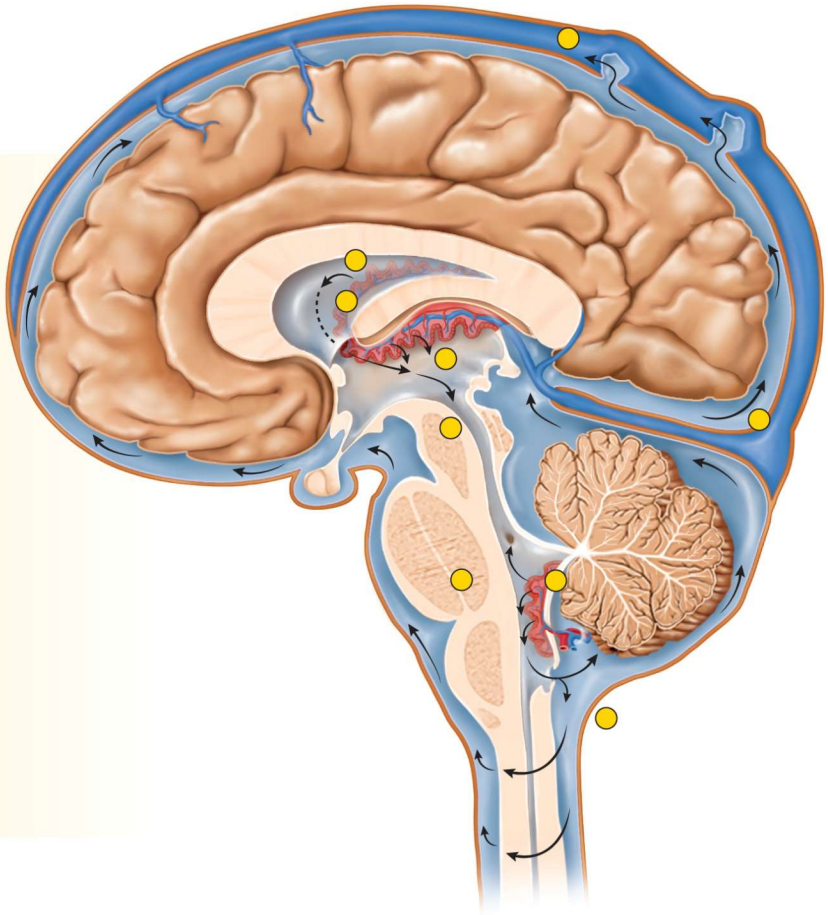
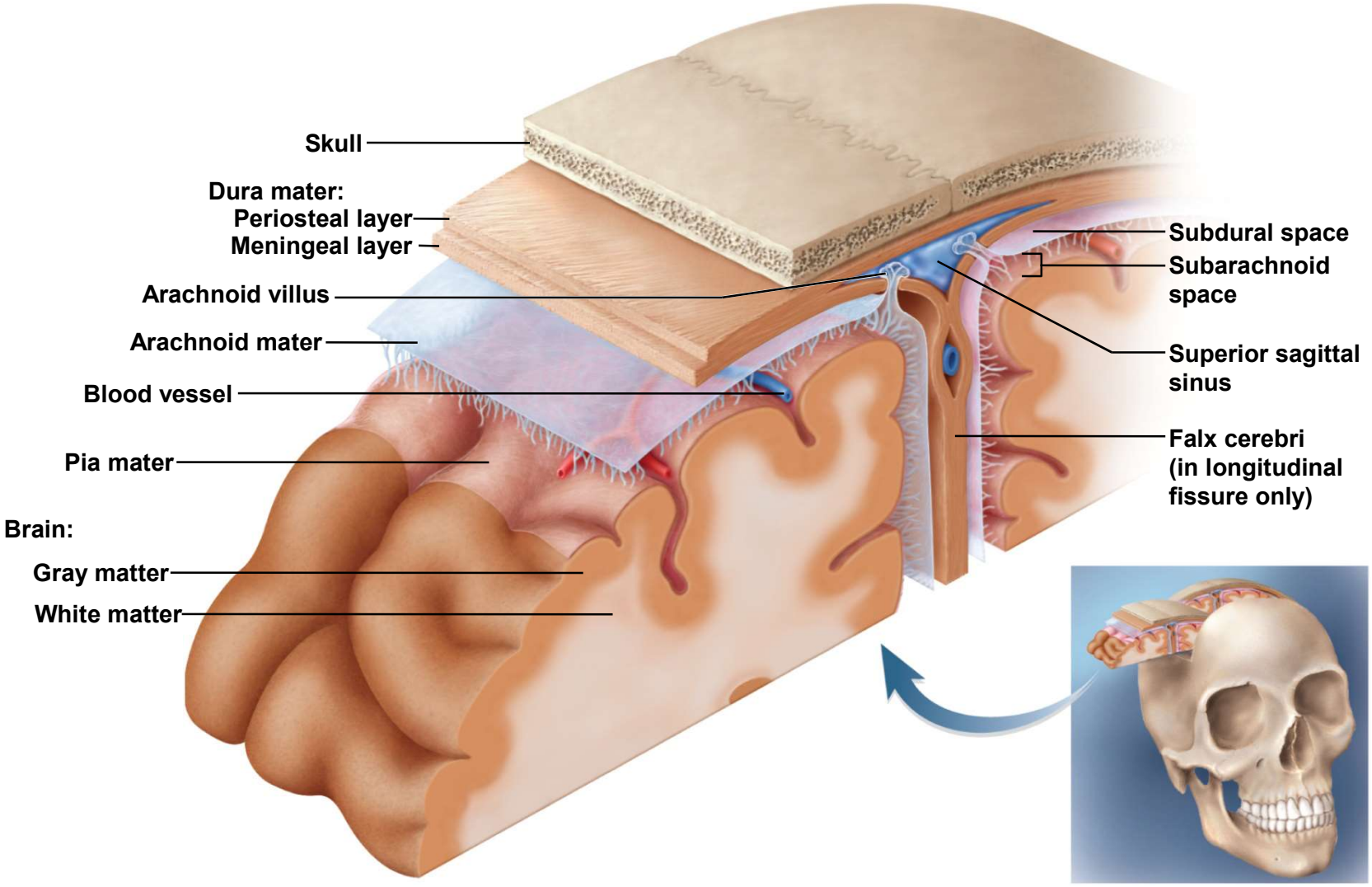
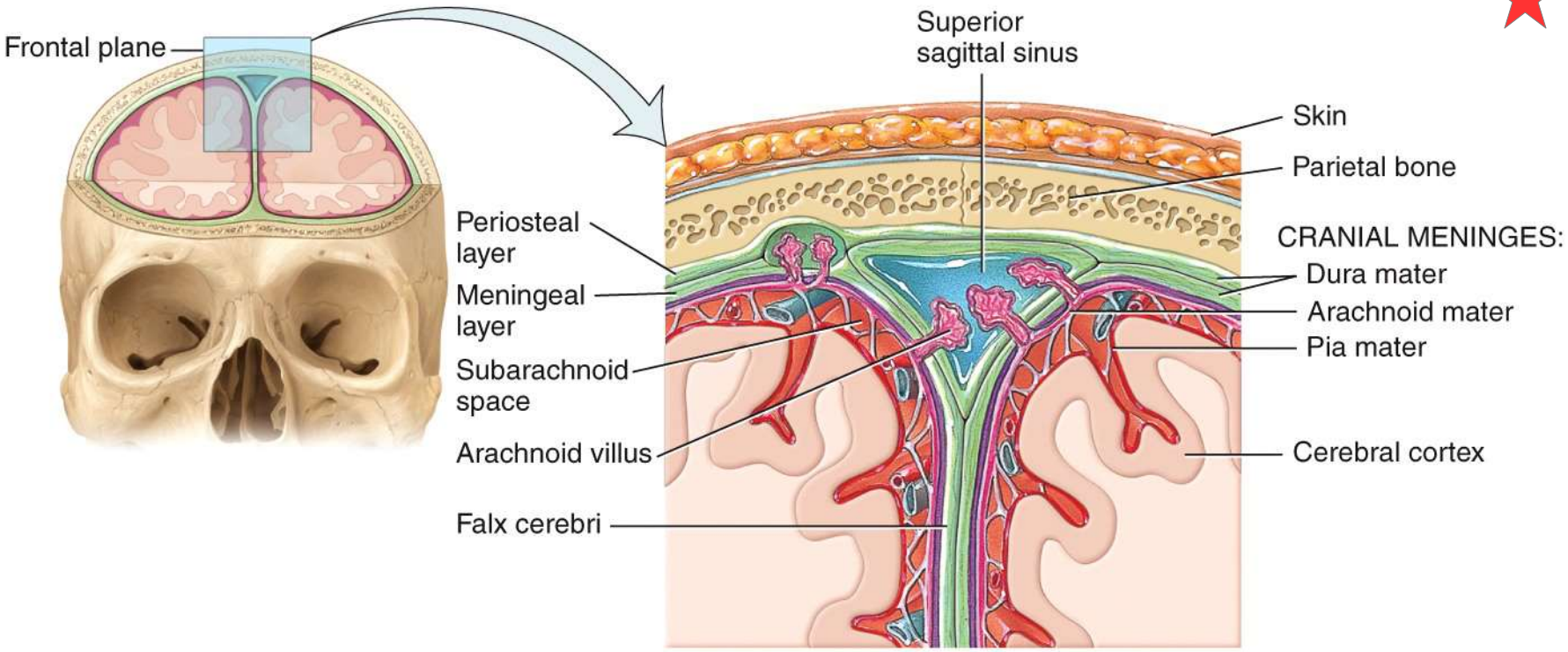
Chapter 14.1

