BIO 004 · HUMAN ANATOMY · SOLANO COMMUNITY COLLEGE

Week 7 Course Notes.

Brain · Brainstem · Meninges & CSF

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BIO 004 · WEEK 7

Contents

The Brain

The Central Nervous System, the Brain

A reference for the brain video and lab. This page covers the development of the brain, the cerebrum with its lobes, white matter tracts, and basal ganglia, the functional areas of the cortex, the diencephalon, the cerebellum, the limbic system, and the arterial supply of the brain. The focus is on the structures and the job each one does.

BY THE END

1. Trace the development of the brain from the neural tube vesicles.
2. Identify the cerebrum, its lobes, white matter tracts, and basal ganglia.
3. Map the functional areas of the cerebral cortex.
4. Name the parts of the diencephalon, the cerebellum, the limbic system, and the arteries that supply the brain.

The Brain, an Overview

The brain sits within the cranial cavity and holds roughly 85 billion neurons. It is the body's master control and integration center. The brain has four major parts.

Brain	the organ within the cranial cavity, the control and integration center of the body
Cerebrum	the largest brain part, the seat of conscious thought, sensation, and voluntary movement
Diencephalon	the deep brain region between the cerebrum and the brainstem
Brainstem	the stalk connecting the brain to the spinal cord, covered on its own sheet
Cerebellum	the structure behind the brainstem that coordinates movement
Gray matter	neuron cell bodies, dendrites, and unmyelinated fibers; on the outside of the brain
White matter	bundles of myelinated axons; on the inside of the brain

Development of the Brain

The brain and spinal cord develop from the ectodermal neural tube. The tube swells at its anterior end into a series of vesicles that mature into the adult brain.

Neural tube	the ectodermal tube from which the entire central nervous system develops
Primary brain vesicles	the first three swellings: the prosencephalon (forebrain), the mesencephalon (midbrain), and the rhombencephalon (hindbrain)
Secondary brain vesicles	the prosencephalon divides into the telencephalon and diencephalon; the rhombencephalon divides into the metencephalon and myelencephalon

Each secondary vesicle matures into specific adult structures. Compare them.

SECONDARY VESICLE	ADULT STRUCTURES
Telencephalon	the cerebrum and the lateral ventricles
Diencephalon	the thalamus, hypothalamus, epithalamus, and third ventricle
Mesencephalon	the midbrain and the cerebral aqueduct
Metencephalon	the pons, the cerebellum, and the upper fourth ventricle
Myelencephalon	the medulla oblongata and the lower fourth ventricle

The Cerebrum

The cerebrum is the largest region of the brain. Its surface is folded to pack more cortex into the skull, and a thick core of white matter lies beneath.

Cerebral hemispheres	the right and left halves of the cerebrum, joined by the corpus callosum, each with five lobes
Cerebral cortex	the outer layer of gray matter, 2 to 4 mm thick, holding billions of neuron cell bodies

Cerebral white matter	the myelinated axons beneath the cortex that connect cortical areas to each other and to lower regions
Gyri	the raised ridges of the folded cortex
Sulci	the shallow grooves between the gyri
Fissures	the deepest grooves, which divide major regions of the brain

Specific named sulci and fissures mark the boundaries on the cerebral surface. Compare them.

STRUCTURE	WHAT IT SEPARATES
Central sulcus	the frontal lobe from the parietal lobe; it divides the primary motor cortex in front from the primary somatosensory cortex behind
Lateral sulcus	the frontal and parietal lobes from the temporal lobe
Parieto-occipital sulcus	the parietal lobe from the occipital lobe
Longitudinal fissure	the left and right cerebral hemispheres
Transverse fissure	the cerebrum from the cerebellum

The Cerebral Lobes

Each hemisphere has five lobes. Four are named for the cranial bone above them; the fifth, the insula, lies hidden deep in the lateral sulcus. Compare them.

LOBE	LOCATION	PRIMARY ROLES
Frontal lobe	the front of the cerebrum	voluntary movement at the precentral gyrus, motor planning, speech production at Broca's area, judgment, and personality
Parietal lobe	behind the central sulcus	somatic sensation at the postcentral gyrus and spatial orientation
Temporal lobe	the lower side of the cerebrum	hearing, language comprehension at Wernicke's area, and memory
Occipital lobe	the back of the cerebrum	visual processing
Insula	deep within the lateral sulcus	taste, visceral sensation, and emotion

Cerebral White Matter Tracts

The white matter beneath the cortex is sorted into three classes of fiber, grouped by where each tract begins and ends. Compare them.

