Neuroscience 101 I

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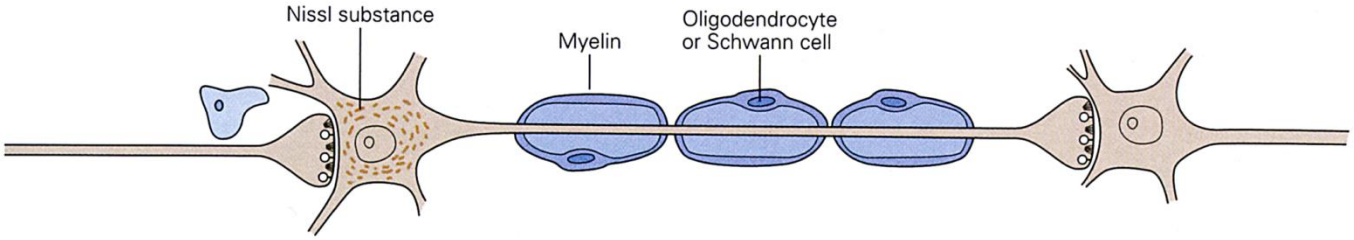
Coffee Hour

Tuesday (Sept 11) 10:00-11:00am
Friday (Sept 14) 8:30-9:30am

Surdyk’s Café in Northrop Auditorium

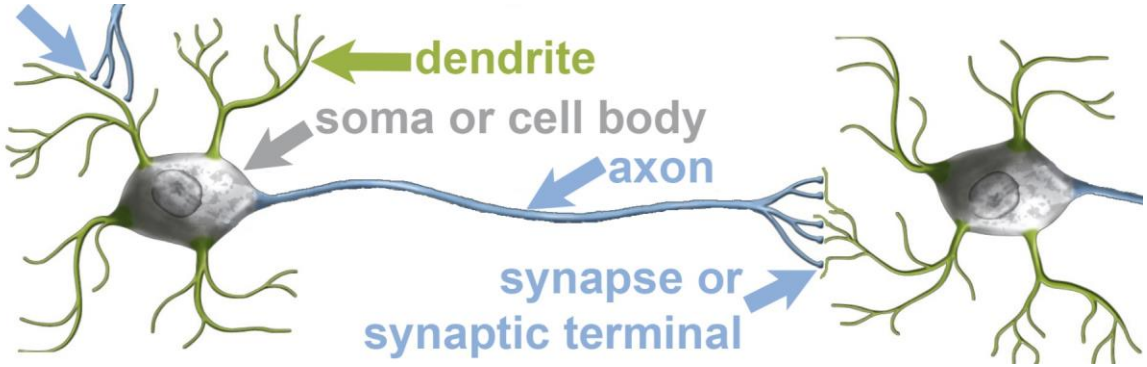
Stop by for a minute or an hour!

Major Cell Types of the Nervous System

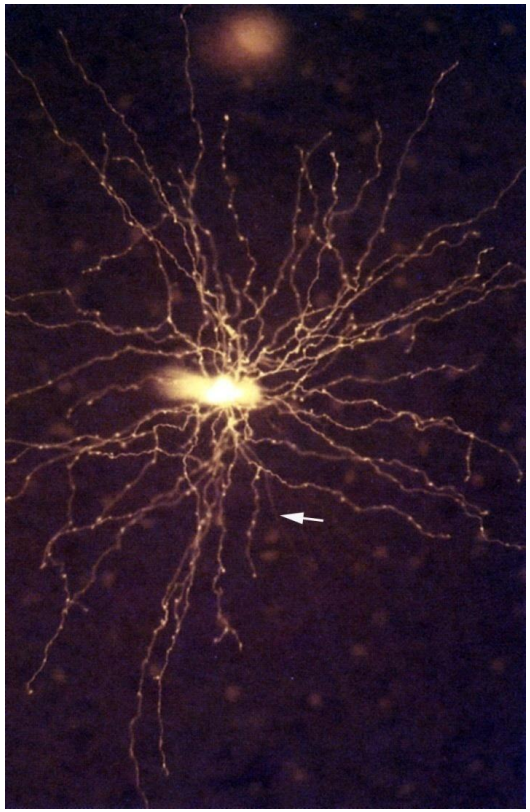


- Neurons
- Macroglia
    - Oligodendrocytes & Astrocytes (CNS)
    - Schwann Cells & Satellite Cells (PNS)
- Microglia
- Cells associated with blood & vessels