The Brain Meninges and Cerebral Spinal Fluid



Meninges of the Brain





(a) Anterior view of frontal section through skull showing the cranial meninges

What is the name of the force that moves fluid into the superior sagittal sinus?

Meninges

- three connective tissue membranes that envelop the brain
  - lies between the nervous tissue and bone
  - similar layers cover the spinal cord but fatty layer between dura mater and bone
    - dura mater
    - arachnoid mater
    - pia mater
  - protect the brain and provide structural framework for its arteries and veins

Dura Mater

- Located in cranial cavity // moat areas the dura is a single layer but in certain areas it separate into two layers to form sinuses
  - outer periosteal (periosteal layer) – equivalent to periosteum of cranial bones
  - inner meningeal (meningeal layer) – continues into vertebral canal and forms dural sac around spinal cord
  - cranial dura mater is pressed closely against cranial bones
    - no epidural space (differ from around spinal cord)
    - attached to foramen magnum, sella turcica, crista galli, and sutures of the skull
    - The separated layers are called dural sinuses – cerebral spinal fluid and blood that circulated through brain return to the systemic circuit by first draining into the sinuses and then enter the jugular veins

Dura Mater Projection Membranes

- Dura mater forms inward folds to extend between three parts of the brain
    - falx cerebri separates the two cerebral hemispheres
    - tentorium cerebelli separates cerebrum from cerebellum
    - falx cerebelli separates the right and left halves of cerebellum

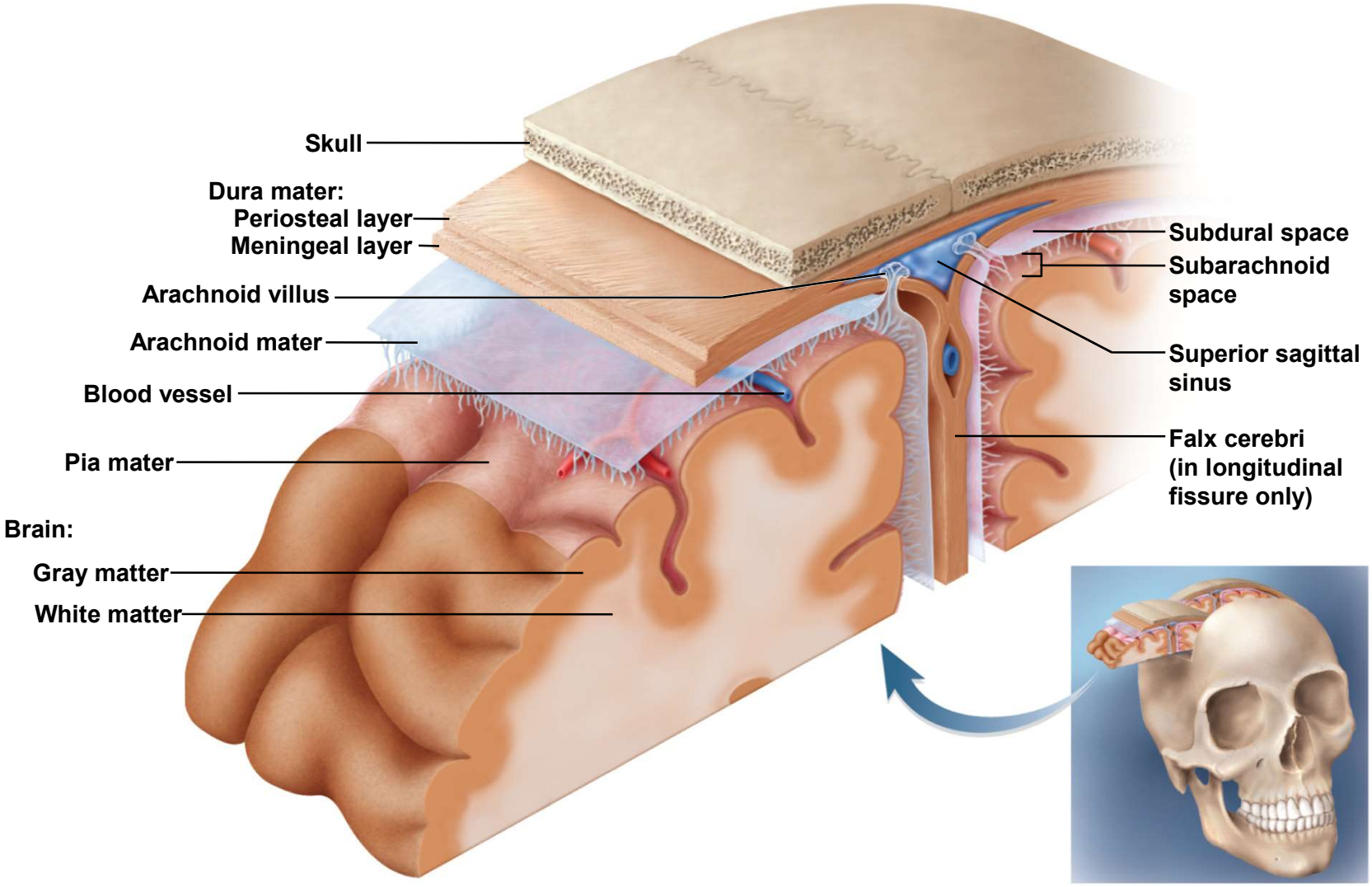
Arachnoid Mater & Pia Mater

- arachnoid mater and pia mater are similar to those in the spinal cord

- **arachnoid mater**
  - transparent membrane over brain surface
  - **subarachnoid space** separates it from pia mater below
  - **subdural space** separates it from dura mater above in some places

- **pia mater**
  - very thin membrane that follows contours of brain, even dipping into sulci
  - not usually visible without a microscope

Meninges of the Brain



Meningitis

- inflammation of the meninges
  - serious disease of infancy & childhood
  - especially between 3 months and 2 years of age
  - always treated as medical emergency
  - death follows as soon as three hours after first symptoms
- caused by bacterial and virus invasion of the CNS by way of the nose and/or throat
- pia mater and arachnoid are most often affected

