Review (lectures 2-9)

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Course News

Midterm Exam Friday, Sept 28

The exam will cover lectures 2-9 and labs 1-2.

A – L last names in MoosT 2-620
M – Z in MoosT 2-650

PLEASE BRING #2 PENCILS!!!

Be sure to check out last year's exam on the course website!!!

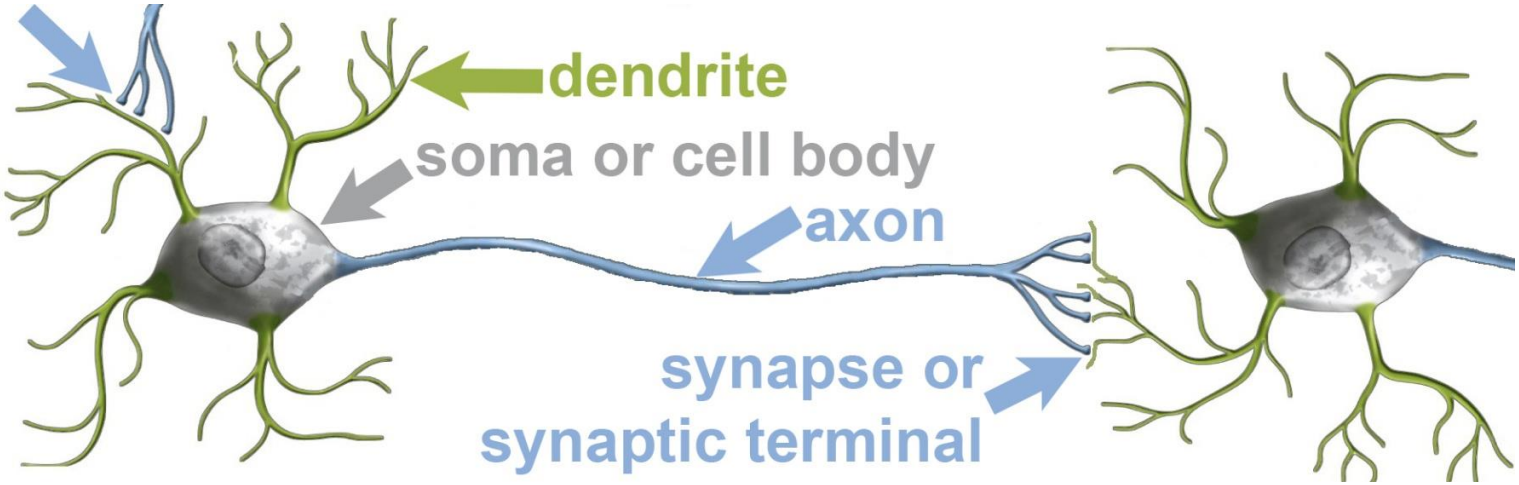
Course News

Dr. McLoon's office hours this week:

Wednesday (Sept 26) 2:30 – 4:30pm

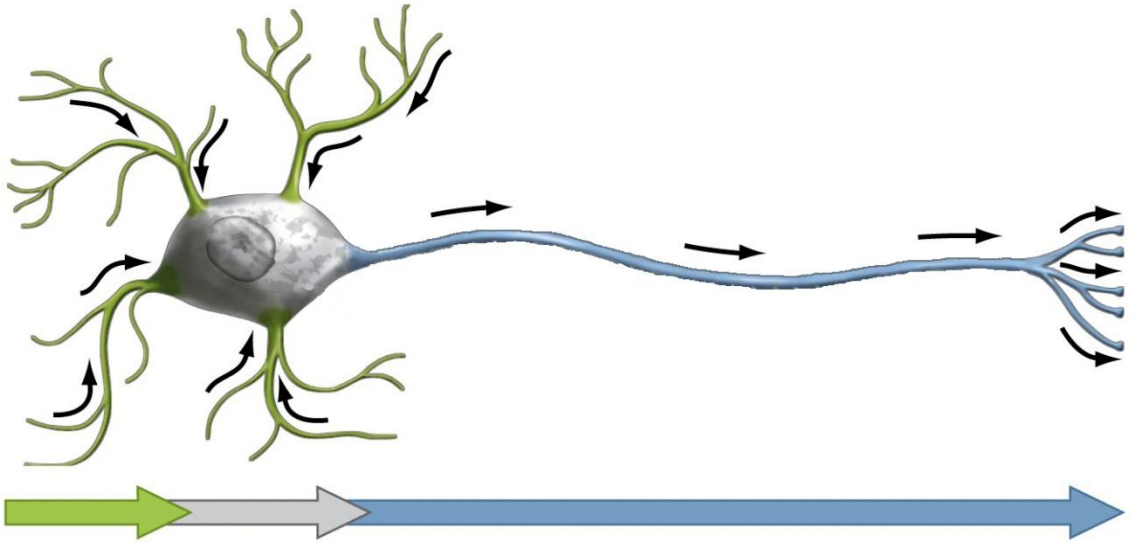
In Jackson Hall 4-158

Anatomy of a ‘Typical’ Neuron



- Soma (cell body)
- Dendrites
- Axon (only one, but can branch)
- Synapses

Flow of Information in Neurons

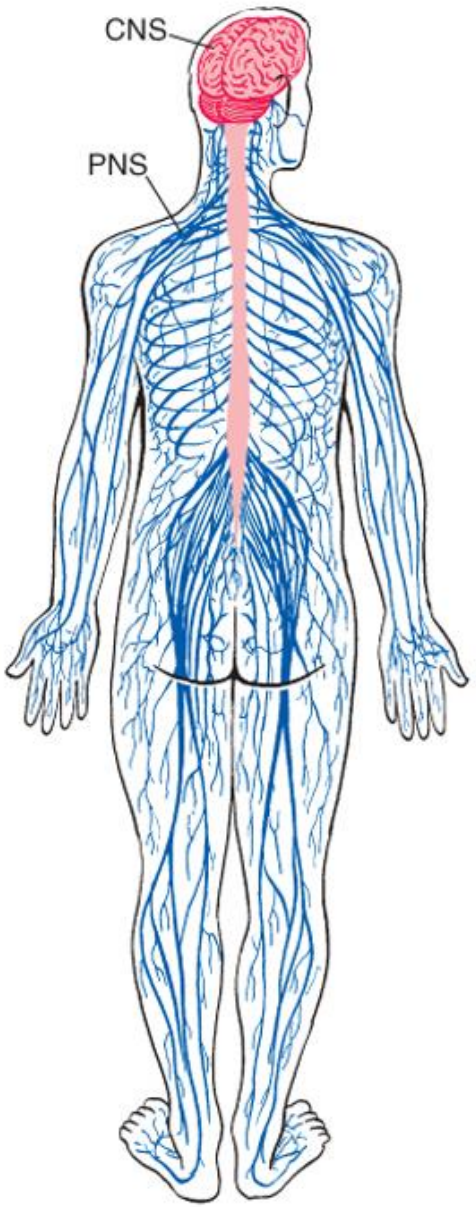


dendrite > soma > axon > synapse

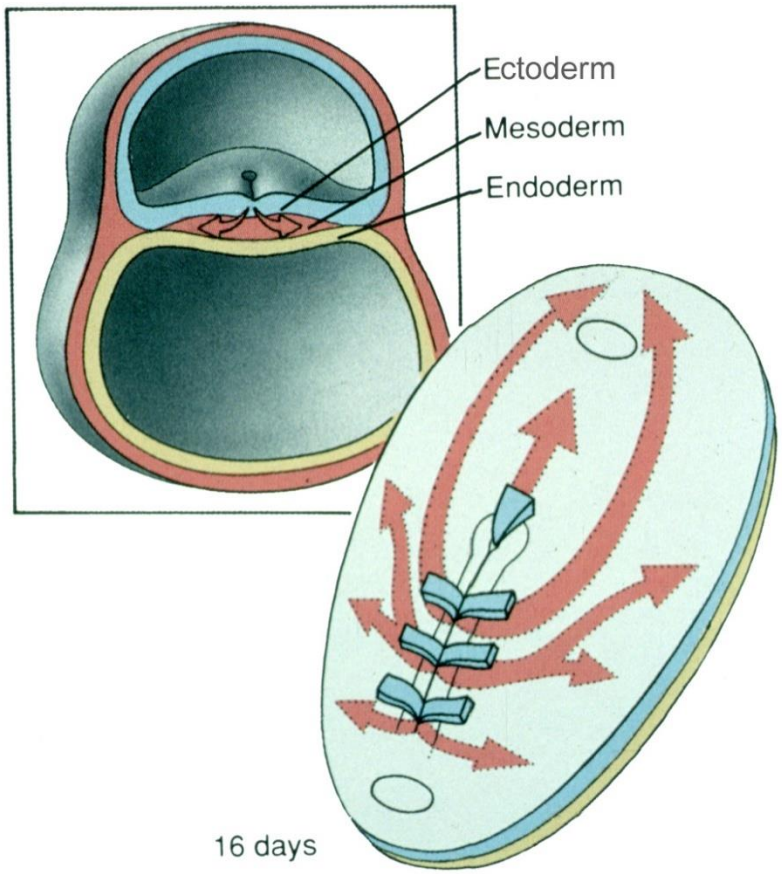
Central vrs. Peripheral Nervous System

- Central nervous system (CNS) includes the brain, spinal cord and retina.
  - Bundles of axons are in tracts or commissures (white matter).
  - Neuronal cell bodies are in nuclei or layered structures (grey matter).

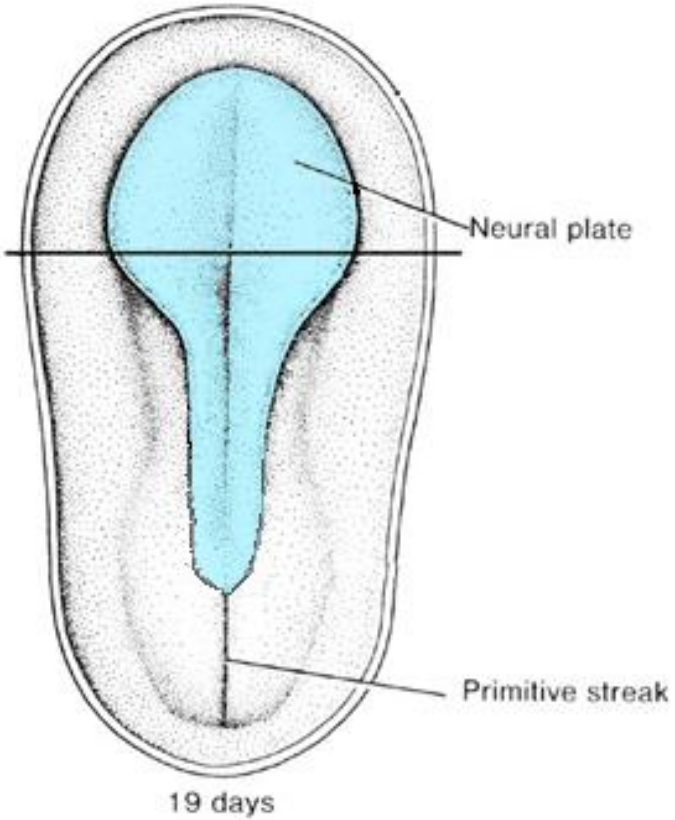
- Peripheral nervous system (PNS) includes nerves and ganglia, which are distributed throughout the body.
  - Bundles of axons are in nerves.
  - Nerves connect to the brain (cranial nerves) or spinal cord (spinal nerves).
  - Ganglia are collections of the somas of neurons.



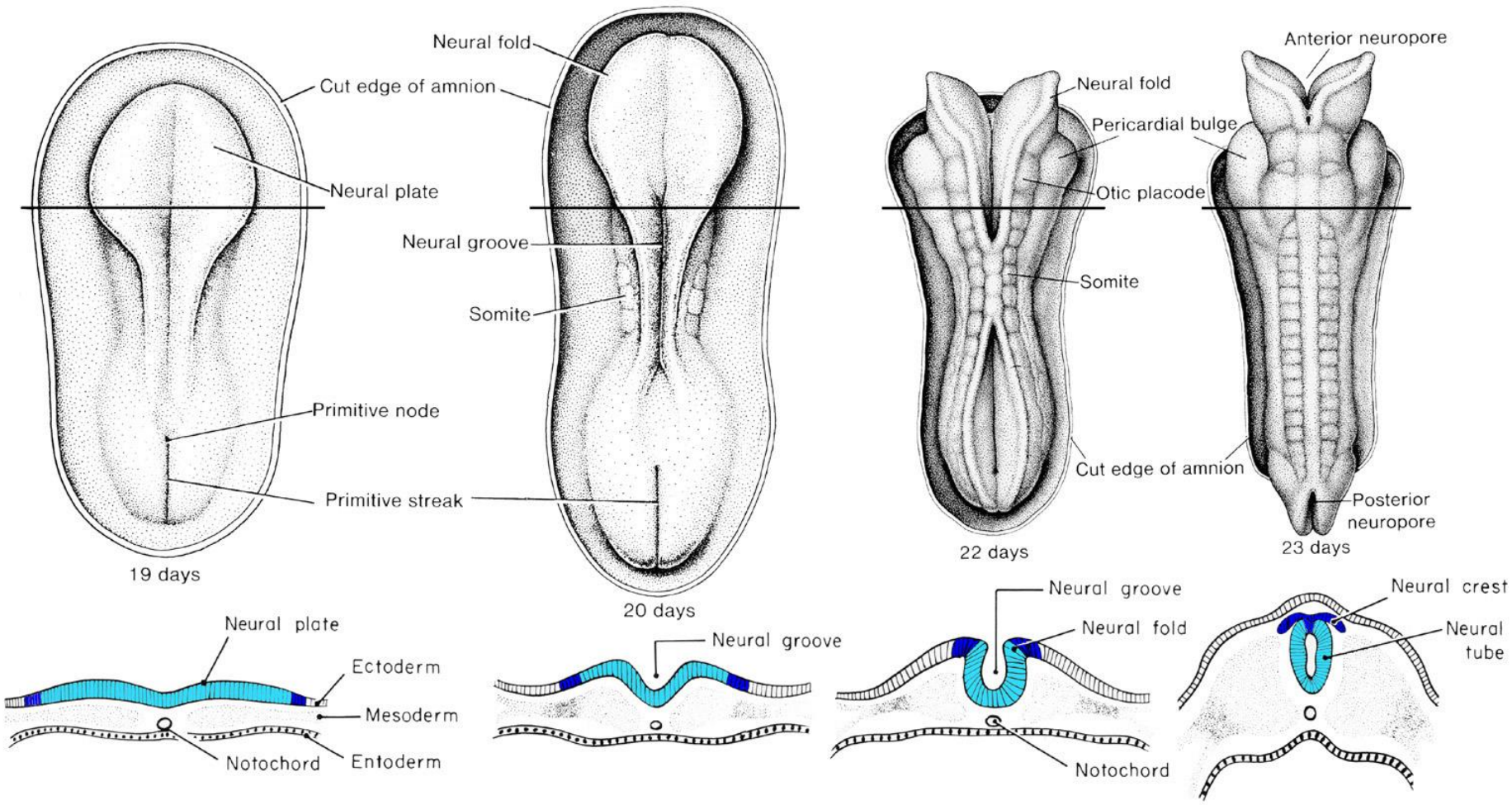
During gastrulation, cells migrate to form a three layered embryo.



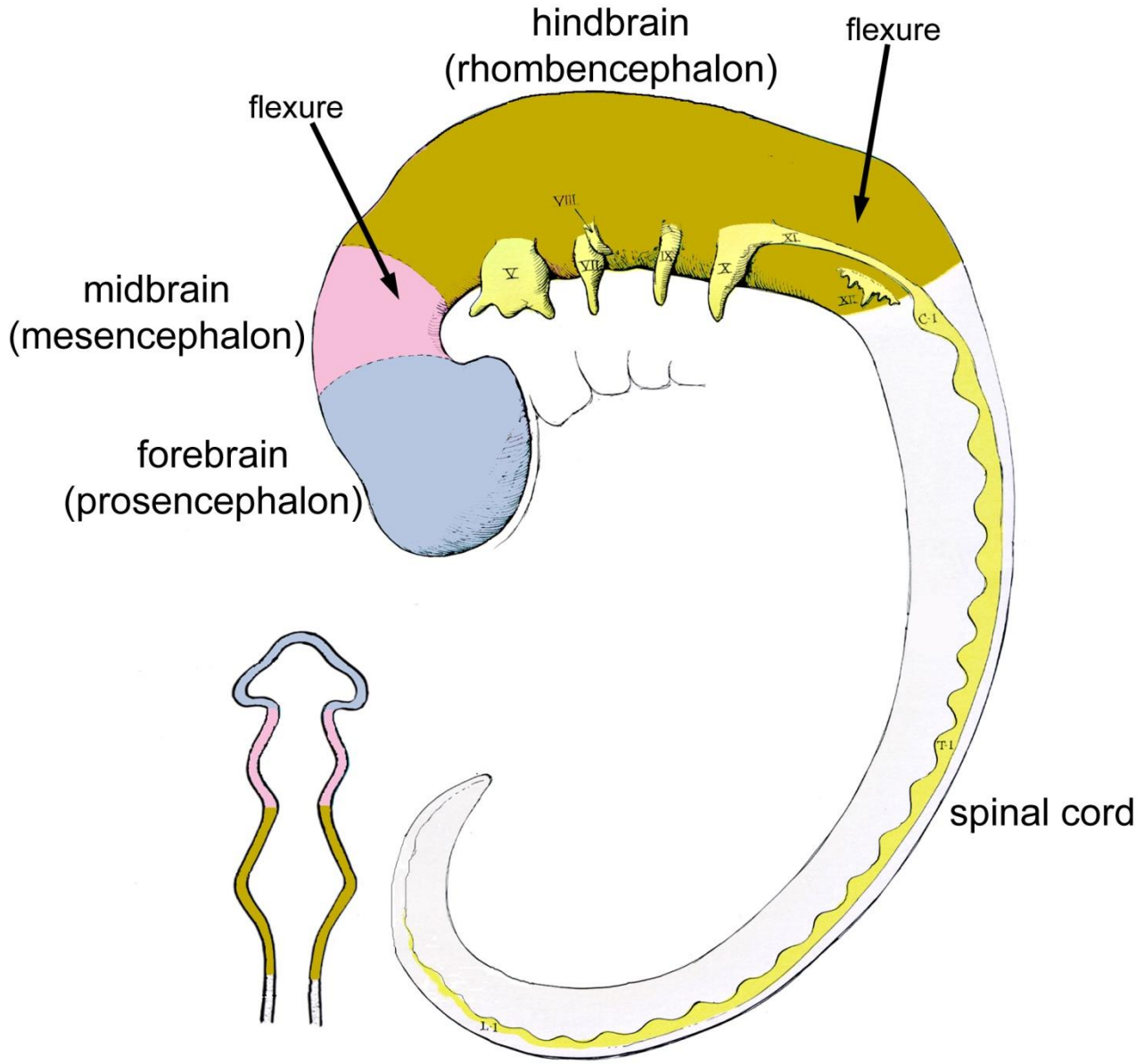
Factors from the midline mesoderm induce nervous system in the overlying ectoderm, and the neural plate forms.