Anatomy of a ‘Typical’ Neuron

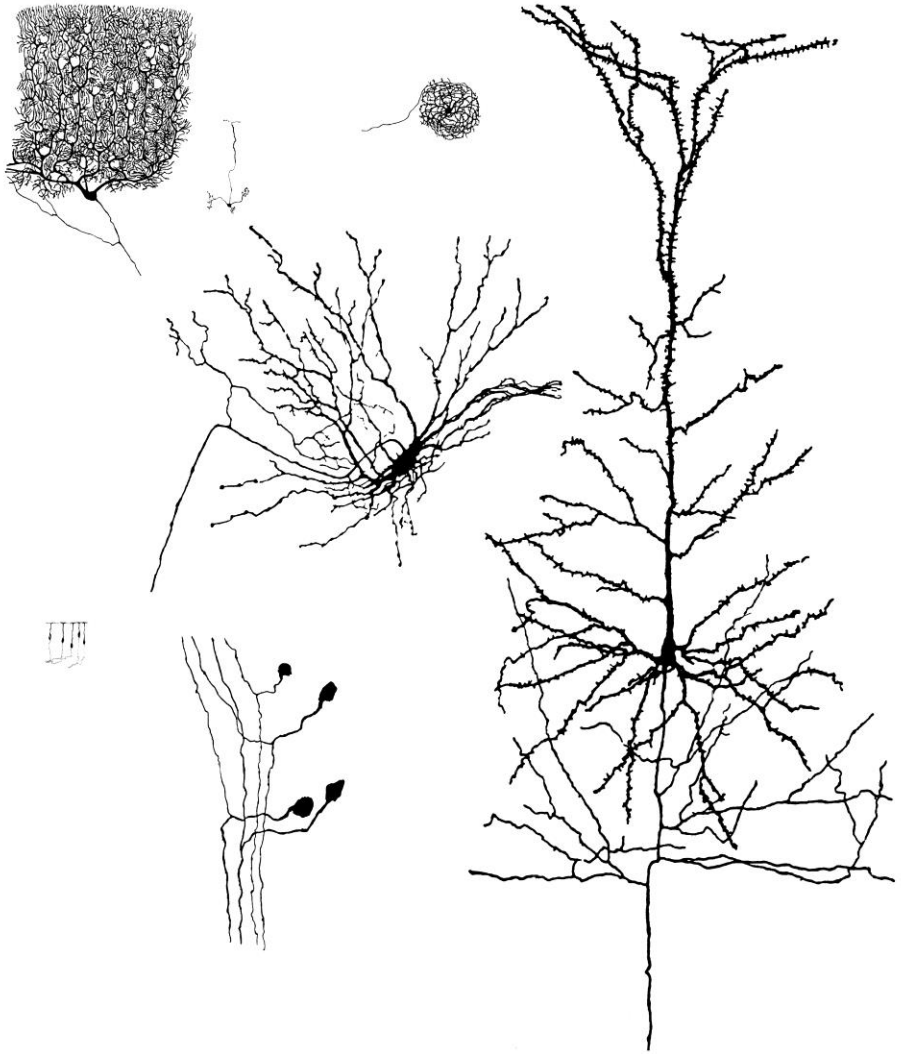


- Soma (cell body)
- Dendrites
- Axon (only one, but can branch)
- Synapses



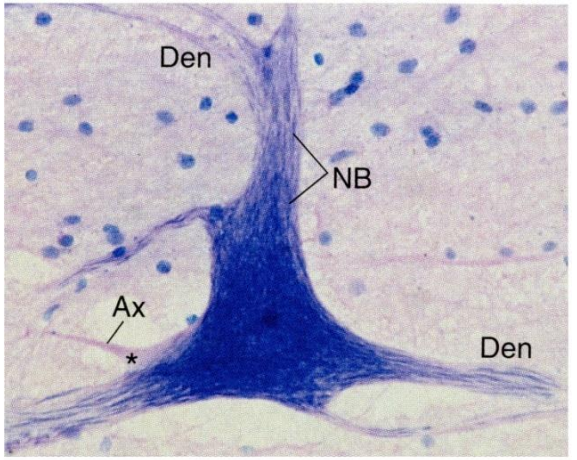
Anatomy of a ‘Typical’ Neuron

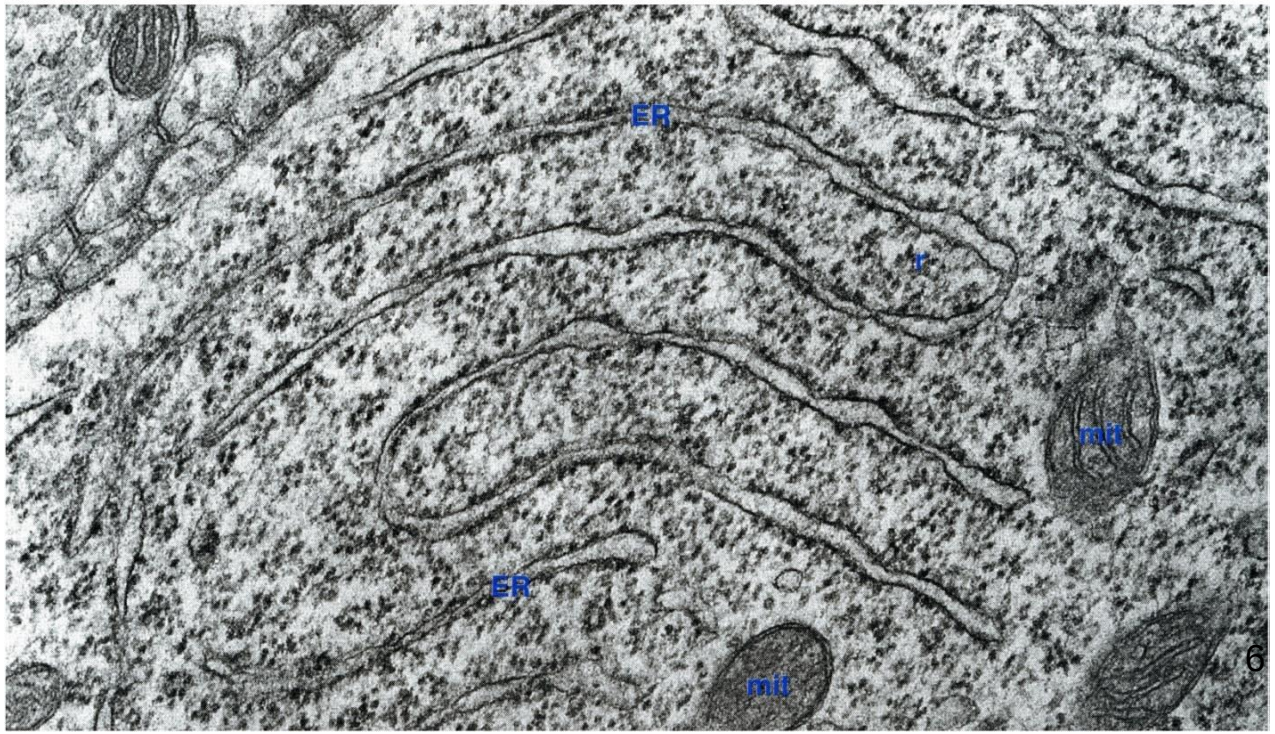
- Neurons come in many shapes and sizes (i.e. there is no ‘typical neuron’).