Meningitis

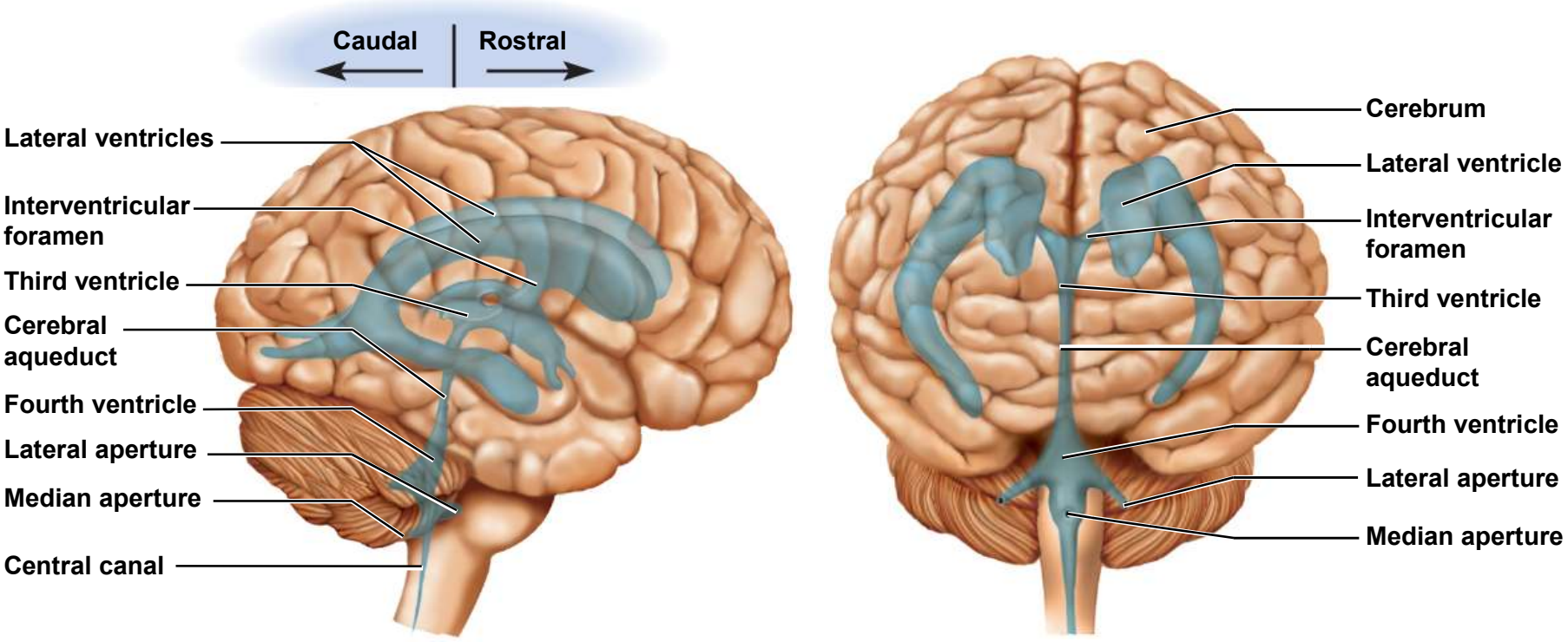
- bacterial meningitis can cause swelling the brain, enlarging the ventricles, and cause hemorrhage

- signs include high fever, stiff neck, drowsiness, and intense headache and may progress to coma – death within hours of onset

- diagnosed by examining the CSF for bacteria

  – lumbar puncture (spinal tap) draws fluid from subarachnoid space between two lumbar vertebrae

