Neuroscience Notes

Contents

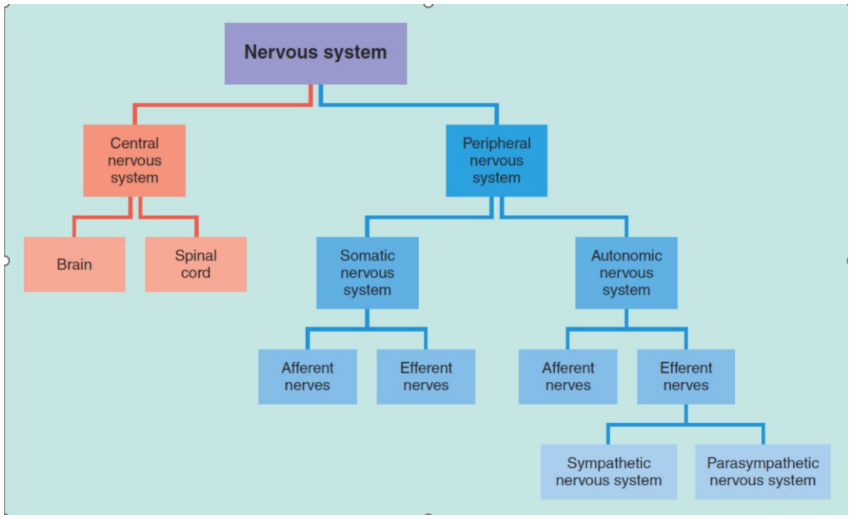

Figure 1: Anatomy of nervous system flowchart

Anatomy of the Nervous System

1 Divisions of the nervous systems

Definition: Vertebrates have two major divisions:

1. **Central Nervous System (CNS), consists of the brain, spinal cord, and retina of the eye.**

2. **Peripheral Nervous System** (PNS): everything outside of the brain, spinal cord, and retina.

   Within the PNS, there are two more subdivisions:

   Somantic Nervous System (SNS): interacts with our surrounding environment.

   Autonomic Nervous System (ANS): regulates our internal environment.

   Each of the above are comprised of afferent and efferent nerves, where:

   (a) **Afferent** = *approach* the CNS.

   (b) **Efferent** = *exiting* the CNS.

1.1 The Somatic Nervous System

Within the SNS:

1. Afferent nerves carry information *from* the sense organs to be the brain and spinal cord.

2. Efferent nerves carry motor/movement signals *from* the brain *to* the muscles.

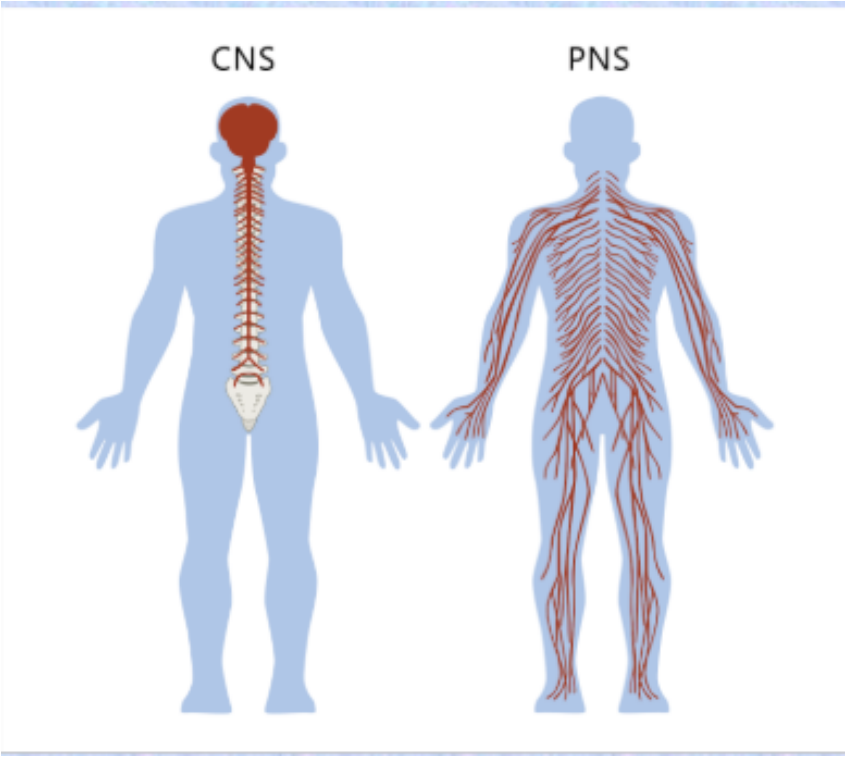

Figure 2: Central Nervous System

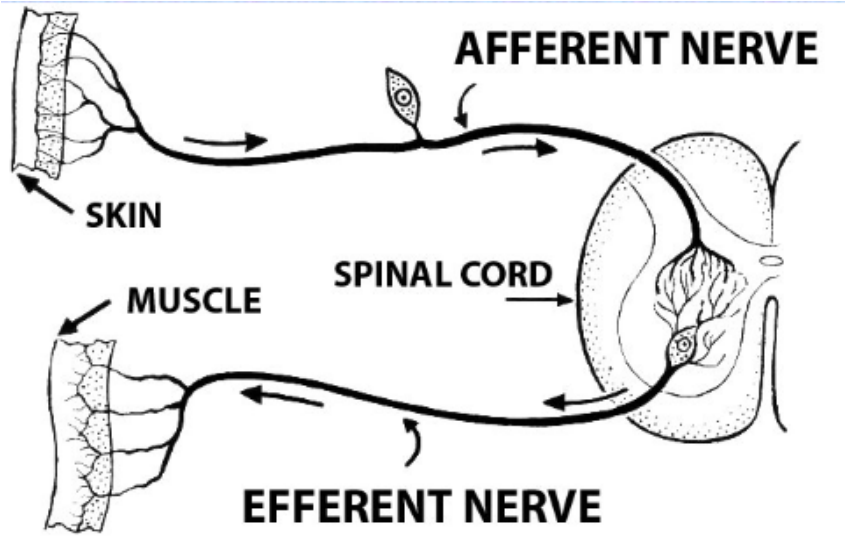

Figure 3: Afferent vs efferent nerve

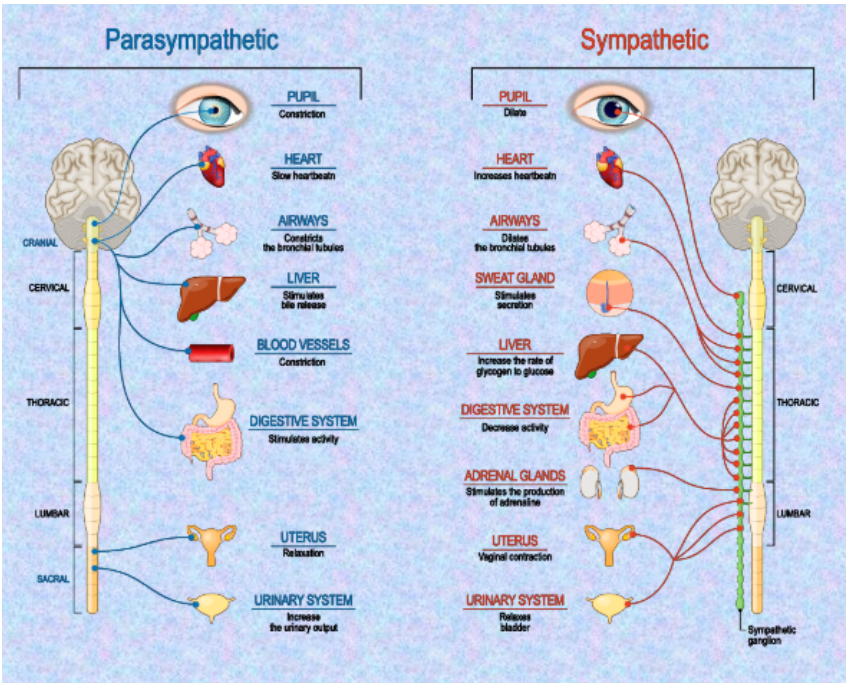

Figure 4: Parasympathetic and sympathetic

1.2 The Autonomic Nervous System

Afferent nerves carry sensory signals *from* internal organs *to* the CNS, while efferent nerves carry motor signals *from* the CNS to smooth muscle and tissue... there are two kinds of efferent nerves:

1. Sympathetic

   Nerves control energy resources during threatening situations.

   Fight or flight

   Example: When you feel nervous, you often feel , that's due to your sympathetic systems trying to protect you.

2. Parasympathetic

   Nerves conserve energy resources

   "Rest and digest"

Both of these have the same targets within the nervous system but opposing functions.

Support Systems

2 Support Systems

2.1 The Meninges

There are three protective membranes surrounding the brain referred to as "meninges..."

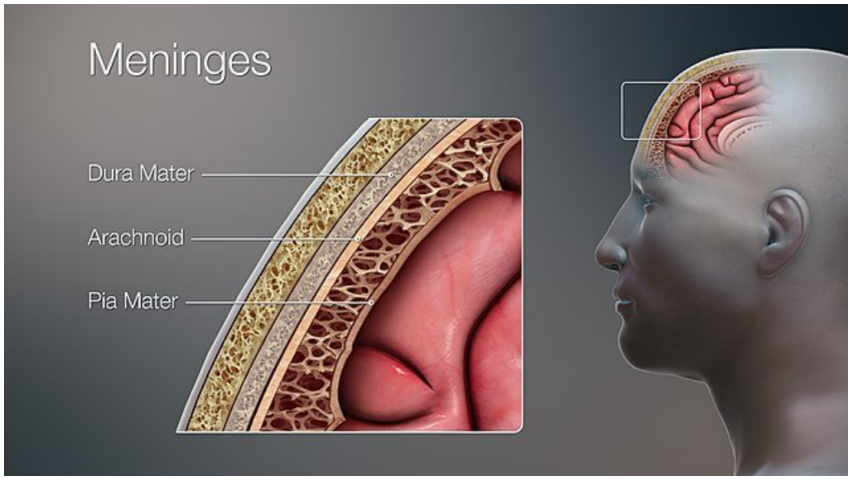

Figure 5: Meninges

1. **Dura Mater**: "hard mother," closest to skull and spine.
2. **Arachnoid Mater**: the middle layer that looks like a spider web; contains the "subarachnoid space" which is comprised of a high concentration of blood vessels.
3. **Pia Mater**: "pious mother" that adheres to the surface of the brain and spinal cord.