FIBER CLASS	WHAT IT CONNECTS	EXAMPLES
Association fibers	gyri within the same hemisphere, allowing communication across one side	the arcuate fasciculus, which links Broca's and Wernicke's areas
Commissural fibers	matching gyri between the two hemispheres	the corpus callosum, the largest; also the anterior and posterior commissures
Projection fibers	the cortex with lower brain regions and the spinal cord, as ascending or descending tracts	the internal capsule, the major projection pathway beside the basal ganglia

The Basal Ganglia

The basal ganglia, also called the cerebral nuclei, are deep masses of gray matter buried within the cerebral white matter. They help regulate movement.

Basal ganglia	the cerebral nuclei, deep gray matter masses that control semi-voluntary movement, such as the arm swing of walking
Caudate nucleus	a long, curved nucleus, one of the core components
Putamen	a core component lying lateral to the globus pallidus
Globus pallidus	a core component lying medial to the putamen
Substantia nigra	a midbrain nucleus grouped with the basal ganglia by function
Subthalamic nucleus	a diencephalic nucleus grouped with the basal ganglia by function

Roles	initiating and regulating movement, suppressing unwanted movement, and modulating muscle tone

Functional Areas of the Cerebral Cortex

The cortex is mapped into specialized areas of three kinds: motor areas that issue commands, sensory areas that receive input, and association areas that interpret and integrate.

Motor areas	issue the commands for voluntary movement; found mainly in the frontal lobe
Sensory areas	receive and begin to process input from the body's receptors
Association areas	integrate sensory input with memory and reasoning to plan a response

Each named area has a fixed location and a specific job. Compare them.

AREA	LOCATION	ROLE
Primary motor cortex	precentral gyrus of the frontal lobe	initiates voluntary movement
Premotor cortex	anterior to the primary motor cortex	plans learned, patterned movements
Supplementary motor area	medial frontal lobe	coordinates complex bilateral movements
Frontal eye field	middle frontal gyrus	controls voluntary eye movement
Broca's area	inferior frontal gyrus, usually the left	controls the motor production of speech
Primary somatosensory cortex	postcentral gyrus of the parietal lobe	receives conscious touch, pressure, and proprioception
Primary visual cortex	occipital lobe, at the calcarine sulcus	receives raw visual input
Primary auditory cortex	superior temporal gyrus	receives auditory input
Primary gustatory cortex	insula and inferior postcentral gyrus	receives taste input
Primary olfactory cortex	medial temporal lobe, at the uncus	receives smell input
Vestibular cortex	posterior insula and the parietal cortex	receives input for balance and spatial orientation
Prefrontal cortex	anterior frontal lobe	executive function: judgment, planning, and personality
Wernicke's area	the temporal and parietal junction, usually the left	comprehension of spoken and written language
Somatosensory association area	posterior to the postcentral gyrus	interprets texture, shape, and spatial orientation
Visual association area	surrounding the primary visual cortex	recognizes faces and objects
Auditory association area	adjacent to the primary auditory cortex	interprets speech and music

The Diencephalon

The diencephalon links the cerebral hemispheres to the brainstem and surrounds the third ventricle. It has three parts: the thalamus, the hypothalamus, and the epithalamus.

Thalamus	paired oval masses of gray matter that form about 80 percent of the diencephalon; the main sensory relay station to the cortex
Massa intermedia	the interthalamic adhesion, a bridge joining the right and left thalami
Thalamic nuclei	the individual nuclei of the thalamus, each one relaying a specific sensory or motor modality
Hypothalamus	the region below the thalamus; the master control center for homeostasis
Hypothalamic roles	controlling the autonomic nervous system, endocrine function through the pituitary, body temperature, hunger and thirst, and sleep-wake rhythms
Epithalamus	the small posterior part of the diencephalon
Pineal gland	the endocrine gland of the epithalamus that secretes melatonin
Habenular nuclei	nuclei of the epithalamus involved in emotional and visceral responses to smell
Third ventricle	the midline fluid-filled cavity enclosed by the diencephalon

The Cerebellum

The cerebellum is the second largest brain region, sitting in the posterior cranial fossa below the occipital lobes. It coordinates movement, posture, and balance.