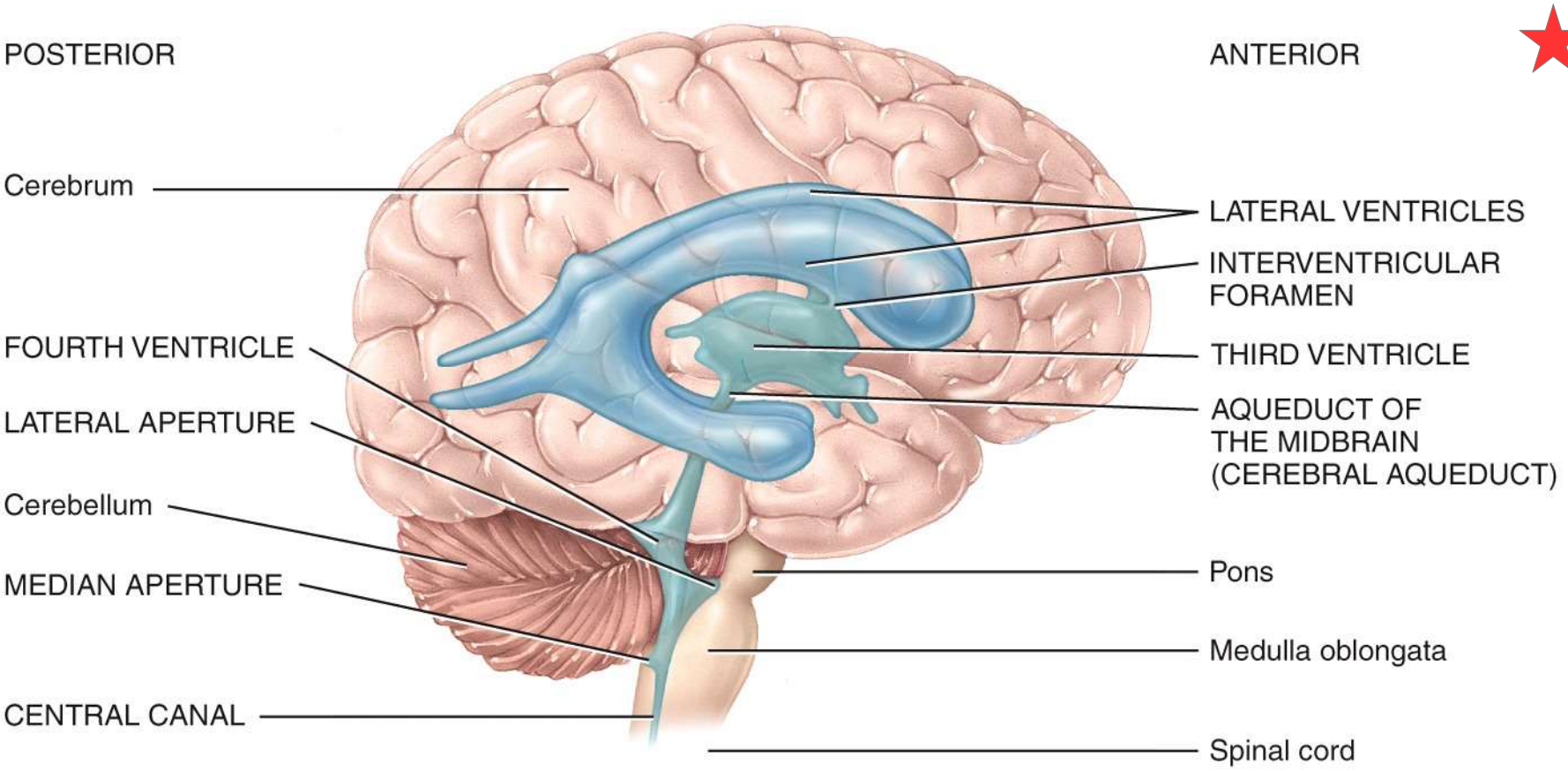
Brain Ventricles



(a) Lateral view

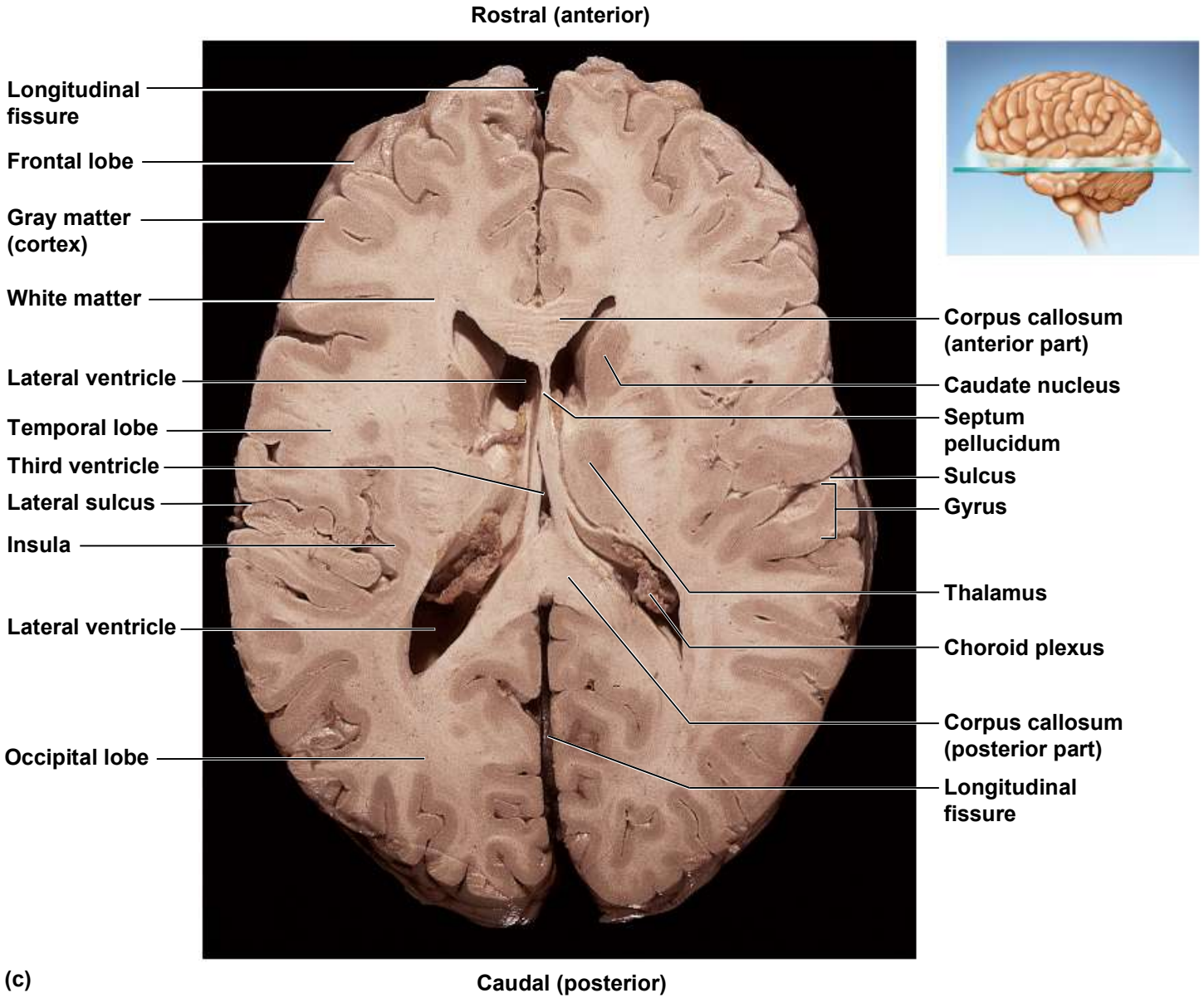
(b) Anterior view

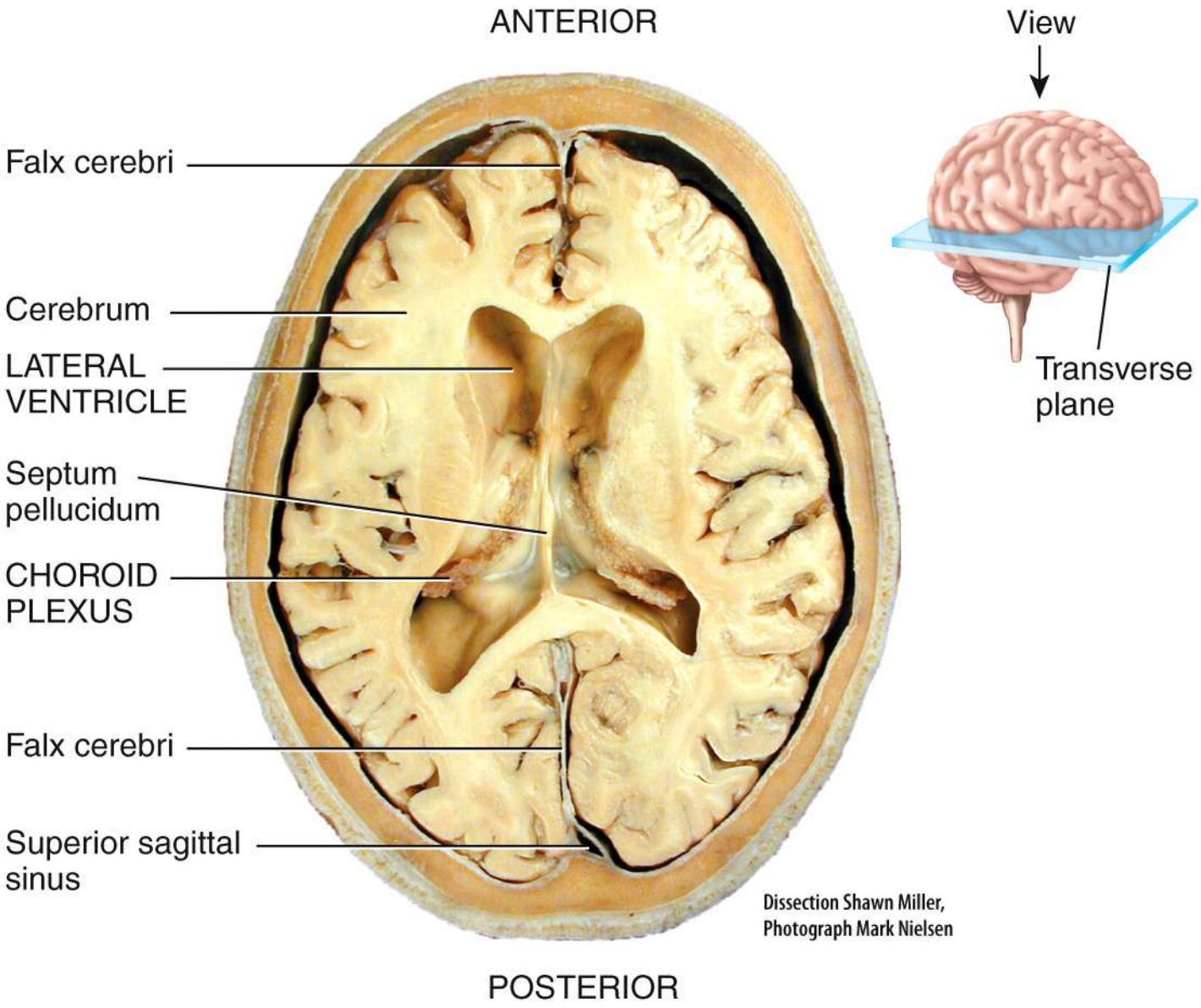
Four fluid filled cavities deep within the brain with walls formed by epidemal cells. These cavities are connected by tubular structures which allows cerebral spinal fluid to flow from the lateral ventricles to the fourth ventricle. CSF in fourth ventricle may flow either into spinal cord's central canal or into the sub arachnoid space surrounding the brain.