2.2 The Ventricular System

First, within our ventricular system, we have cerebrospinal fluid:

- CFS supports and cushions the central nervous system.
- CSF is produced by the choroid plexus, which is a network of capillaries.

There are also various ventricles and canals that are a part of our ventricular system:
Cerebral ventricles

1. Lateral ventricles
2. Third ventricle
3. Fourth ventricle

Central canal: channel that runs the length of the spinal cord.

2.3 A Disorder of the Ventricular System

Hydrocephalus

- If a block of CSF occurs, this may result in a buildup of fluid in the ventricles, leading to hydrocephalus.
- Caused by tumor, infection, birth defects, traumatic brain injury.
- Treatment approach is to drain excess fluid and remove obstruction.

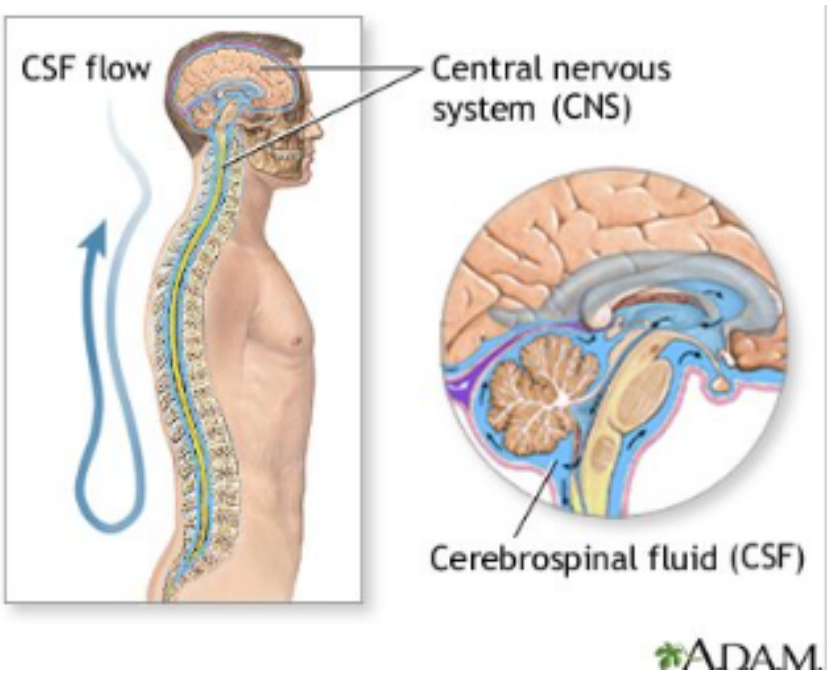

Figure 6: Cerebrospinal fluid (CSF)

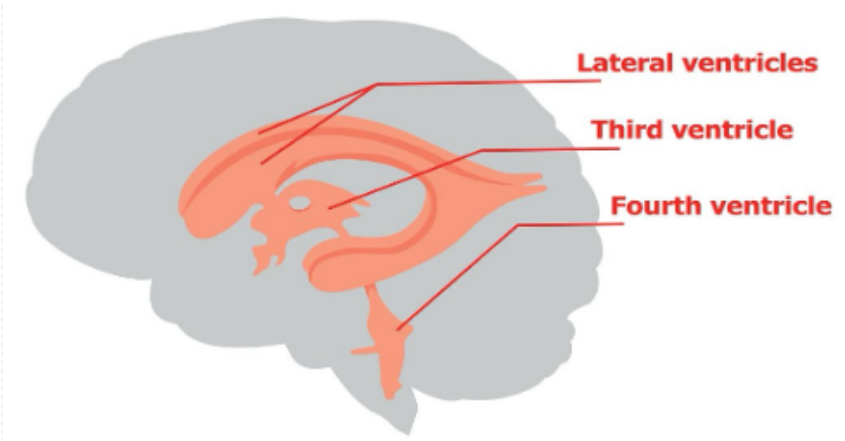

Figure 7: Cerebral ventricles

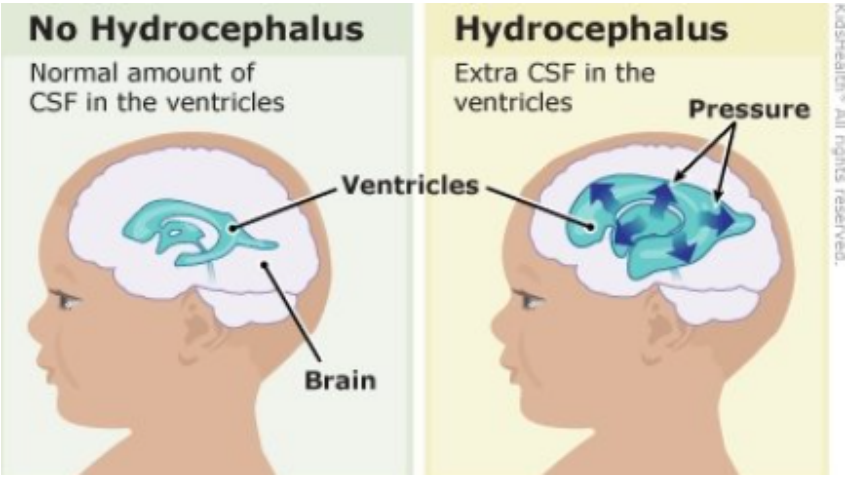

Figure 8: Hydrocephalus

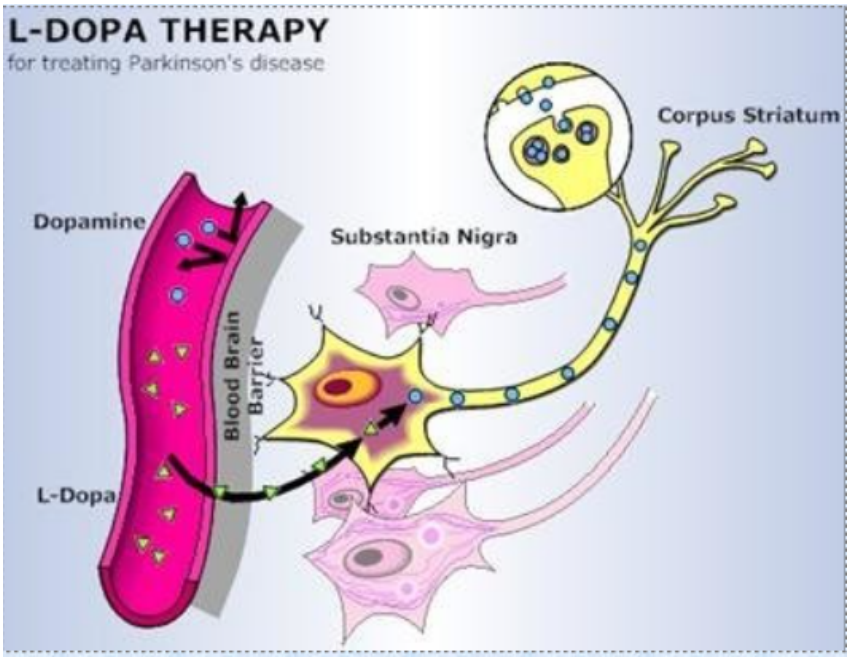

Figure 9: The Blood-Brain Barrier

2.4 The Blood-Brain Barrier

The brain simutaneously needs nutrients and protection from invaders:

- The BBB is formed by tightly packed walls of blood vessels, which prevents most chemicals from entering the brain.
- What can cross
  1. Small, uncharged molecules such as oxygen (02) and carbon dioxide (CO2).
  2. Specific fat-soluble vitamins such as Vitamins A and D.
  3. Glucose and other amino acids pumped across by active transport systems.
- So, what can't cross?
  1. Most viruses and bacteria, except for rabies and herpes.
  2. Most drugs

     This can be a challenge, because sometimes with therapeutic development, we want drugs to be able to cross the BBB.

     Example: L-DOPA for Parkinson's treatment.

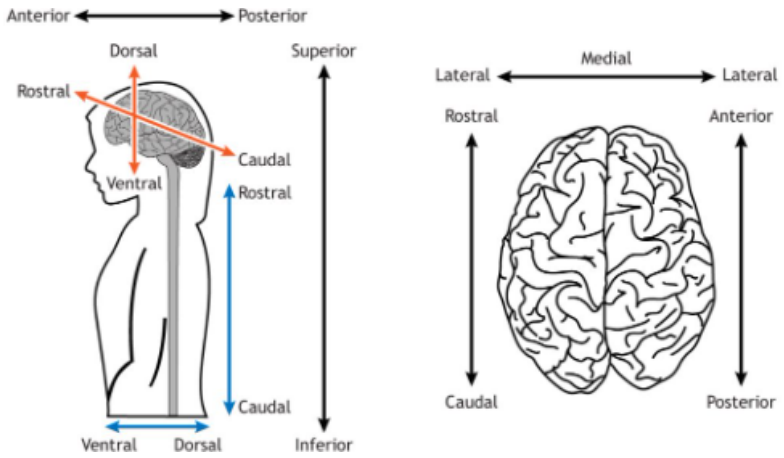

Figure 10: Directions of the Vertebrate Nervous System

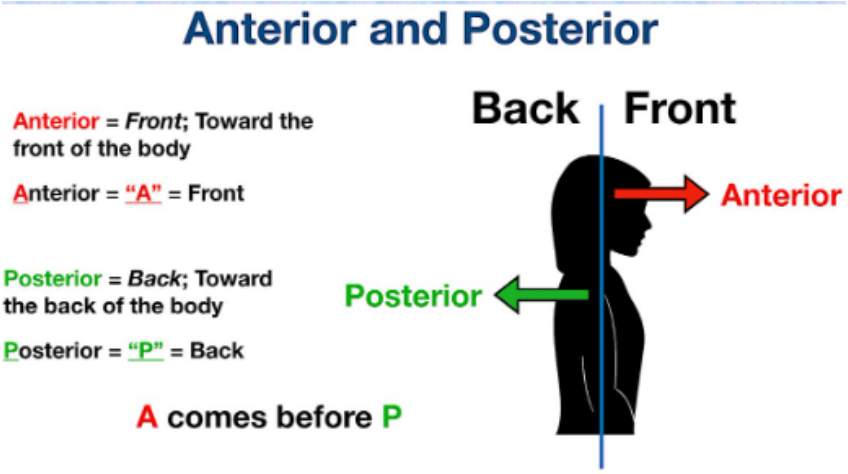

Figure 11: Directions of the vertebrate nervous systems / anterior - posterior

Directions and Planes of the Nervous System

3 Directions and Planes of the Nervous System

3.1 Directions of the Vertebrate Nervous Systems

We use special terms to describes the directions or view of the brain and body in relation to the spinal cord. Here are some of our axes:

1. Anterior / Posterior

   Anterior: also referred to "rostral", toward the nose end.