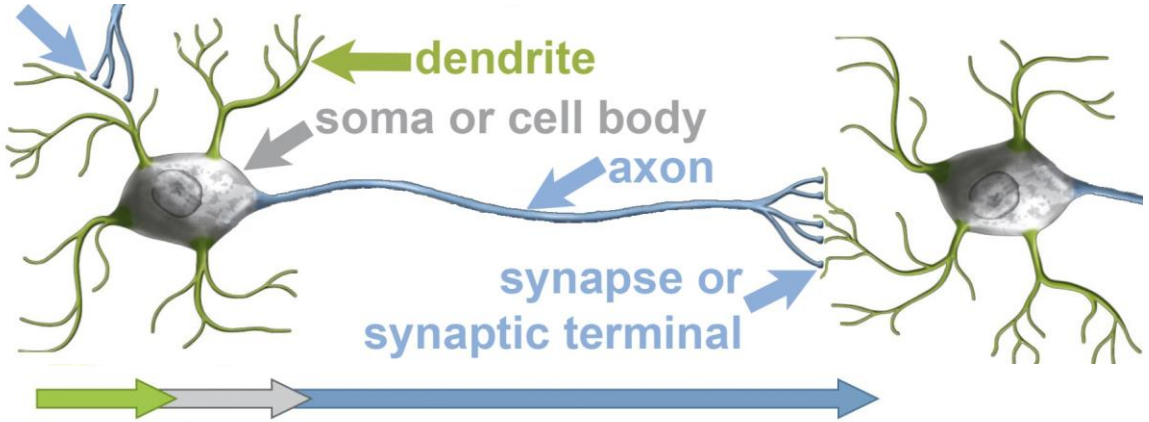
Anatomy of a ‘Typical’ Neuron

- Neurons have large amounts of rough endoplasmic reticulum (rER) or Nissl substance in their somas and larger dendrites.
- Many neurotransmitters as well as various vesicle and structural proteins are synthesized in the soma and delivered to the axon and synaptic terminals via axoplasmic transport.
- Axoplasmic transport goes anterograde and retrograde.



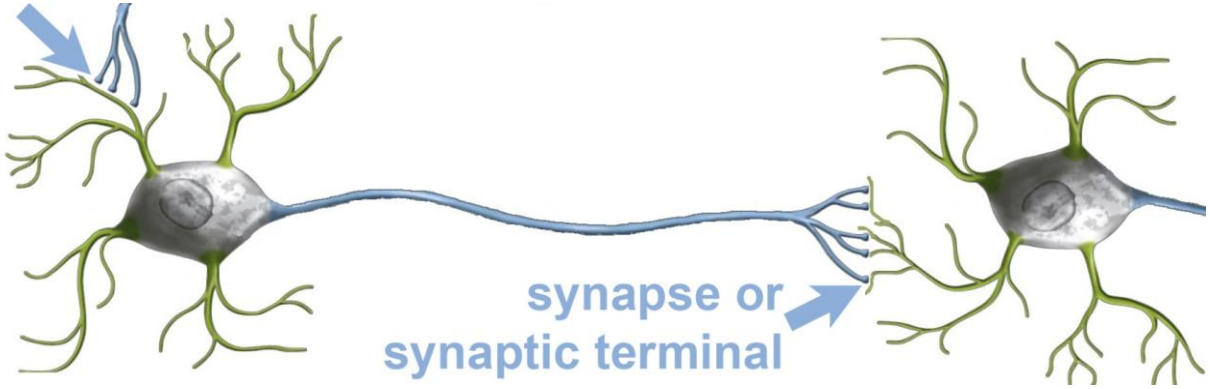


Neurons communicate with other cells via synapses.



- Flow of information:
  dendrite > soma > axon > synapse
- Neurotransmitter is released from the presynaptic cell at the synapse.
- The transmitter diffuses across the synaptic cleft to the postsynaptic cell.

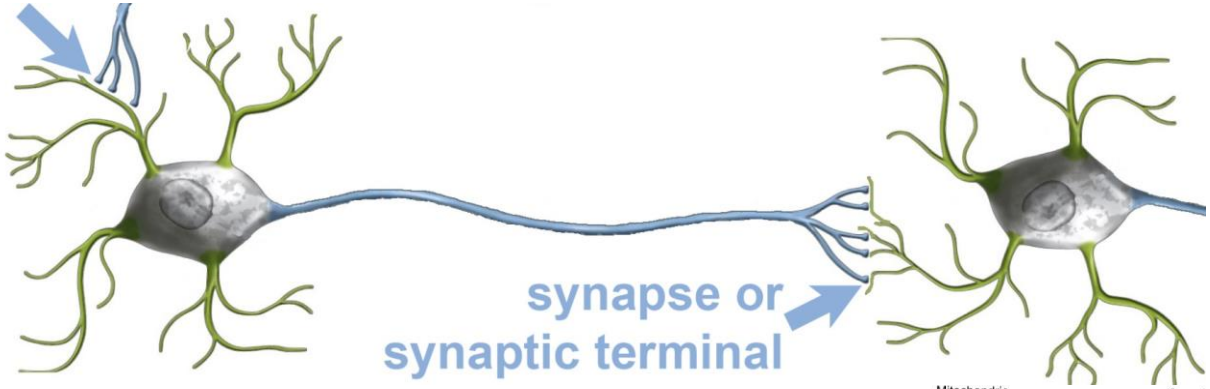
Neurons communicate with other cells via synapses.