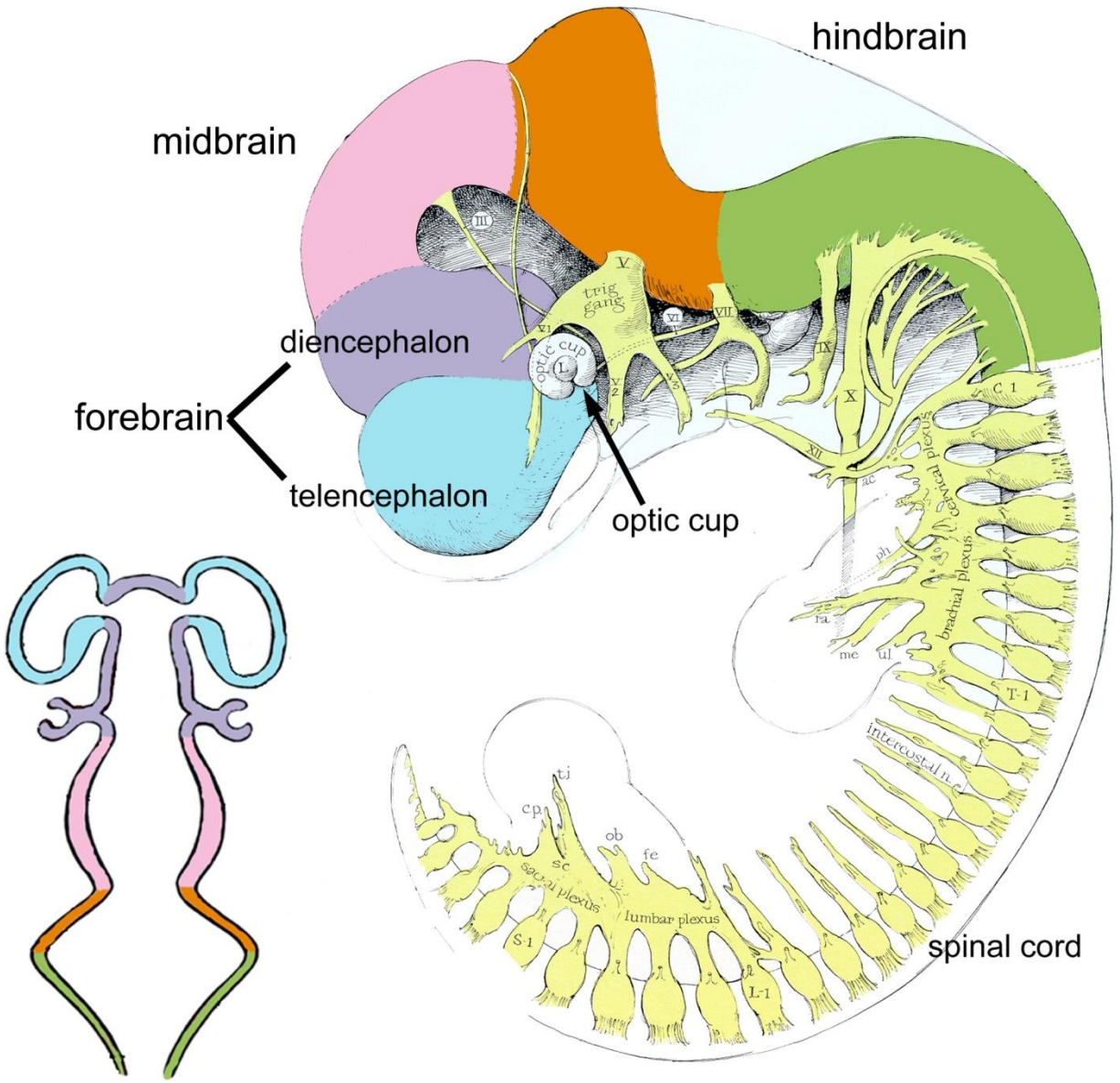
The neural tube develops from the neural plate in a process called neurulation.



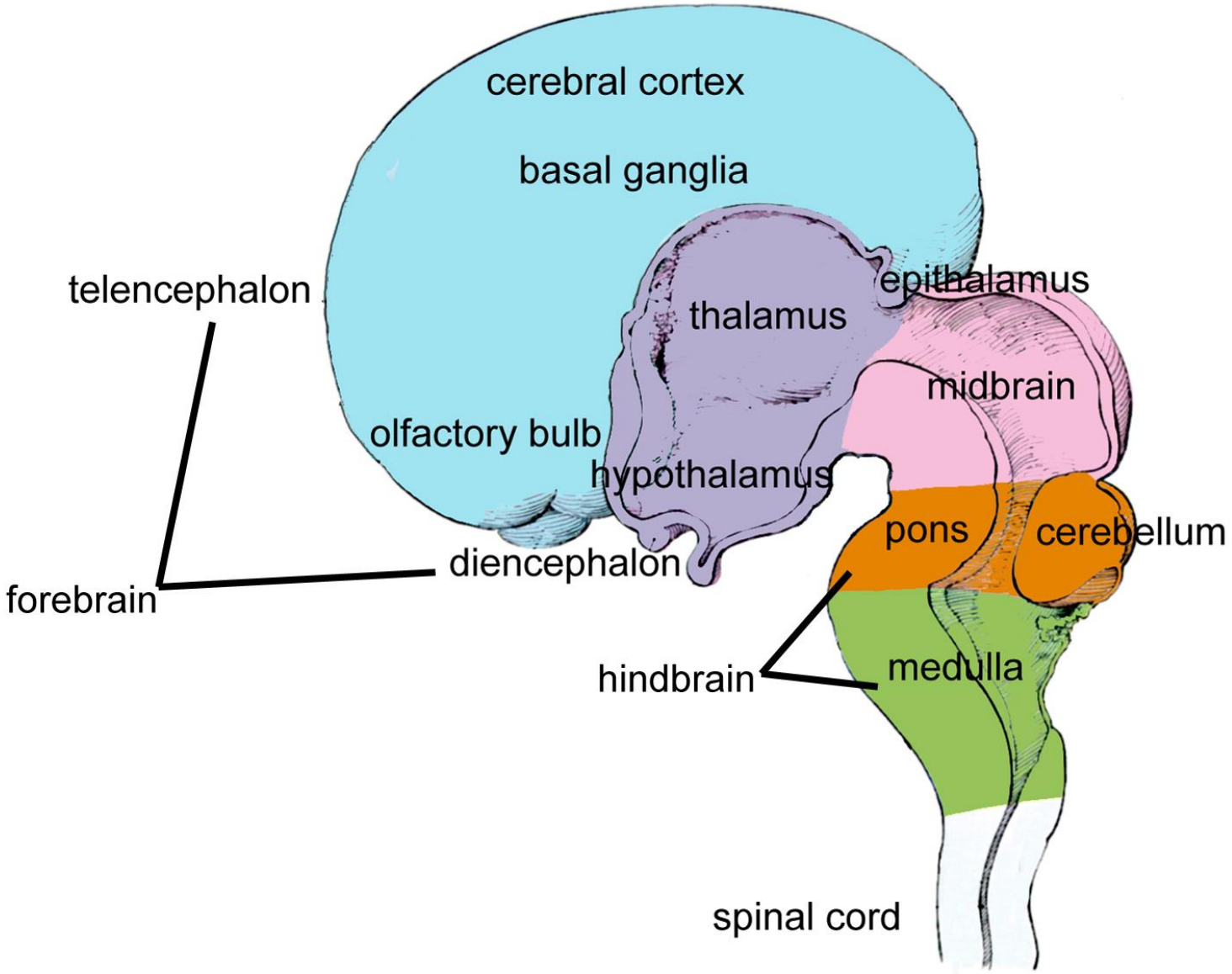
Neural tube gives rise to three primary brain vesicles and spinal cord.



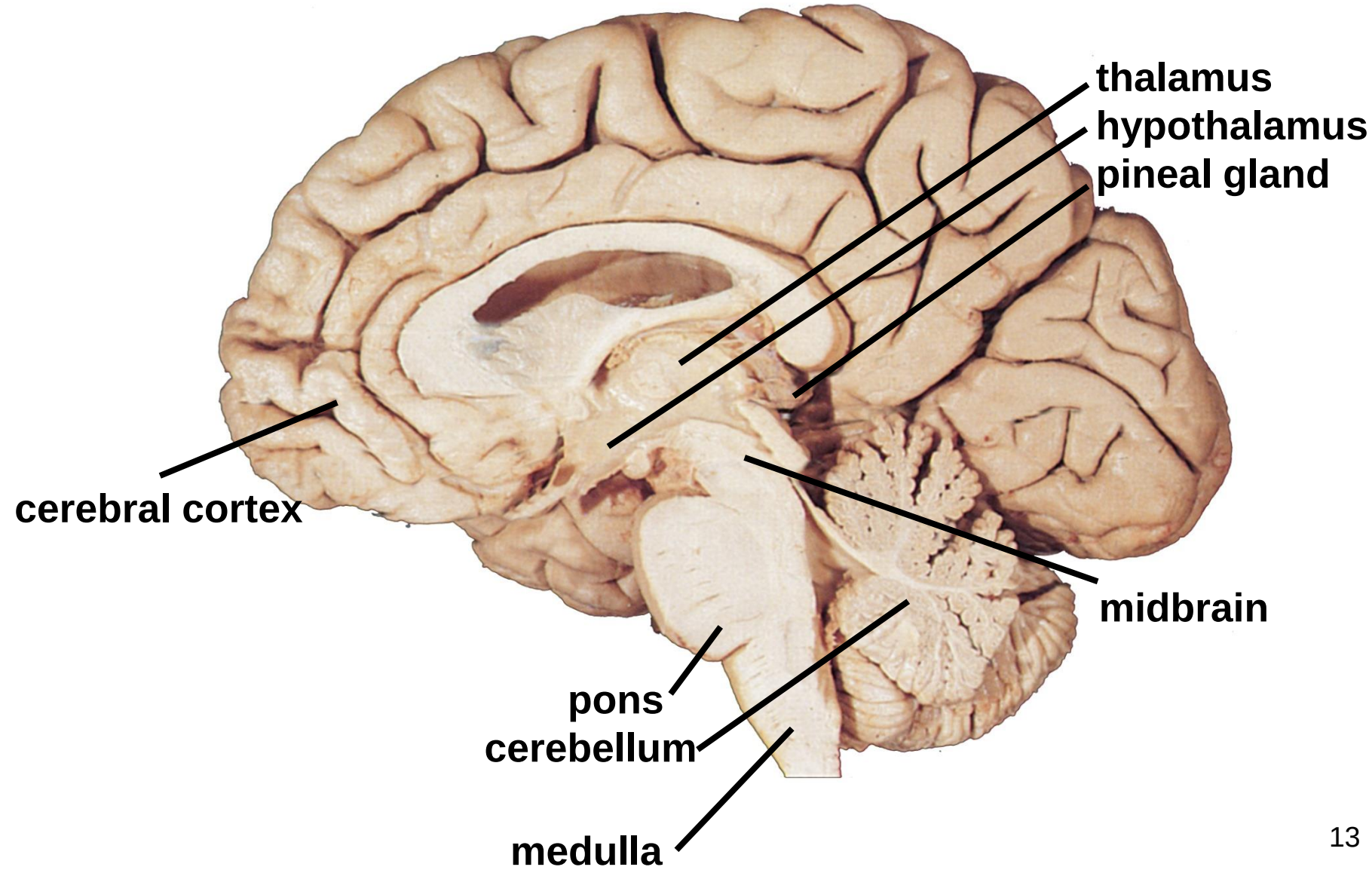
Additional changes form the five secondary brain vesicles.



Each major adult brain region develops from a brain vesicle.

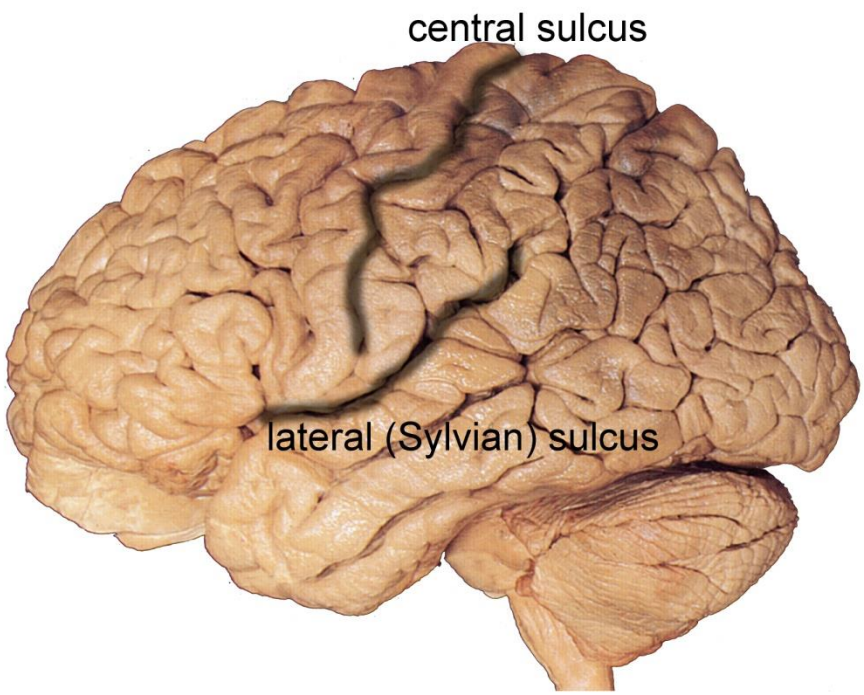


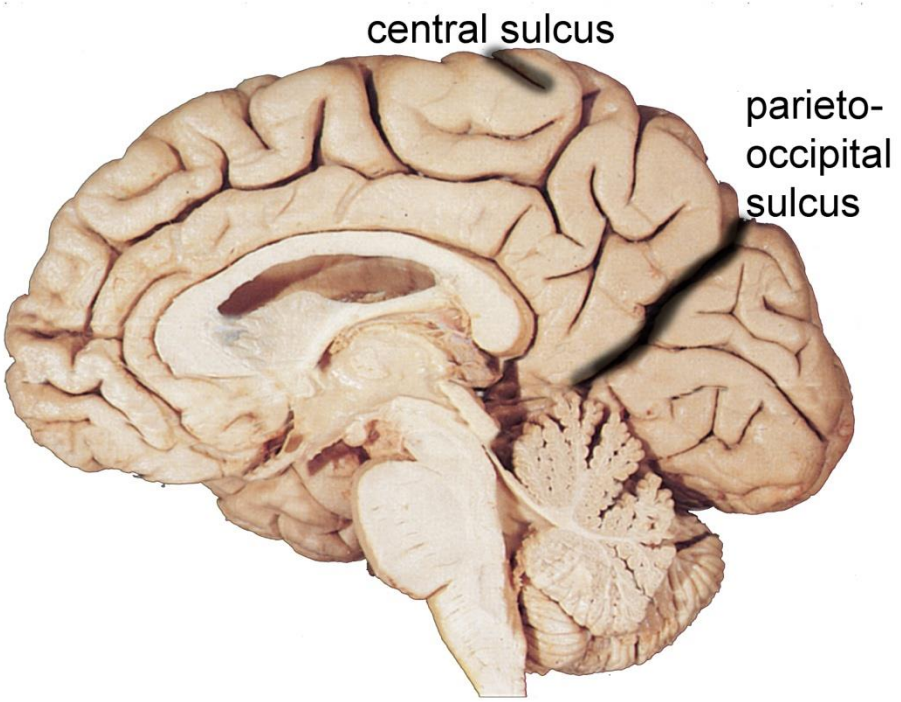
Medial Surface of the Brain
(brain cut in sagittal plane through medial longitudinal fissure)



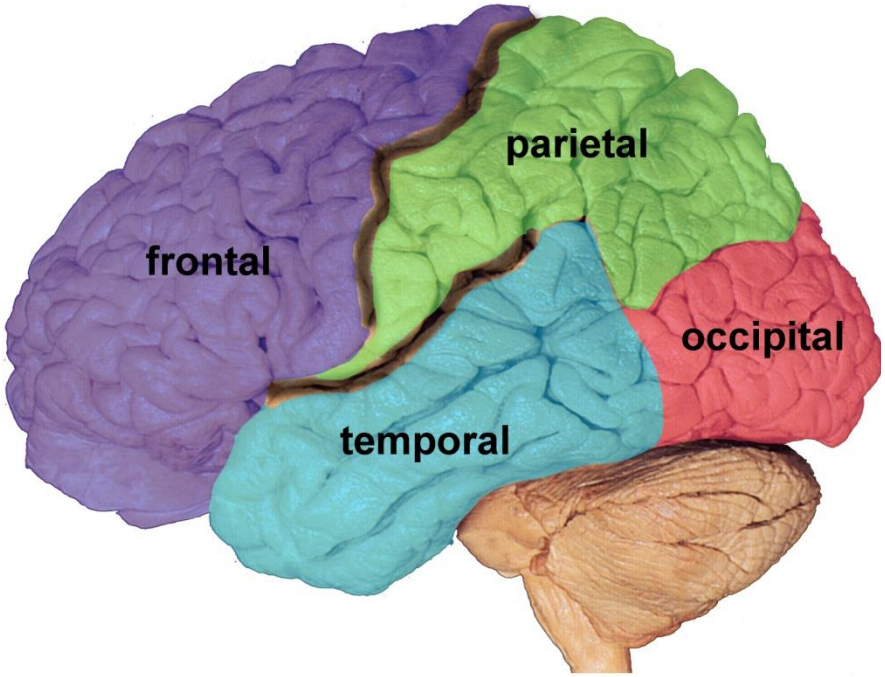
Gyri and Sulci of Cerebral Cortex

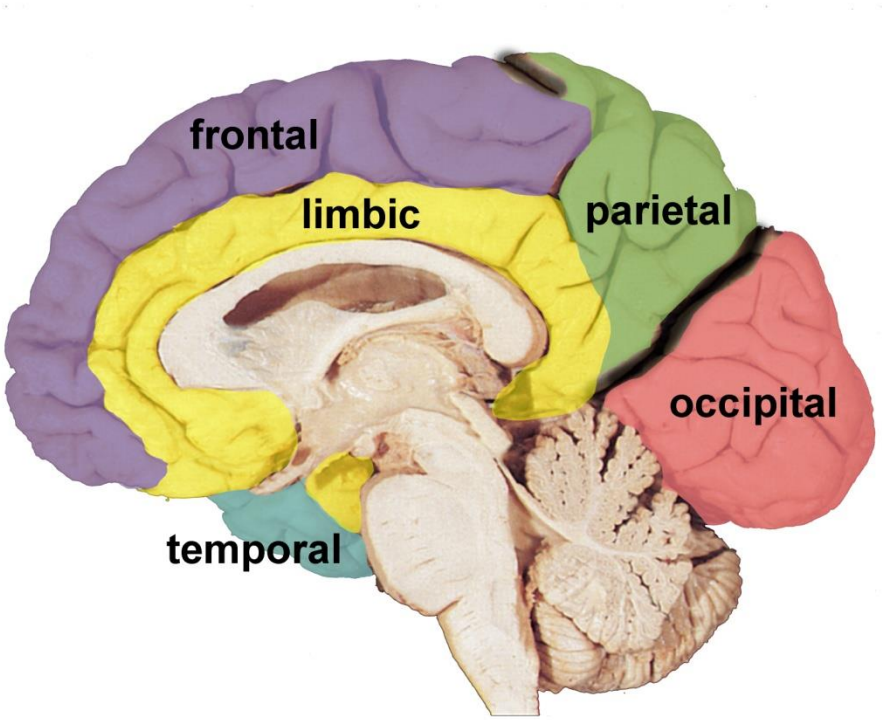
Deep & consistently present sulci are useful landmarks :





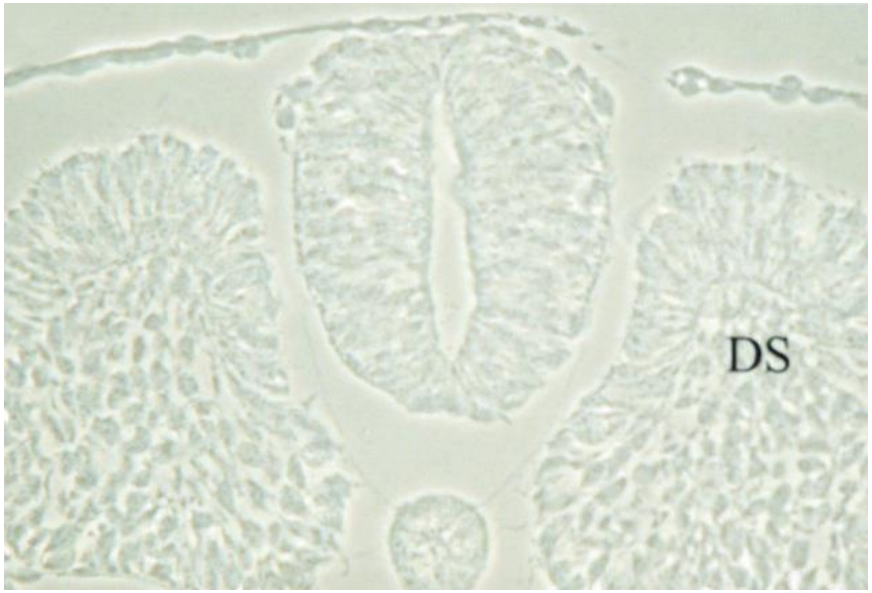
Cerebral Cortex is divided into five lobes.

