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Brain Anatomy and How the Brain Works

Brain, Nerves and Spine (https://www.hopkinsmedicine.org/health/brain-nerves-and-spine)

What is the brain?

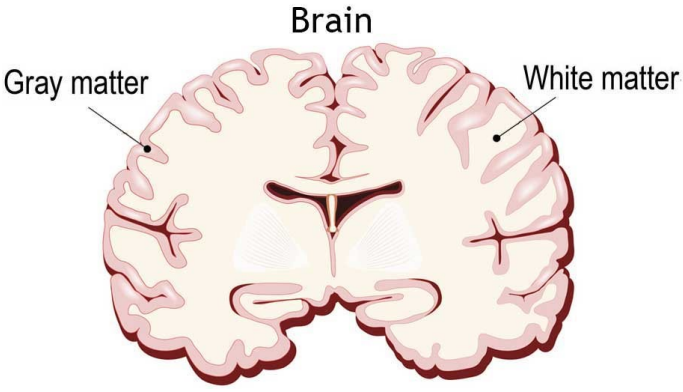
The brain is a complex organ that controls thought, memory, emotion, touch, motor skills, vision, breathing, temperature, hunger and every process that regulates our body. Together, the brain and spinal cord that extends from it make up the central nervous system, or CNS.

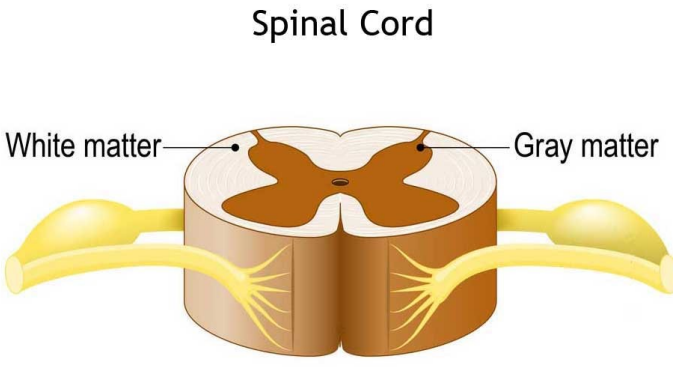
What is the brain made of?

Weighing about 3 pounds in the average adult, the brain is about 60% fat. The remaining 40% is a combination of water, protein, carbohydrates and salts. The brain itself is a not a muscle. It contains blood vessels and nerves, including neurons and glial cells.

What is the gray matter and white matter?