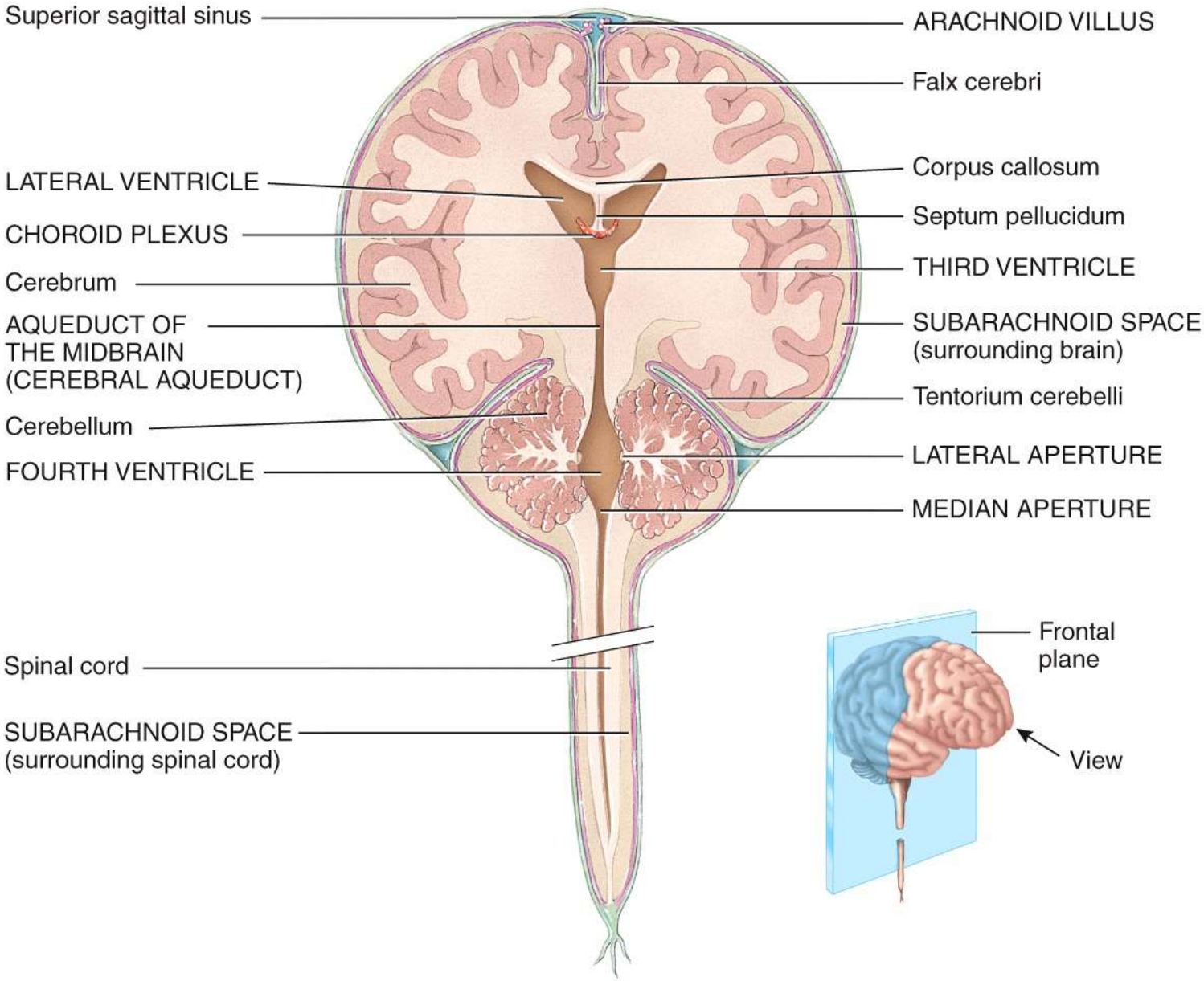
Right lateral view of brain

Ventricles of the Brain





(a) Superior view of transverse section of brain showing choroid plexuses



(c) Frontal section of brain and spinal cord

Functions of CSF

- **buoyancy**
  - allows brain to attain considerable size without being impaired by its own weight
  - if it rested heavily on floor of cranium, the pressure would kill the nervous tissue
- **protection**
  - protects the brain from striking the cranium when the head is jolted
  - **shaken child syndrome** and **concussions** do occur from severe jolting
- **chemical stability**
  - flow of CSF rinses away metabolic wastes from nervous tissue and homeostatically regulates its chemical environment

Ventricles and Cerebrospinal Fluid

- ventricles – four internal chambers within the brain
  - two lateral ventricles – one in each cerebral hemisphere
    - interventricular foramen - a tiny pore that connects to third ventricle
  - third ventricle - single narrow medial space beneath corpus callosum
  - *cerebral aqueduct* runs through midbrain and connects third and fourth ventricle
  - fourth ventricle – small triangular chamber between pons and cerebellum // connects to central canal runs down through spinal cord
    - One medial and two lateral appentures // allow CSF to enter subarachnoid space

Ventricles and Cerebrospinal Fluid

- choroid plexus – spongy mass of blood capillaries on the ceiling of each of the four ventricles

- ependyma – neuroglia that lines the ventricles and covers the choroid plexus // produces 30% of the cerebrospinal fluid

Cerebrospinal Fluid (CSF)

- clear, colorless liquid that fills the ventricles and canals of CNS // also bathes brains external surface

