by decreasing absorption. Compression of internal jugular vein also raises the CSF pressure.

■ FUNCTIONS OF CEREBROSPINAL FLUID

1. *Protective Function*

CSF acts as fluid buffer and protects the brain from shock. Since, the specific gravity of brain and CSF is more or less same, brain floats in CSF. When head receives a blow, CSF acts like a cushion and prevents the movement of brain against the skull bone and thereby, prevents the damage of brain.

However, if the head receives a severe blow, the brain moves forcefully and hits against the skull bone, leading to the damage of brain tissues. Brain strikes against the skull bone at a point opposite to the point where the blow was applied. So, this type of damage to the brain is known as **countercoup injury.**

2. *Regulation of Cranial Content Volume*

Regulation of cranial content volume is essential because, brain may be affected if the volume of cranial content increases. It happens in cerebral hemorrhage and brain tumors.

Increase in cranial content volume is prevented by greater absorption of CSF to give space for the increasing cranial contents.

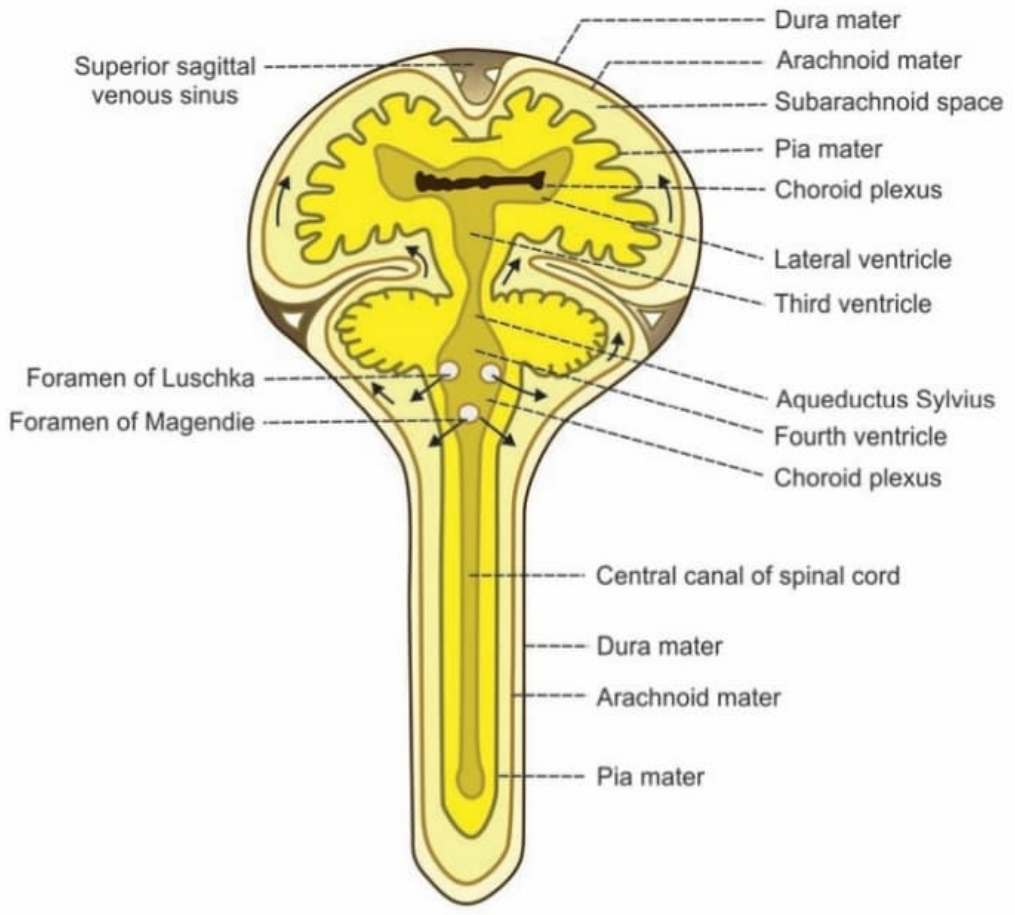

FIGURE 163.2: Circulation of cerebrospinal fluid

3. *Medium of Exchange*

CSF is the medium through which many substances, particularly nutritive substances and waste materials are exchanged between blood and brain tissues.

■ COLLECTION OF CEREBROSPINAL FLUID

CSF is collected either by **cisternal puncture** or **lumbar puncture.** In cisternal puncture, the CSF is collected by passing a needle between the occipital bone and atlas, so that it enters cisterna magna. In lumbar puncture, the lumbar puncture needle is introduced into subarachnoid space in lumbar region, between the third and fourth lumbar spines.