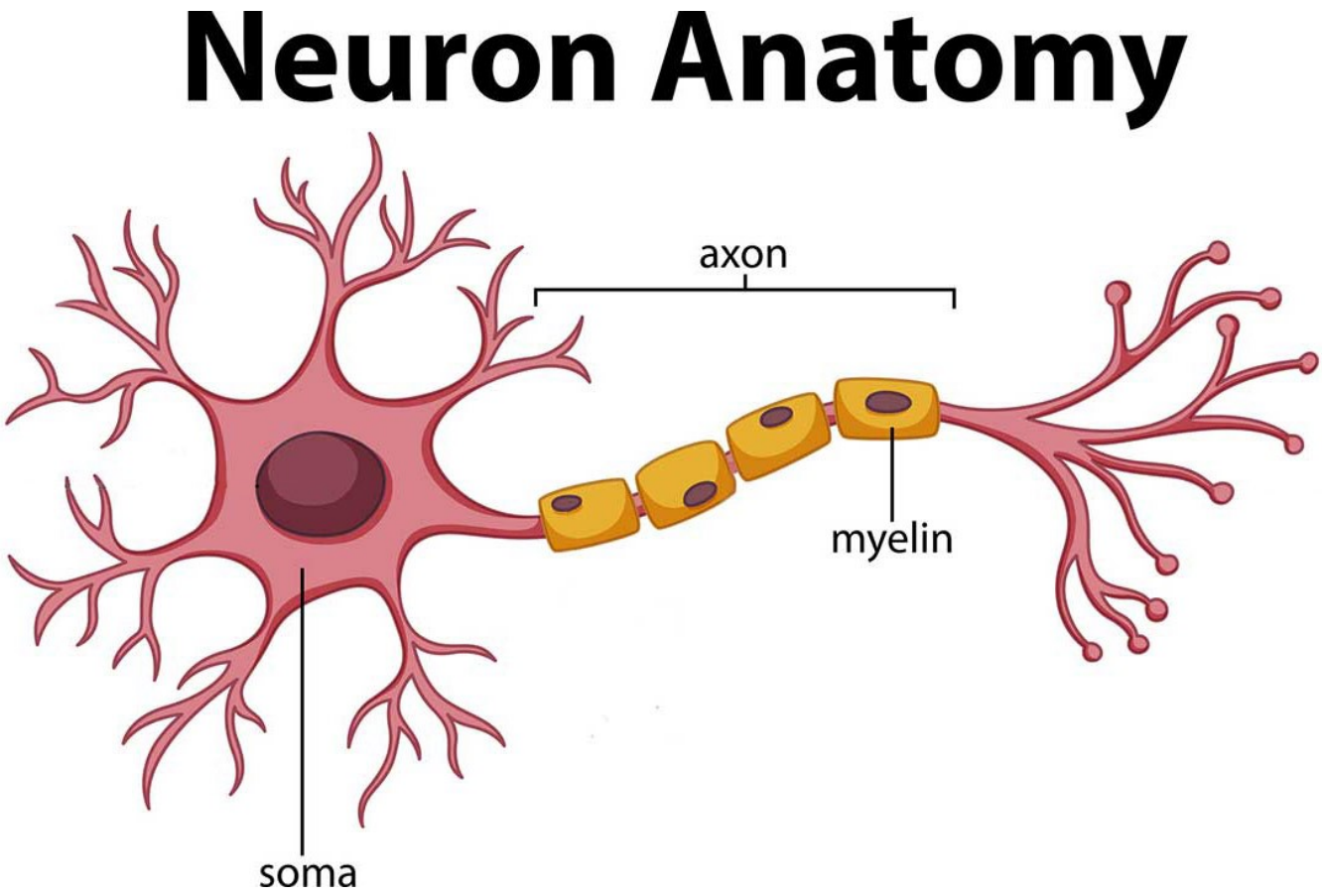
Gray and white matter are two different regions of the central nervous system. In the brain, gray matter refers to the darker, outer portion, while white matter describes the lighter, inner section underneath. In the spinal cord, this order is reversed: The white matter is on the outside, and the gray matter sits within.





Gray matter is primarily composed of neuron somas (the round central cell bodies), and white matter is mostly made of

axons (the long stems that connects neurons together) wrapped in myelin (a protective coating). The different composition of neuron parts is why the two appear as separate shades on certain scans.



Each region serves a different role. Gray matter is primarily responsible for processing and interpreting information, while white matter transmits that information to other parts of the nervous system.

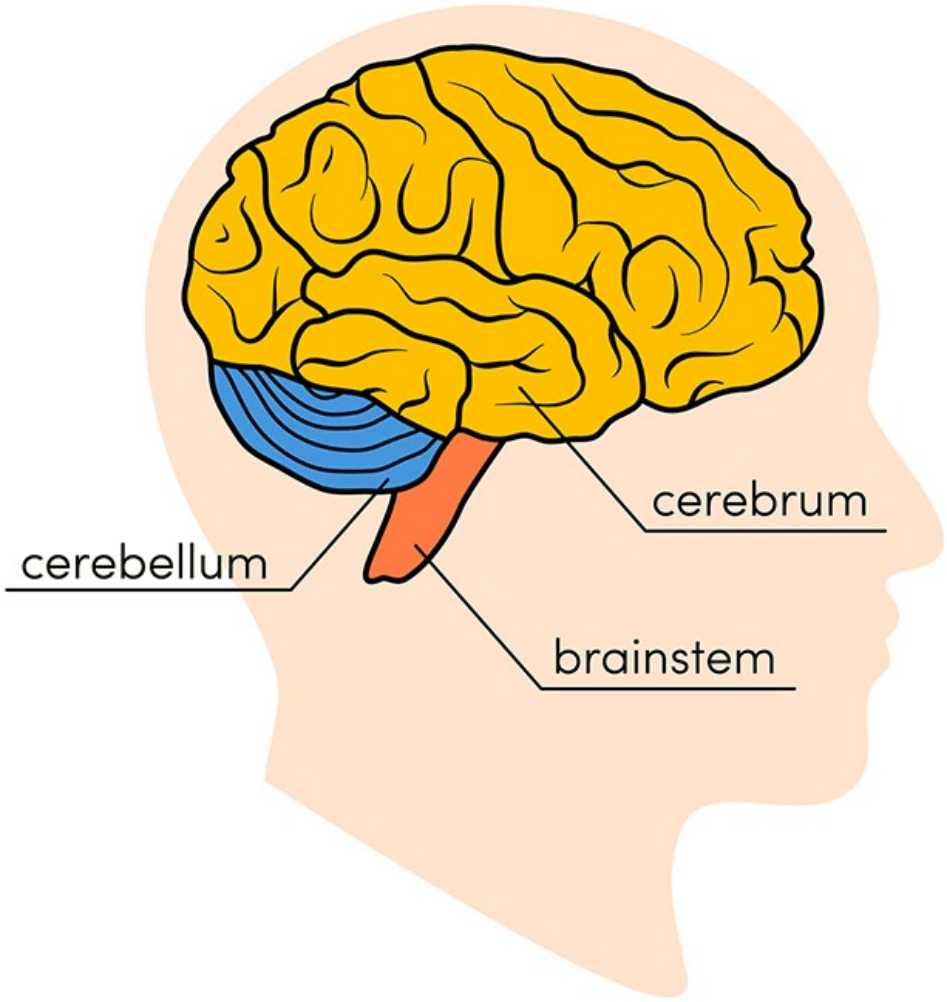
How does the brain work?