   Whatever we're looking at is more so towards the nose, the front.

   Posterior: also referred to as "caudal", toward the tail end.

   Whatever we're looking at is more so towards the tail, the back.

2. Dorsal / ventral

   Dorsal: towards the back or top of the head.

   Ventral: towards the chest or bottom of the head.

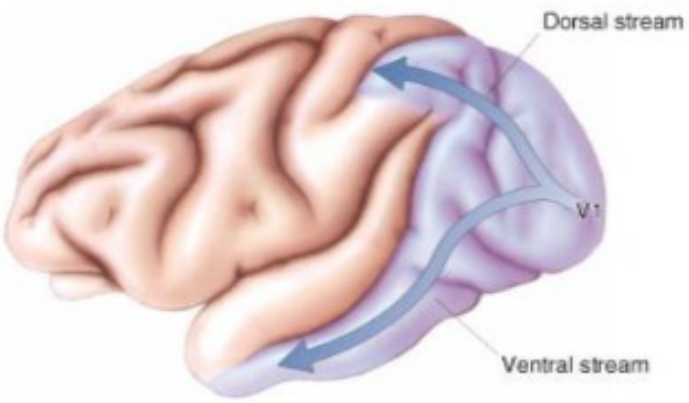

Figure 12: Directions of the Vertebrate Nervous System / Dorsal - ventral

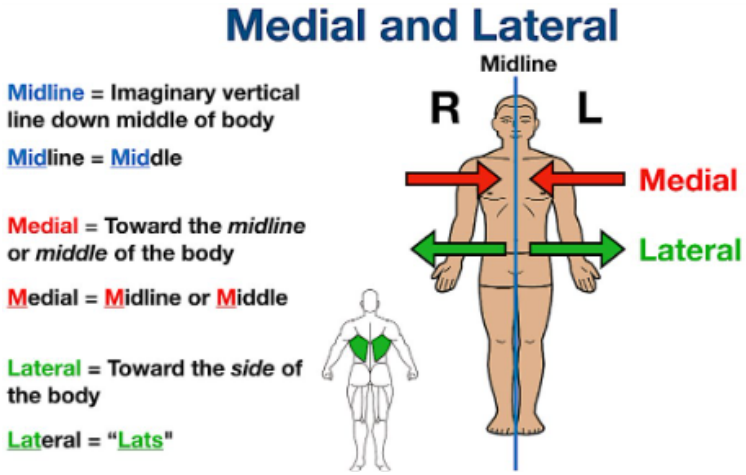

Figure 13: Directions of the Vertebrate Nervous System / Medial lateral

3. Medial / Lateral

   Medial: towards the middle of the body or brain.

   Lateral: away from the middle of the body or brain.

   The following are only used for primates, such as humans, that walk upright...

4. Superior / Inferior

   Superior: towards the top of the head.

   Inferior: towards the bottom of the head.

5. Proximal / distal

   Proximal: Closer to or towards the appendage of the body.

   Distal: Away from the appendage.

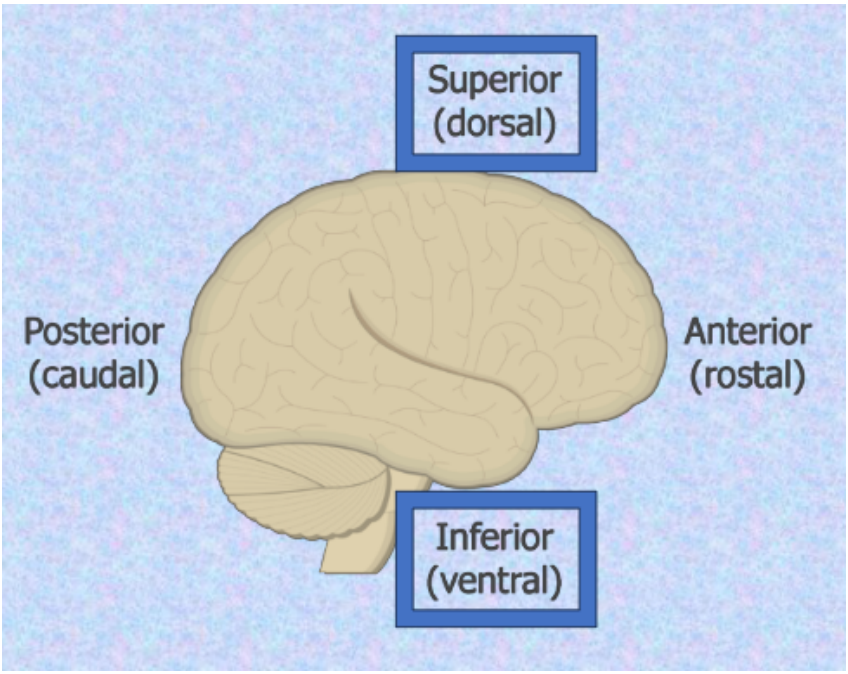

Figure 14: Directions of the Vertebrate Nervous System / Superior - Inferior

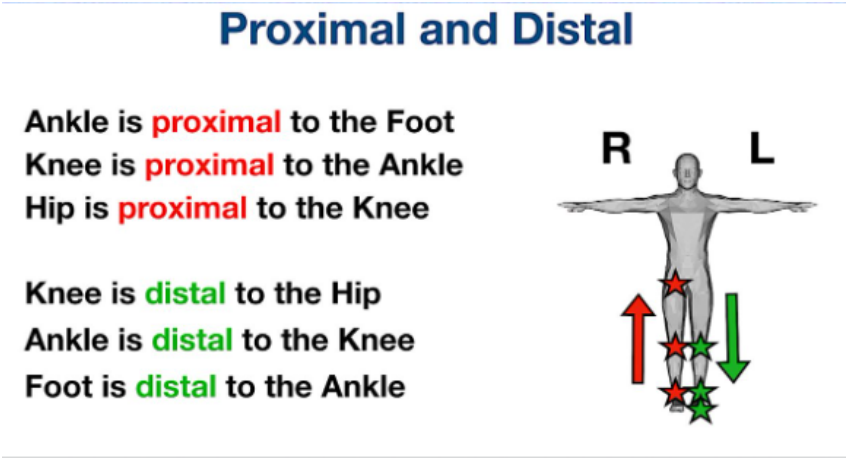

Figure 15: Directions of the Vertebrate Nervous System / Proximal and Distal

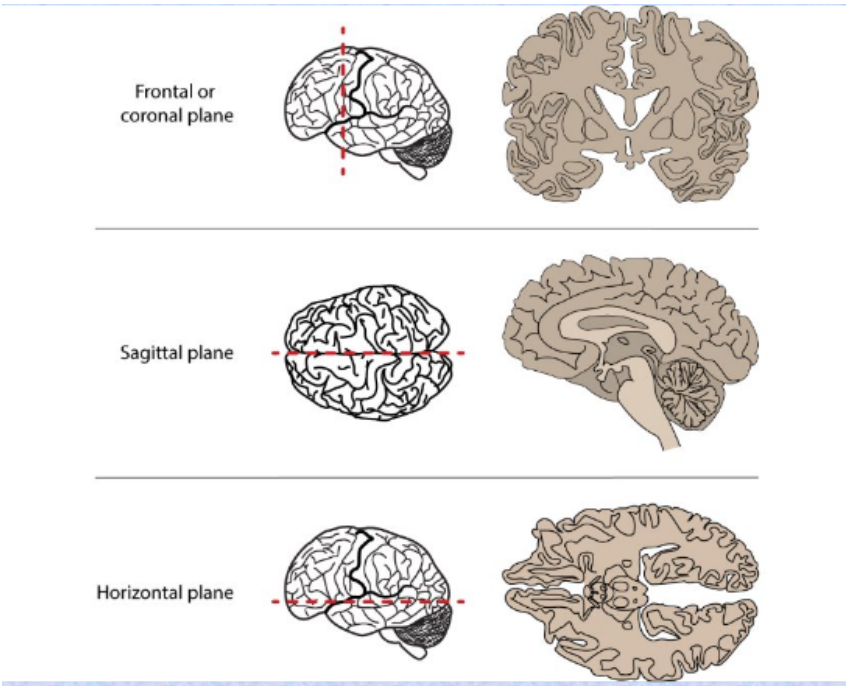

Figure 16: Directions and Planes of Nervous System

Telencephalon	Cerebral cortex	Neocortex Hippocampus	Diencephalon	Thalamus	Massa intermedia Lateral geniculate nuclei Medial geniculate nuclei Ventral posterior nuclei
	Major fissures	Central fissure Lateral fissure Longitudinal fissure		Hypothalamus	Mammillary bodies
	Major gyri	Precentral gyrus Postcentral gyrus Superior temporal gyrus Cingulate gyrus		Optic chiasm	
	Four lobes	Frontal lobe Temporal lobe Parietal lobe Occipital lobe		Pituitary gland	
	Limbic system	Amygdala Hippocampus Fornix Cingulate cortex Septum Mammillary bodies	Mesencephalon	Tectum	Superior colliculi Inferior colliculi
	Basal ganglia	Amygdala Caudate } Striatum Putamen } Globus pallidus		Tegmentum	Reticular formation Cerebral aqueduct Periaqueductal gray Substantia nigra Red nucleus
	Cerebral commissures	Corpus callosum	Metencephalon	Reticular formation Pons Cerebellum	
			Myelencephalon or Medulla	Reticular formation	

Figure 17: Summary of the major brain structures

3.2 Directional Planes of the Nervous System

Major Structures of the Central Nervous System

4 Major Structures of the Central Nervous System

4.1 The Spinal Cord

Just like the brain, the spinal cord is composed of both grey and white matter.