Neurons communicate via synapses with:

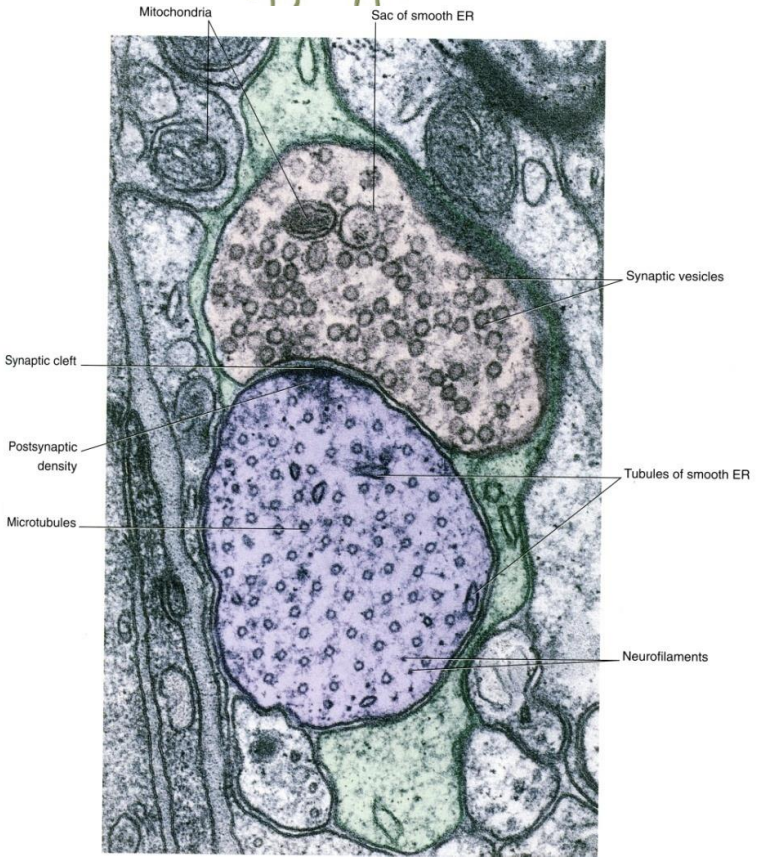
- Neurons
    - Axodendritic synapses
    - Axosomatic synapses
    - Axoaxonic synapses
    - Dendrodendritic synapses
- Other cell types (e.g. muscle, gland, blood vessel)
    - Neuromuscular synapses

Neurons communicate with other cells via synapses.



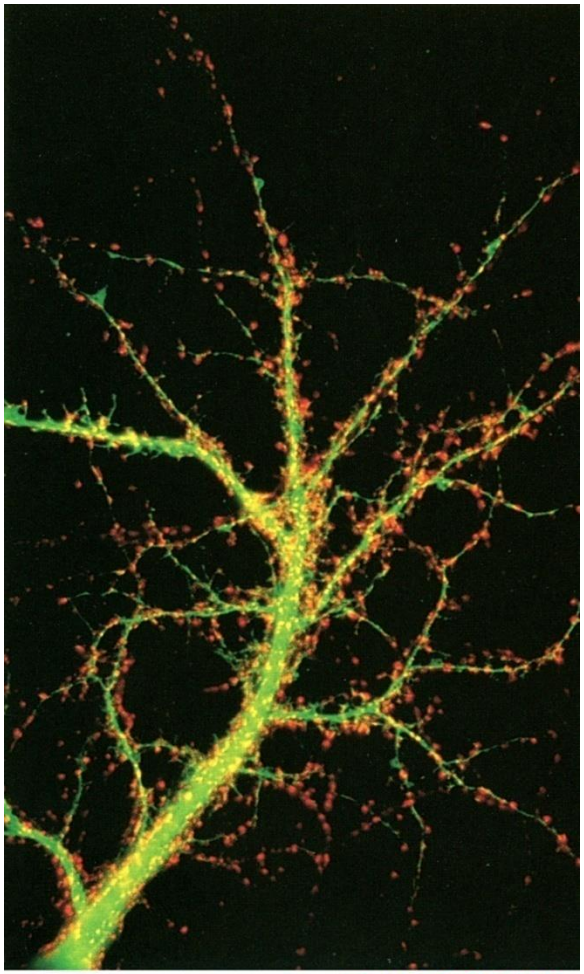
Structure of a typical synapse:

- Presynaptic terminal
    - Synaptic vesicles containing neurotransmitter
    - Presynaptic density
- Synaptic cleft
- Postsynaptic element
    - Neurotransmitter receptors
    - Postsynaptic density