The brain sends and receives chemical and electrical signals throughout the body. Different signals control different processes, and your brain interprets each. Some make you feel tired, for example, while others make you feel pain.

Some messages are kept within the brain, while others are relayed through the spine and across the body's vast network of nerves to distant extremities. To do this, the central nervous system relies on billions of neurons (nerve cells).

Main Parts of the Brain and Their Functions

At a high level, the brain can be divided into the cerebrum, brainstem and cerebellum.



Cerebrum

The cerebrum (front of brain) comprises gray matter (the cerebral cortex) and white matter at its center. The largest part of the brain, the cerebrum initiates and coordinates movement and regulates temperature. Other areas of the cerebrum enable speech, judgment, thinking and reasoning, problem-solving, emotions and learning. Other functions relate to vision, hearing, touch and other senses.

Cerebral Cortex

Cortex is Latin for “bark,” and describes the outer gray matter covering of the cerebrum. The cortex has a large surface area due to its folds, and comprises about half of the brain’s weight.

The cerebral cortex is divided into two halves, or hemispheres. It is covered with ridges (gyri) and folds (sulci). The two halves join at a large, deep sulcus (the interhemispheric fissure, AKA the medial longitudinal fissure) that runs from the front of the head to the back. The right hemisphere controls the left side of the body, and the left half controls the right side of the body. The two halves communicate with one another through a large, C-shaped structure of white matter

and nerve pathways called the corpus callosum. The corpus callosum is in the center of the cerebrum.

Brainstem

The brainstem (middle of brain) connects the cerebrum with the spinal cord. The brainstem includes the midbrain, the pons and the medulla.

Midbrain. The midbrain (or mesencephalon) is a very complex structure with a range of different neuron clusters (nuclei and colliculi), neural pathways and other structures. These features facilitate various functions, from hearing and movement to calculating responses and environmental changes. The midbrain also contains the substantia nigra, an area affected by Parkinson's disease that is rich in dopamine neurons and part of the basal ganglia, which enables movement and coordination.

Pons. The pons is the origin for four of the 12 cranial nerves, which enable a range of activities such as tear production, chewing, blinking, focusing vision, balance, hearing and facial expression. Named for the Latin word for "bridge," the pons is the connection between the midbrain and the medulla.

Medulla. At the bottom of the brainstem, the medulla is where the brain meets the spinal cord. The medulla is essential to survival. Functions of the medulla regulate many bodily activities, including heart rhythm, breathing, blood flow, and oxygen and carbon dioxide levels. The medulla produces reflexive activities such as sneezing, vomiting, coughing and swallowing.

The **spinal cord** extends from the bottom of the medulla and through a large opening in the bottom of the skull. Supported by the vertebrae, the spinal cord carries messages to and from the brain and the rest of the body.