- **Grey matter**: Cell bodies / somas of neurons.
  Appears as H shape in cross-section.
- **White matter**: Myelinated axons
  Surrounds the grey matter.

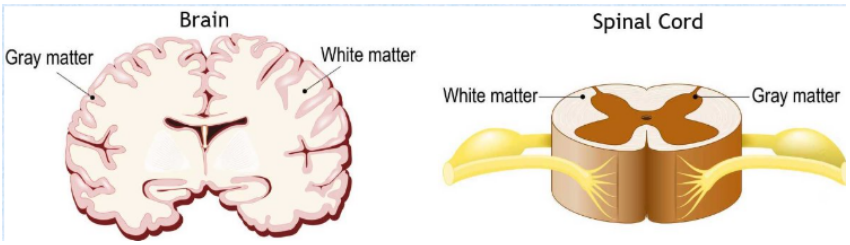

Figure 18: the spinal cord

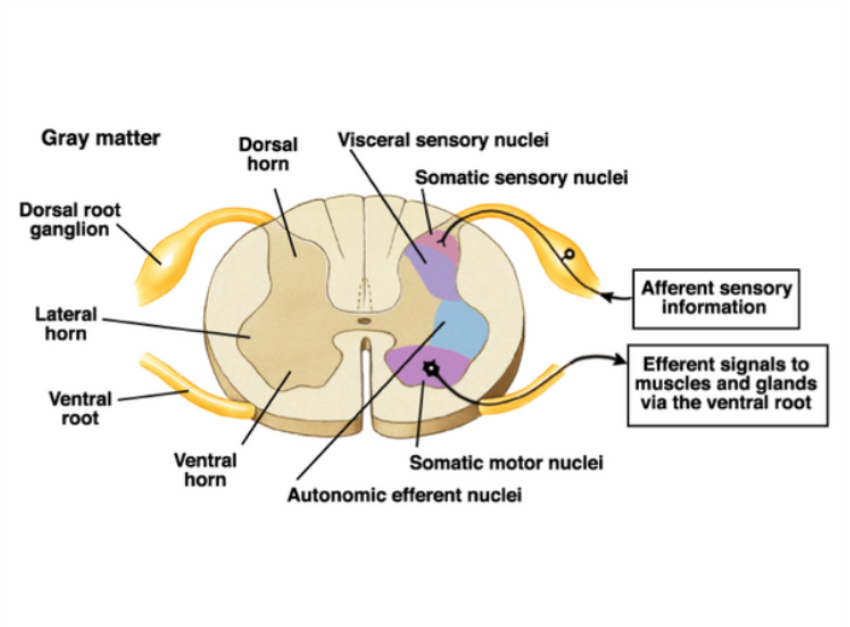

Figure 19: the afferent nerves and the efferent nerves travel into the spinal cord

There are **31 pairs** of **spinal nerves** that exit the spinal cord from either side.
As a reminder:

- **Afferent nerves** carry sensory information from the body.
- **Efferent nerves** carry motor information to the muscles.

The spinal cord, with the above nerve projections, is important for reflexes and more complex sensorimotor functions.

4.2 Divisions of the brain

Starting out with a tube like structure, then at a certain point in our development, it start to swell.

Three swellings form during embryonic development.

These three swellings form **five major divisions** by birth:

1. Hindbrain: **myelencephalon, metencephalon**
2. Midbrain: **mesencephalon**
3. Forebrain: **diencephalon, telencephalon**

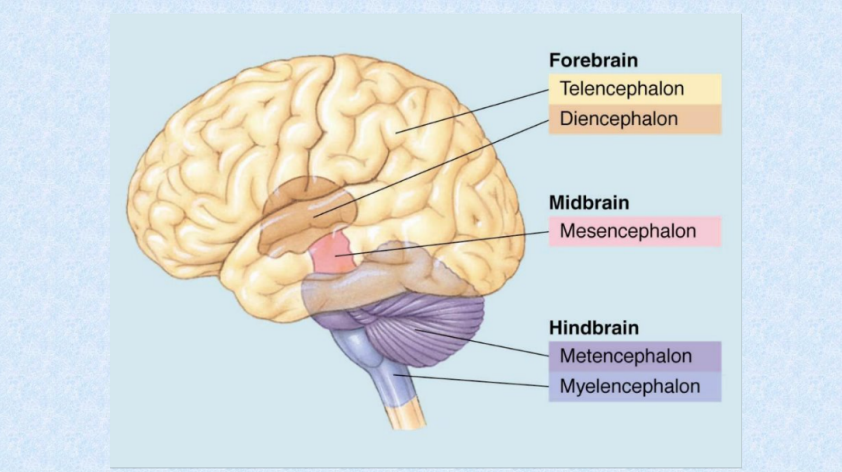

Figure 20: Divisions of the brain

4.3 Hindbrain

4.3.1 The Myelencephalon

- The **medulla**
- Composed of tracts (bundles of axons) carrying signals between the rest of the brain and the body.
- The **reticular formation**

  Controls sleep, attention, movement, and vital reflexes.
- Activity is suppressed by opiate drugs (like heroin or morphine).

4.3.2 The Metencephalon

- Contains the **pons** and the **cerebellum**

  Sleep paralysis has something to do with abnormal activity in the pons.

  Sensorimotor functions
- Also houses part of the reticular formation.

4.4 Midbrain

4.4.1 The Mesencephalon

- **Tectum** (dorsal surface or "root")

  Superior colliculi - processing of visual information.

  Inferior colliculi - processing of auditory information.
- **Tegmentum** (ventral surface or "floor")

  Periaqueductal grey - analgesia (pain relief)

  Substantia nigra and red nucleus - motor (movement) functions.

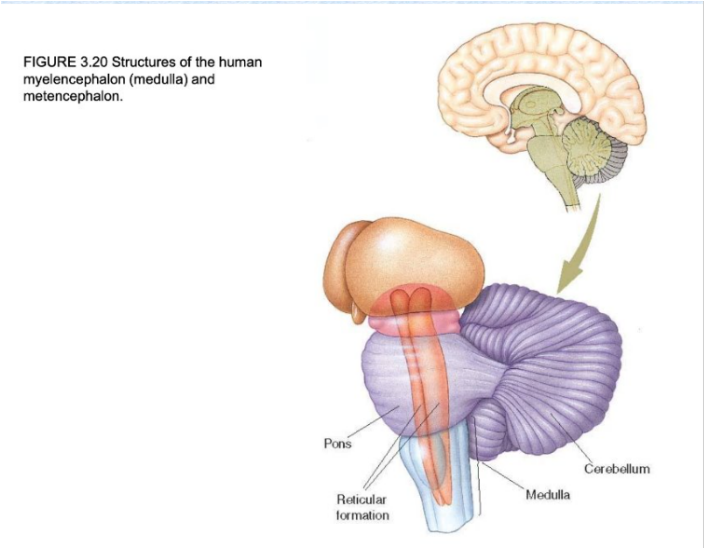

Figure 21: Structures of the human myelencephalon(medulla) and metencephalon

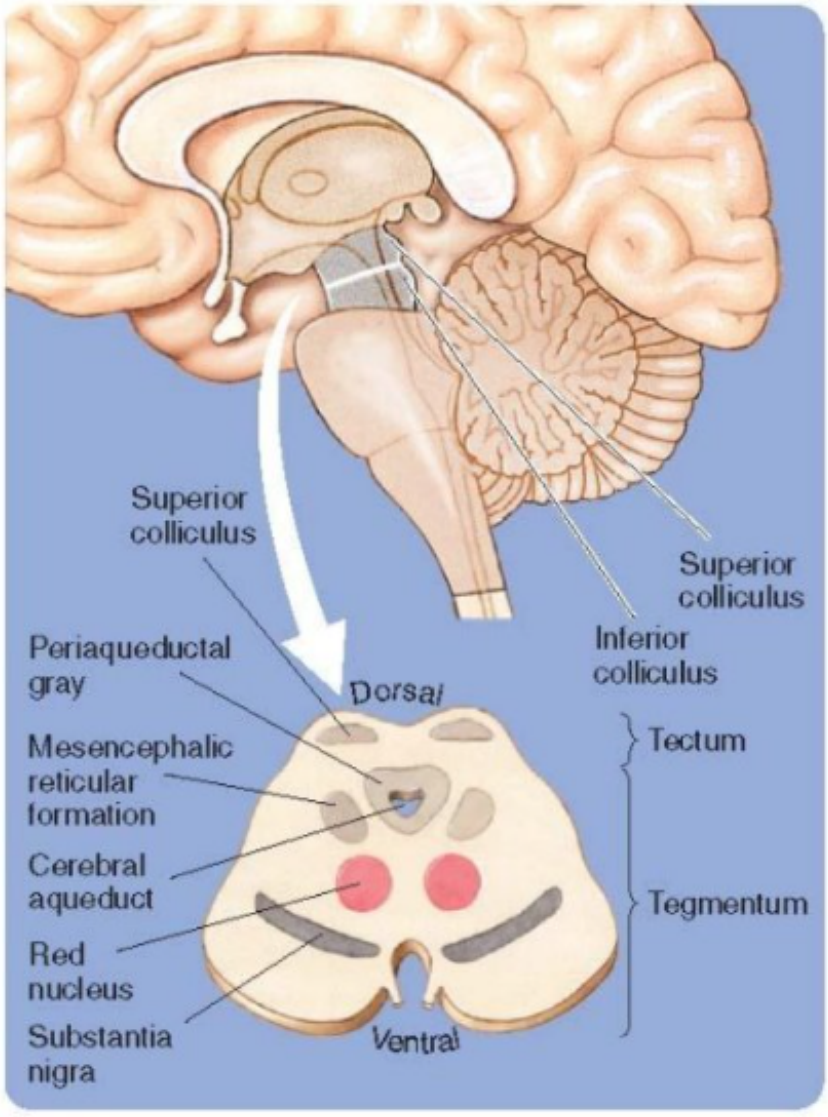

Figure 22: The human mesencephalon (midbrain)