■ LUMBAR PUNCTURE

Posture of Body for Lumbar Puncture

The reclining body is bent forward, so as to flex the vertebral column as far as possible. Then the body is brought near edge of a table. The highest point of iliac crest is determined by palpation. A line is drawn on the back of the subject by joining the highest points of **iliac crests** of both sides. Opposite to midplane, this line crosses the fourth lumbar spine.

After determining the area of fourth lumbar spine, third lumbar spine is palpated. The needle is introduced into subarachnoid space by passing through soft tissue space between the two spines.

Reasons for selecting this site

1. Spinal cord will not be injured, because, it terminates below the lower border of the first lumbar vertebra. Cauda equina may be damaged. But it is regenerated.
2. Subarachnoid space is wider in this site. It is because the pia mater is reduced very much.

Uses of Lumbar Puncture

Lumbar puncture is used for:

1. Collecting CSF for diagnostic purposes
2. Injecting drugs (intrathecal injection) for spinal anesthesia, analgesia and chemotherapy
3. Measuring the pressure exerted by CSF.

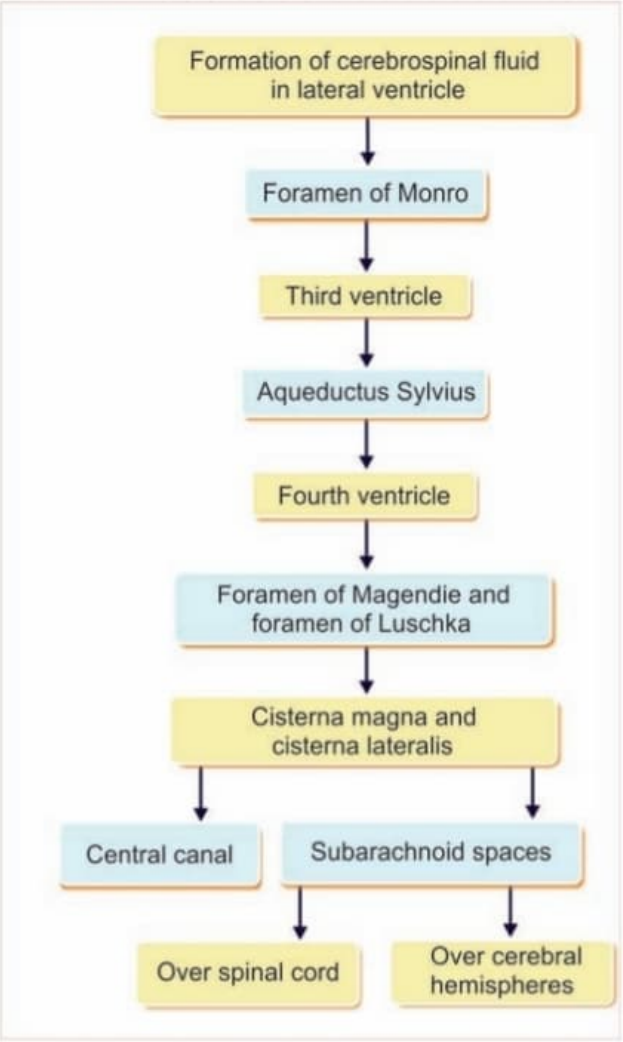

FIGURE 163.3: Cerebrospinal fluid circulation

■ BLOOD-BRAIN BARRIER

Blood-brain barrier (BBB) is a neuroprotective structure that prevents the entry of many substances and pathogens into the brain tissues from blood.

It was observed more than 50 years ago, that when **trypan blue,** the acidic dye was injected into living animals, all the tissues of body were stained by it, except the brain and spinal cord. This observation suggested that there was a hypothetical barrier, which prevented the diffusion of trypan blue into the brain tissues from the capillaries. This barrier was named as blood-brain barrier (BBB). It exists in the capillary membrane of all parts of the brain, except in some areas of hypothalamus.

■ STRUCTURE OF BLOOD-BRAIN BARRIER

Tight junctions in the endothelial cells of brain capillaries are responsible for BBB mechanism.

In capillaries of other organs, adjacent endothelial cells leave the cleft called **fenestra,** which allows **transcytosis** of several substances through endothelium (Chapter 111). However, in capillaries of brain, fenestra are absent because, the endothelial cells fuse with each other by tight junctions (Fig. 163.4).