Cerebellum

The cerebellum ("little brain") is a fist-sized portion of the brain located at the back of the head, below the temporal and occipital lobes and above the brainstem. Like the cerebral cortex, it has two hemispheres. The outer portion contains neurons, and the inner area communicates with the cerebral cortex. Its function is to coordinate voluntary muscle movements and to maintain posture, balance and equilibrium. New studies are exploring the cerebellum's roles in thought, emotions and social behavior, as well as its possible involvement in addiction, autism and schizophrenia.

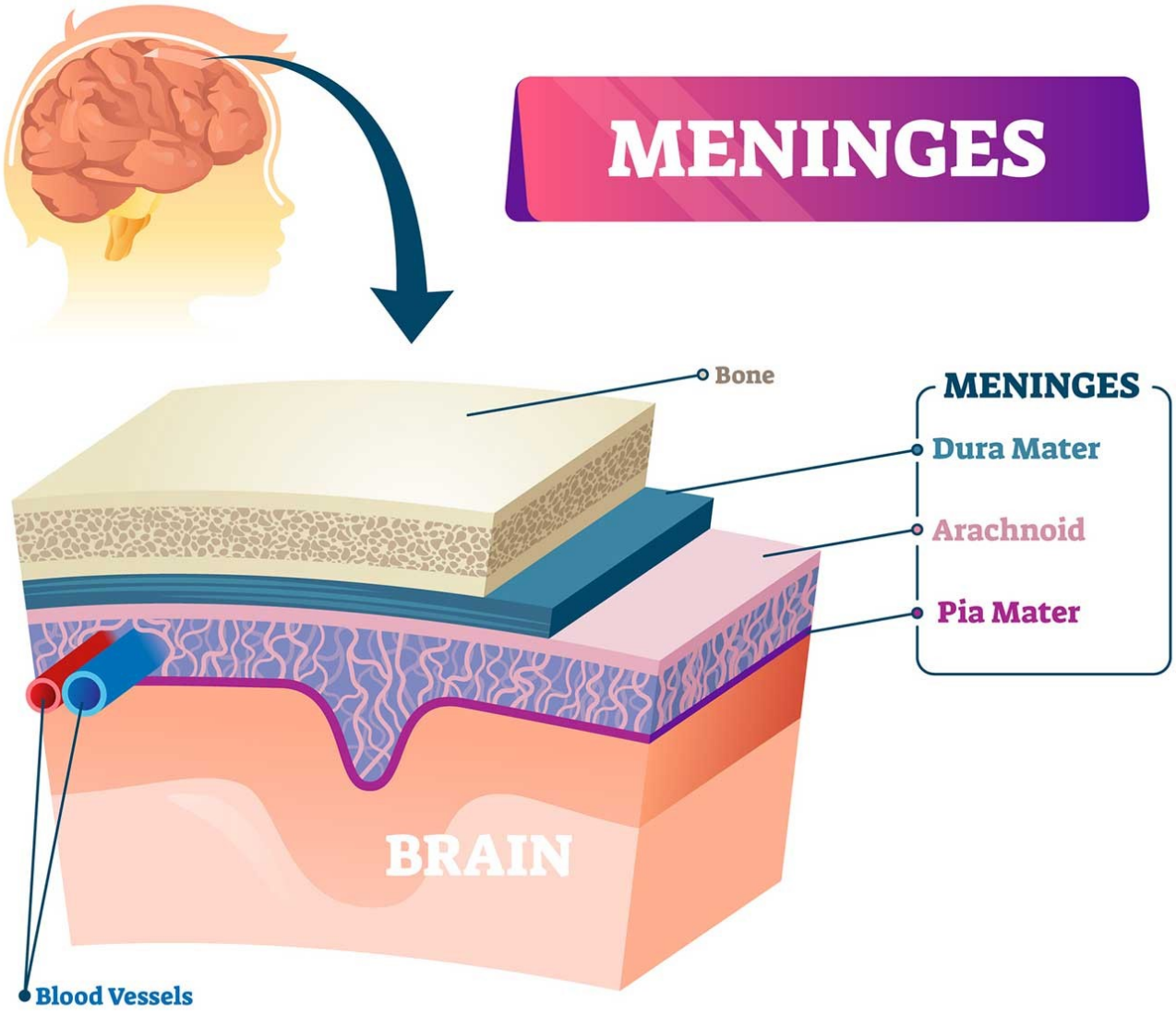
Brain Coverings: Meninges

Three layers of protective covering called **meninges** surround the brain and the spinal cord.