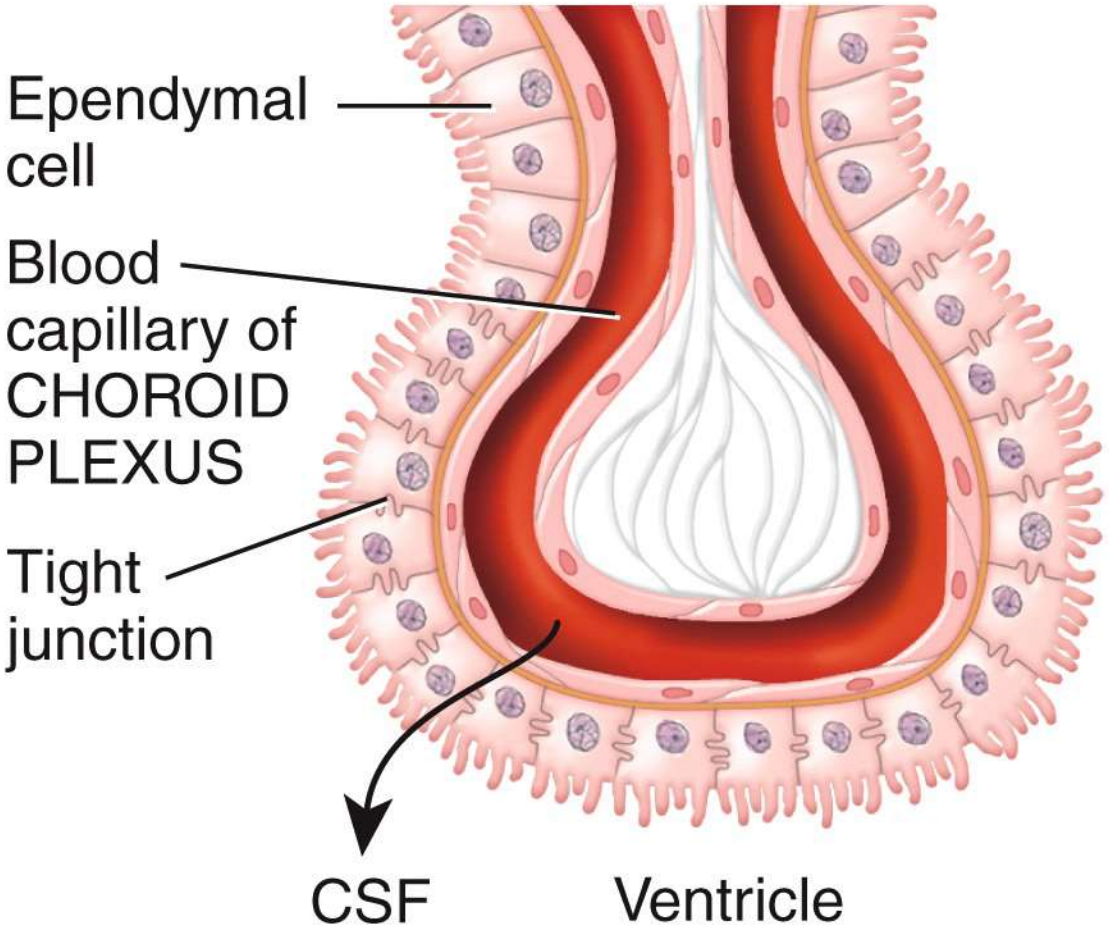
- brain produces and absorbs 500 mL/day

  – 100 – 160 mL normally present at one time

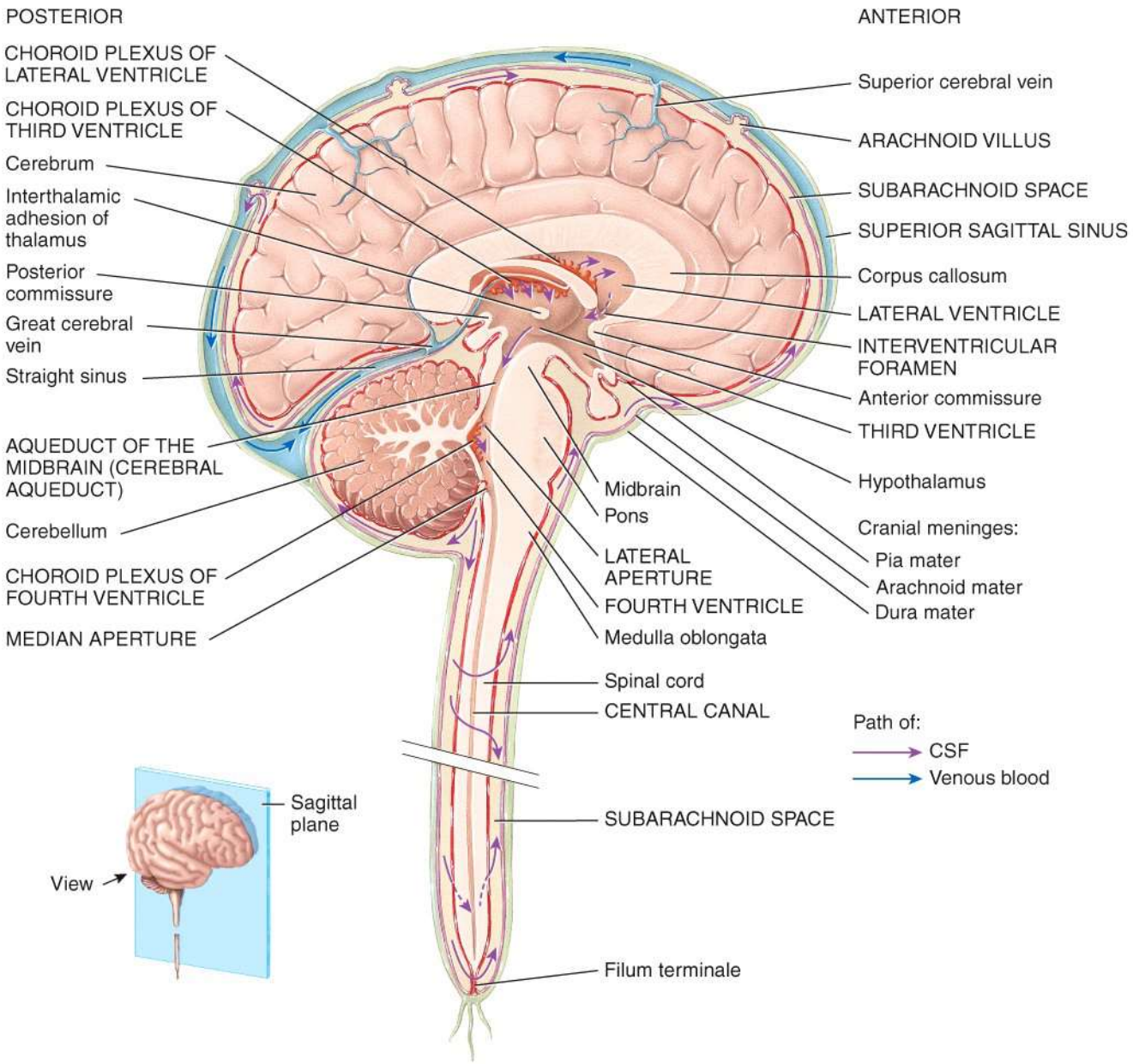
  – 40% formed in subarachnoid space external to brain

  – 30% by the general ependymal lining of the brain ventricles

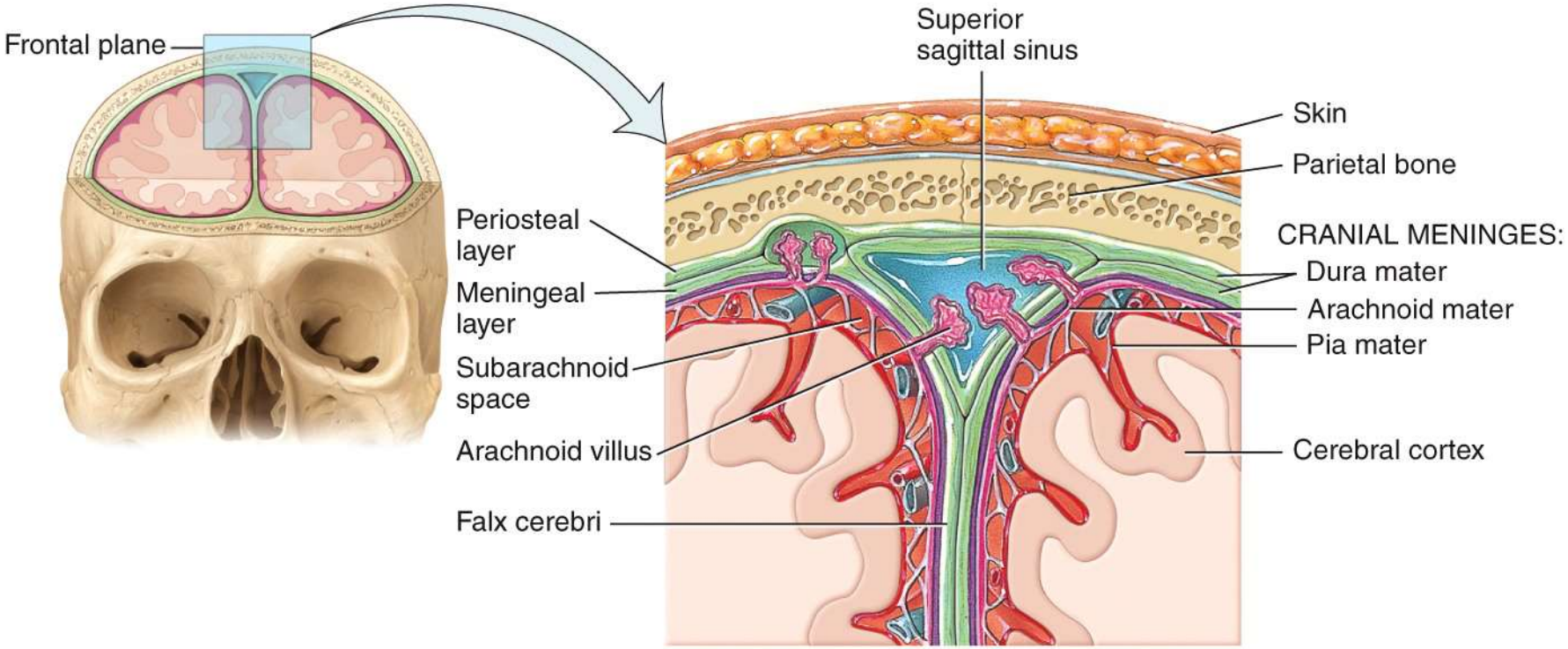
  – 30% by the choroid plexuses /// Note: Choroid plexuses is responsible for the **Blood – CSF Barrier** // **this adjusts the chemistry of the CSF to meet special needs of the neurons.**



Details of a section through a choroid plexus (arrow indicates direction of filtration from blood to CSF)



(b) Sagittal section of brain and spinal cord



(a) Anterior view of frontal section through skull showing the cranial meninges

Cerebrospinal Fluid (CSF)

- production begins with the filtration of blood plasma through the capillaries of the brain
  - ependymal cells modify the filtrate /// so CSF has more sodium and chloride than plasma, but less potassium, calcium, glucose, and very little protein