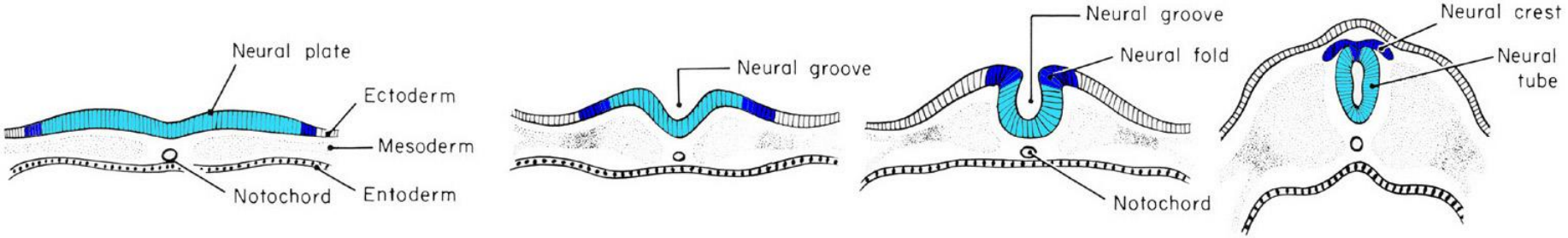




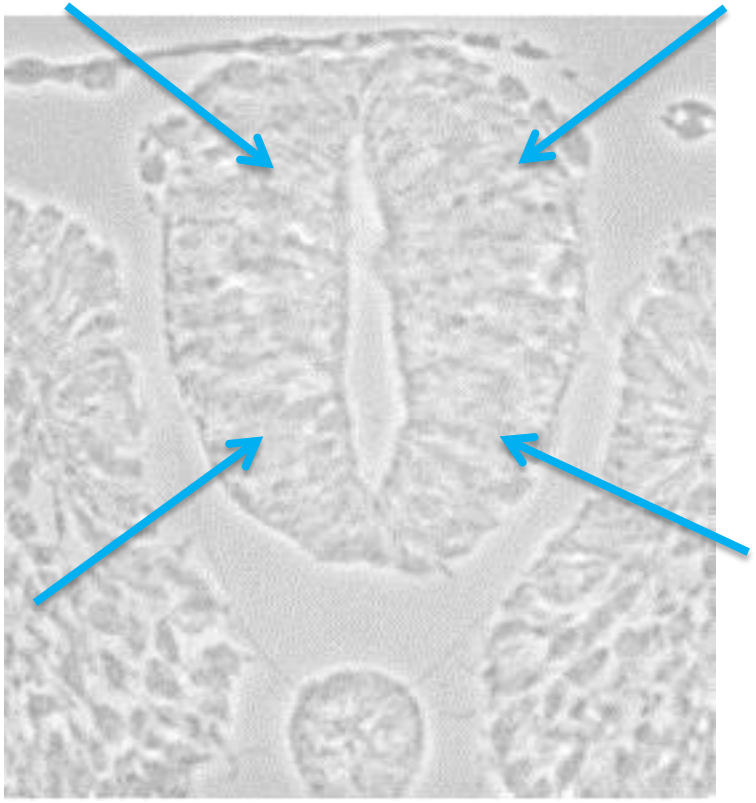
Neural crest gives rise to the peripheral nervous system.

- Neural crest cells leave the neural tube just after the tube closes.



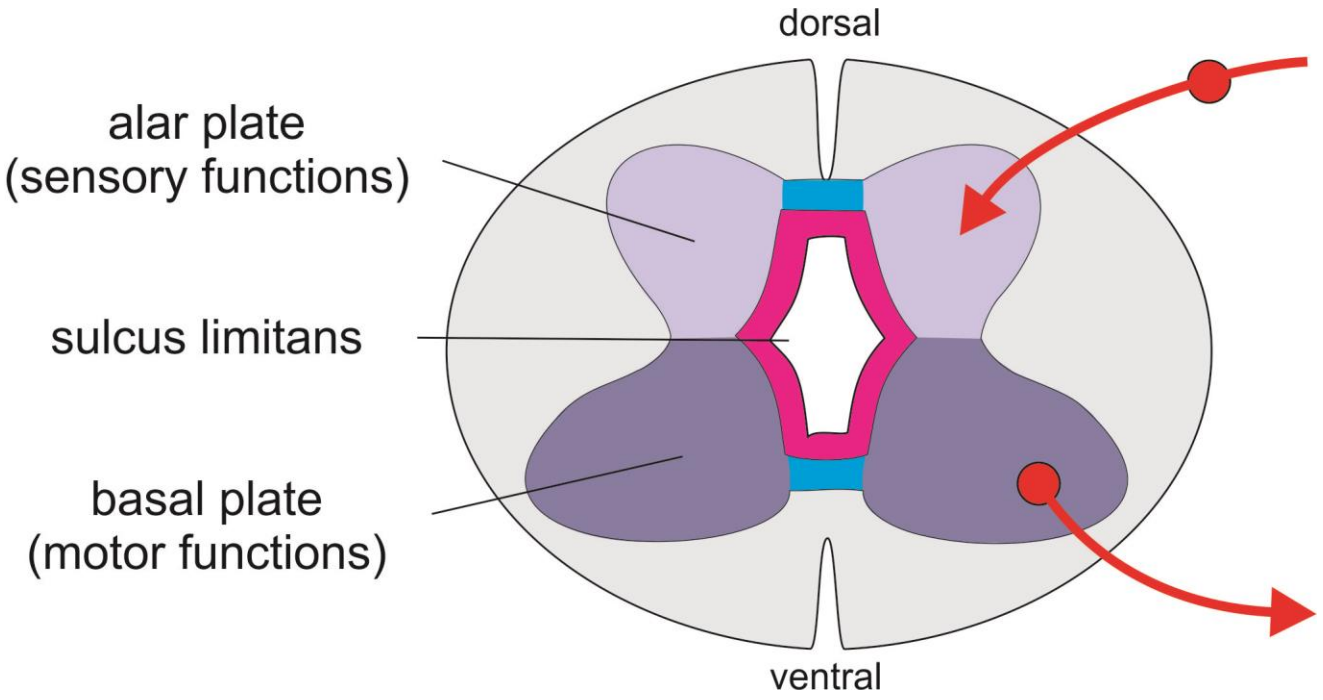


Cell division is not uniform around the neural tube.

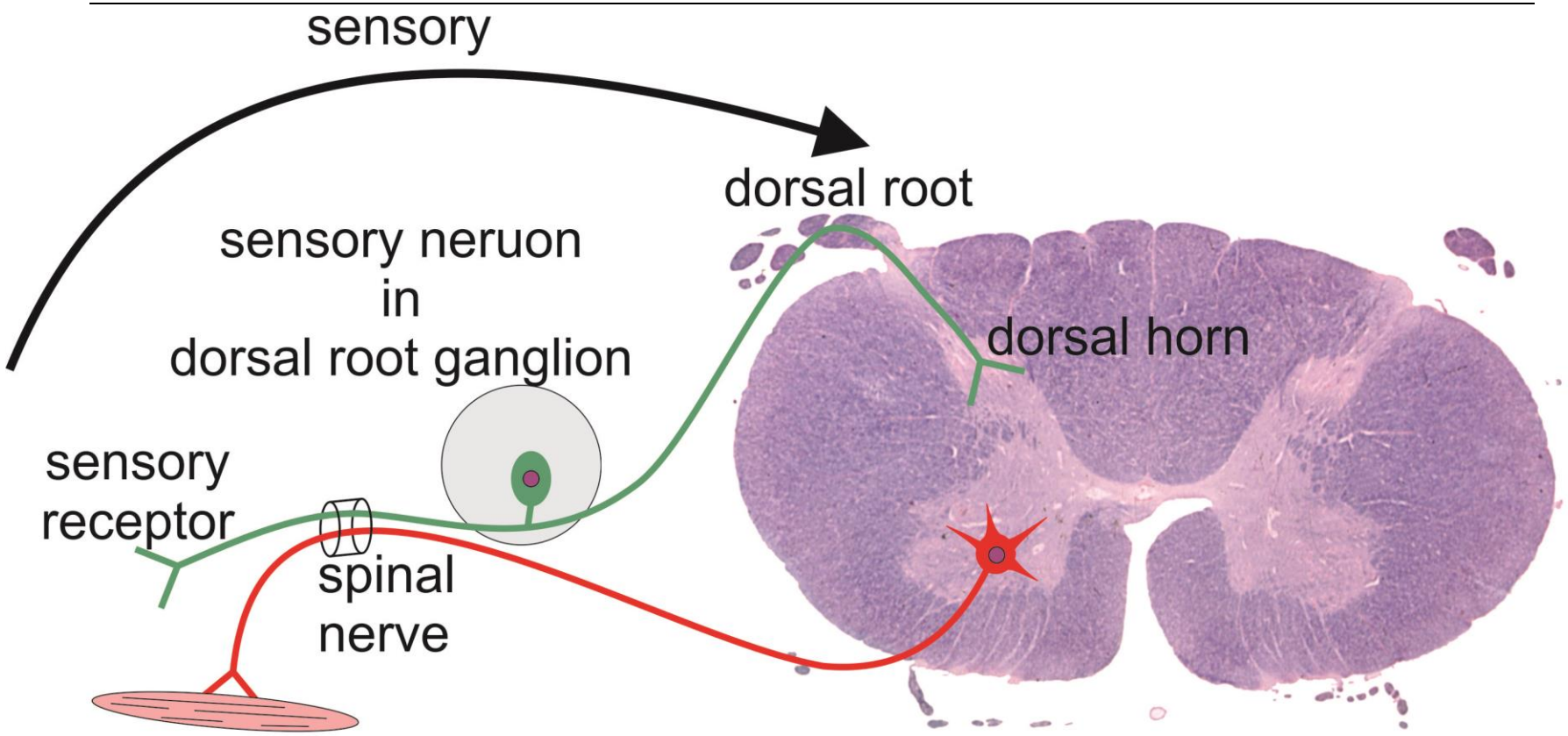


Arrows indicate areas of more cell division.

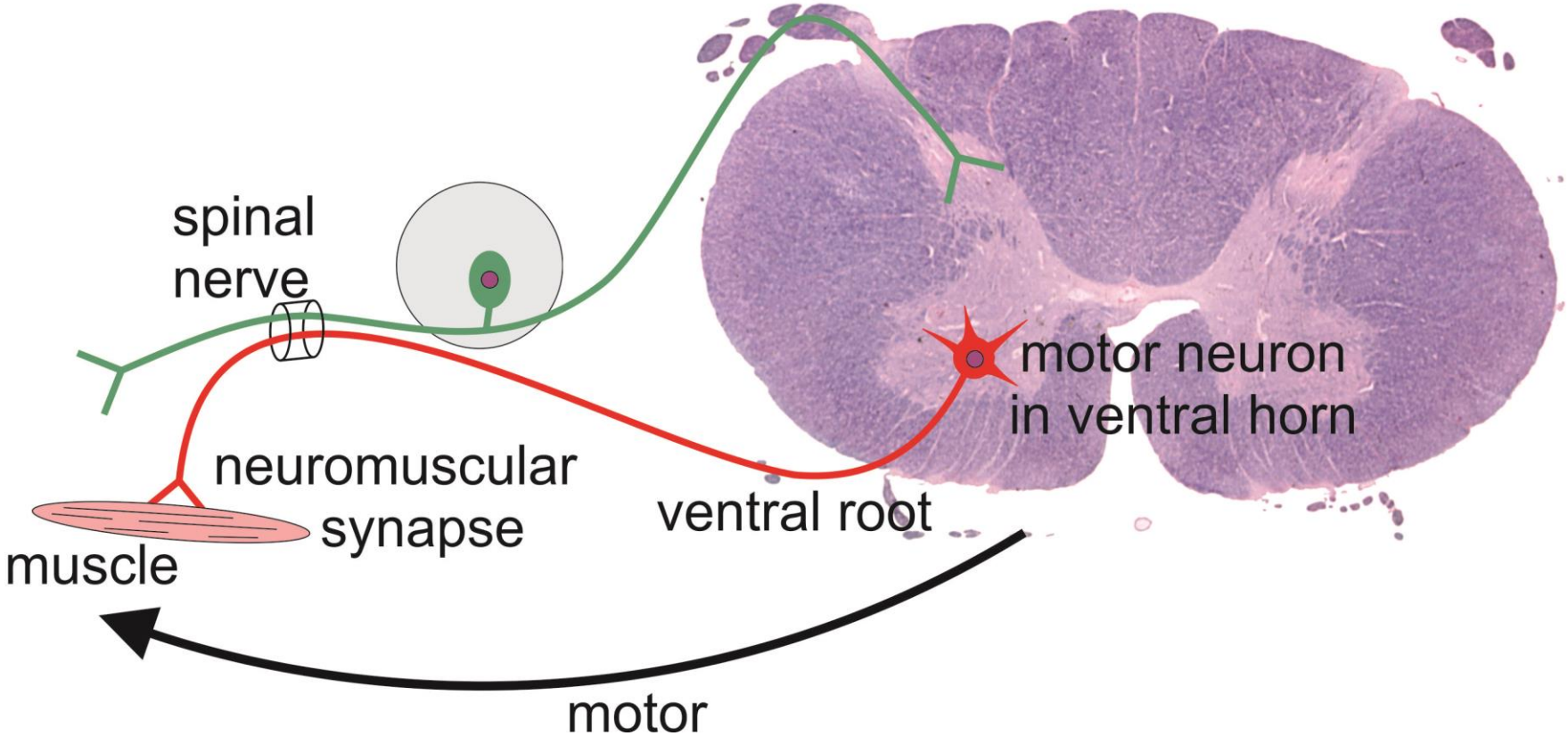
Alar and basal plates represent functional domains.



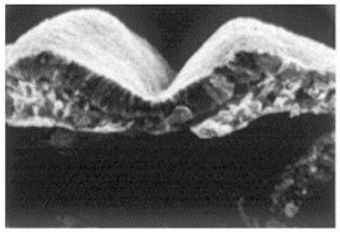
Sensory Input to the Spinal Cord

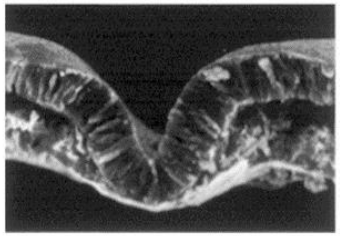


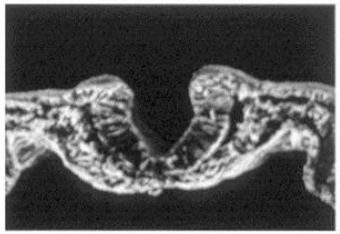
Motor Output from the Spinal Cord

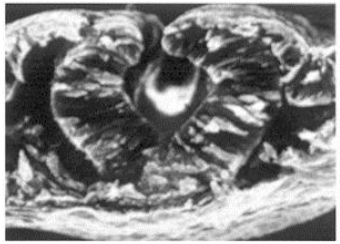


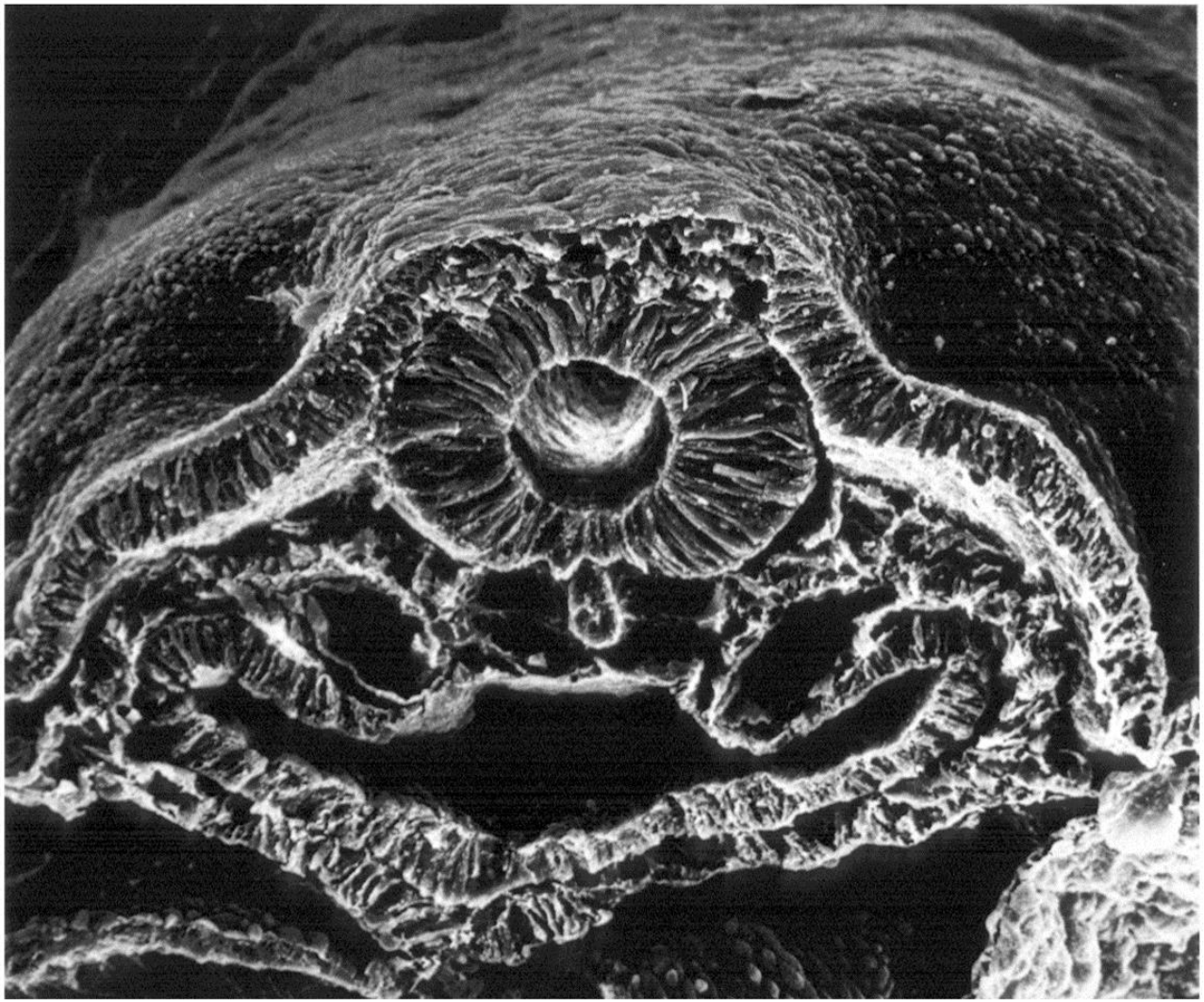
The lumen of the neural tube persists in the adult brain as the ventricular system.