The outermost layer, the **dura mater**, is thick and tough. It includes two layers: The periosteal layer of the dura mater lines the inner dome of the skull (cranium) and the meningeal layer is below that. Spaces between the layers allow for the passage of veins and arteries that supply blood flow to the brain.

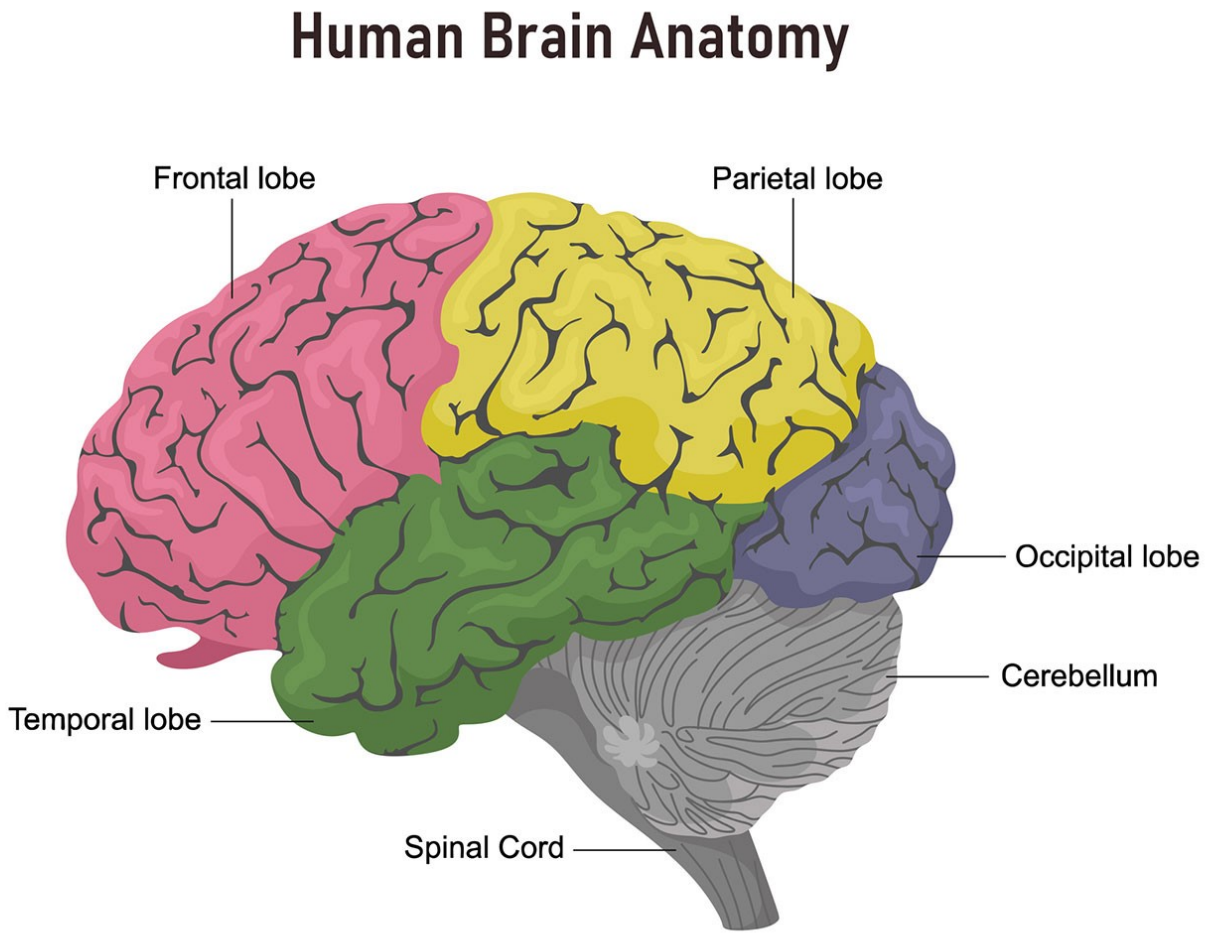
The **arachnoid** mater is a thin, weblike layer of connective tissue that does not contain nerves or blood vessels. Below the arachnoid mater is the cerebrospinal fluid, or CSF. This fluid cushions the entire central nervous system (brain and spinal cord) and continually circulates around these structures to remove impurities.