Cerebellar hemispheres the two lateral halves of the cerebellum

Vermis the narrow midline band connecting the two hemispheres

Cerebellar lobes each hemisphere has an anterior, a posterior, and a flocculonodular lobe

Folia the fine, leaf-like folds of the cerebellar surface

Cerebellar cortex the outer gray matter of the cerebellum

Arbor vitae the branching, tree-like pattern of cerebellar white matter

Deep cerebellar nuclei gray matter nuclei embedded in the white matter, such as the dentate nucleus

Three pairs of cerebellar peduncles, stalks of white matter, connect the cerebellum to the brainstem. Compare them.

PEDUNCLE	WHAT IT CONNECTS
Superior cerebellar peduncle	connects to the midbrain; carries mostly output from the cerebellum
Middle cerebellar peduncle	connects to the pons; carries input from the pontine nuclei
Inferior cerebellar peduncle	connects to the medulla; carries input from the spinal cord and vestibular system

The Limbic System

The limbic system is a functional system, not a single structure. Its parts ring the diencephalon and reach into the cerebrum. It sets emotional state and supports memory.

Limbic system a functional system spanning the cerebrum and diencephalon that sets emotional state and supports memory

Amygdala the limbic structure for fear and aggression, linking emotion to memory

Hippocampus the limbic structure essential for forming new long-term memories

Cingulate gyrus the limbic gyrus arching above the corpus callosum, involved in expressing emotion

Limbic roles establishing emotional states and drives, linking conscious thought to brainstem responses, and supporting long-term memory

Cerebral Arterial Supply: The Circle of Willis

The brain is fed by two arterial systems that join in a ring at the base of the brain, the cerebral arterial circle, also called the Circle of Willis. The ring lets blood cross from one source to another if a vessel narrows or is blocked.

Anterior circulation the blood supply from the internal carotid arteries; it feeds most of the cerebrum

Posterior circulation the blood supply from the vertebral and basilar arteries; it feeds the brainstem, cerebellum, and occipital lobe

Cerebral arterial circle the Circle of Willis, the ring of arteries at the base of the brain that joins the anterior and posterior circulations

Anastomosis a connection between two arteries that gives blood an alternate route if one path is blocked

The thirteen named arteries of the cerebral arterial supply. Compare what each one feeds.

ARTERY	WHAT IT SUPPLIES
Anterior cerebral artery	the medial surface of the frontal and parietal lobes
Anterior communicating artery	a short bridge joining the right and left anterior cerebral arteries; it closes the front of the ring
Internal carotid artery	the main feed of the anterior circulation; it enters the skull and divides into the anterior and middle cerebral arteries
Middle cerebral artery	the lateral surface of the cerebrum, including the motor and sensory cortex for the body; the largest branch of the internal carotid
Posterior communicating artery	joins the internal carotid to the posterior cerebral artery on each side, linking the anterior and posterior circulations

ARTERY	WHAT IT SUPPLIES
Posterior cerebral artery	the occipital lobe and the inferior surface of the temporal lobe
Basilar artery	formed by the union of the two vertebral arteries; it runs up the front of the pons and supplies the brainstem
Superior cerebellar artery	a branch of the basilar artery to the superior surface of the cerebellum
Anterior inferior cerebellar artery (AICA)	a branch of the basilar artery to the anterior and inferior cerebellum
Vertebral arteries	the paired arteries that enter through the foramen magnum and unite to form the basilar artery
Posterior inferior cerebellar artery (PICA)	a branch of the vertebral artery to the inferior cerebellum and the lateral medulla
Anterior spinal artery	a single midline artery formed from both vertebral arteries; it runs down the front of the spinal cord
Posterior spinal arteries	paired arteries from the vertebral arteries that run down the back of the spinal cord

Location names the deficit

Because each cerebral **lobe** and cortical area has its own job, the location of an injury predicts the loss. Damage to the **occipital lobe** takes vision; damage to **Broca's area** takes fluent speech while comprehension stays intact. A clinician can often estimate where a stroke struck from the pattern of symptoms alone.

The **projection fibers** of the **internal capsule** funnel nearly all traffic between the cortex and the body into one narrow band. A small stroke there severs a great deal of wiring at once, which is why such a tiny lesion can weaken an entire side of the body.