Cerebrospinal Fluid (CSF) Circulation

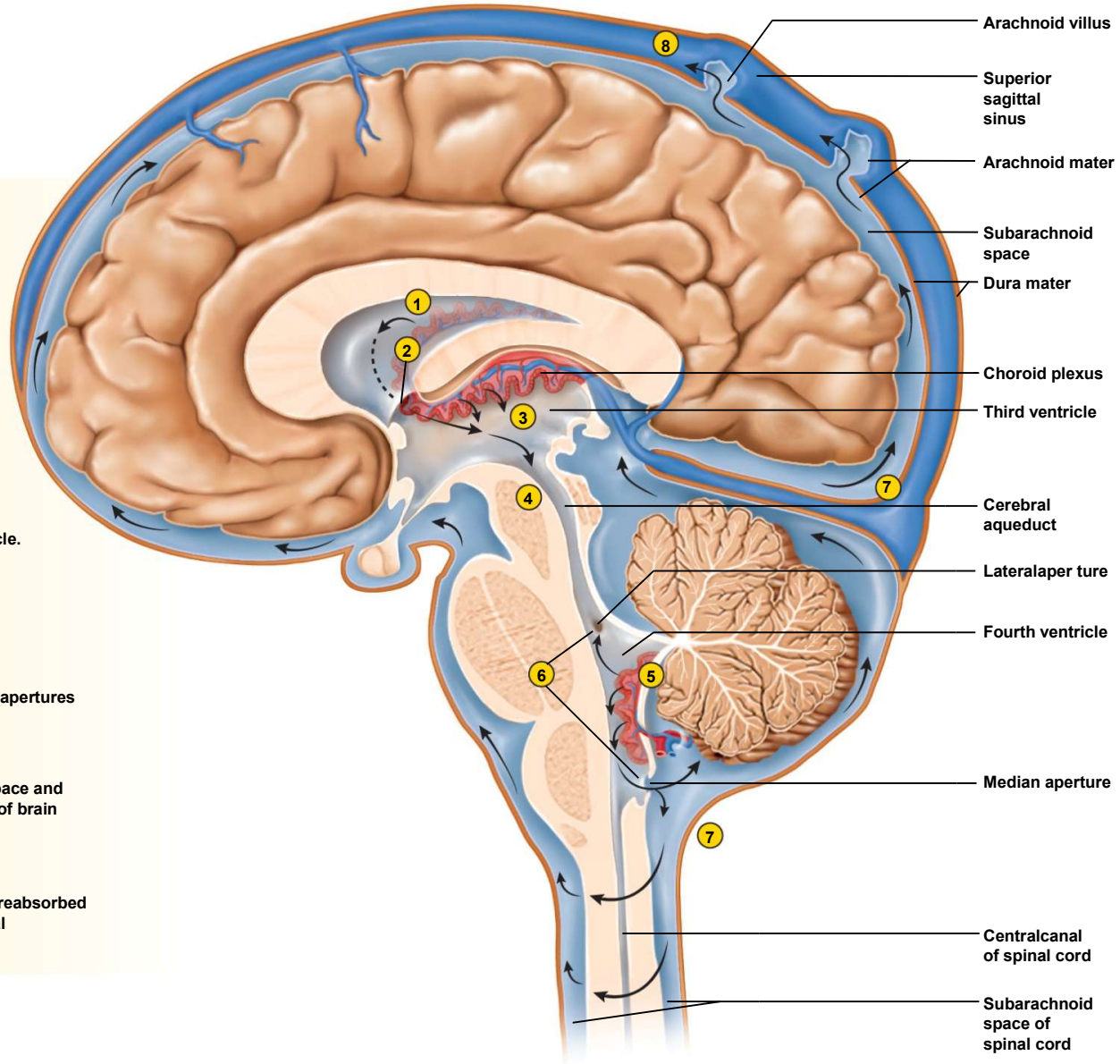
- CSF continually flows through and around the CNS
  - driven by its own pressure, beating of ependymal cilia, and pulsations of the brain produced by each heartbeat
- CSF secreted in lateral ventricles flows through interventricular foramina into third ventricle
- then down the cerebral aqueduct into the fourth ventricle
- third and fourth ventricles add more CSF along the way

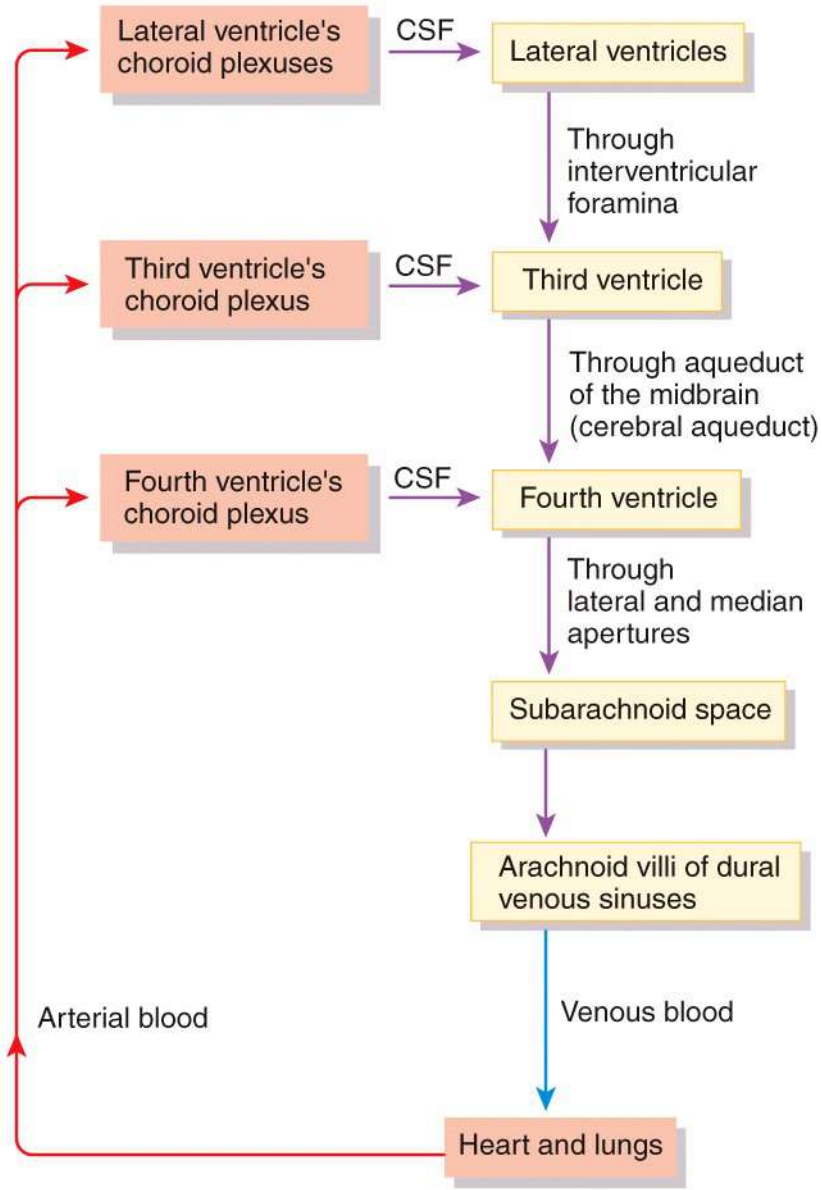
Cerebrospinal Fluid (CSF) Circulation

- small amount of CSF fills the central canal of the spinal cord
  - all escapes through three pores
    - median aperture and two lateral apertures
    - leads into subarachnoid space of brain and spinal cord surface
- CSF is reabsorbed by arachnoid villi
  - cauliflower-shaped extension of the arachnoid meninx // protrudes through dura mater
  - into superior sagittal sinus // CSF penetrates the walls of the villi and mixes with the blood in the sinus