The **pia mater** is a thin membrane that hugs the surface of the brain and follows its contours. The pia mater is rich with veins and arteries.



Lobes of the Brain and What They Control

Each brain hemisphere (parts of the cerebrum) has four sections, called lobes: frontal, parietal, temporal and occipital. Each lobe controls specific functions.



Frontal lobe. The largest lobe of the brain, located in the front of the head, the frontal lobe is involved in personality characteristics, decision-making and movement. Recognition of smell usually involves parts of the frontal lobe. The frontal lobe contains Broca's area, which is associated with speech ability.

Parietal lobe. The middle part of the brain, the parietal lobe helps a person identify objects and understand spatial relationships (where one's body is compared with objects around the person). The parietal lobe is also involved in interpreting pain and touch in the body. The parietal lobe houses Wernicke's area, which helps the brain understand spoken language.

Occipital lobe. The occipital lobe is the back part of the brain that is involved with vision.

Temporal lobe. The sides of the brain, temporal lobes are involved in short-term memory, speech, musical rhythm and some degree of smell recognition.

Deeper Structures Within the Brain

Pituitary Gland

Sometimes called the "master gland," the pituitary gland is a pea-sized structure found deep in the brain behind the bridge of the nose. The pituitary gland governs the function of other glands in the body, regulating the flow of hormones from the thyroid, adrenals, ovaries and testicles. It receives chemical signals from the hypothalamus through its stalk and blood supply.

Hypothalamus

The hypothalamus is located above the pituitary gland and sends it chemical messages that control its function. It regulates body temperature, synchronizes sleep patterns, controls hunger and thirst and also plays a role in some aspects of memory and emotion.

Amygdala

Small, almond-shaped structures, an amygdala is located under each half (hemisphere) of the brain. Included in the limbic system, the amygdalae regulate emotion and memory and are associated with the brain's reward system, stress, and the "fight or flight" response when someone perceives a threat.

Hippocampus

A curved seahorse-shaped organ on the underside of each temporal lobe, the hippocampus is part of a larger structure called the hippocampal formation. It supports memory, learning, navigation and perception of space. It receives information from the cerebral cortex and may play a role in Alzheimer's disease.