The **Circle of Willis** is the brain's insurance policy. Because the ring connects the anterior and posterior circulations, a slow blockage in one vessel can sometimes be bypassed through the **communicating arteries**. A sudden blockage gives the anastomosis no time to open, and the territory beyond it dies.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Name the lobes of the cerebrum and one function associated with each.
2. Compare the three types of white matter tracts, association, commissural, and projection, by what each connects.
3. Name the parts of the diencephalon and the job of each.
4. Explain what the basal ganglia and the cerebellum each contribute to movement.

The Brainstem

The Central Nervous System, the Brainstem

A reference for the brainstem video and lab. This page covers the three regions of the brainstem, the midbrain, the pons, and the medulla oblongata, the structures within each, and the reticular formation that runs through them. The focus is on the structures and the job each one does.

BY THE END

1. Name the three regions of the brainstem and locate each one.
2. Identify the key structures of the midbrain, the pons, and the medulla oblongata.
3. Describe the reticular formation and the reticular activating system.

The Brainstem, an Overview

The brainstem connects the cerebrum, the diencephalon, and the cerebellum to the spinal cord. Every ascending and descending tract passes through it, and it holds the nuclei for ten of the twelve cranial nerves.

Brainstem	the stalk of the brain connecting the higher regions to the spinal cord; the midbrain, pons, and medulla
Midbrain	the most superior region of the brainstem, also called the mesencephalon
Pons	the middle region of the brainstem, a bridge to the cerebellum
Medulla oblongata	the most inferior region of the brainstem, continuous with the spinal cord
Cranial nerve nuclei	the clusters of gray matter in the brainstem that give rise to or receive cranial nerves III through XII
Passing tracts	the brainstem carries every ascending sensory tract and descending motor tract between the brain and the cord

The Midbrain

The midbrain, or mesencephalon, is the short, most superior region of the brainstem. It surrounds the cerebral aqueduct.

Tectum	the roof of the midbrain, made of four rounded bumps called colliculi
Superior colliculi	the upper pair of colliculi; centers for visual reflexes, such as turning the eyes and head toward a sight
Inferior colliculi	the lower pair of colliculi; centers for auditory reflexes, such as turning toward a sound
Cerebral peduncles	the paired stalks on the front of the midbrain that carry descending motor tracts
Substantia nigra	a darkly pigmented midbrain nucleus that helps regulate movement, working with the basal ganglia
Cerebral aqueduct	the narrow channel through the midbrain that carries cerebrospinal fluid from the third to the fourth ventricle
Cranial nerve nuclei	the midbrain holds the nuclei for CN III, the oculomotor nerve, and CN IV, the trochlear nerve

The Pons

The pons is the rounded, middle region of the brainstem. Its name means bridge.

Pons	the middle region of the brainstem; a bridge between the medulla, the midbrain, and the cerebellum
Pontine nuclei	clusters of gray matter that relay motor information from the cerebral cortex to the cerebellum
Middle cerebellar peduncles	the thick stalks that carry signals from the pontine nuclei into the cerebellum
Fourth ventricle	the cerebrospinal fluid space that lies behind the pons and the upper medulla
Cranial nerve nuclei	the pons holds the nuclei for CN V (trigeminal), CN VI (abducens), CN VII (facial), and CN VIII (vestibulocochlear)

The Medulla Oblongata

The medulla oblongata is the most inferior region of the brainstem. It is continuous with the spinal cord at the foramen magnum and contains centers that keep the body alive.

Medulla oblongata	the most inferior region of the brainstem; it merges into the spinal cord
Pyramids	a pair of ridges on the front of the medulla formed by the descending corticospinal motor tracts
Olives	the pair of oval bulges lateral to the pyramids, each formed by the underlying inferior olivary nucleus
Decussation of the pyramids	the crossover point where most corticospinal fibers pass to the opposite side; it is why one hemisphere controls the opposite side of the body

Cardiac center	the medullary center that adjusts the rate and force of the heartbeat
Respiratory center	the medullary center that sets the basic rhythm of breathing
Vasomotor center	the medullary center that adjusts the diameter of blood vessels, and so blood pressure
Cranial nerve nuclei	the medulla holds nuclei for CN VIII (cochlear), CN IX, CN X, CN XI, and CN XII

The Three Regions Compared

Each region of the brainstem has its own structures and its own set of cranial nerve nuclei. Compare them.