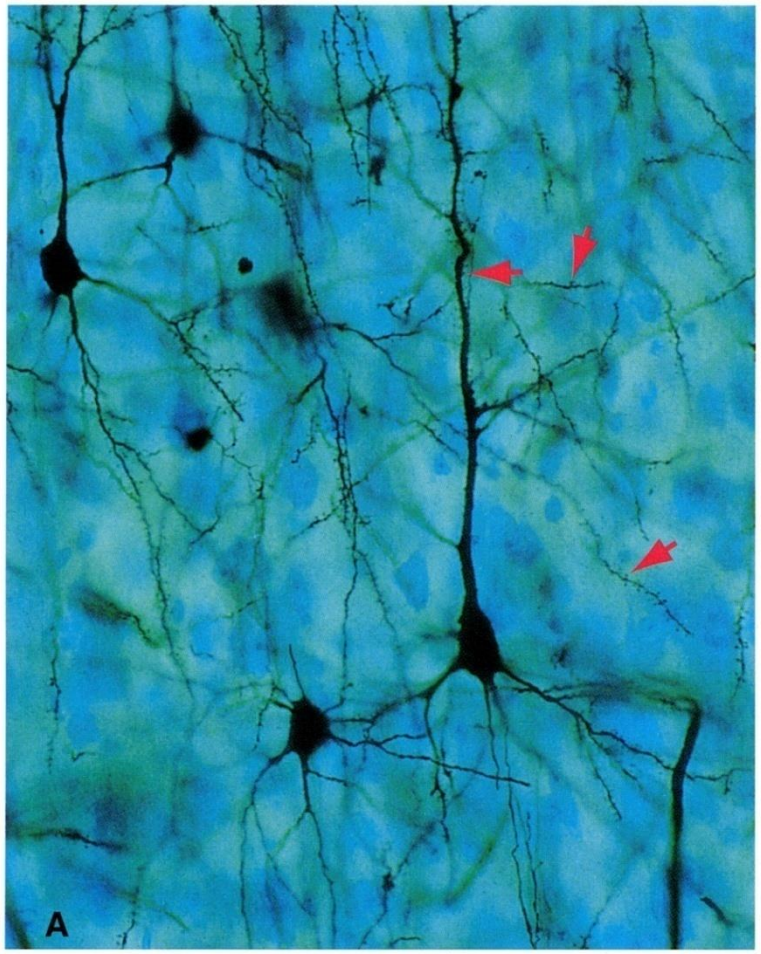
Neurons communicate with other cells via synapses.

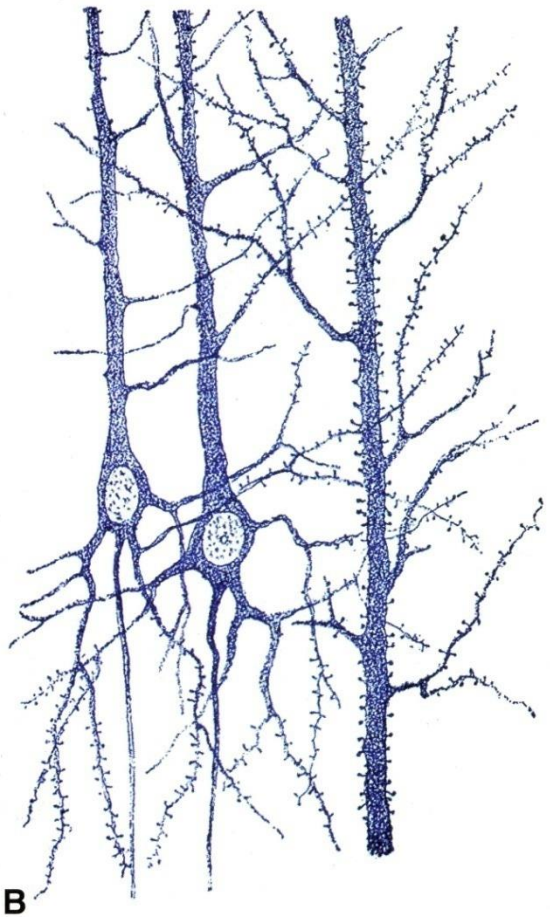
- An individual neuron can have one to thousands of synapses.



Neurons communicate with other cells via synapses.

- Many neurons have dendritic spines for receiving synapses.





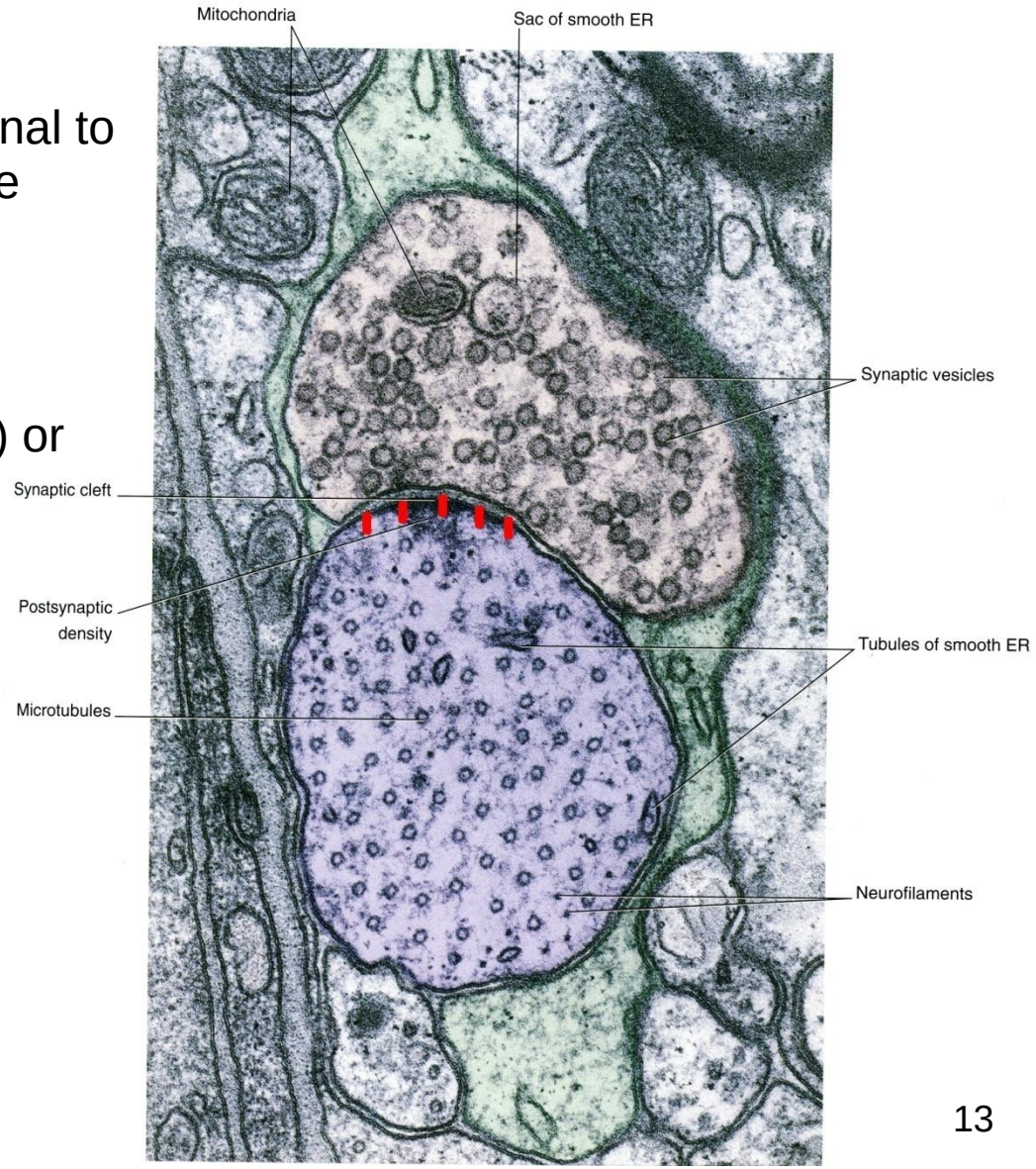
Neurons communicate with other cells via synapses.