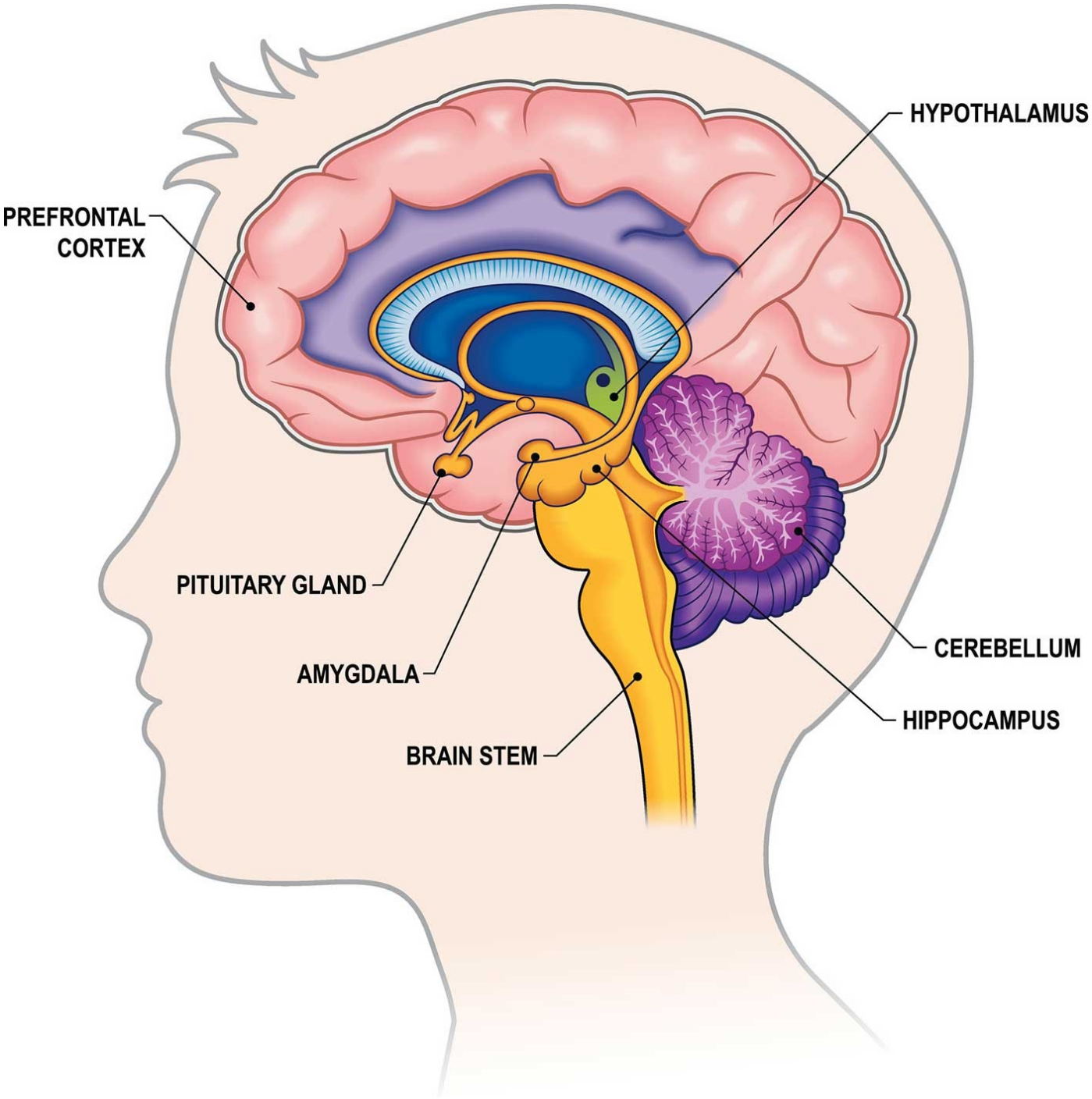
Pineal Gland

The pineal gland is located deep in the brain and attached by a stalk to the top of the third ventricle. The pineal gland responds to light and dark and secretes melatonin, which regulates circadian rhythms and the sleep-wake cycle.

Ventricles and Cerebrospinal Fluid

Deep in the brain are four open areas with passageways between them. They also open into the central spinal canal and the area beneath arachnoid layer of the meninges.

The ventricles manufacture **cerebrospinal fluid**, or CSF, a watery fluid that circulates in and around the ventricles and the spinal cord, and between the meninges. CSF surrounds and cushions the spinal cord and brain, washes out waste and impurities, and delivers nutrients.