REGION	KEY STRUCTURES	CRANIAL NERVE NUCLEI
Midbrain	the tectum, with superior colliculi for visual reflexes and inferior colliculi for auditory reflexes; the cerebral peduncles carrying descending motor tracts; the substantia nigra	III and IV
Pons	a bridge between the medulla, midbrain, and cerebellum; contains the pontine nuclei that relay motor information to the cerebellum	V, VI, VII, and VIII
Medulla oblongata	contains the pyramids, where the corticospinal tracts decussate; holds the vital centers for heart rate, breathing, and blood vessel diameter	VIII through XII

The Reticular Formation

The reticular formation is not one structure. It is a net of gray matter cell bodies woven through the white matter of the entire brainstem.

Reticular formation	a network of gray matter neurons spread through the core of the brainstem
Reticular activating system	the RAS, the ascending part of the network; it keeps the cortex awake, alert, and attentive
Functions of the RAS	maintaining consciousness and arousal, holding attention, and filtering out unimportant incoming stimuli so the brain is not overloaded

Descending component	the part that helps set the muscle tone of resting skeletal muscle and coordinates motor activity with autonomic reflexes
Loss of RAS activity	when the ascending system is shut down the result is sleep, and severe damage can cause coma

A small region with vital jobs

The medulla holds the **cardiac**, **respiratory**, and **vasomotor** centers. Because these centers run the heartbeat and breathing, injury to the medulla, unlike injury to a single cortical area, is immediately life-threatening.

The **decussation of the pyramids** in the medulla is the anatomical reason a stroke in the right hemisphere weakens the left side of the body. The motor fibers have already crossed by the time they reach the cord.

The **reticular activating system** explains the link between the brainstem and consciousness. A patient can lose a great deal of cortex and stay awake, but damage to the small ascending reticular network can drop them into a coma. The **substantia nigra** ties the brainstem to movement: its loss is the basis of Parkinson disease.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Name the three regions of the brainstem from superior to inferior.
2. For each brainstem region, name one structure or function it is known for.
3. Explain why damage to the brainstem is far more dangerous than damage to a single cerebral lobe.
4. Describe where the brainstem sits relative to the cerebrum and the spinal cord.

CNS Meninges and CSF

The Meninges and Cerebrospinal Fluid

A reference for the meninges and CSF video and lab. This page covers the cranial and spinal meninges, the dural reflections, the meningeal spaces, where the spinal cord ends and the lumbar puncture, the ventricles, cerebrospinal fluid and its circulation, and the blood-brain barrier.

BY THE END

1. Name the cranial and spinal meninges and the spaces between them.
2. Identify where the spinal cord ends and the layers a lumbar puncture passes.
3. Describe cerebrospinal fluid, where it is found, and where it is made.
4. Trace the circulation of CSF from production to reabsorption.

An Overview

The brain and spinal cord are soft and irreplaceable, so they are protected four ways: by bone, by the meninges, by a cushioning fluid, and by a barrier that screens the blood.

Protection of the CNS the brain and spinal cord are shielded by bone, by membranes, by fluid, and by a blood barrier

Bony protection the cranium encloses the brain; the vertebral column encloses the spinal cord

Meninges the three connective tissue membranes that wrap the brain and spinal cord

Cerebrospinal fluid the clear fluid that surrounds, cushions, and floats the central nervous system

Blood-brain barrier the barrier that controls what passes from the blood into the brain tissue

The Cranial Meninges

Three connective tissue membranes wrap the brain. Their Latin names run from tough mother on the outside to tender mother within. Compare them.

LAYER	POSITION	DESCRIPTION
Dura mater	the outermost layer	a tough membrane with two layers: an outer periosteal layer against the skull and an inner meningeal layer; the two are fused except where they part to form the dural venous sinuses
Arachnoid mater	the middle layer	a delicate, lace-like membrane
Pia mater	the innermost layer	a thin membrane, rich in blood vessels, that clings directly to the surface of the brain

No cranial epidural space the periosteal dura is attached directly to the skull, so there is no epidural space inside the cranium, unlike the vertebral canal

The Dural Reflections

In a few places the inner meningeal dura folds inward as a partition that anchors the brain and separates its parts. These folds are the dural reflections, also called the dural extensions.