Ventricular System

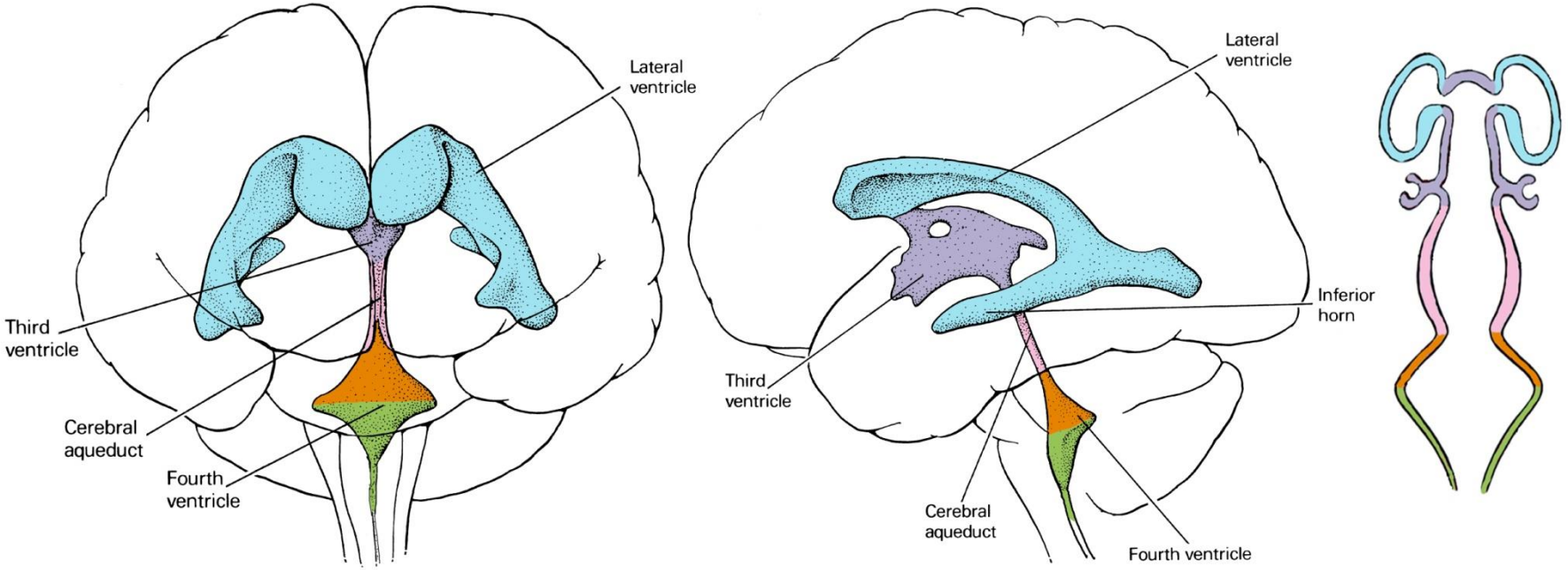
Lateral ventricles (x2) – in cerebral cortex

Third ventricle – in diencephalon

Cerebral aqueduct – in midbrain

Fourth ventricle – in pons/cerebellum and medulla

Central canal – in spinal cord



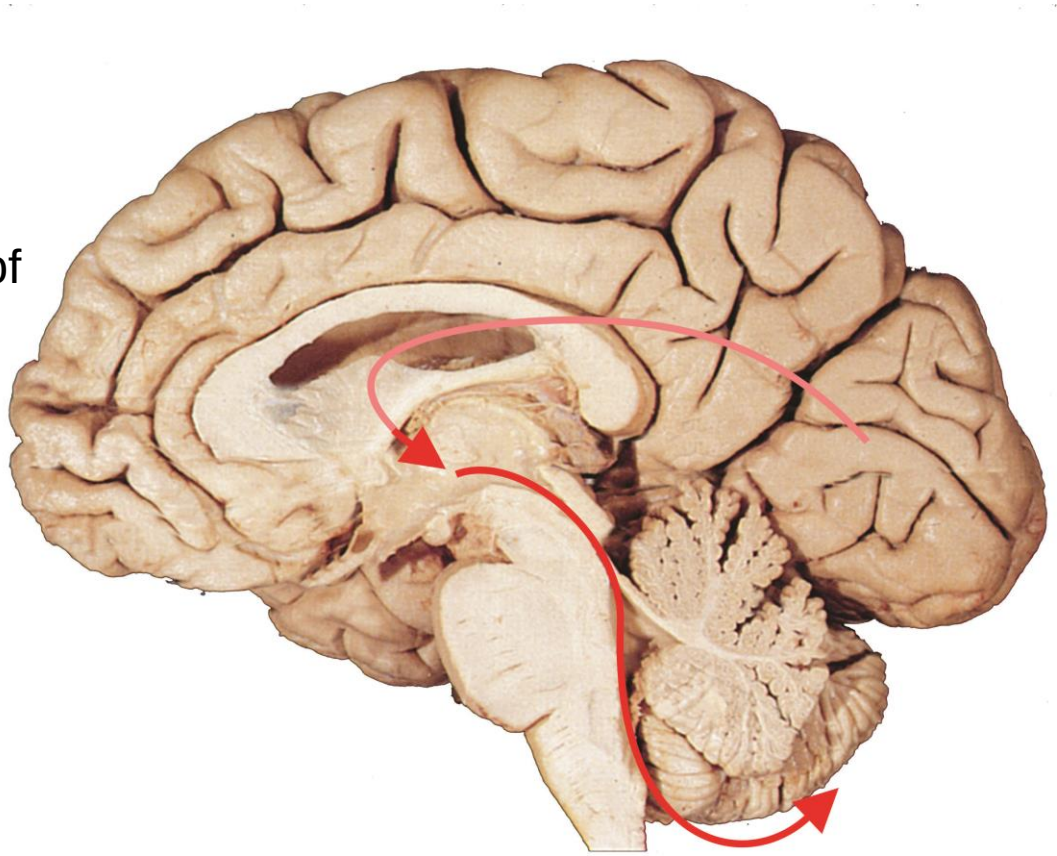
Cerebrospinal Fluid (CSF)

- Ventricular system is filled with CSF.
- CSF is a watery solution.
- It is an ultrafiltrate of blood produced by the choroid plexus in the ventricles.
- CSF also contains some molecules produced by neurons of the brain.

Ventricles to Subarachnoid Space

- CSF flows from the lateral ventricles towards the IV ventricle in the medulla.

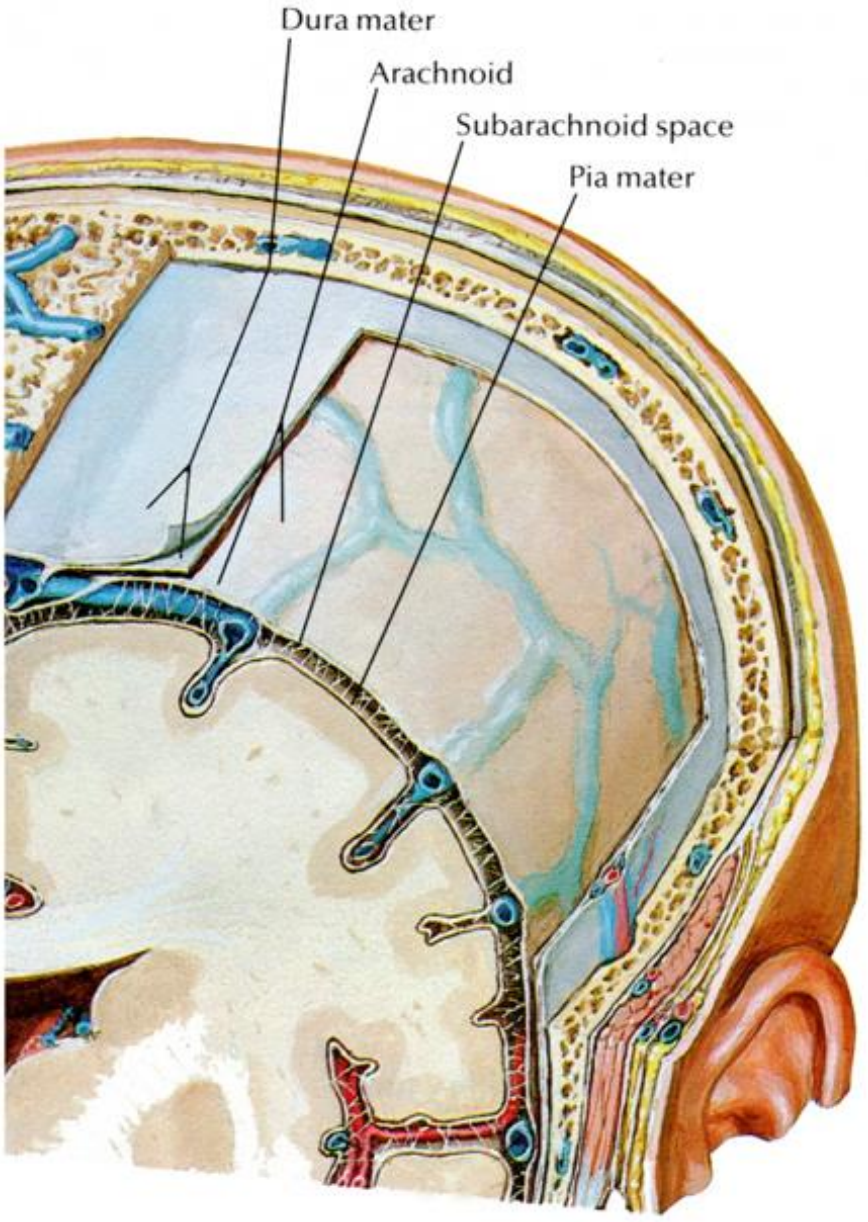
- In the IV ventricle, CSF flows out of the ventricular system via three openings into the subarachnoid space.



Layers of the Meninges

The meninges are three layers of membrane and a fluid-filled space between the skull and brain.

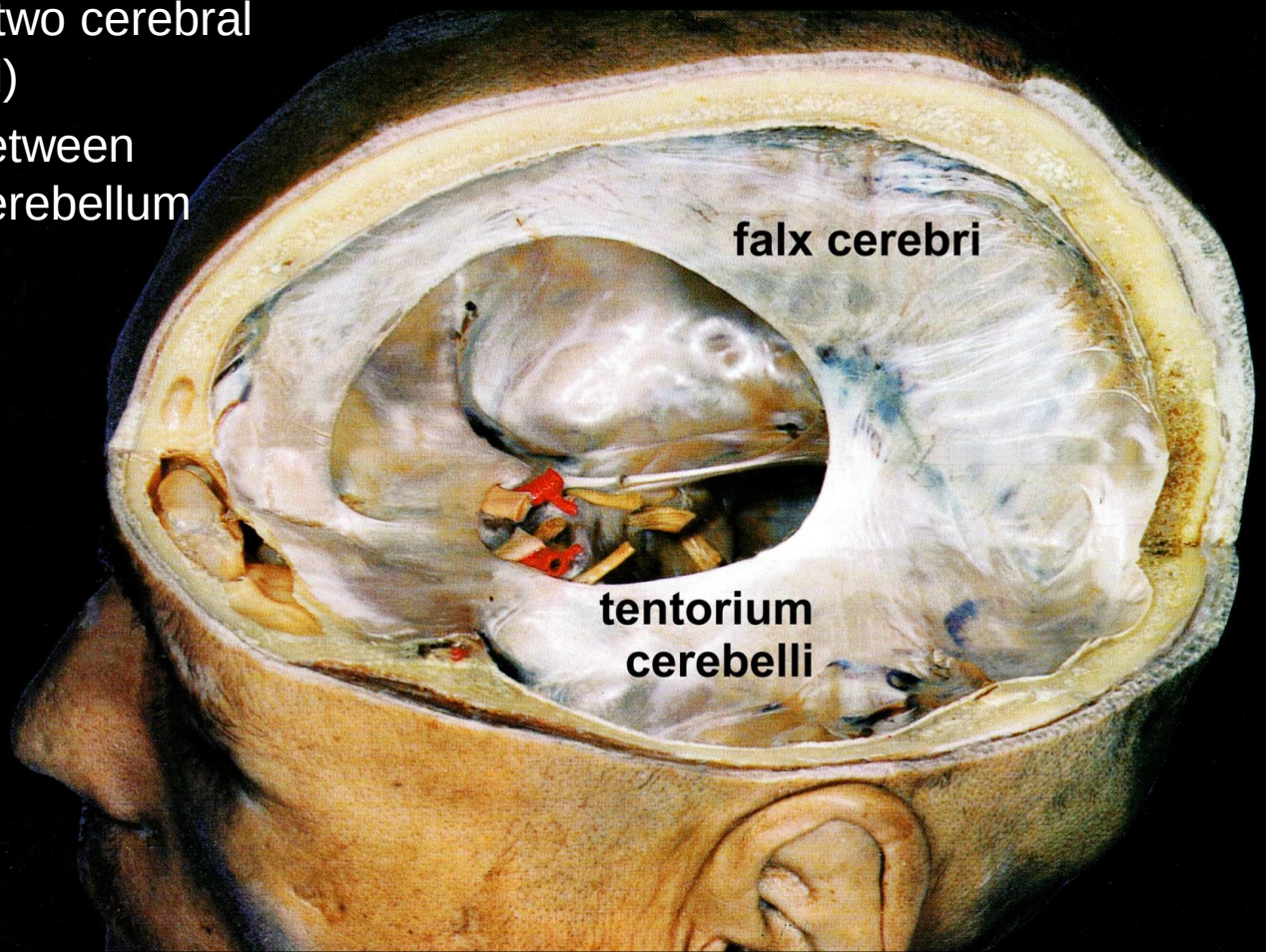
- dura mater
- arachnoid
- subarachnoid space filled with CSF
- pia mater



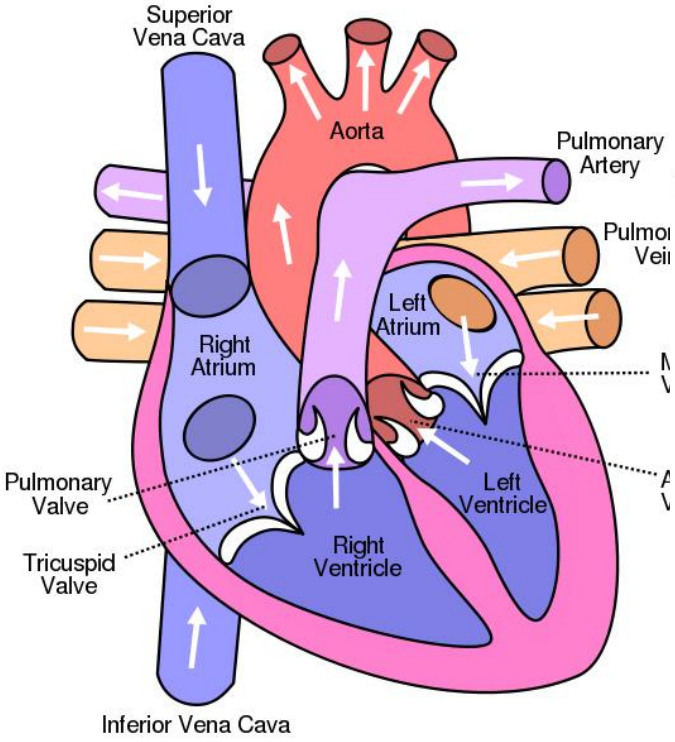
Dural septa further support the brain.

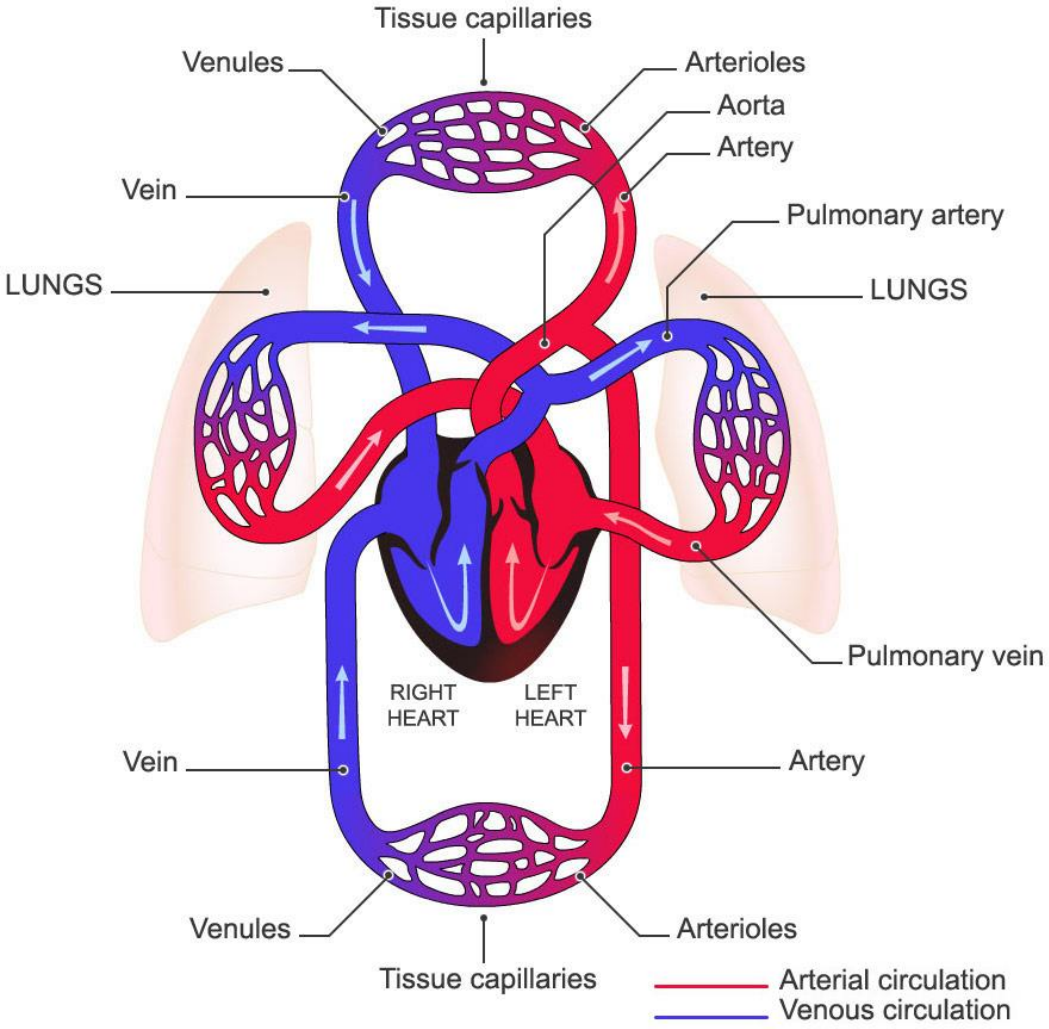
Dural septa are sheets of dura suspended from the skull that separate certain brain regions:

- Falx cerebri between two cerebral hemispheres (vertical)
- Tentorium cerebelli between cerebral cortex and cerebellum (horizontal)



Circulatory System



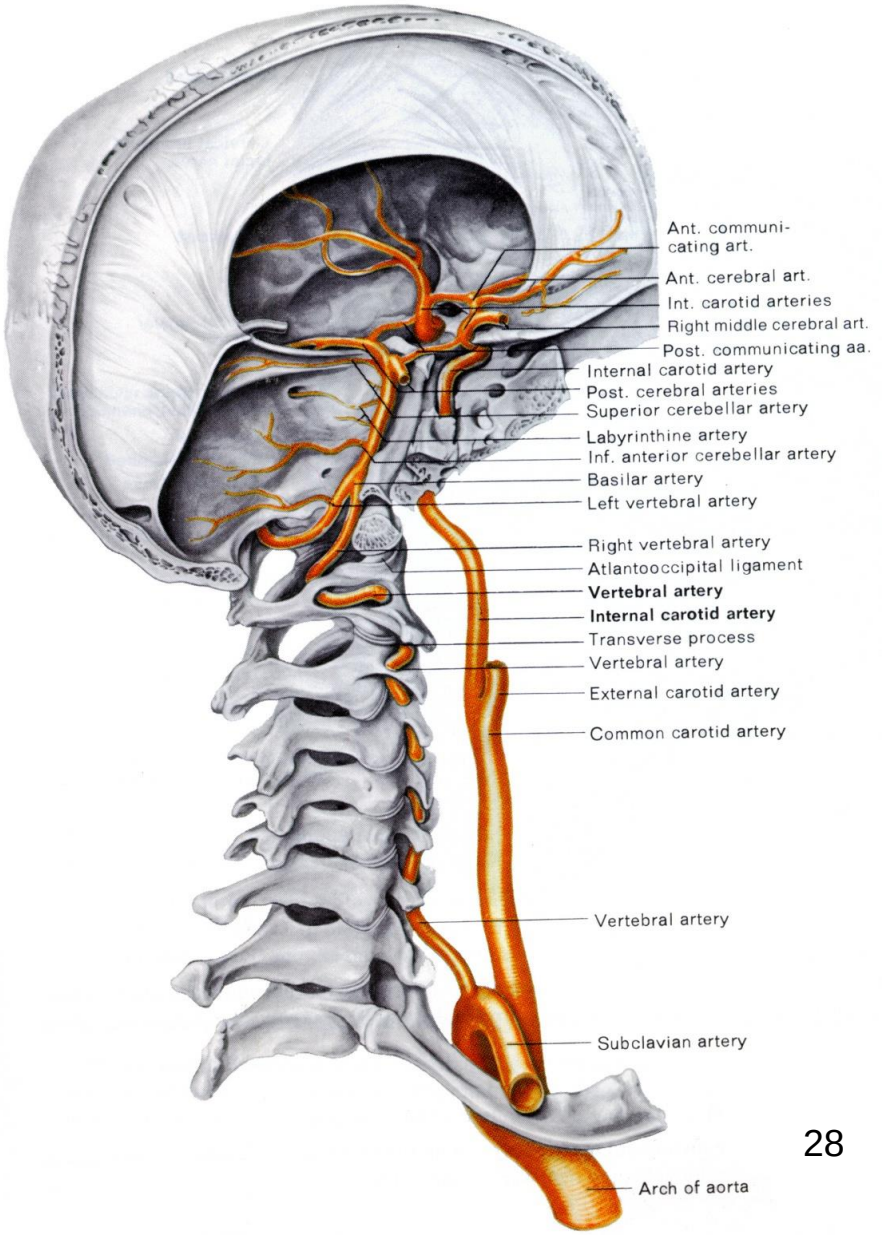


Blood Supply for the Brain

Two major pairs of arteries supply the brain:

- Internal cartoid artery (x2), which enters the cranium from the front of the neck.