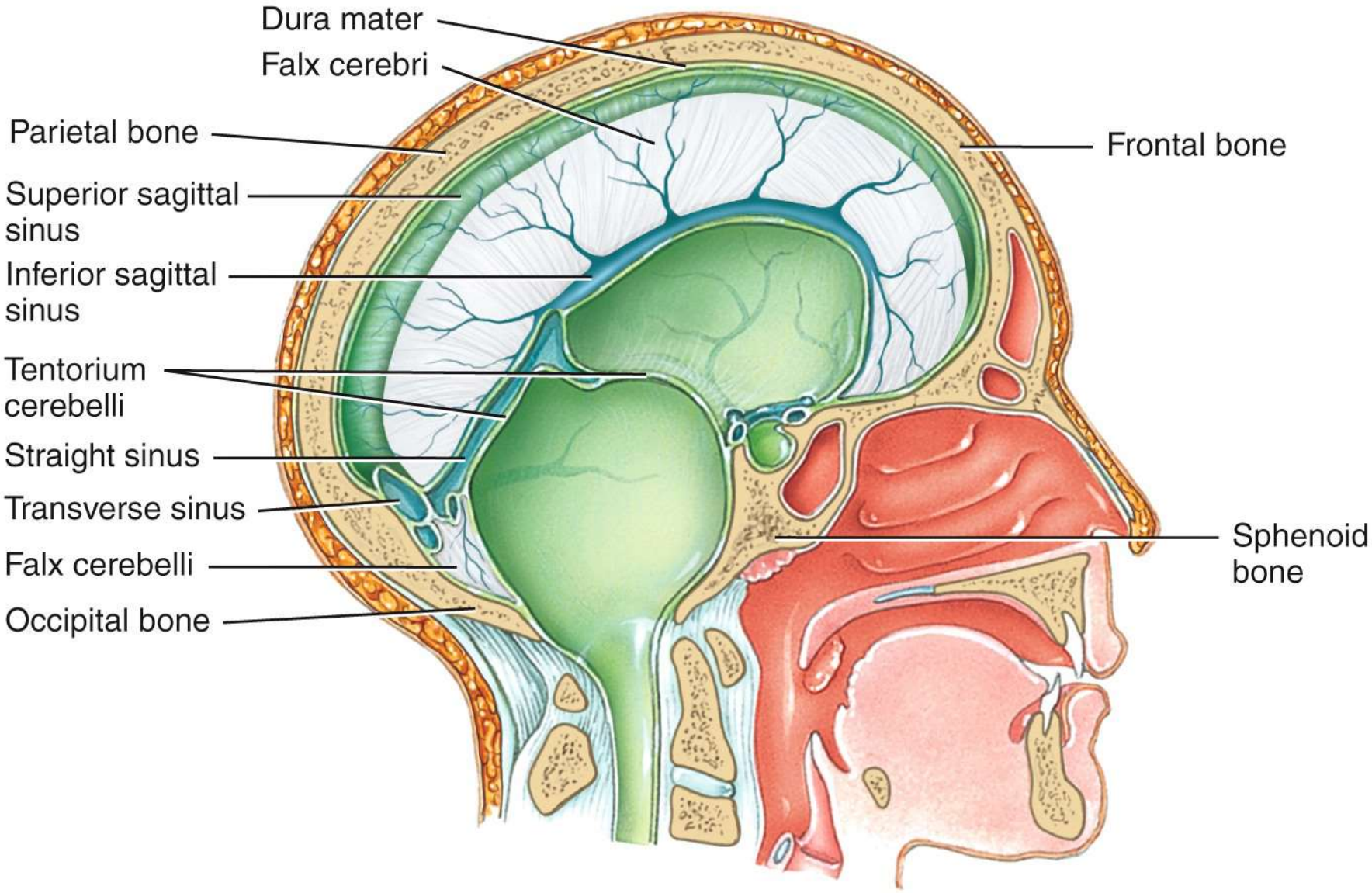
Flow of Cerebrospinal Fluid

1. CSF is secreted by choroid plexus in each lateral ventricle.
2. CSF flows through Interventricular foramina into third ventricle.
3. Choroid plexus in third ventricle adds more CSF.
4. CSF flows down cerebral aqueduct to fourth ventricle.
5. Choroid plexus in fourth ventricle adds more CSF.
6. CSF flows out two lateral apertures and one median aperture.
7. CSF fills subarachnoid space and bathes external surfaces of brain and spinal cord.
8. At arachnoid villi, CSF is reabsorbed into venous blood of dural venous sinuses.





(d) Summary of the formation, circulation, and absorption of cerebrospinal fluid (CSF)



(b) Sagittal section of extensions of the dura mater

Blood Supply to the Brain

- brain is only 2% of the adult body weight, and receives 15% of the blood // 750 mL/min

- neurons have a high demand for ATP, and therefore, oxygen and glucose, so a constant supply of blood is critical to the nervous system

  - 10 second interruption of blood flow may cause loss of consciousness

  - 1 – 2 minute interruption can cause significant impairment of neural function

  - 4 minutes with out blood causes irreversible brain damage

Brain Barriers

- blood is also a source of antibodies, macrophages, bacterial toxins, and other harmful agents

- **Blood brain barriers** – these structures strictly regulates what substances can move between the bloodstream to the neuron or to the brain's interstitial fluid

- two separate groups of capillaries which represent potential transit points of entry for substances to the neuron or brain tissue:

  - blood capillaries throughout the brain tissue (into neurons)

  - capillaries of the choroid plexus (into ventricles)

Blood Brain Barrier System

- Protects blood capillaries throughout brain tissue
  - consists of tight junctions between endothelial cells that form the capillary walls
  - astrocytes reach out and contact capillaries with their perivascular feet
  - induce the endothelial cells to form tight junctions that completely seal off gaps between them
  - anything leaving the blood must pass through the cells, and not between them
  - **endothelial cells** can exclude harmful substances from passing to the brain tissue while allowing necessary ones to pass

Blood CSF Barrier System

- Blood-CSF barrier – another type of barrier designed to protects the brain at the level of the choroid plexus
  - form tight junctions between the ependymal cells
  - tight junctions are absent from ependymal cells elsewhere
  - important to allow exchange between brain tissue and CSF
  - Note: no CSF-brain barrier

Brain Barrier System

- The blood barrier system is highly permeable to water, glucose, and lipid-soluble substances such as oxygen, carbon dioxide, alcohol, caffeine, nicotine, and anesthetics

- Slightly permeable to sodium, potassium, chloride, and the waste products urea and creatinine

- Obstacle for delivering medications such as antibiotics and cancer drugs

- Trauma and inflammation can damage BBS and allow pathogens to enter brain tissue

“Breakdown” of the Blood-Brain Barrier by Design

- Circumventricular organs (CVOs)
  - *places in the third and fourth ventricles where the blood brain barrier is absent*
    - blood has direct access to the brain
    - enables the brain to monitor and respond to fluctuations in blood glucose, pH, osmolarity, and other variables
    - CVOs afford a route for invasion by the human immunodeficiency virus (HIV)

Recent Research Findings

1. **Glymphatic** discovered in brain tissue
2. This is a drainage system formed by astrocytes. These glial cells form a perivascular space around arteries and veins within the brain. This drainage system is most active when the animal is sleeping.
3. Implicated in removal of proteins which were discarded by cells through normal cellular metabolism.
4. We know many different neurodegenerative diseases exhibit a build up of “old proteins” which disrupts normal brain function.
5. This is also an example how basic research opens new ways to study pathophysiology.

See Archival Articles / Brain / review article Brain Drain – see next slide

Clearing the Head

An intricate system of vessels—the glymphatic system—snakes throughout the brain, carrying fluid that rids the organ of discarded proteins and other wastes that can clump together and turn toxic if left in place. The protein fragments known as beta-amyloid peptides, which are present in Alzheimer's disease, are examples of the cellular detritus cleared through the drainage system, mostly during sleep.

Incoming Fluid
Cerebrospinal fluid (CSF) from the subarachnoid space, between the skull and the brain, travels through a cavity (the periarterial space) surrounding an artery, propelled along by the pulsing of blood flow. This fluid enters tiny channels that extend from the cavity into cells called astrocytes, whose end feet form the periarterial space by encircling blood vessels. The CSF then moves out of the astrocytes and travels by convective flow through brain tissue.

Outgoing Wastes
The fluid, having picked up wastes from brain tissue, is transported to the perivenous space, which surrounds a network of veins that drains blood from the brain. In this cavity, the fluid passes around progressively larger veins that eventually reach the neck (*detail of brain above*). The wastes then move into the lymphatic system and eventually the bloodstream.