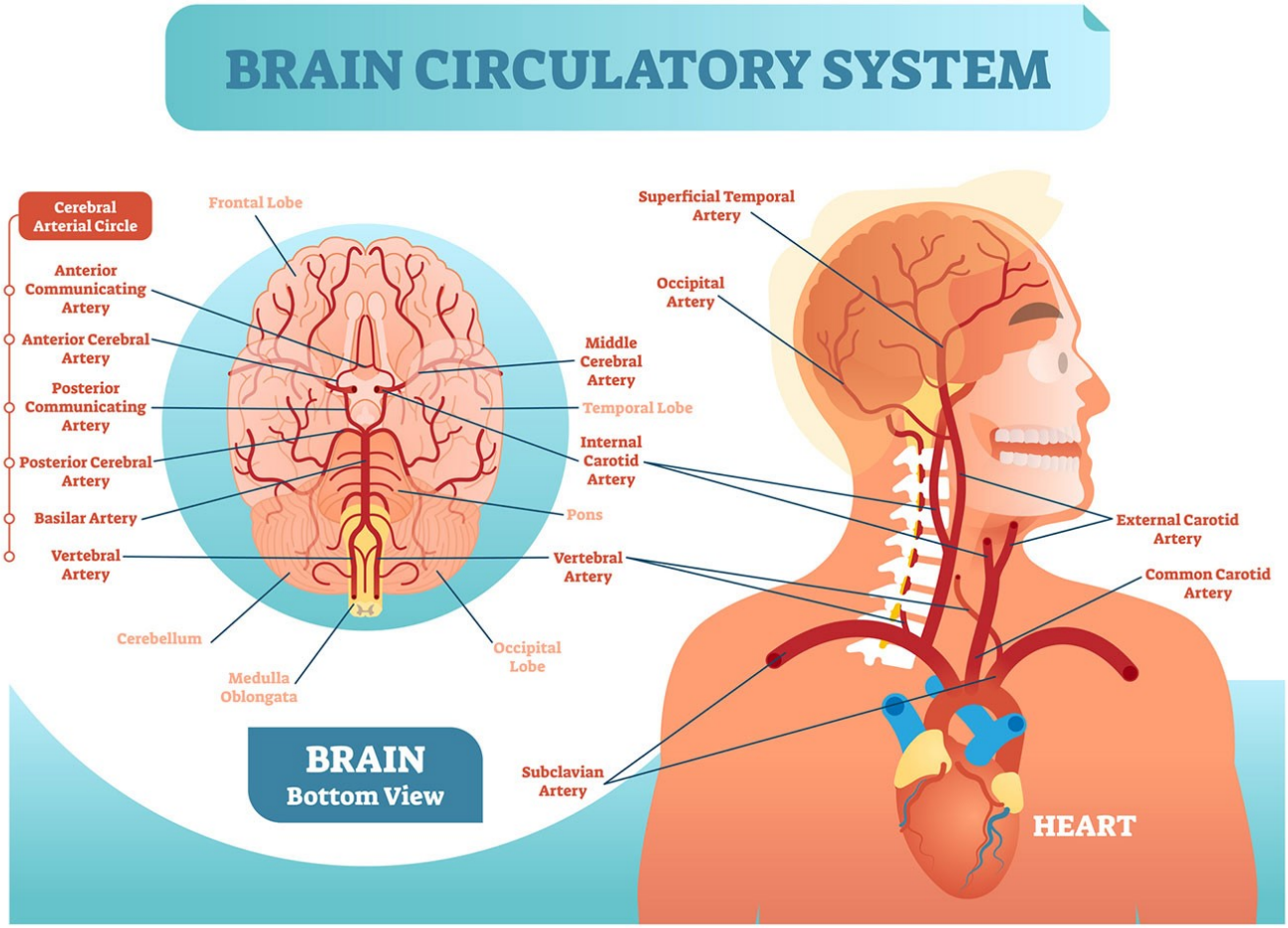
Blood Supply to the Brain

Two sets of blood vessels supply blood and oxygen to the brain: the **vertebral arteries** and the **carotid arteries.**

The external carotid arteries extend up the sides of your neck, and are where you can feel your pulse when you touch the area with your fingertips. The internal carotid arteries branch into the skull and circulate blood to the front part of the brain.

The vertebral arteries follow the spinal column into the skull, where they join together at the brainstem and form the **basilar artery**, which supplies blood to the rear portions of the brain.

The **circle of Willis**, a loop of blood vessels near the bottom of the brain that connects major arteries, circulates blood from the front of the brain to the back and helps the arterial systems communicate with one another.



Cranial Nerves

Inside the cranium (the dome of the skull), there are 12 nerves, called cranial nerves:

Cranial nerve 1: The first is the **olfactory nerve,** which allows for your sense of smell.

Cranial nerve 2: The **optic nerve** governs eyesight.

Cranial nerve 3: The **oculomotor nerve** controls pupil response and other motions of the eye, and branches out from the area in the brainstem where the midbrain meets the pons.

Cranial nerve 4: The **trochlear nerve** controls muscles in the eye. It emerges from the back of the midbrain part of the brainstem.

Cranial nerve 5: The **trigeminal nerve** is the largest and most complex of the cranial nerves, with both sensory and motor function. It originates from the pons and conveys sensation from the scalp, teeth, jaw, sinuses, parts of the mouth and face to the brain, allows the function of chewing muscles, and much more.

Cranial nerve 6: The **abducens nerve** innervates some of the muscles in the eye.

Cranial nerve 7: The **facial nerve** supports face movement, taste, glandular and other functions.

Cranial nerve 8: The **vestibulocochlear nerve** facilitates balance and hearing.

Cranial nerve 9: The **glossopharyngeal nerve** allows taste, ear and throat movement, and has many more functions.

Cranial nerve 10: The **vagus nerve** allows sensation around the ear and the digestive system and controls motor activity

in the heart, throat and digestive system.

Cranial nerve 11: The **accessory nerve** innervates specific muscles in the head, neck and shoulder.

Cranial nerve 12: The **hypoglossal nerve** supplies motor activity to the tongue.

The first two nerves originate in the cerebrum, and the remaining 10 cranial nerves emerge from the brainstem, which has three parts: the midbrain, the pons and the medulla.

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