- Different types of neurons release different neurotransmitters.
- Some common neurotransmitters:

class	***transmitter***
biogenic amines	acetylcholine
	dopamine
	norepinephrine (noradrenaline)
	epinephrine (adrenaline)
	serotonin
amino acids	γ-aminobutyric acid (GABA)
	glutamate
	glycine
peptides	vasoactive intestinal polypeptide
	substance P
	enkephalin
	endorphin

Neurons communicate with other cells via synapses.

- Neurochemical communication requires the postsynaptic terminal to have the proper receptor for the neurotransmitter.
- The transmitter-receptor pair determines whether the active synapse will excite (depolarize) or inhibit (hyperpolarize) the postsynaptic cell.

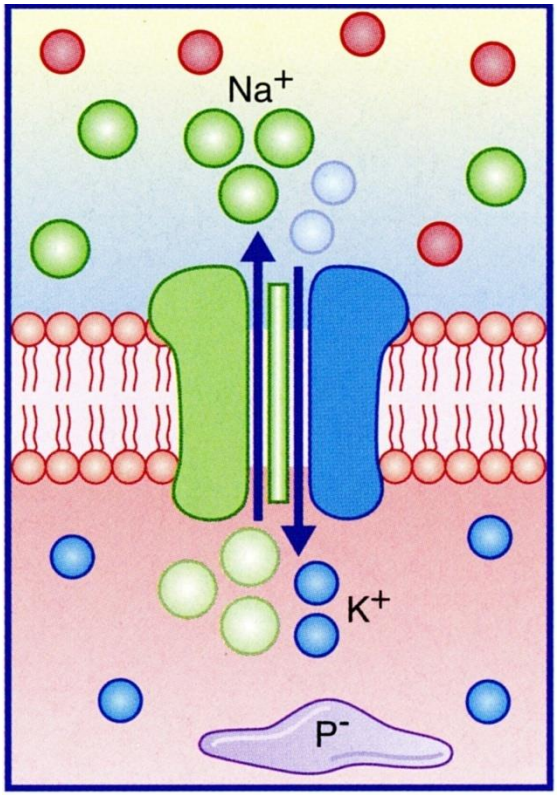


Electrical Properties of Neurons

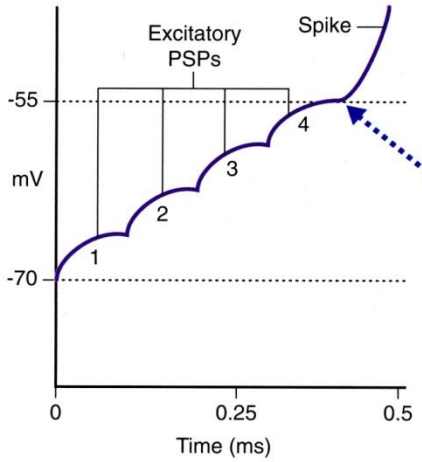
- A neuron at rest, that is a neuron receiving no synaptic input, maintains a higher concentration of K^+ and a lower concentration of Na^+ and Cl^- in its cytoplasm than outside the cell.

- A sodium-potassium pump maintains this ion differential.

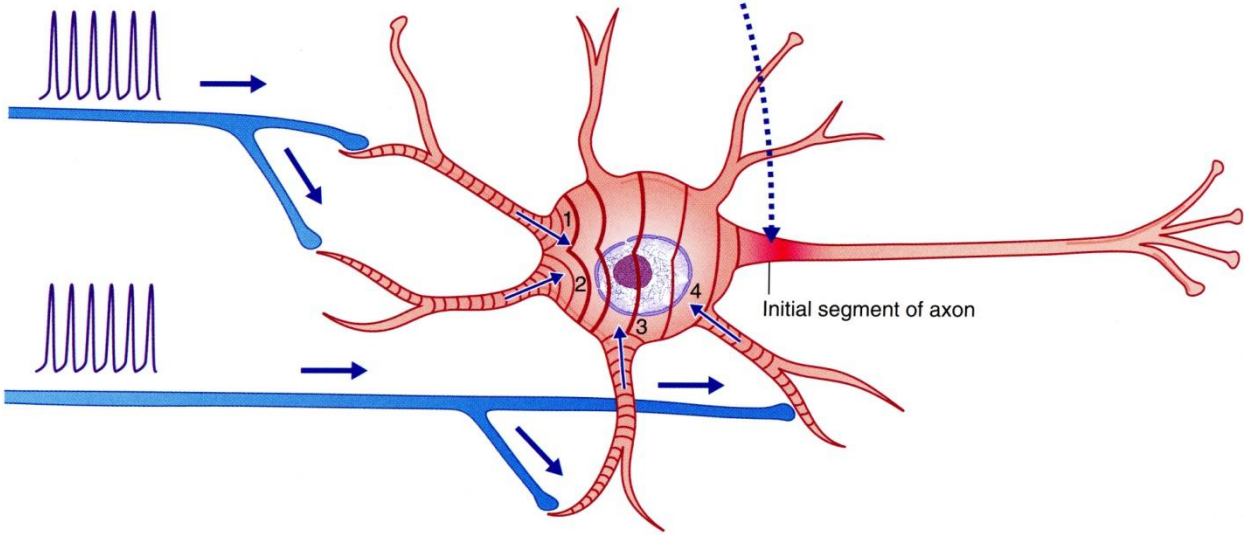
- A 'resting membrane potential' can be measured with electrodes on the inside and outside of the cell; this is typically -65mV.