Dural reflections inward folds of the meningeal dura that partition the cranial cavity

Falx cerebri the fold that dips into the longitudinal fissure, separating the right and left cerebral hemispheres

Falx cerebelli the fold that separates the right and left cerebellar hemispheres

Tentorium cerebelli the fold that separates the cerebrum above from the cerebellum below

Where the two dural layers part within these folds, they form the dural venous sinuses. The sinuses collect venous blood from the brain, along with the CSF returned by the arachnoid granulations, and drain it toward the heart. Follow the main drainage route.

1. **Superior sagittal sinus** runs along the top edge of the falx cerebri; receives CSF from the arachnoid granulations

2. **Confluence of sinuses** the meeting point of the major sinuses, at the internal occipital protuberance
3. **Transverse sinuses** the paired sinuses running laterally from the confluence
4. **Sigmoid sinuses** the S-shaped sinuses that curve down toward the jugular foramen
5. **Internal jugular veins** carry the blood out of the skull and back toward the heart

The Spinal Meninges

The same three membranes continue down around the spinal cord, with one important difference: the vertebral canal has a true epidural space, and the cranium does not.

Spinal dura mater	a single tough layer around the cord, not fused to bone, unlike the two-layered cranial dura
Spinal arachnoid mater	the middle membrane, continuous with the cranial arachnoid
Spinal pia mater	the innermost membrane, clinging to the surface of the cord
Epidural space	the space between the spinal dura and the vertebral bone, filled with fat and veins; the site of an epidural injection
Denticulate ligaments	tooth-like extensions of pia mater that anchor the cord to the dura along its length
Filum terminale	a thread of pia mater that extends from the end of the cord and anchors it to the coccyx

The Meningeal Spaces

The gaps around and between the meninges are named spaces. Each one matters in the clinic, whether for an injection, a bleed, or a spinal tap. Compare them.

SPACE	LOCATION	CONTENTS
Epidural space	between the spinal dura and the vertebral bone	fat and veins; present in the vertebral canal but not the cranium
Subdural space	between the dura mater and the arachnoid mater	a potential space only, with a thin film of fluid
Subarachnoid space	between the arachnoid mater and the pia mater	cerebrospinal fluid; this is where CSF is found around the brain and cord

Where the Spinal Cord Ends

The spinal cord is shorter than the vertebral column. It ends high in the lumbar region, and the subarachnoid space continues below it as a pool of CSF.

Conus medullaris	the tapered end of the spinal cord, at the level of the L1 to L2 intervertebral disc in the adult
Cauda equina	the hair-like bundle of nerve roots that descends past the conus medullaris within the vertebral canal
Filum terminale	the pia mater thread running from the conus medullaris to anchor on the coccyx
Lumbar cistern	the enlarged subarachnoid space below the conus medullaris, filled with CSF and the floating cauda equina

The Lumbar Puncture

A lumbar puncture, or spinal tap, draws CSF from the lumbar cistern. The needle enters in the midline between the L3 to L4 or L4 to L5 spines, safely below the end of the cord. Follow the structures it passes, superficial to deep.

1. **Skin** the epidermis and dermis of the lower back
2. **Subcutaneous fat** the superficial fascia beneath the skin
3. **Supraspinous ligament** the ligament running along the tips of the spinous processes
4. **Interspinous ligament** the ligament between adjacent spinous processes
5. **Ligamentum flavum** the tough elastic ligament joining the laminae of adjacent vertebrae

6. **Epidural space** the fat-filled and vein-filled space inside the vertebral canal
7. **Dura mater** the tough outer meningeal membrane
8. **Arachnoid mater** the delicate middle meningeal membrane
9. **Subarachnoid space** the needle reaches the lumbar cistern, where CSF is withdrawn

The Ventricles of the Brain

The ventricles are connected, fluid-filled chambers deep within the brain, lined by ependymal cells. Cerebrospinal fluid is made in them. Compare them.

VENTRICLE	LOCATION	CONNECTS TO
Lateral ventricles	one in each cerebral hemisphere	the third ventricle, through the interventricular foramina of Monro
Third ventricle	in the diencephalon	the fourth ventricle, through the cerebral aqueduct of Sylvius
Fourth ventricle	between the brainstem and the cerebellum	the central canal and the subarachnoid space, through three apertures
Central canal	runs the length of the spinal cord	continuous above with the fourth ventricle

Choroid plexus	networks of capillaries, wrapped in ependymal cells, that produce CSF; found in the lateral, third, and fourth ventricles
Ependymal cells	the glial cells that line the ventricles and central canal and help circulate CSF

Cerebrospinal Fluid

Cerebrospinal fluid is the clear liquid cushion of the central nervous system. It is made, circulated, and reabsorbed continuously, keeping a steady volume.