Tight junctions are formed between endothelial cells of the capillaries at childhood. At the same time, cytoplasmic foot processes of astrocytes (neuroglial cells) develop around capillaries and reinforce the barrier. Astocytes envelop the vasculature almost completely.

Pericytes also form the important cellular constituent of BBB. These cells play an important role in formation and maintenance of tight junction and structural stability of the barrier. In brain, pericytes function as macrophages and play an important role in the defense.

■ FUNCTIONS OF BLOOD-BRAIN BARRIER

BBB acts as both a mechanical barrier and transport mechanisms. It prevents potentially harmful chemical substances and permits metabolic and essential materials into the brain tissues. By preventing injurious materials and organisms, BBB provides healthy environment for the nerve cells of brain.

Substances which can Pass through Blood-Brain Barrier

1. Oxygen
2. Carbon dioxide
3. Water
4. Glucose
5. Amino acids
6. Electrolytes
7. Drugs such as L-dopa, 5-hydroxytryptamine sulfonamides, tetracycline and many lipid-soluble drugs
8. Lipid-soluble anesthetic gases such as ether and nitrous oxide
9. Other lipid-soluble substances.

Substances which cannot Pass through Blood-Brain Barrier

1. Injurious chemical agents
2. Pathogens such as bacteria
3. Drugs such as Penicillin and the catecholamines. Dopamine also cannot pass through BBB. So, parkinsonism is treated with L-dopa, instead of dopamine.

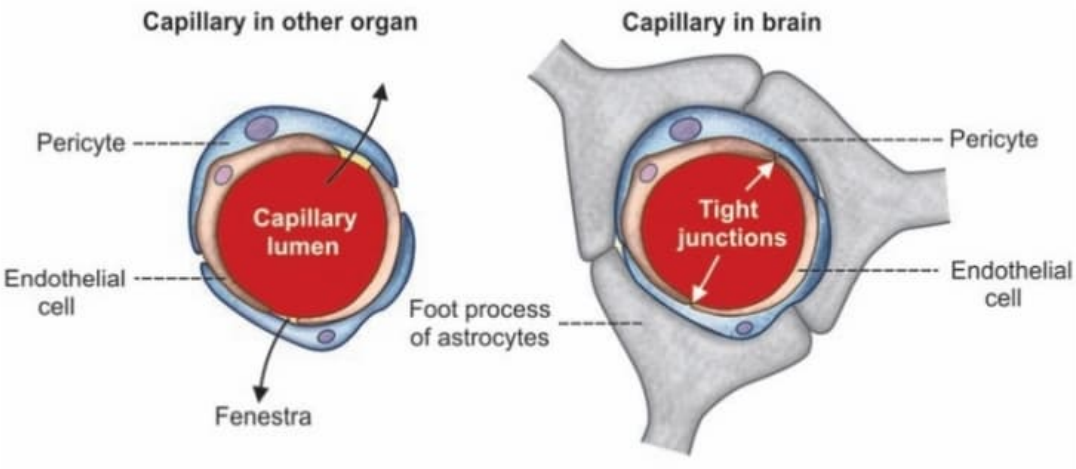

FIGURE 163.4: Blood-brain barrier

4. Bile pigments: However, since the barrier is not well developed in infants, the bile pigments enter the brain tissues. During **jaundice** in infants, the bile pigments enter brain and causes damage of **basal ganglia,** leading to **kernicterus** (refer Chapter 21 for details).

■ BLOOD-CEREBROSPINAL FLUID BARRIER

Blood-CSF barrier is the barrier between blood and cerebrospinal fluid that exists at the choroid plexus. The function of this barrier is similar to that of BBB. It does not allow the movement of many substances from blood to cerebrospinal fluid. It allows the movement of only those substances which are allowed by BBB.

■ APPLIED PHYSIOLOGY – HYDROCEPHALUS

Abnormal accumulation of CSF in the skull, associated with enlargement of head is called hydrocephalus. During obstruction of any foramen, through which CSF escapes, the ventricular cavity dilates and this condition is called **internal hydrocephalus.** It is also known as **non-communicating** hydrocephalus.

On the other hand, if the arachnoid villi are blocked, **external** or **communicating hydrocephalus** occurs.

Hydrocephalus along with increased intracranial pressure causes headache and vomiting. In severe conditions, it leads to atrophy of brain, mental weakness and convulsions.