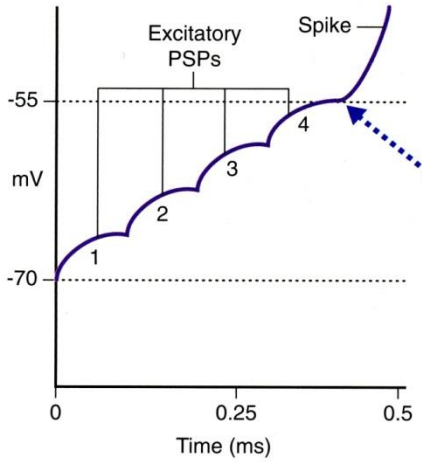
Electrical Properties of Neurons



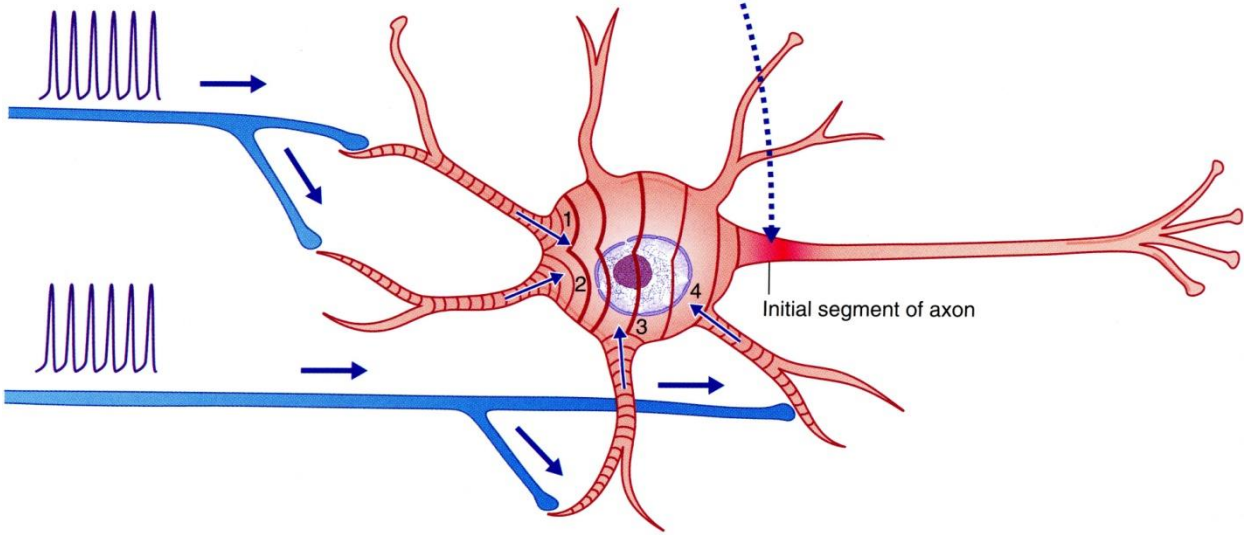
- Activation of neurotransmitter receptors causes changes in the ion conductance in the dendrites and soma.
- Inhibitory synaptic activity hyperpolarizes the neuron (i.e. the membrane potential becomes more negative).
- Excitatory synaptic activity depolarizes the neuron (i.e. makes it more positive).