Cerebrospinal fluid	CSF, the clear, watery fluid that surrounds and fills the central nervous system
Where CSF is found	in the four ventricles, in the central canal of the spinal cord, and in the subarachnoid space around the whole brain and cord, including the lumbar cistern
Site of production	the choroid plexus within the ventricles
Site of reabsorption	the arachnoid granulations, which return CSF to the venous blood of the dural sinuses
Buoyancy	the fluid floats the brain, reducing its effective weight so it does not crush its own base
Protection	the fluid cushions the CNS against jolts and blows
Chemical stability	the fluid carries nutrients, removes wastes, and keeps a stable environment around the neurons

The Circulation of CSF

Cerebrospinal fluid follows a one-way loop, produced in the ventricles and reabsorbed into the blood. The ventricles below hold choroid plexus, where ependymal cells produce CSF. Follow it in order.

1. **Lateral ventricles** hold choroid plexus, where ependymal cells produce CSF; one ventricle sits in each cerebral hemisphere
2. **Interventricular foramina of Monro** CSF passes through these paired openings into the third ventricle
3. **Third ventricle** in the diencephalon; also holds choroid plexus, adding more CSF
4. **Cerebral aqueduct of Sylvius** CSF flows down this channel through the midbrain
5. **Fourth ventricle** between the pons and the cerebellum; also holds choroid plexus
6. **Apertures of the fourth ventricle** CSF exits through the two lateral apertures of Luschka and the median aperture of Magendie
7. **Subarachnoid space** CSF bathes the whole surface of the brain and spinal cord; some passes into the central canal
8. **Arachnoid granulations** CSF is reabsorbed here into the venous blood of the superior sagittal sinus, completing the loop

The Blood-Brain Barrier

The blood-brain barrier is the structural seal that keeps brain tissue separate from the changing chemistry of the blood. It is built from three components.

Blood-brain barrier	the BBB, a selective barrier between the blood and the brain tissue
Capillary endothelial cells	the cells lining brain capillaries, joined by tight junctions and lacking the pores of ordinary capillaries
Basement membrane	the supporting layer that wraps the capillary endothelium
Astrocyte end-feet	the foot-like projections of astrocytes that envelop the capillary and help control the barrier

Disorders of the Meninges and CSF

Compare the common disorders by the structure each one affects.

DISORDER	STRUCTURE AFFECTED	WHAT IT IS
Meningitis	the meninges	inflammation of the meninges, usually from infection; diagnosed by testing CSF drawn at a lumbar puncture
Hydrocephalus	the ventricles	a buildup of CSF that enlarges the ventricles and raises intracranial pressure
Epidural hematoma	the epidural space	bleeding between the dura mater and the skull
Subdural hematoma	the subdural space	bleeding between the dura mater and the arachnoid mater
Subarachnoid hemorrhage	the subarachnoid space	bleeding into the CSF-filled space around the brain

The cord ends, but the fluid does not

The spinal cord stops at the **conus medullaris** near the L1 to L2 disc, yet the **subarachnoid space** runs lower still, as the **lumbar cistern**. That mismatch is the whole basis of the lumbar puncture: a needle placed between the L3 to L4 or L4 to L5 spines reaches a pool of CSF with only the floating **cauda equina** there to drift aside.

Knowing the layers in order is what makes the tap safe. The needle crosses skin, fat, three ligaments, the **epidural space**, and then the dura and arachnoid before CSF appears. A clinician feels the firm **ligamentum flavum** give way as a landmark.

The named spaces also tell a bleed apart. An **epidural hematoma** sits outside the dura, a **subdural hematoma** just beneath it, and a **subarachnoid hemorrhage** mixes into the CSF itself. Each location is found, and treated, differently.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Name the three meningeal layers from superficial to deep and what sits between them.
2. Trace the circulation of cerebrospinal fluid from where it is made to where it is reabsorbed.
3. Name the four ventricles and describe how they connect.
4. Explain why the spinal cord ends where it does, and how that makes a lumbar puncture safe.