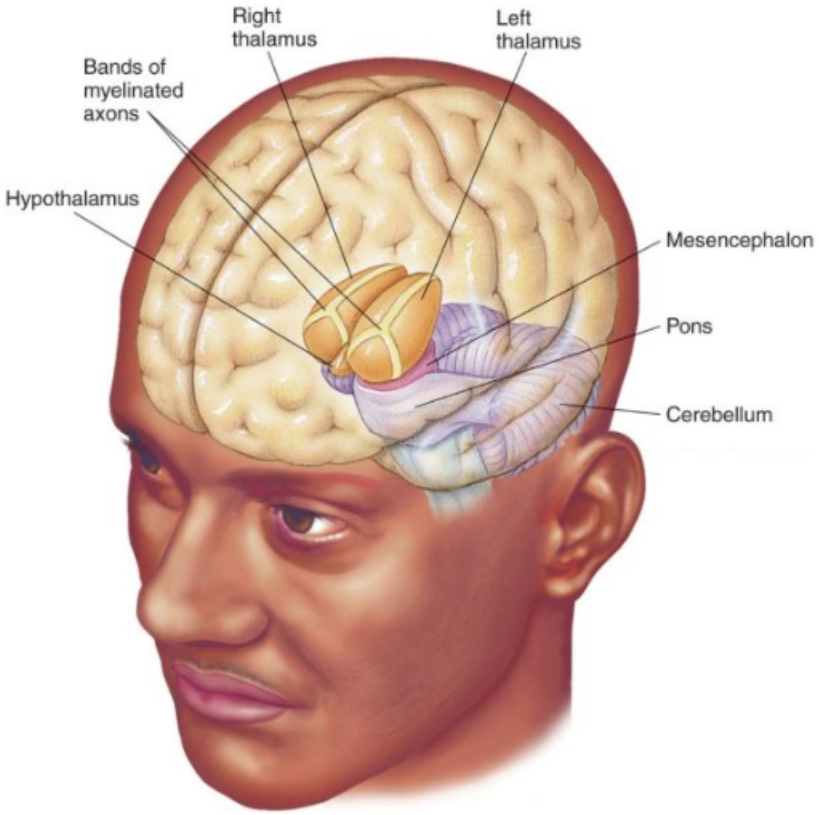

Figure 23: The human diencephalon

4.5 Forebrain

4.5.1 The Diencephalon

- **Thalamus**: this is considered our "sensory relay station". Nuclei (subregions) of the thalamus receive information from sensory receptors and relay the signals to the cerebral cortex.
- **Hypothalamus**: controls motivated behaviors (sleepng, eating, and sex).

  Regulates hormone release from the **pituitary gland**.
- **Optic chiasm**: the point at which the nerves from each eye come together.
- **Mamillary bodies**: control aspects of memory.

4.5.2 The Telencephalon

1. **The Cerebral Cortex**
   - Comprised of a left and right hemisphere.
   - Hemispheres are divided by the **medial longitudinal fissure**.
   - Hemispheres are connected by the **cerebral commissures**.

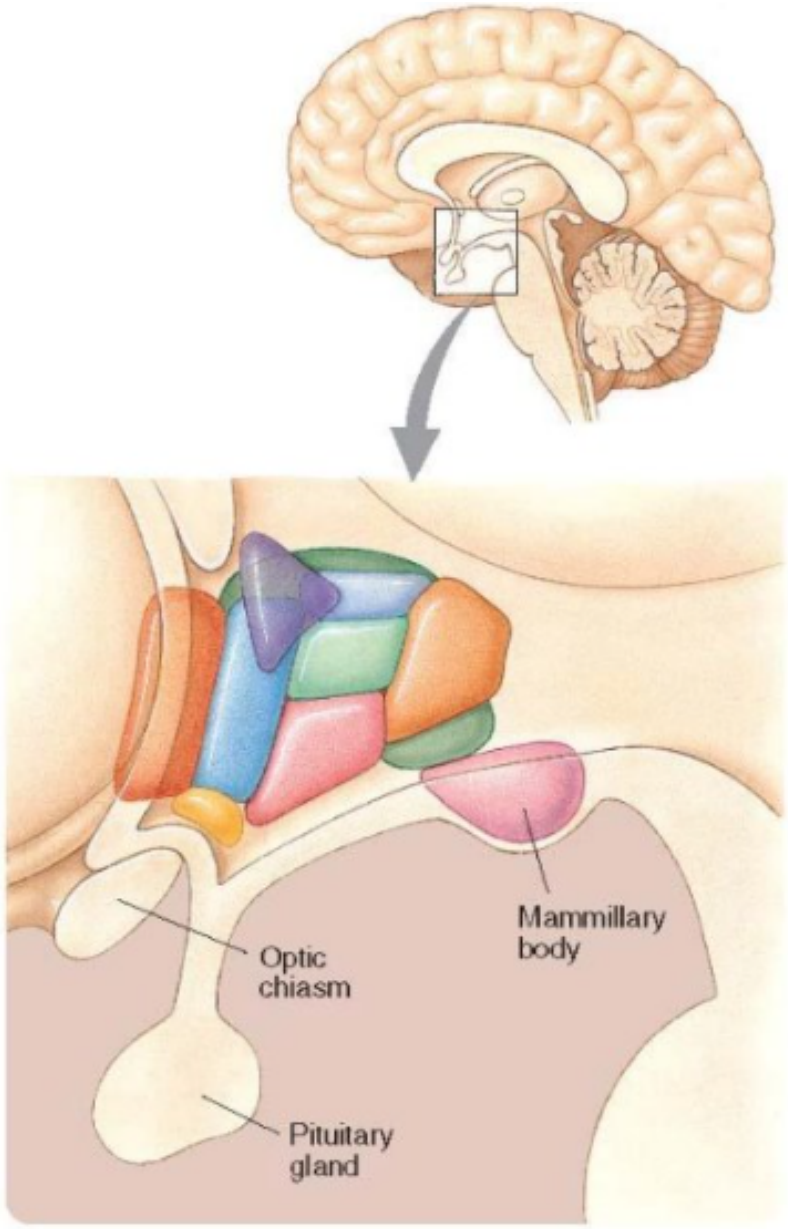

Figure 24: The human hypothalamus (in color) in relation to the optic chiasm and the pituitary gland

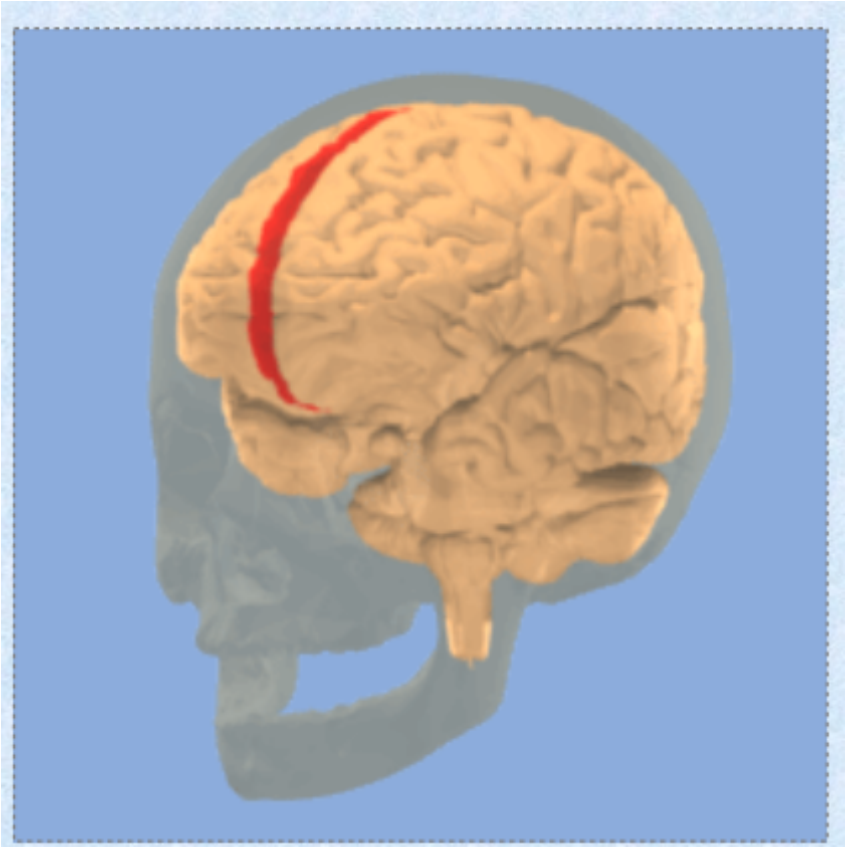

Figure 25: Medial Longitudinal Fissure

Figure 26: The Corpus Callosum

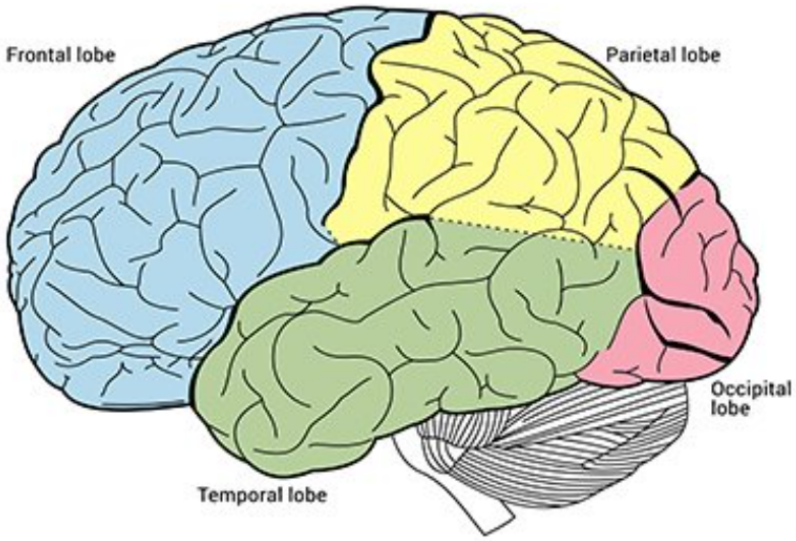

Figure 27: Four lobes of the human brain

Example: **The corpus callosum**

- **Convolutions** (furrows) serve the increase surface area.