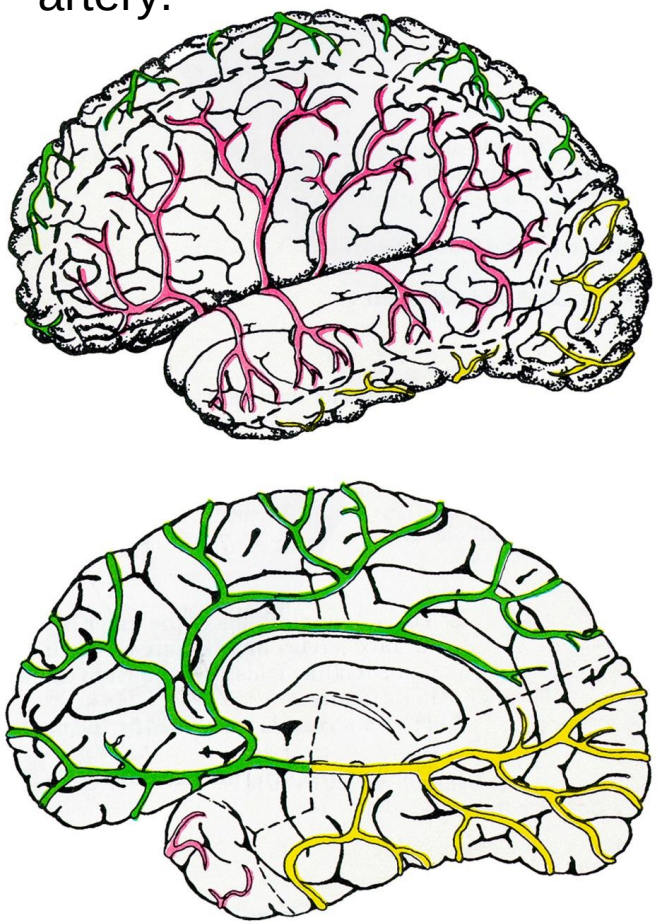
- Vertebral artery (x2), which enters the cranium via the foramen magnum.

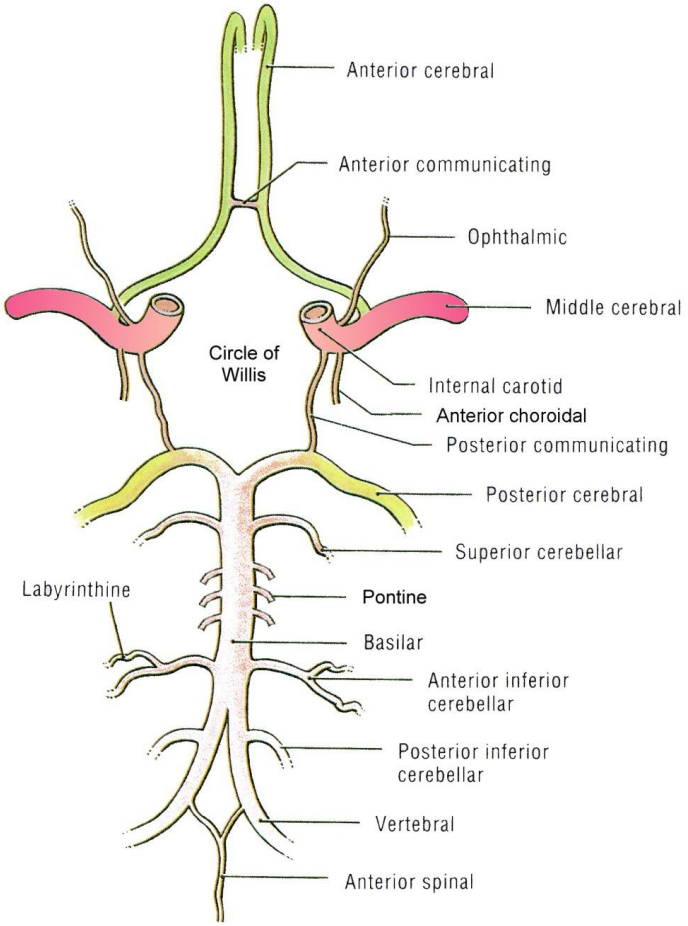


Blood Supply for the Brain

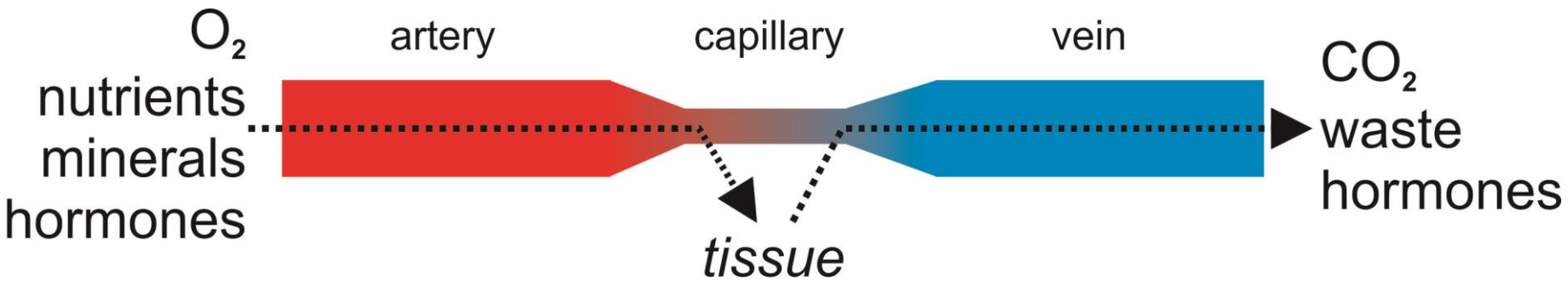
Circle of Willis:

- Anterior and middle cerebral arteries are the largest branches of the internal carotid arteries.
- Posterior cerebral arteries are the largest branches of the basilar artery.



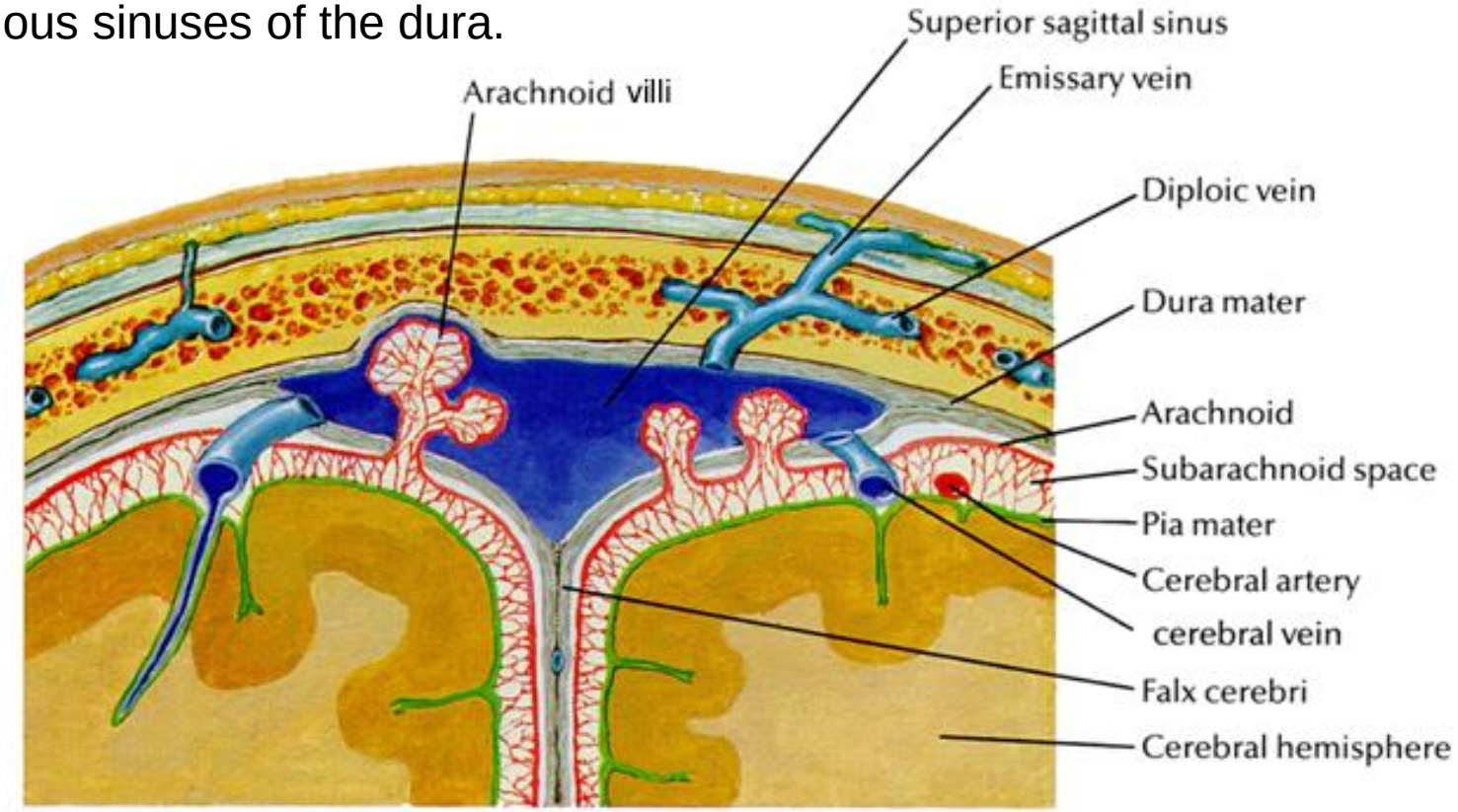


Blood Supply for the Brain



Blood Supply for the Brain

In some regions, the dura is split forming a chamber filled with venous blood, the venous sinuses of the dura.

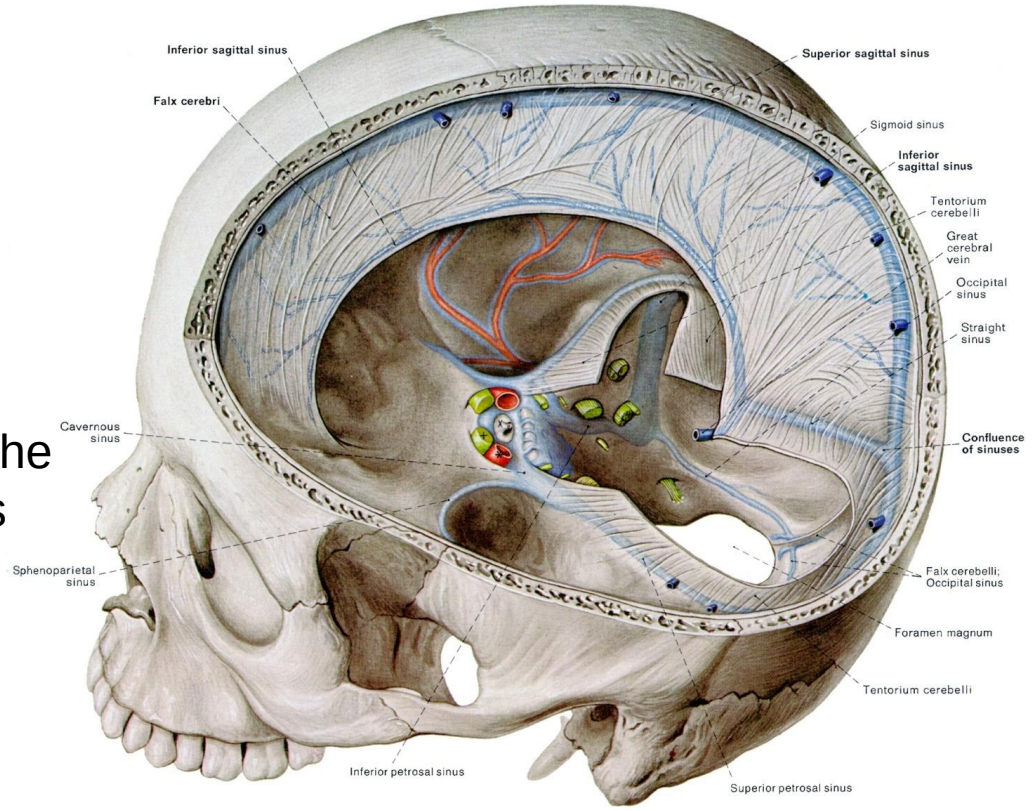


Blood Supply for the Brain

Blood veins from the brain drain into the dural venous sinuses.

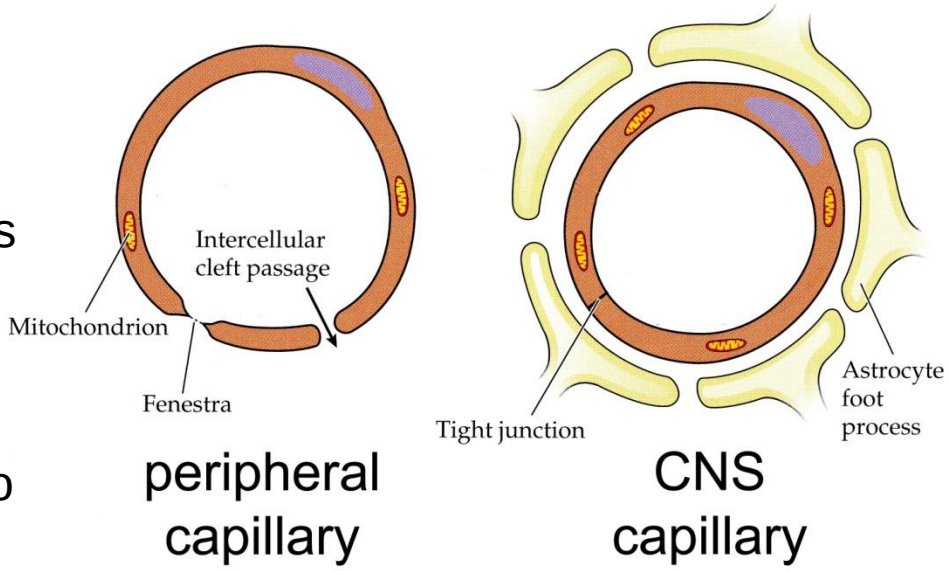
A network of these venous sinuses collects most of the blood from the brain.

The dural venous sinuses collect in the base of the skull and exit the skull as the internal jugular veins.



Blood-brain Barrier

- Capillaries in the brain are not as permeable as they are in other parts of the body. This blood-brain barrier serves to regulate what gets into and out of the brain.
- Endothelial cells that line the capillary wall are tightly adherent to one another by ‘tight junctions’.
- Endfeet of astrocytes surround the capillaries and further regulate what can pass.

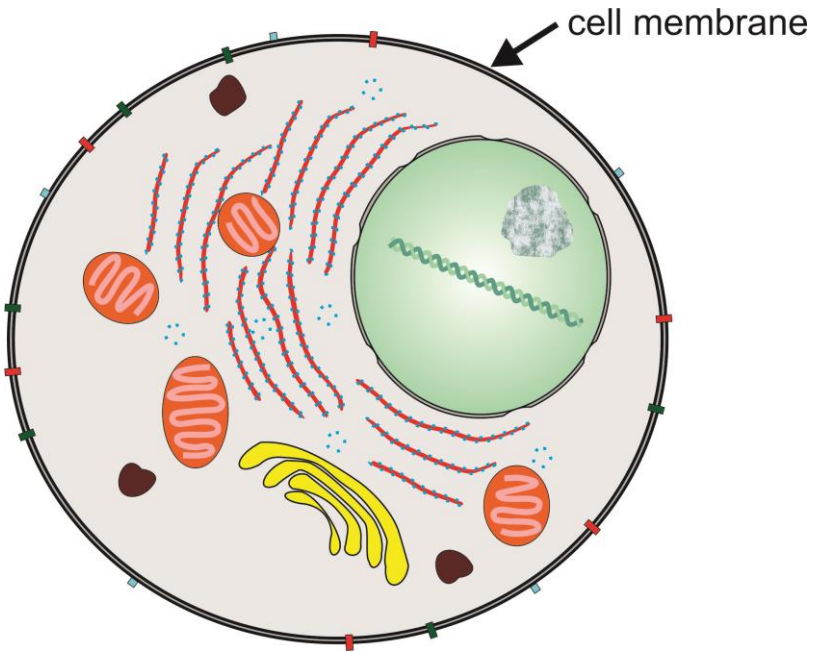


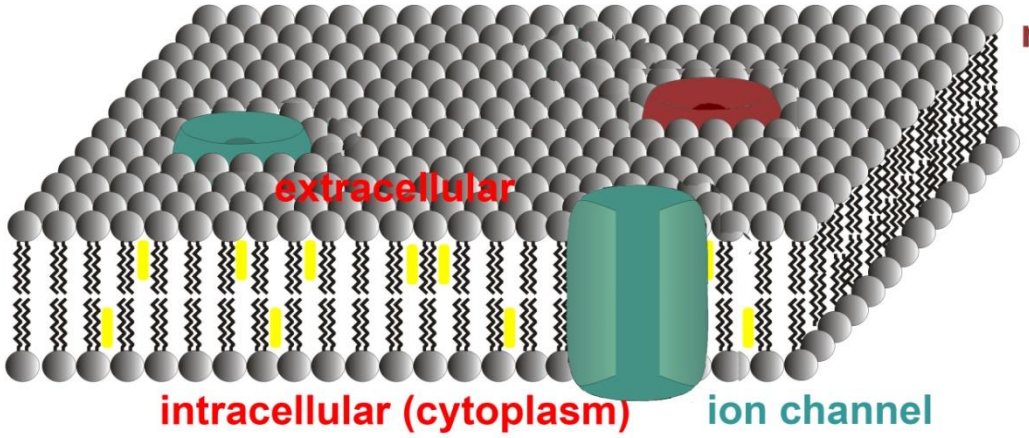
Organelles of Cells

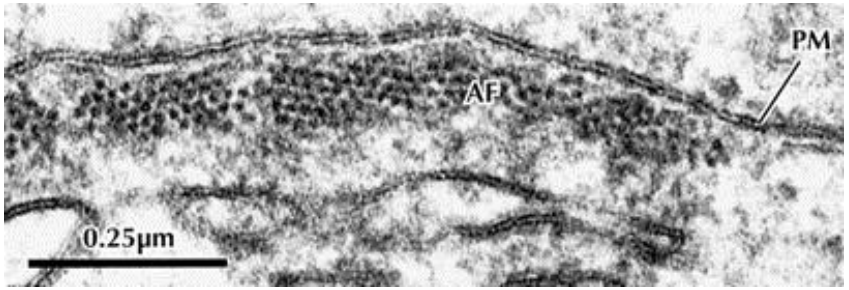
Cell membrane:

- Composed of a phospholipid bilayer.