2. **The Cerebral Cortex**: each hemisphere can be divided into four lobes:
   - **Frontal lobe** - responsible for complex cognition and some motor functions.
   - **Parietal lobe** - touch sensations, attention, and spatial awareness.
   - **Temporal lobe** - hearing, language, visual patterns, learning and memory.
   - **Occipital lobe** - Vision.

3. Subcortical System
   - The **limbic system** circles the thalamus.
     Amygdala, fornix, cingulate gyrus, and hippocampus.
     Motivated behaviors, emotion, learning and memory.
   - The **basal ganglia** on each side of the thalamus.
     Caudate nucleus and **putamen (striatum), globus pallidus**.
     Voluntary movements.

Cells of the Nervous System

5 Cells of the Nervous System

There are two main types of cells in the CNS:

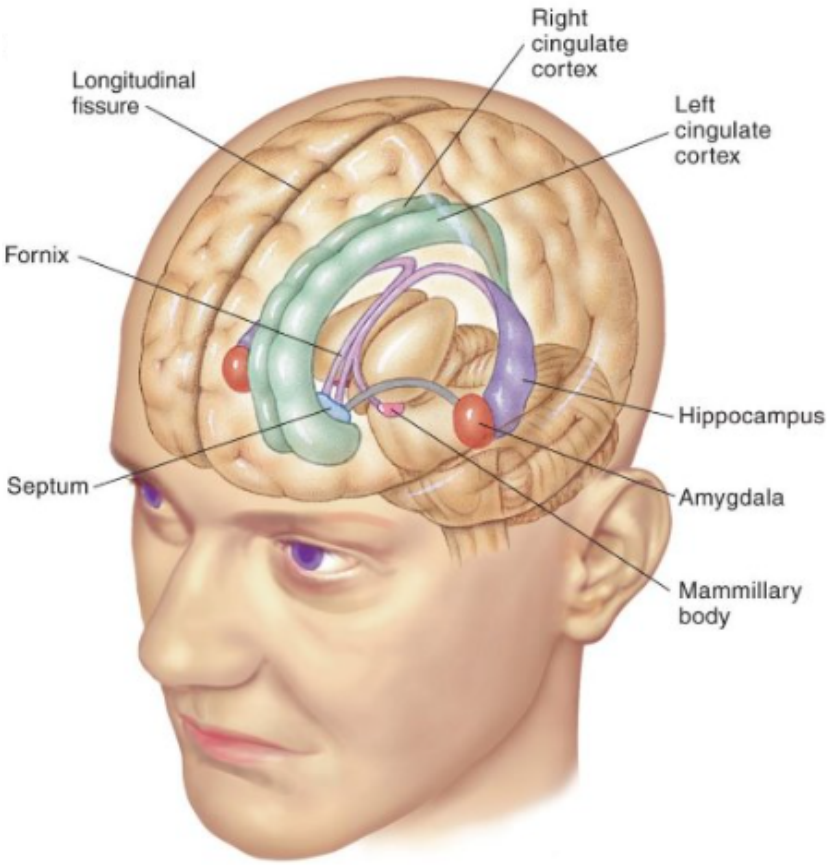

Figure 28: The major structures of the limbic system: amygdala, hippocampus, cingulate cortex, fornix, septum, and mammillary body.

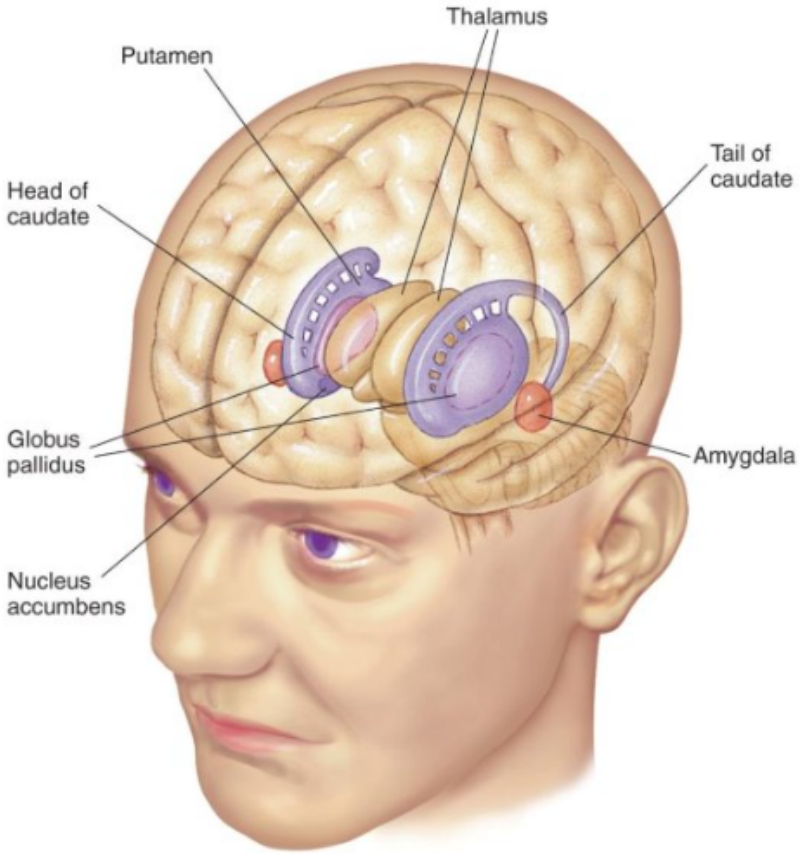

Figure 29: The basal ganglia: amygdala, striatum (caudate plus putamen), and globus pallidus. Notice that, in this view, the right globus pallidus is largely hidden behind the right thalamus and the left globus pallidus is totally hidden behind the left putamen. Although the globus pallidus is usually considered to e a telencephalic structure, it actually originates from diencephalic tissue that migrates into its telencephalic location during the course of prenatal development.

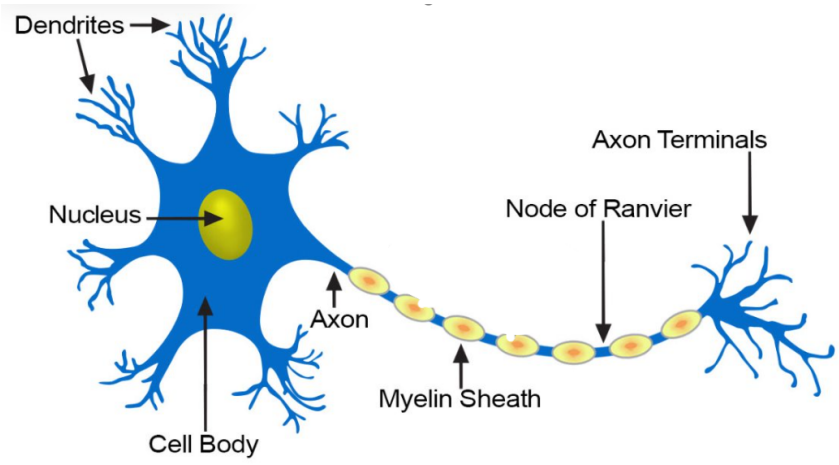

Figure 30: Neuron anatomy Summary

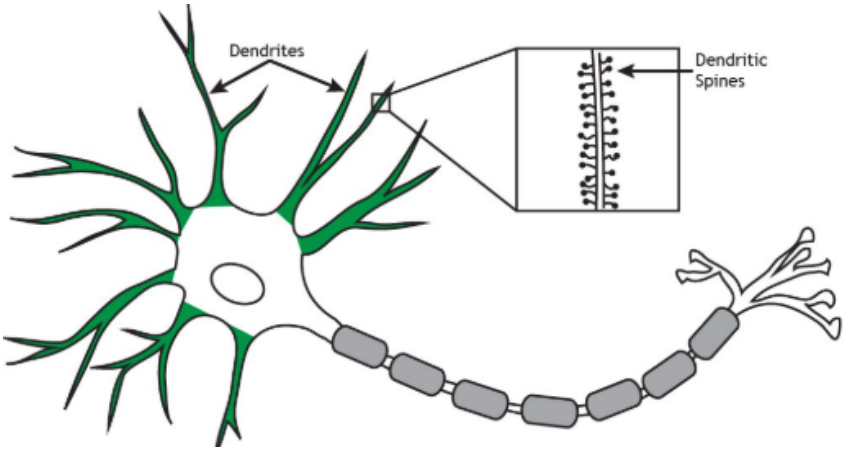

Figure 31: Schematics of a dendrite

5.1 Neurons

- These are specialized for the reception, conduction, and transmission of electrochemical signals.
- The main part of the neuron are comprised of the:

  Dendrites

  Cell body

  Cell membrane

  Axon hillock

  Axon - myelin sheath and **Nodes of Ranvier**

  Terminal buttons / presynaptic terminals/axon terminals.

5.1.1 Dendrites

Dendrites are the short branches at the receiving end of the neuron (typically at the "top" of a neuron in illustrations; branch from soma)

- **Receptors** on the surface of dendrites receive information from other preceding neurons.
- **Dendritic spines**: short outgrowths to increase surface area for signal input and receival.
- The shapes of dendrites and spines vary across cells, and can vary within a cell as well based on the environment.

  Can change due to learning, stress, and drugs.

5.1.2 The Soma, or cell body

- The soma serves as the metabolic center of the neuron.
- Contains: organelles such as the nucleus, mitochondria, and ribosomes.
- Contains DNA.