- Many proteins pass through or are attached to the membrane including:
  - Cell adhesion molecules
  - Ion channels & pumps
  - Receptors







Genes & Protein Synthesis

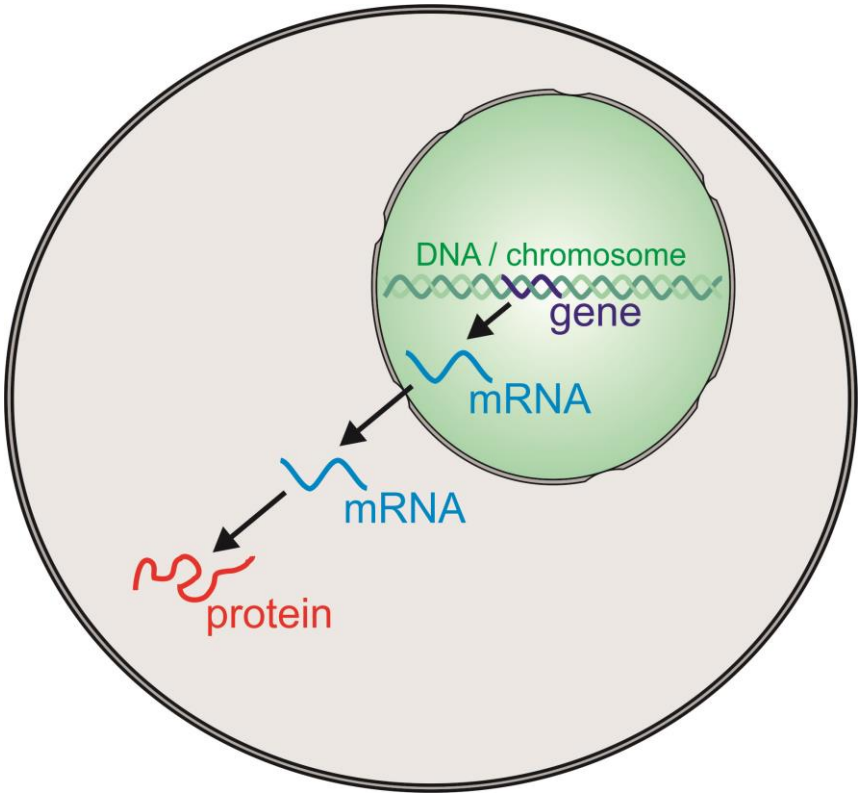
Protein synthesis:

- A gene is used as a template for synthesis of messenger RNA (mRNA) in the nucleus

- mRNA is used as a template for synthesis of a protein in the cytoplasm.

  DNA (gene) > mRNA > protein

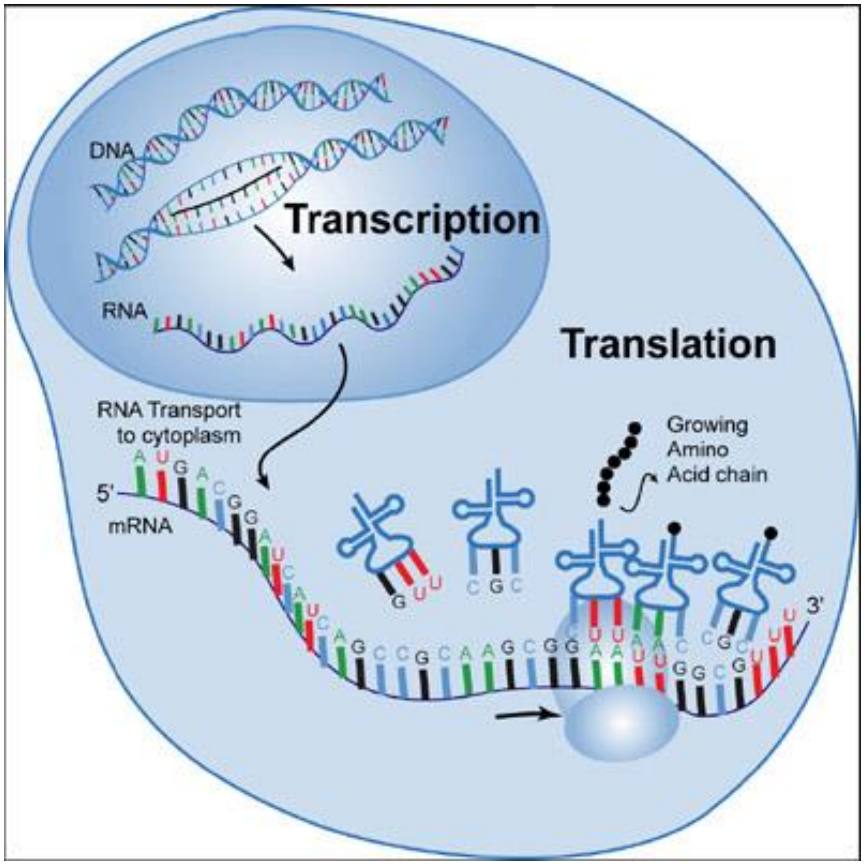
- Different cell types express only certain proteins. The function of a cell is determined by the proteins it expresses.



Genes & Protein Synthesis

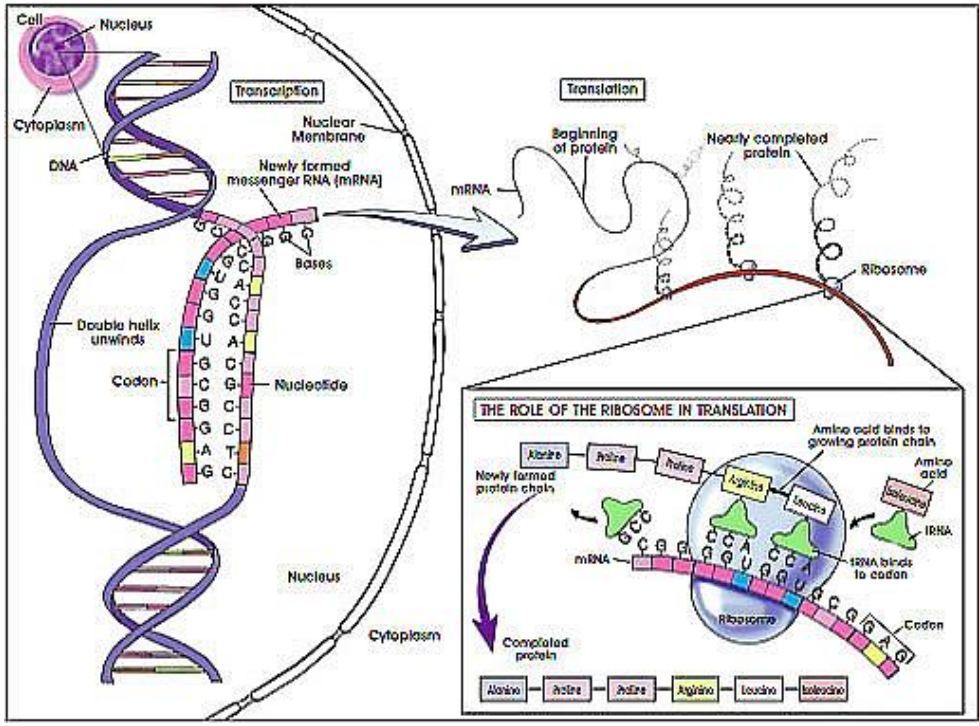
- Synthesis of mRNA from DNA in the nucleus is a process called transcription.

- Synthesis of protein from mRNA in the cytoplasm is a process called translation.



Genes & Protein Synthesis

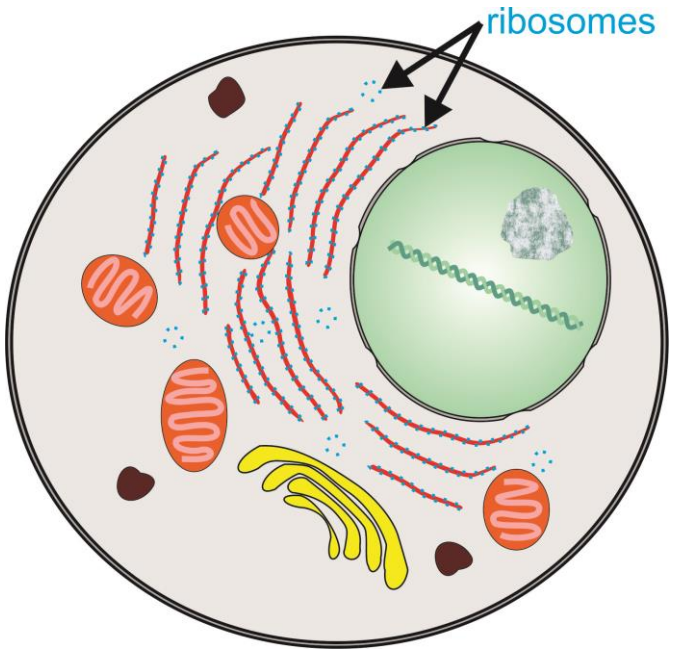
- DNA is a chain of four nucleotides.
- mRNA is a chain of four slightly different nucleotides.
- Protein is a chain of amino acids.
- The sequence of three nucleotides in the mRNA specifies the amino acid to assemble into the protein being synthesized.
- Thus, the sequence of nucleotides in a gene (DNA) ultimately determines the sequence of amino acids in a protein.



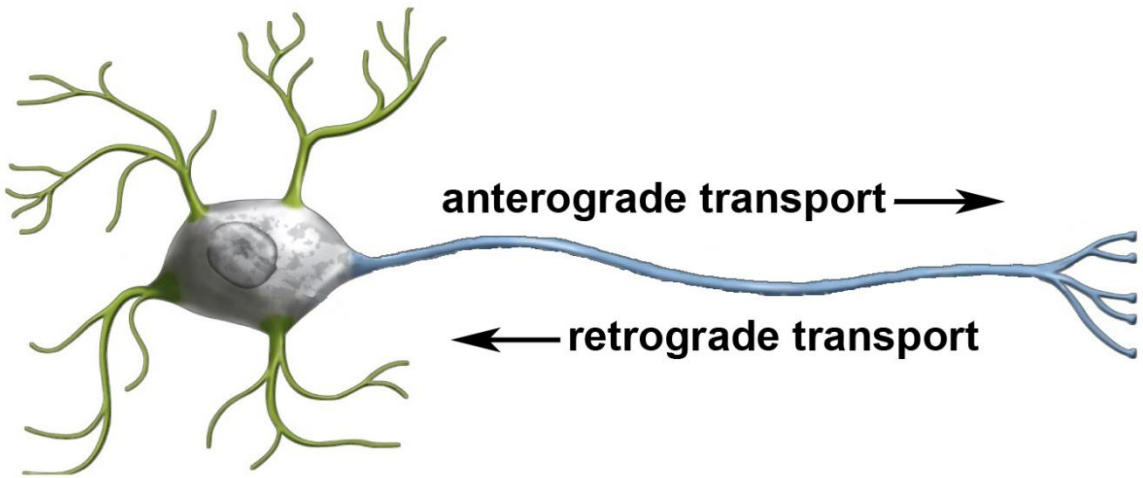
Organelles of Cells

Ribosome:

- Reads the sequence of mRNA to synthesize proteins.

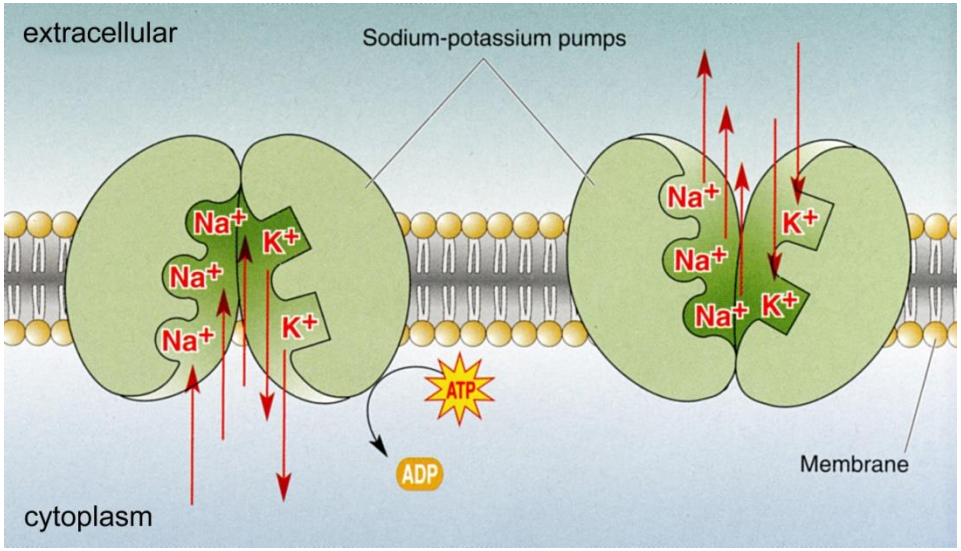


Axonal Transport



- Different components of the cytoskeleton are involved in transport within the axon to and from the soma.

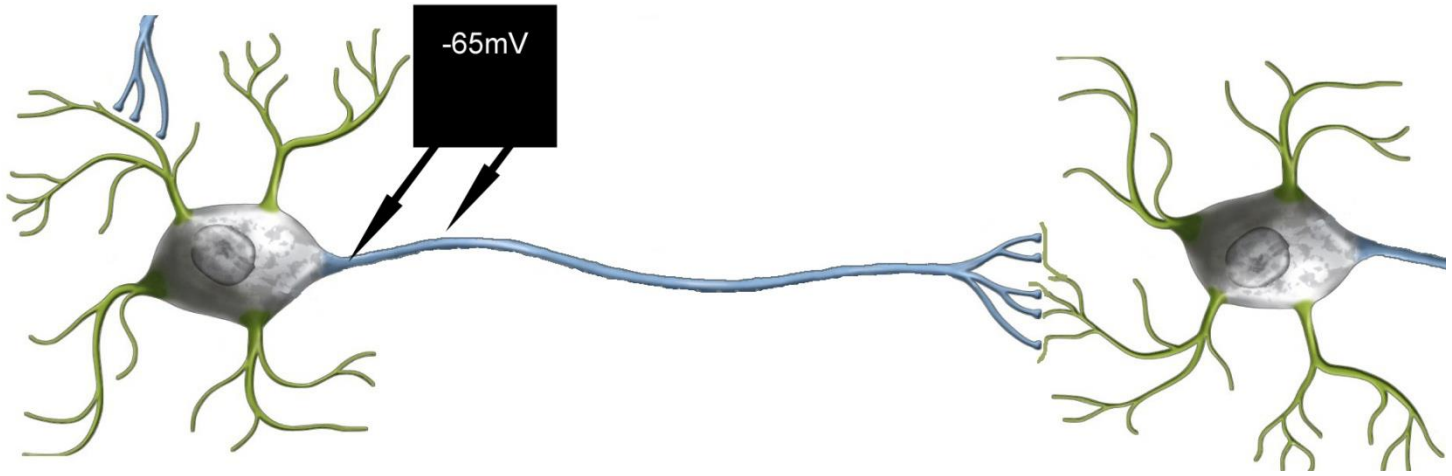
Resting Membrane Potential



The sodium-potassium pump…

- moves 3 sodium ions out of the neuron and 2 potassium ions into the neuron.
- requires energy in the form of adenosine triphosphate (ATP).

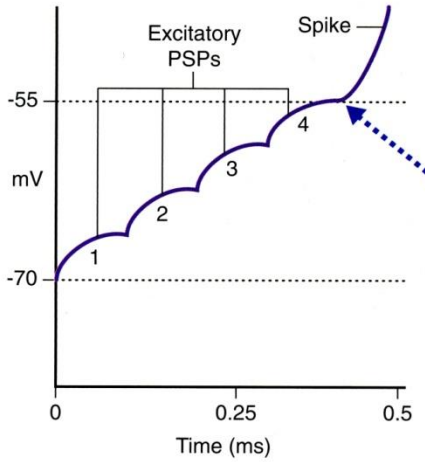
Resting Membrane Potential



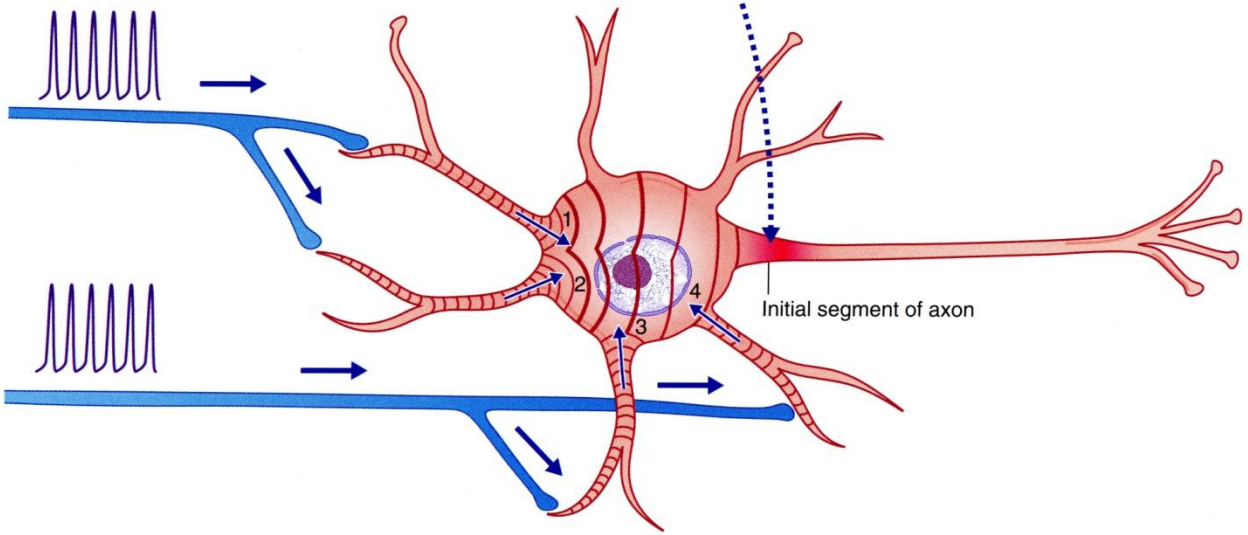
- The electrical charge from proteins, ions moving through unregulated channels and ion pumps reaches an equilibrium in a neuron at rest.

- The ‘resting membrane potential’ can be measured with electrodes on the inside and outside of the cell; this is typically -65mV.