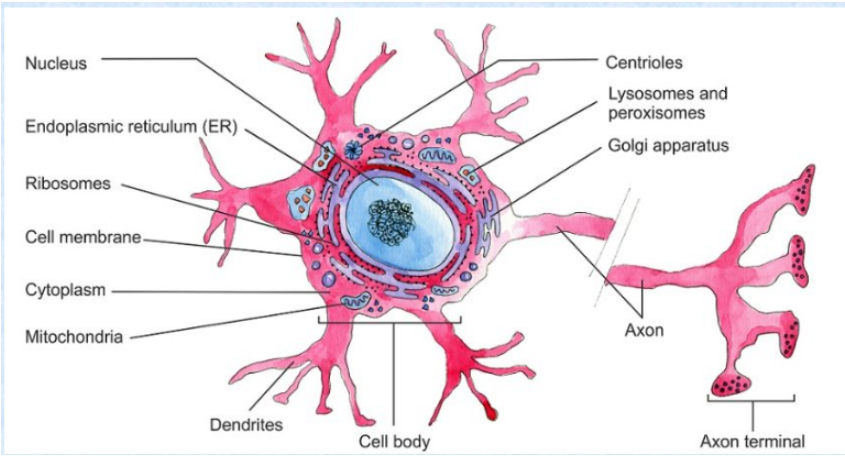

Figure 32: Schematic of cell body/axon

5.1.3 The Cell Membrane

- The cell membrane of a neuron is composed of a **lipid bilayer** (two layers of **fat molecules**).
- Numerous different **protein molecules** are embedded within the lipid bilayer.

5.1.4 The Axon Hillock

- Portion of the soma that connects to the axon.
- Involved in the control of initiation of electrical impulse upon the receival of signals from the environment or other neurons.

5.1.5 The Axon

- Long, thin fiber extending from the cell body.
- The neuron's "information sender..." the axon is responsible for transmitting electrical impulses to carry to other neurons.
- Many axons are insulated with a **myelin sheath**.

5.1.6 The Myelin Sheath

- Fatty white substance insulating axons.
- **Propagates** and increases the speed of signal conduction down the neuron.
- The myelin sheath is interrupted by the **Nodes of Ranvier**, which allows the signal to jump from node to node via **saltatory conduction**.

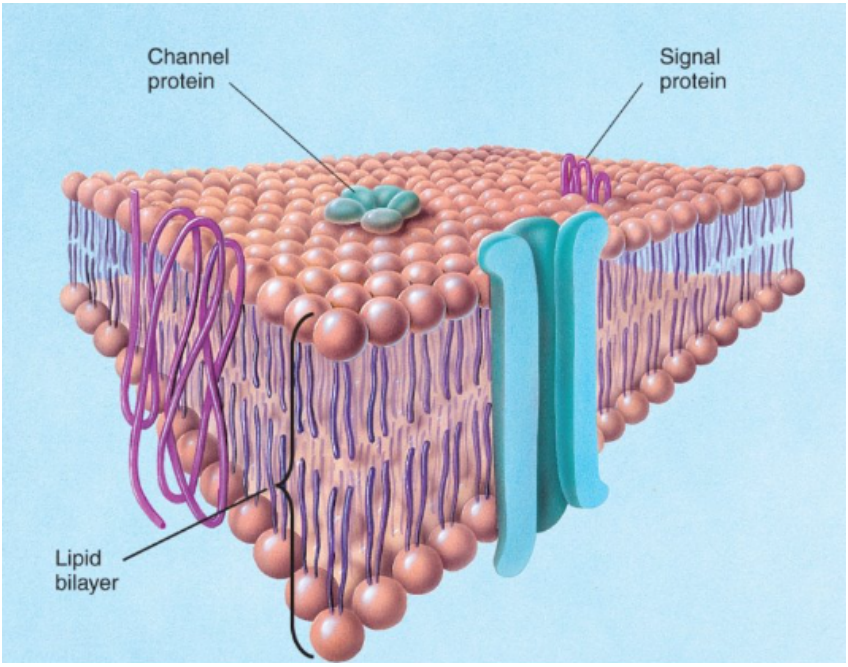

Figure 33: Cell membrane

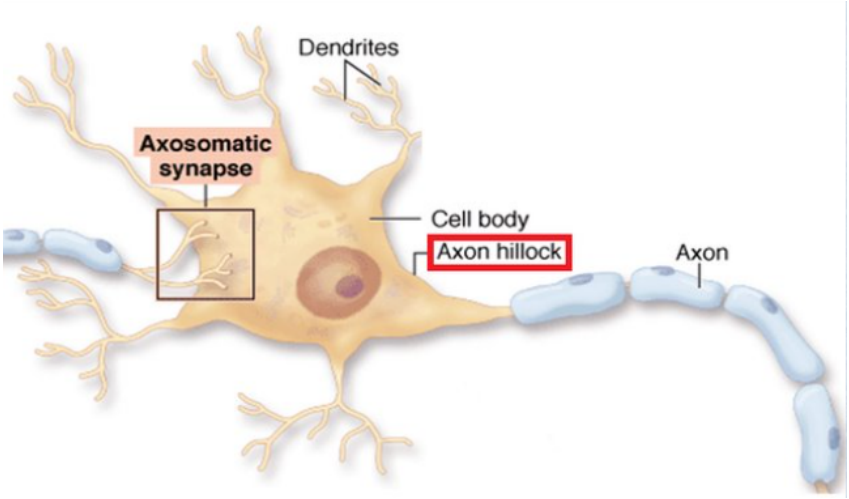

Figure 34: Axon hillock

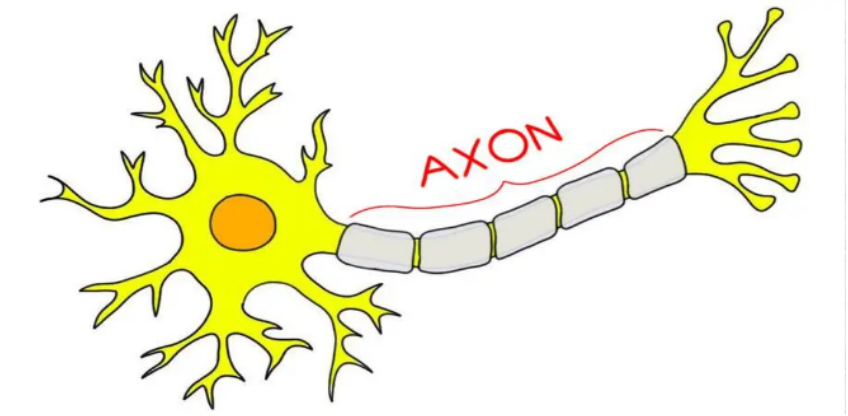

Figure 35: Axon

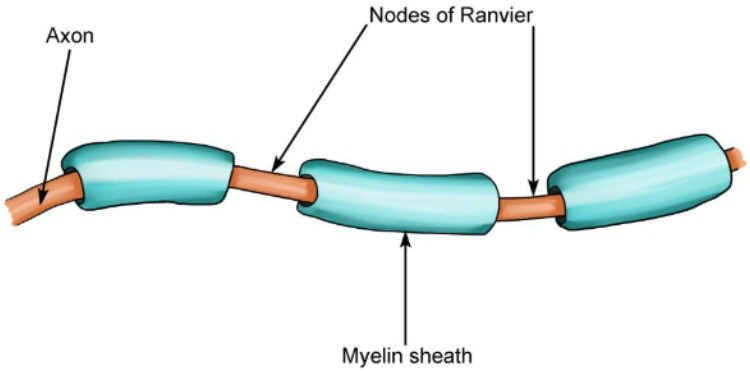

Figure 36: Myelin Sheath

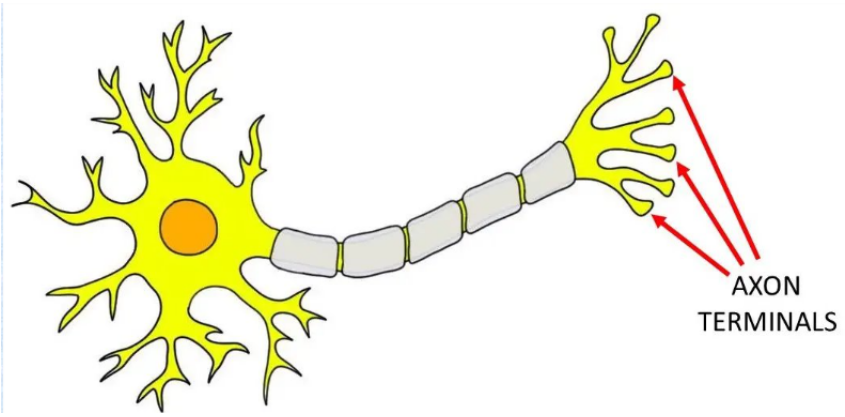

Figure 37: Axon Terminals

5.1.7 Axon Terminals

- AKA **presynaptic terminals** or **terminal buttons**
- These are the endpoints of axon branches.
- Site of release of chemical signals that will reach other neurons.

5.1.8 Neuron Classification

Neurons can be classified by their shape, or differing structures based off their functions and processes...

We have more Glial cells than neurons.