Graded Potentials in Dendrites & Soma

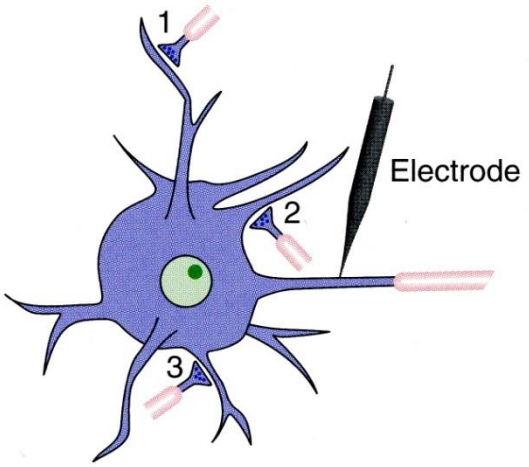


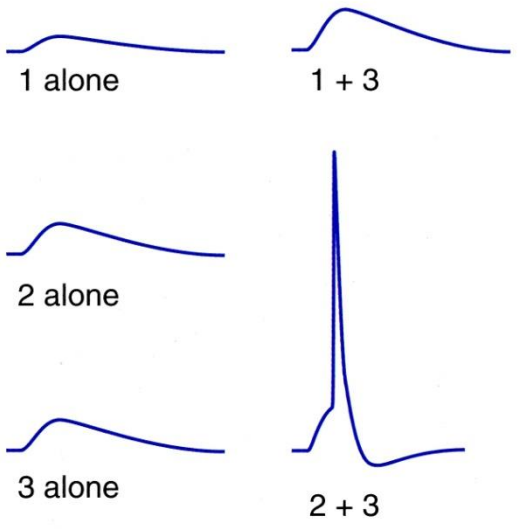
- Activation of neurotransmitter receptors causes changes in the ion conductance in the dendrites and soma.
- Inhibitory synaptic activity <u>hyperpolarizes</u> the neuron (i.e. the membrane potential becomes more negative).
- Excitatory synaptic activity <u>depolarizes</u> the neuron (i.e. makes it more positive).



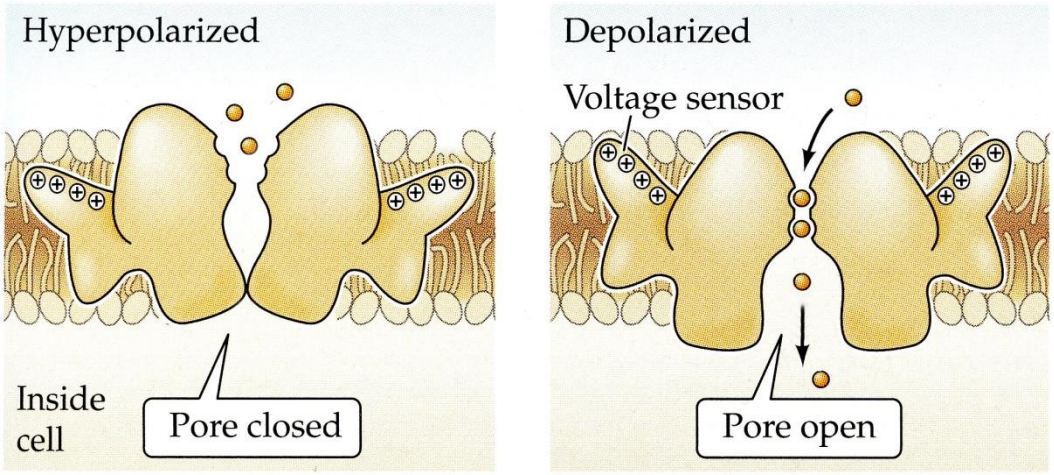
Action Potentials in the Axon

- The sum of all excitatory and inhibitory inputs to the cell is monitored by the initial segment of the axon.
- When the initial segment reaches threshold (i.e. when it is sufficiently depolarized) an action potential is generated.





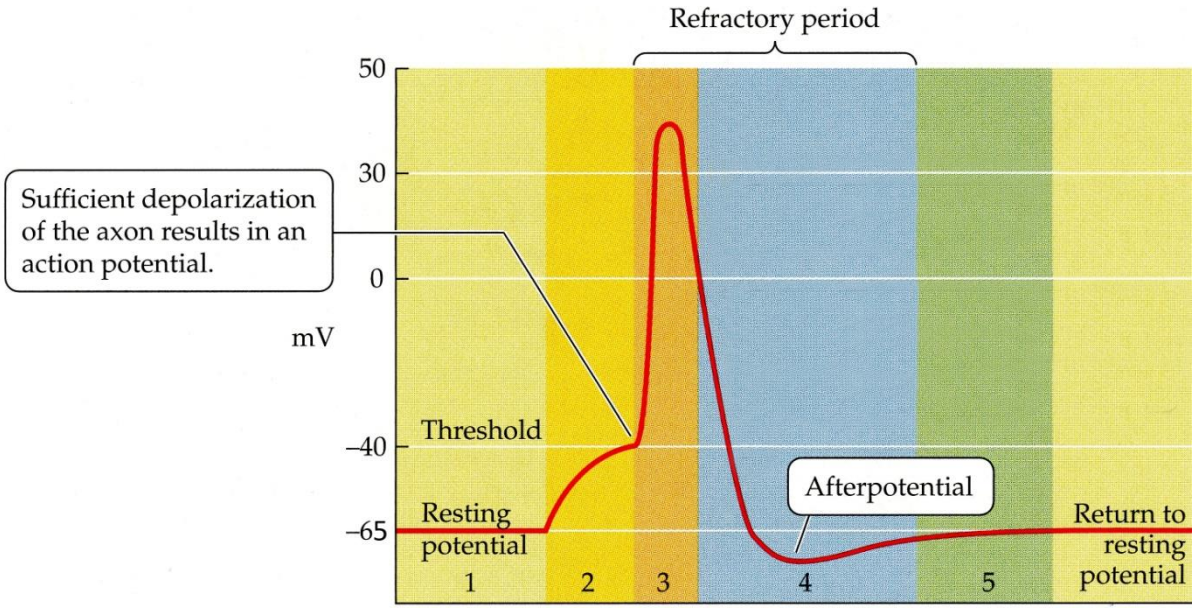
Action Potentials in the Axon



- Voltage-gated sodium (Na^+) channels monitor the neuron's level of activity.

- When threshold is reached in the initial segment, the voltage-gated Na^+ channels open allowing Na^+ to enter the axon.

Action Potentials in the Axon

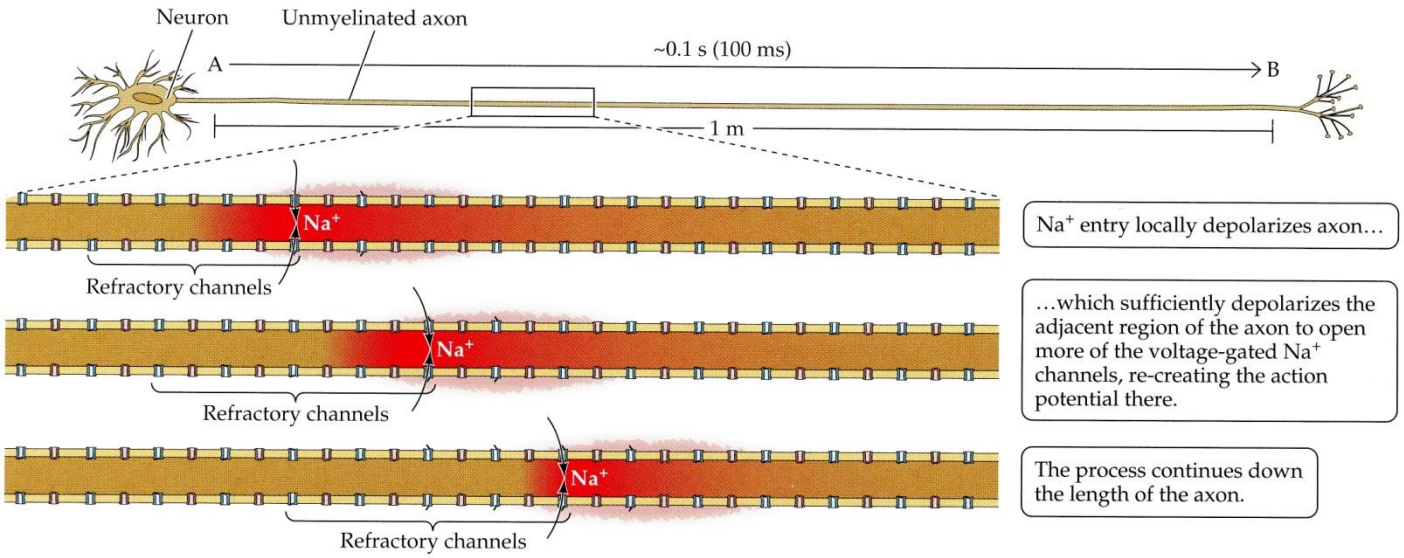


- Opening the voltage-gated Na^+ channels further depolarizes the axon and is the start of the action potential.

- Later voltage-gated K^+ channels open and voltage-gated Na^+ channels close, which starts repolarizing the cell.

- Repolarization slightly overshoots making the axon briefly hyperpolarized until it finally returns to the resting membrane potential.

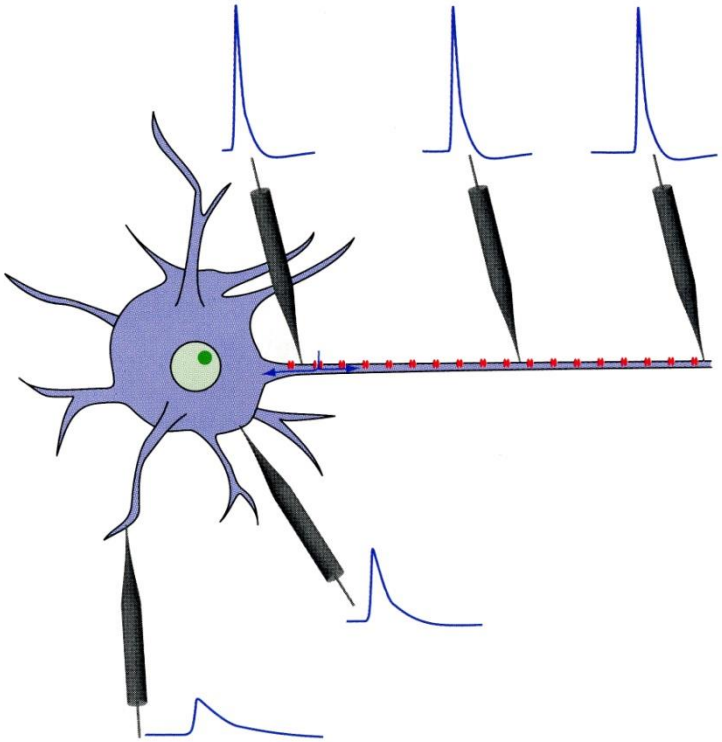
Action Potentials in the Axon



- Opening of the voltage-gated Na^+ channels in one segment of the axon causes depolarization of the voltage-gated Na^+ channels further down the axon.

- This results in the action potential self-propagating down the entire length of the axon.

Action Potentials in the Axon

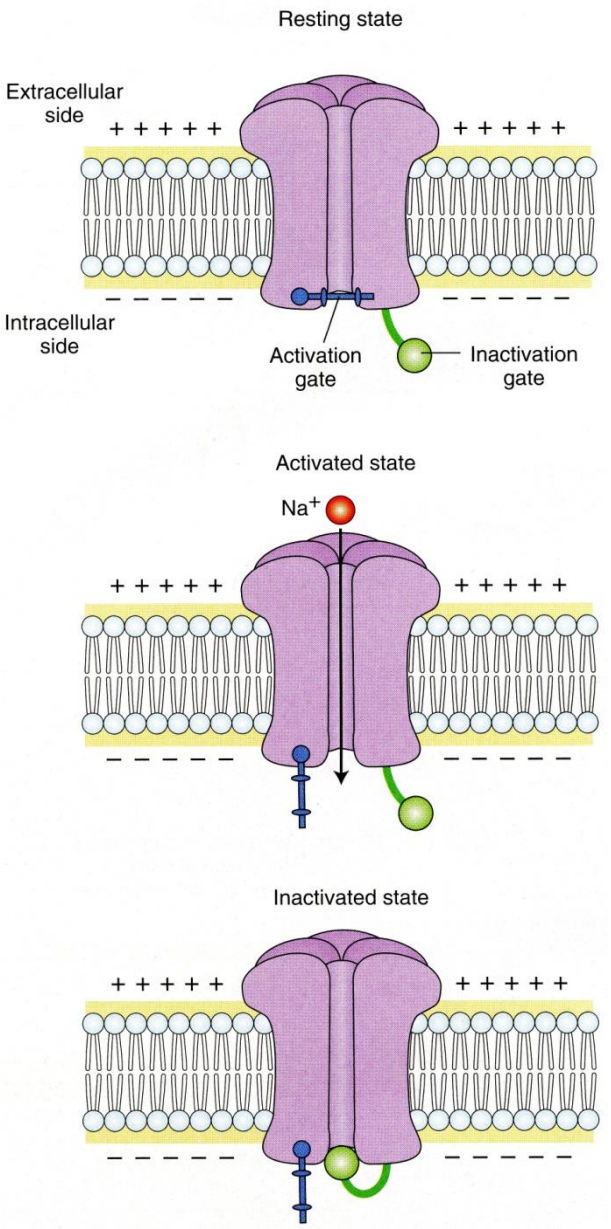


- The level of depolarization reached is the same along the entire length of the axon. (Thus, there is no decrement in the strength of the action potential along the length of the axon.)

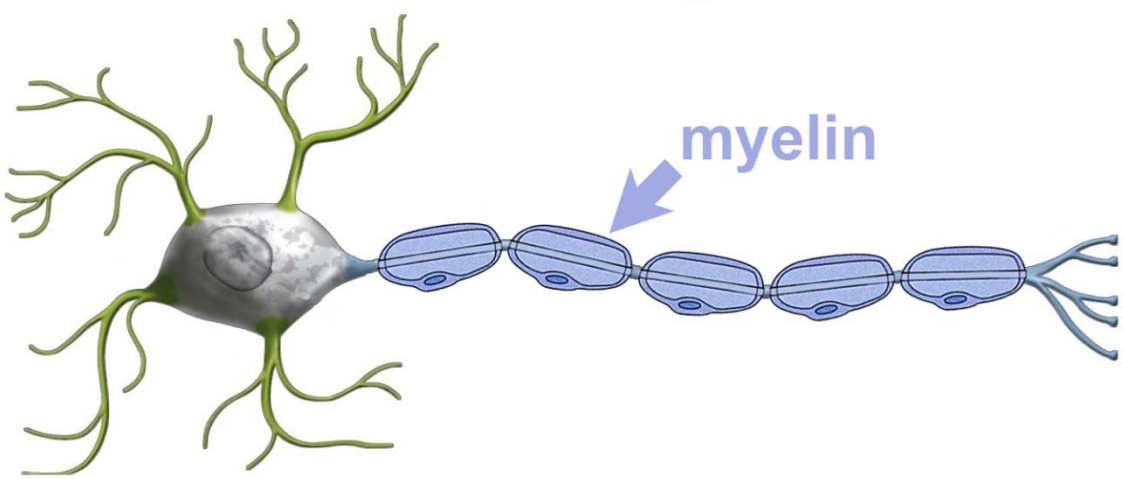
- The action potential is described as an all-or-none event. (That is once started in the initial segment, it is destined to go to the end of the axon.)

Action Potentials in the Axon

- After opening, voltage-gated Na^+ channels have a brief period in which they are blocked and cannot be activated.
- A new action potential cannot be generated during this period, the refractory period.
- This limits the potential frequency of action potentials.



Myelin

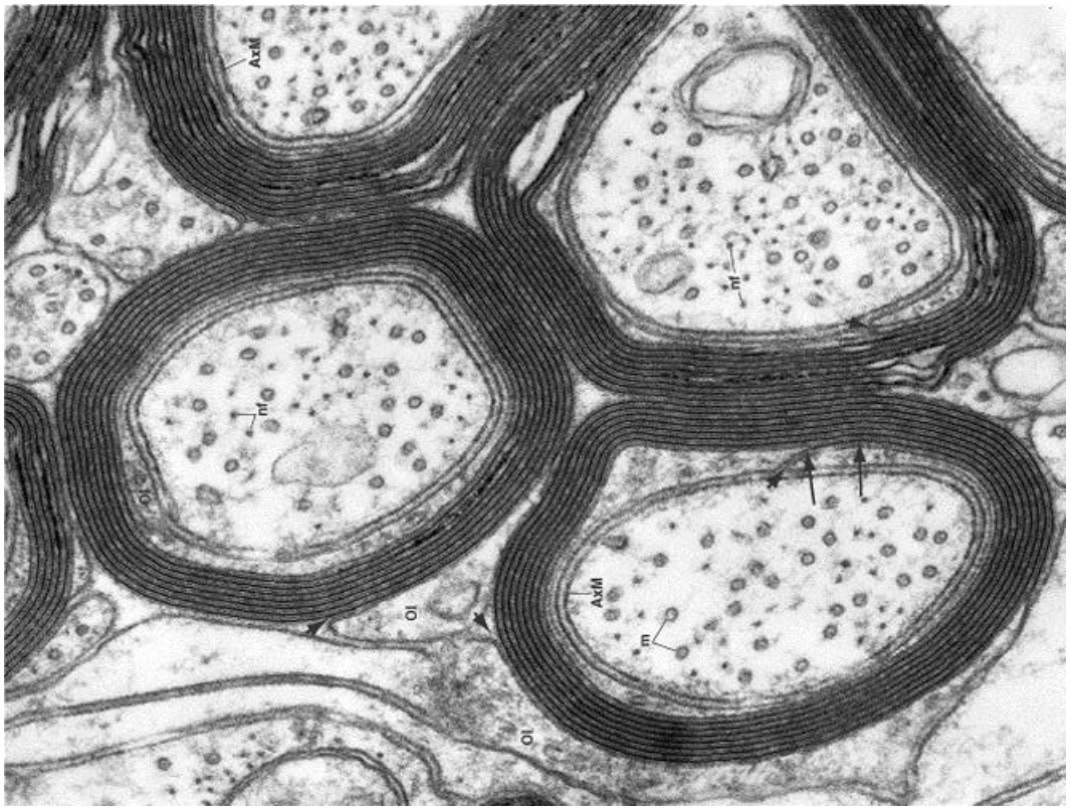


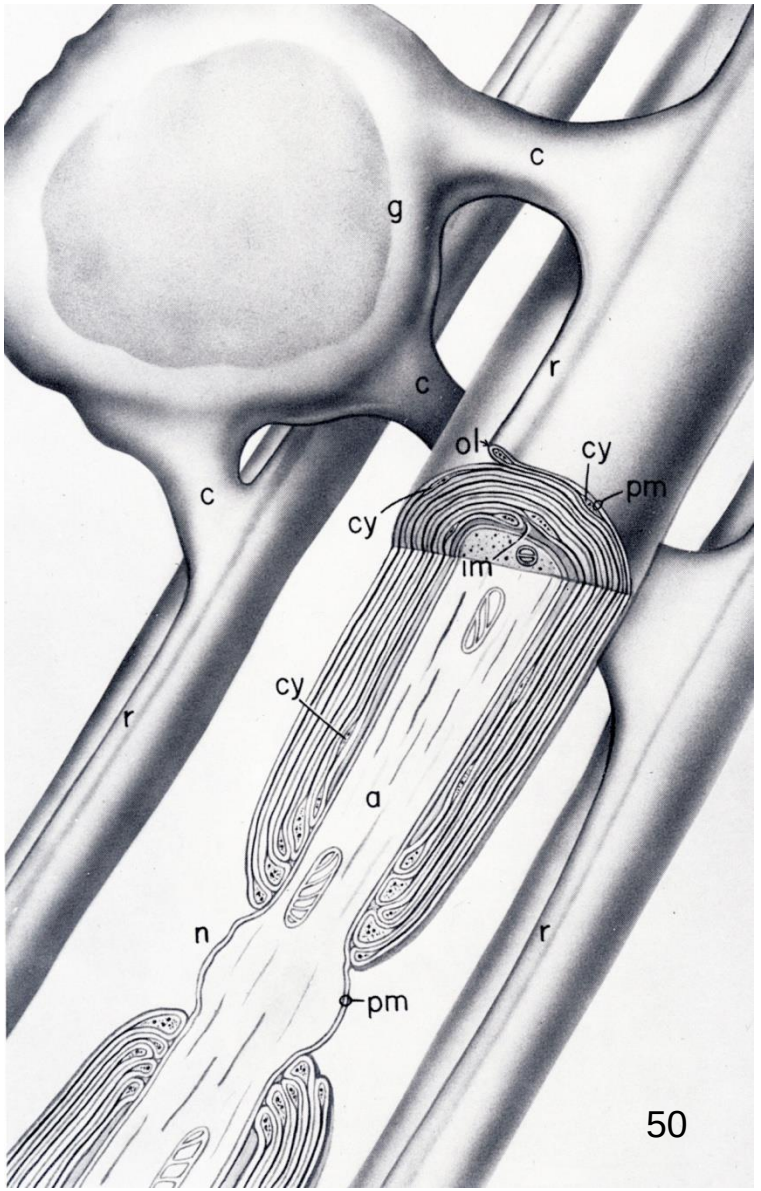
- Most axons have a covering of myelin.
- Myelin speeds the conduction of action potentials down the axon.

Myelin

Myelin is formed by glial cells wrapping their membranes around an axon:

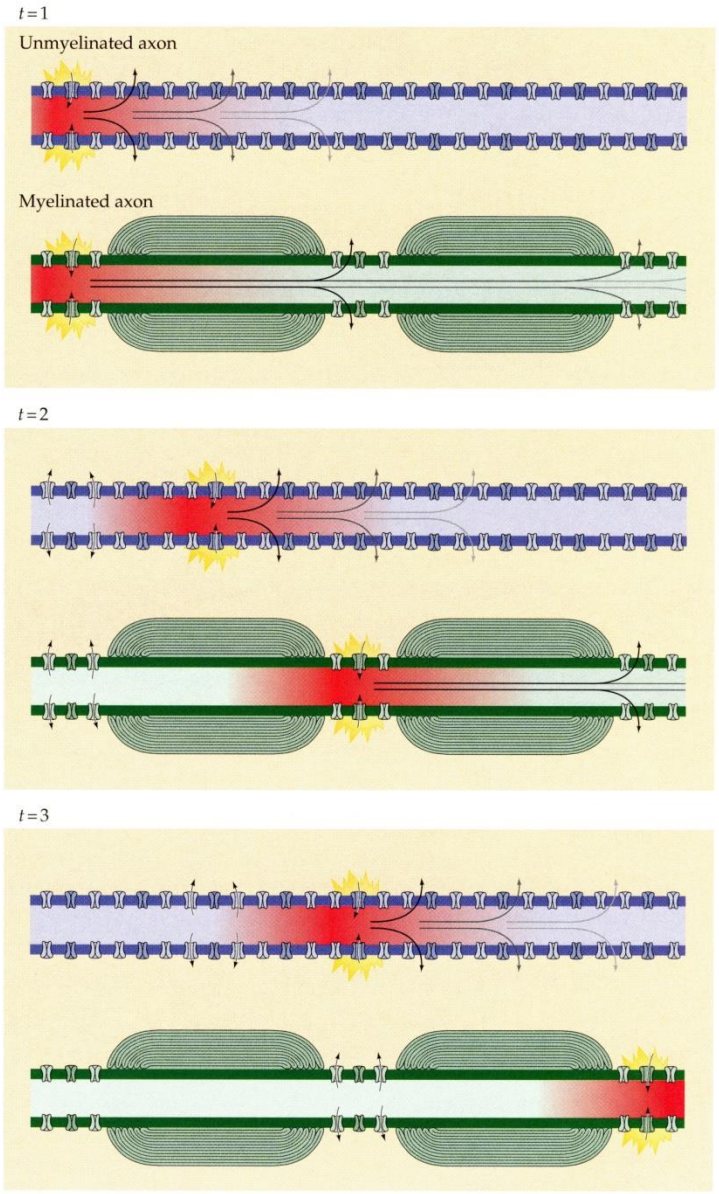
- Schwann cells in the PNS.
- Oligodendrocytes in the CNS.



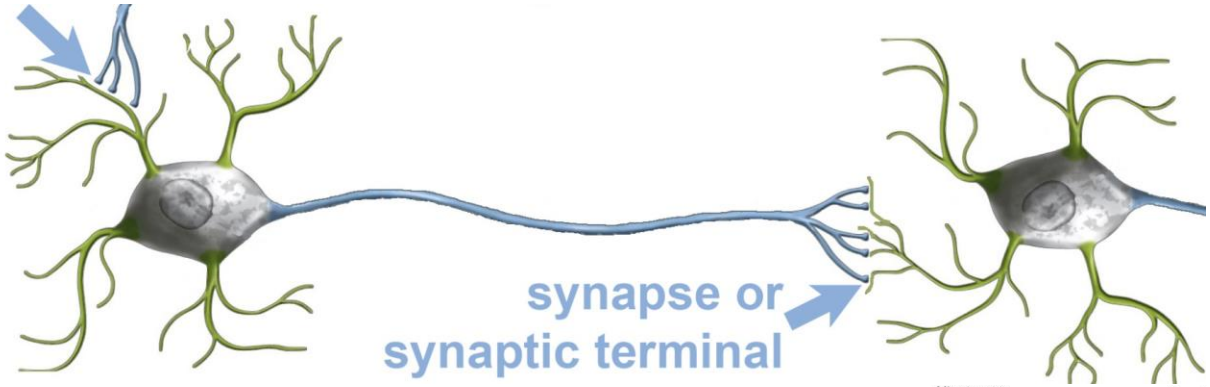


Saltatory Conduction

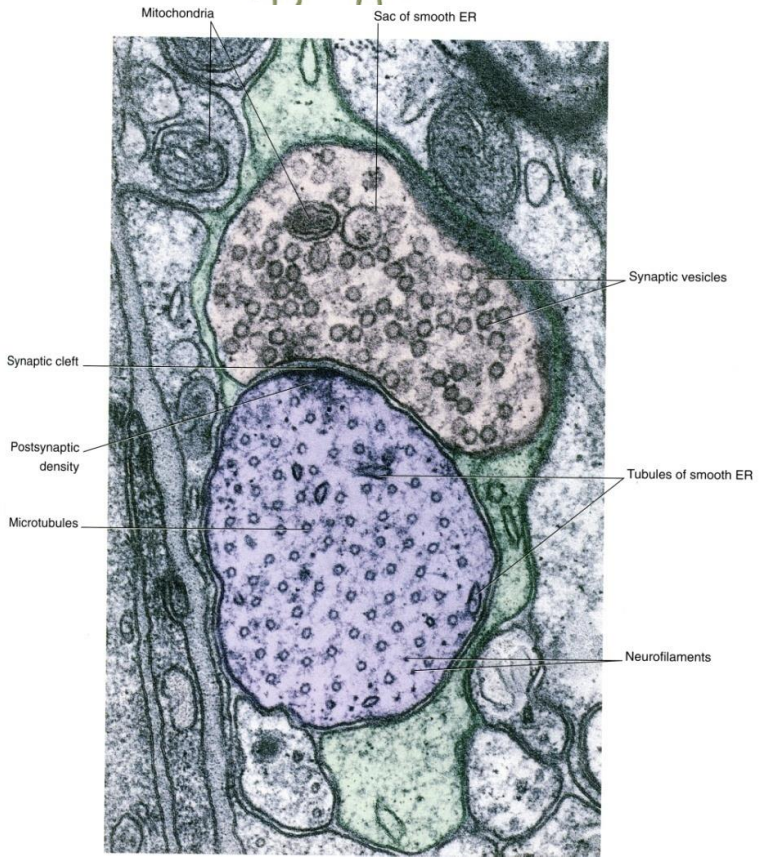
- The membrane wrapped by myelin is not excitable, and there is a high density of voltage-gated Na^+ channels in the nodes between the myelin.
- The action potential moves rapidly from node to node.
- Myelinated axons have a much faster <u>conduction velocity</u> than unmyelinated axons.



Neurochemical Communication

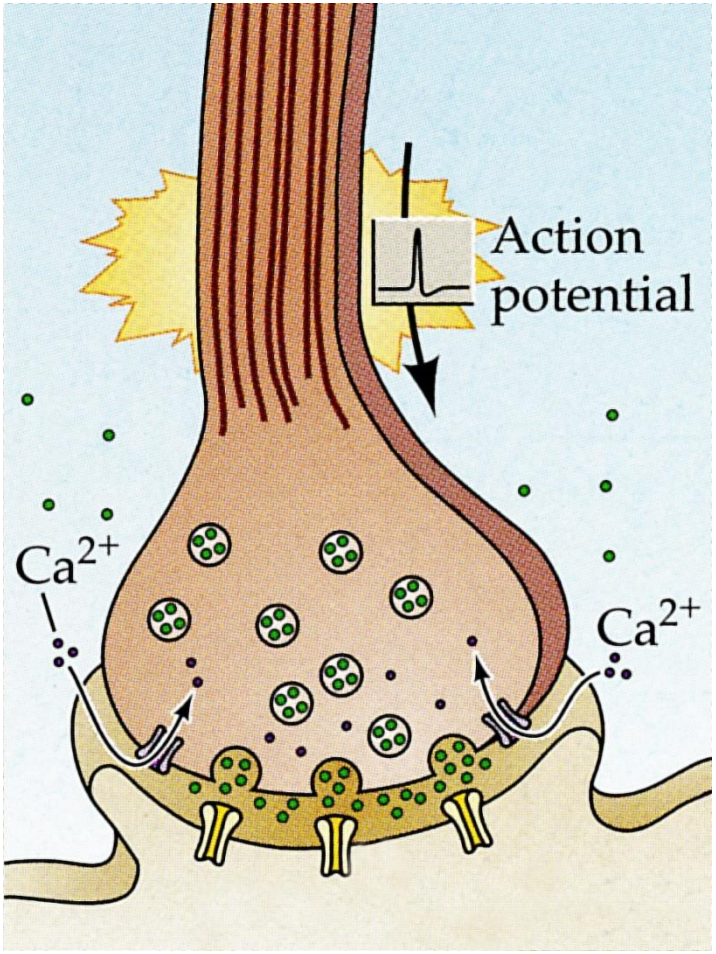


- When an action potential reaches the synapse, it initiates release of neurotransmitter into the synaptic cleft.



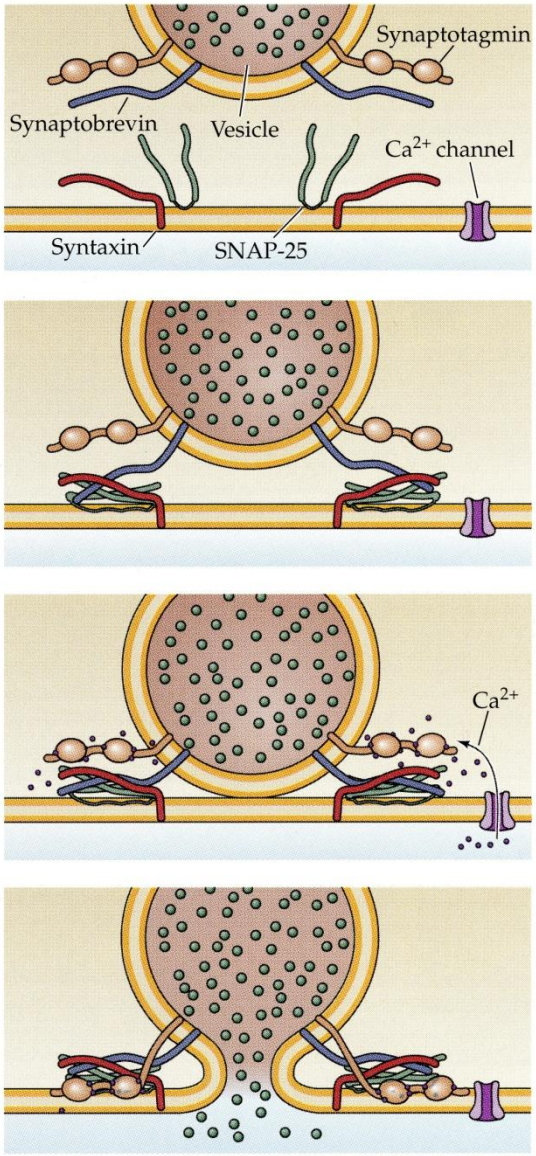
Neurotransmitter Release

- The arrival of an action potential depolarizes the axon terminal, which opens voltage-gated calcium (Ca^{++}) channels.



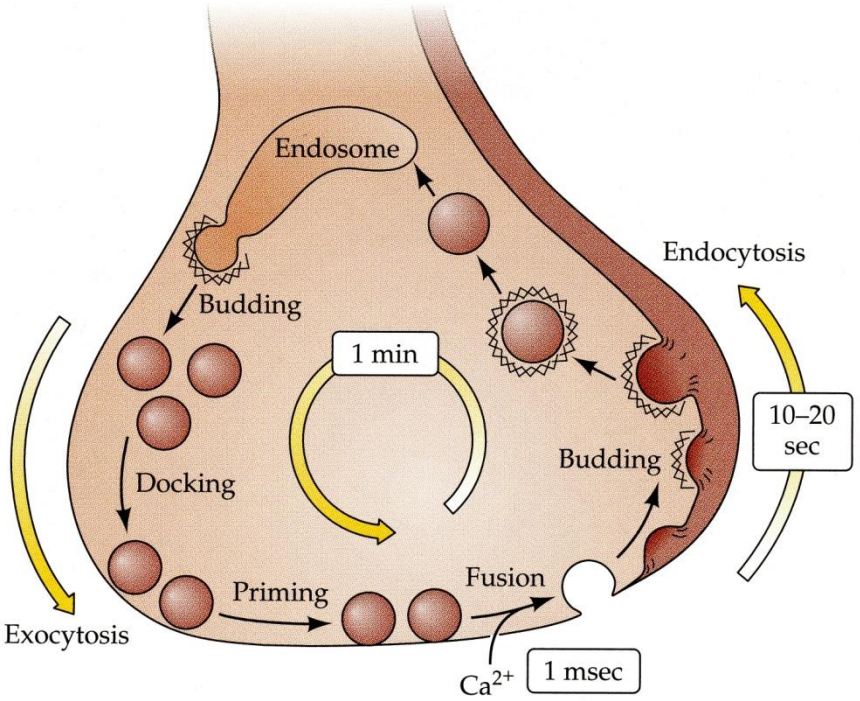
Neurotransmitter Release

- Synaptic vesicles filled with neurotransmitter are ‘docked’ at the active zone.
- Ca^{++} initiates an interaction between snare proteins on the vesicle with snare proteins on the cell membrane.
- The vesicle membrane is pulled into contact with the cell membrane, and the two fuse.
- Neurotransmitter is released into the synaptic cleft.
- This process is called exocytosis.



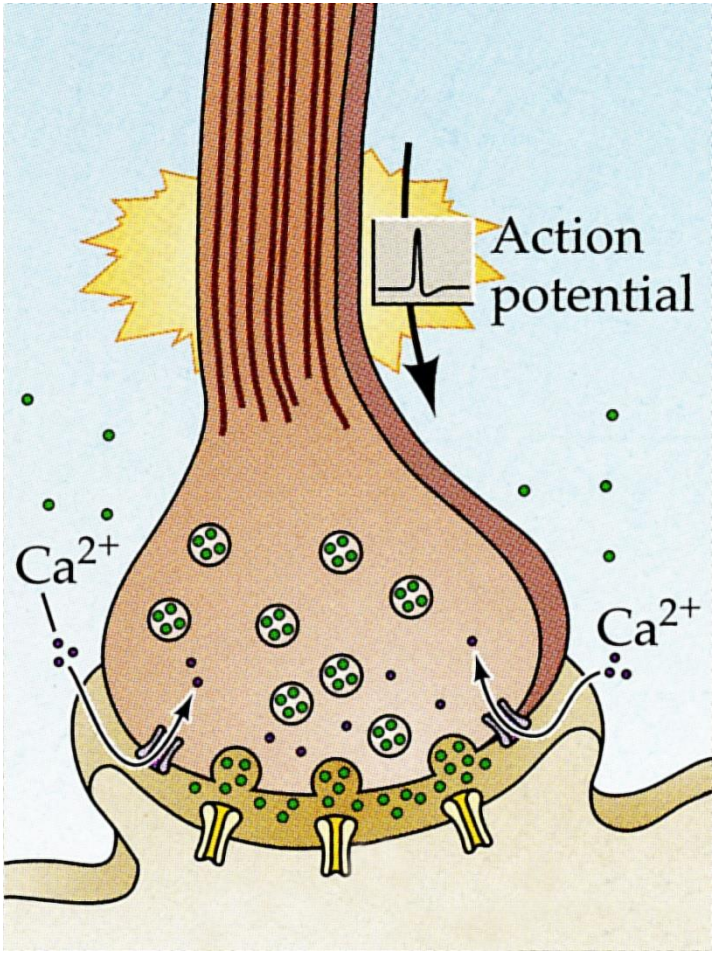
Neurotransmitter Release

- Vesicle membrane is removed from the cell membrane and recycled through a local endosome.



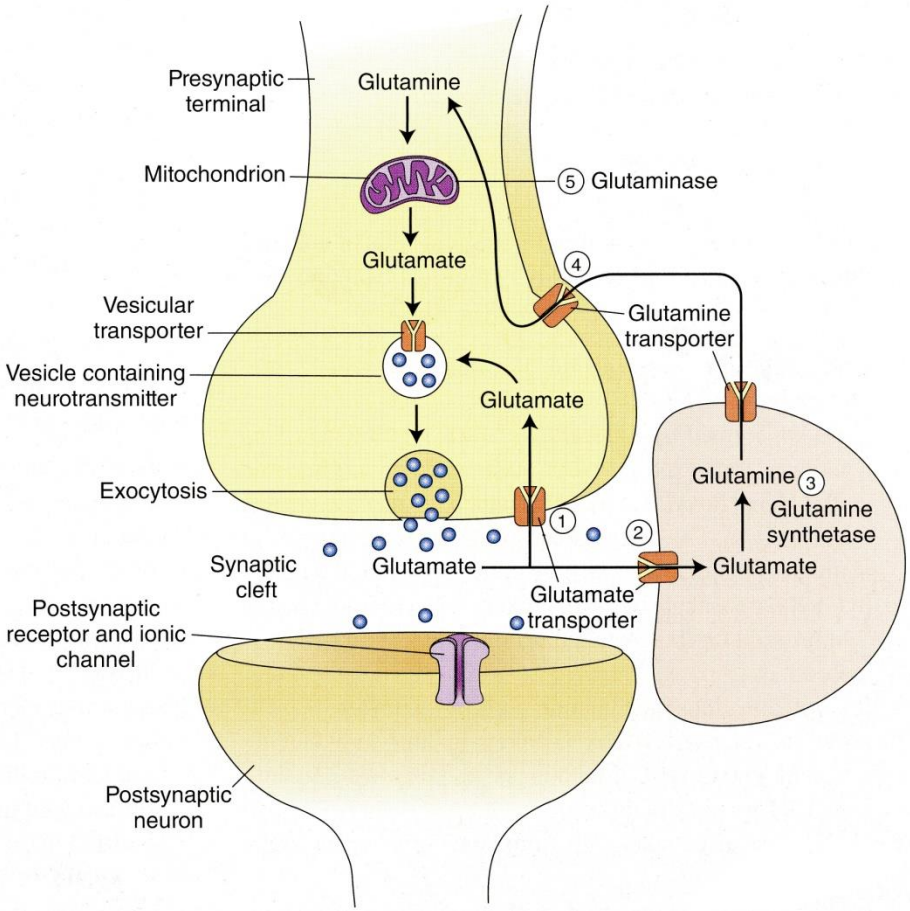
Neurotransmitter Release

- Neurotransmitter released from vesicles diffuses across the synaptic cleft and binds its receptors in the postsynaptic cell membrane.



Neurotransmitter Clearance

- Neurotransmitters must be rapidly cleared from the synaptic cleft so that they do not continually activate their receptors.



Neurotransmitter Receptors

- Two families of neurotransmitter receptors:
  - Ionotropic (ligand-gated ion channels)
    - Fast & short acting
  - Metabotropic (G-protein coupled)
    - Slow and long acting