5.2 Glial cells

- Glia are non-neuronal cells that come in a variety of sizes, shapes, and types and differ in functions:

  Microglia

  Oligodendrocytes and Schwann cells

  Astrocytes

  Radial Glia

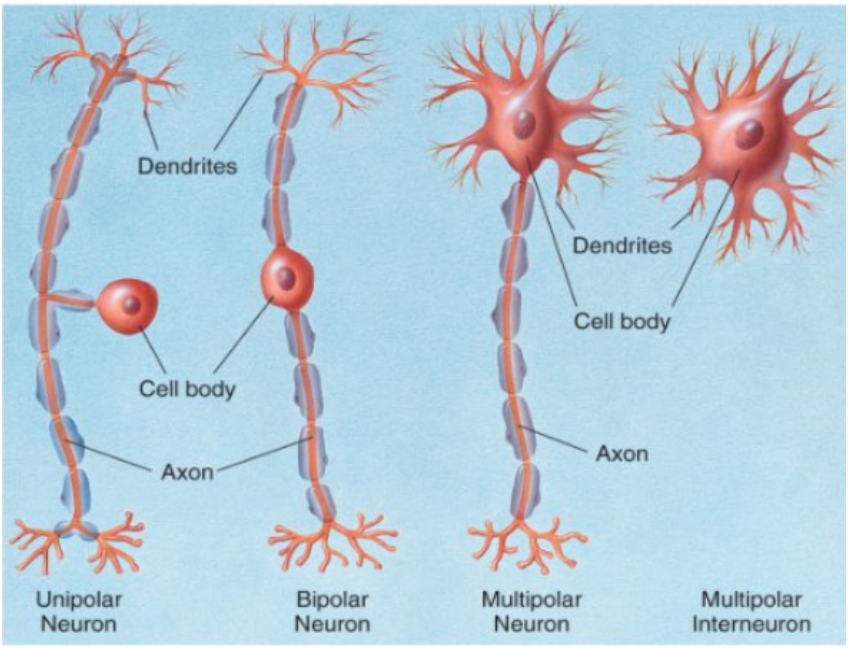

Figure 38: Neuron classification

5.2.1 Microglia

Microglia are small "scavenger" cells that respond to disease and injury.

- Engulf and destroy viruses, bacteria, and other microorganisms (phagocytosis).
- Go from a dormant to activated state during CNS inflammation.
- Act as trash pickup for neurons.

5.2.2 Oligodendrocytes and Schwann Cells

- **Oligodendrocytes** build the myelin sheath that wraps around cells in the CNS.
- **Schwann cells** build the myelin sheath that wraps around cells in the PNS.

5.2.3 Astrocytes

Astrocytes are star-shaped cells with a variety of functions:

- Cover outer surface of blood vessels in the brain to assist with **BBB** function.
- Synchronize activity of neurons by wrapping around the **synapses**, which is the gap or connective point between neurons.
- Also synthesize certain neurotransmitters (i.e., glutamate) and mediate neurotransmission.

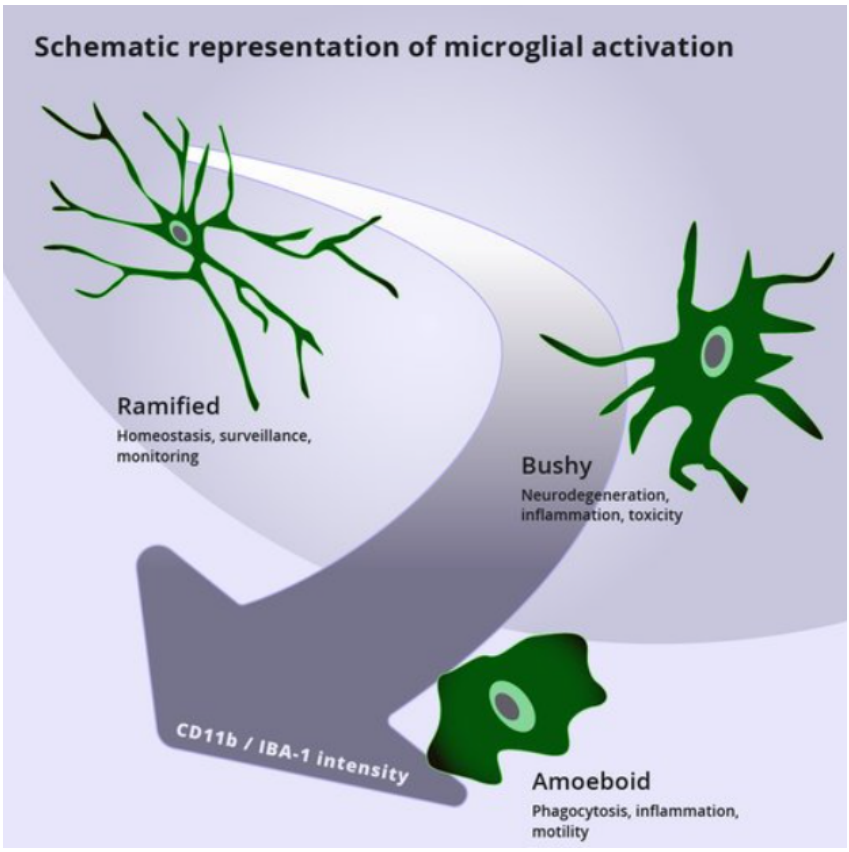

Figure 39: Microglia

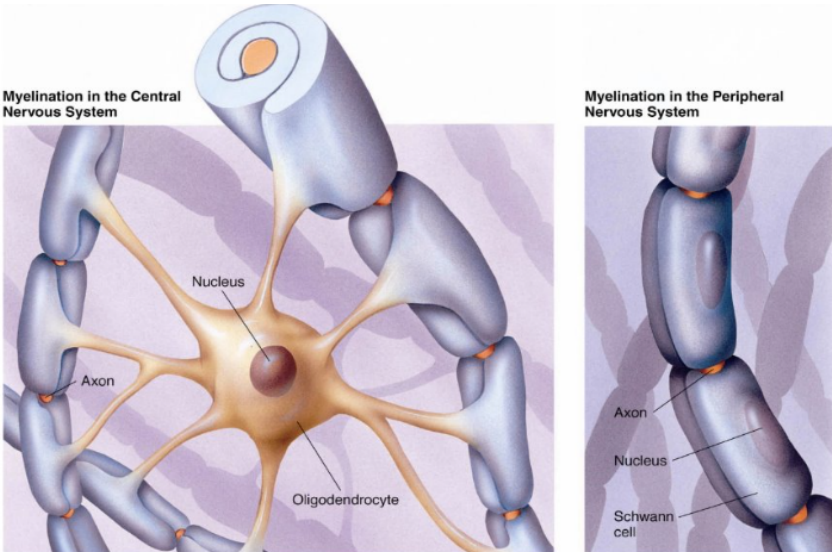

Figure 40: Oligodendrocytes and Schwann Cells

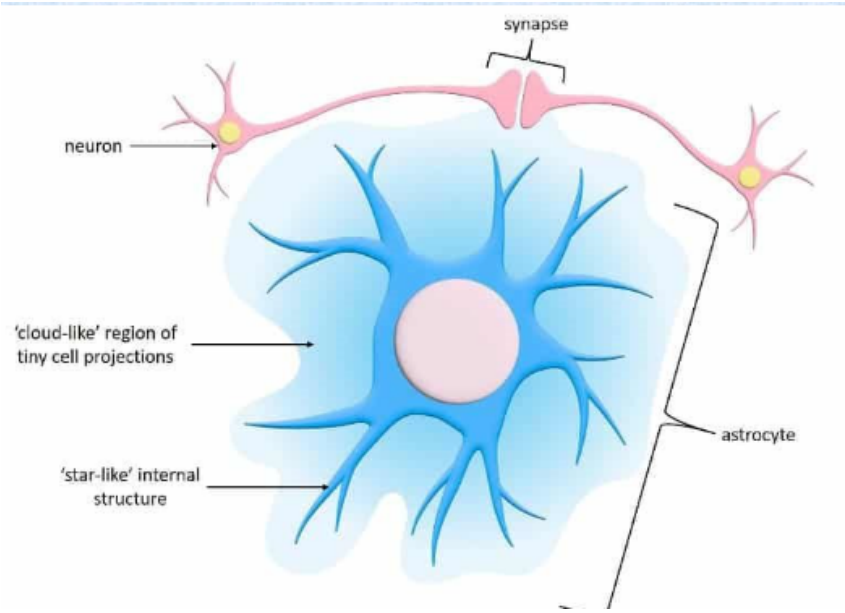

Figure 41: Astrocytes

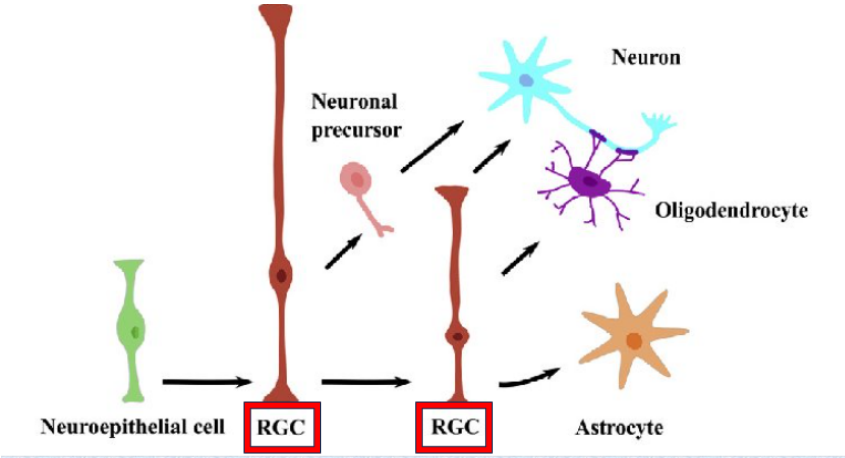

Figure 42: Radial Glia

5.2.4 Radial Glia

- Guide migration and growth of neurons during brain development.
- Later differentiate into neurons or other types of glial cells.

6 References

As mentioned in the lecture (Laura Mcauliffe, Ph.D Candidate, 2025),

References

[1] Laura Mcauliffe, *The Anatomy of the Nervous System*, Biopsychology (PSYC 372), George Mason Univerity, 2025. PowerPoint presentation.

[2] Laura Mcauliffe, *Support Systems*, Biopsychology (PSYC 372), George Mason Univerity, 2025. PowerPoint presentation.

[3] Laura Mcauliffe, *The Directions and Planes of the Nervous System*, Biopsychology (PSYC 372), George Mason Univerity, 2025. PowerPoint presentation.

[4] Laura Mcauliffe, *Major Structures of the CNS*, Biopsychology (PSYC 372), George Mason Univerity, 2025. PowerPoint presentation.

[5] Laura Mcauliffe, *Cells of the CNS*, Biopsychology (PSYC 372), George Mason Univerity, 2025. PowerPoint presentation.