Electrical Properties of Neurons

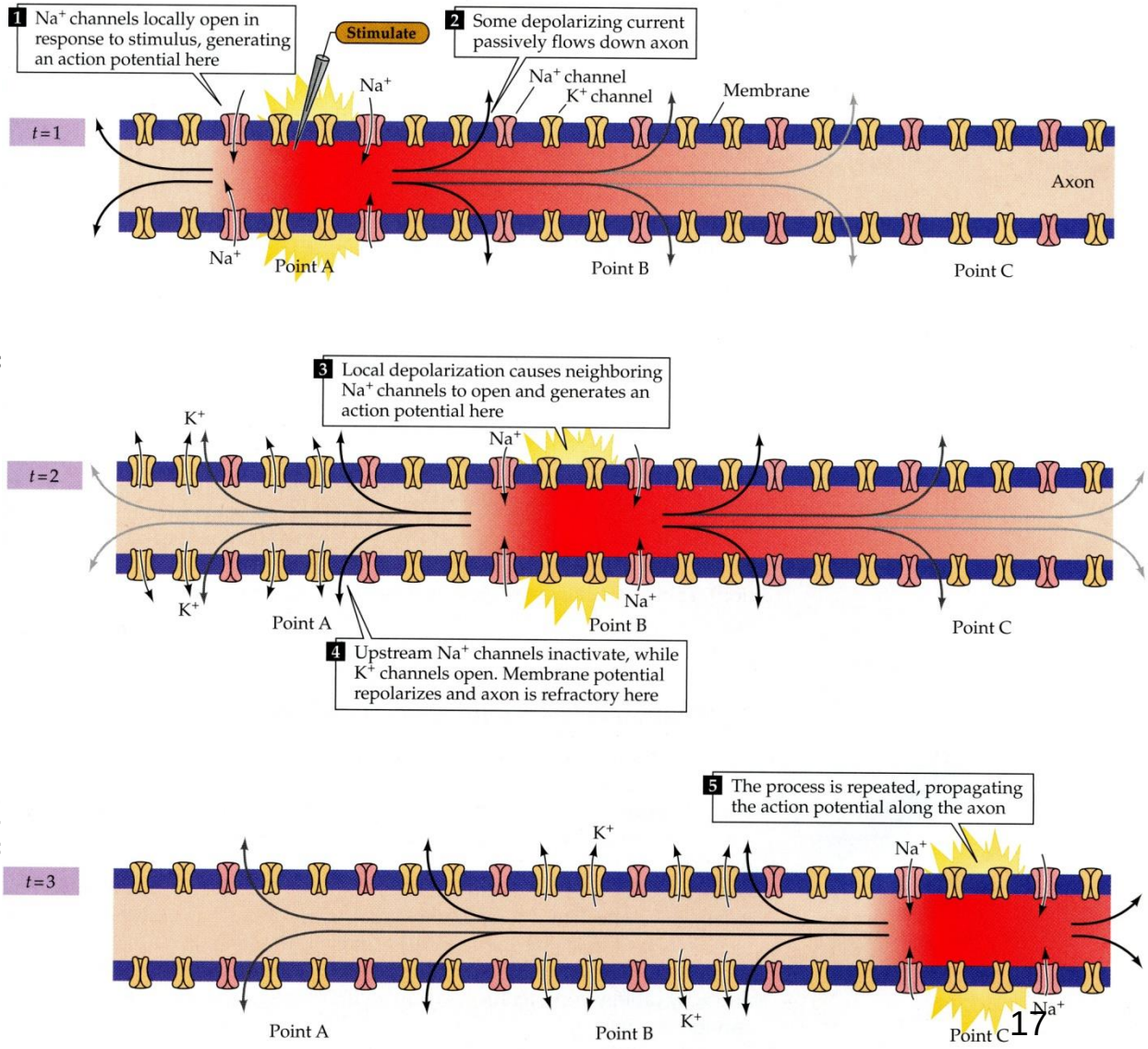


- The graded effect of all the synapses is summed at the initial segment of the axon.
- When the initial segment becomes sufficiently depolarized, voltage-gated sodium channels open and an action potential is generated.
- The influx of Na^+ into the axon is followed by an outflow of K^+.



Electrical Properties of Neurons

- The influx of Na^+ into one segment of the axon results in opening of the sodium channels in the next part of the axon.
- The action potential is self propagated down the axon.
- The strength of the action potential is unchanged along the entire length of the axon.
- When an action potential reaches the synapse, it initiates release of neurotransmitter into the synaptic cleft.

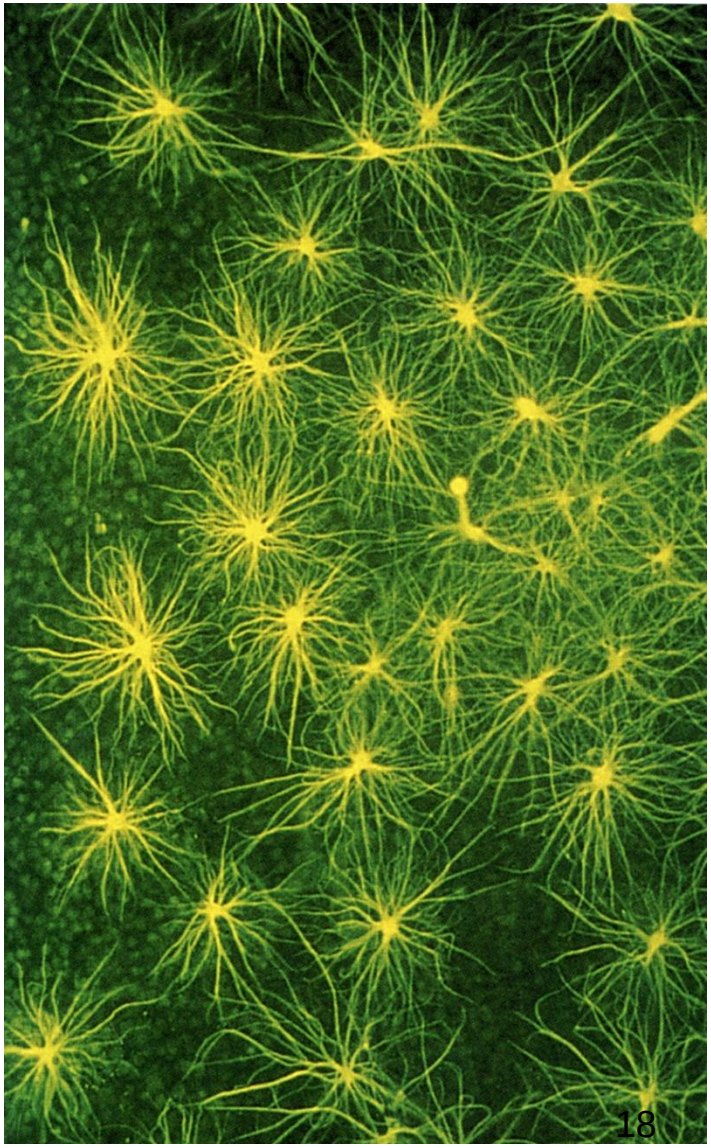


Astrocytes

- Star-shaped glial cells in the CNS
- Most abundant cell type of the brain and spinal cord
- Surround most synaspes

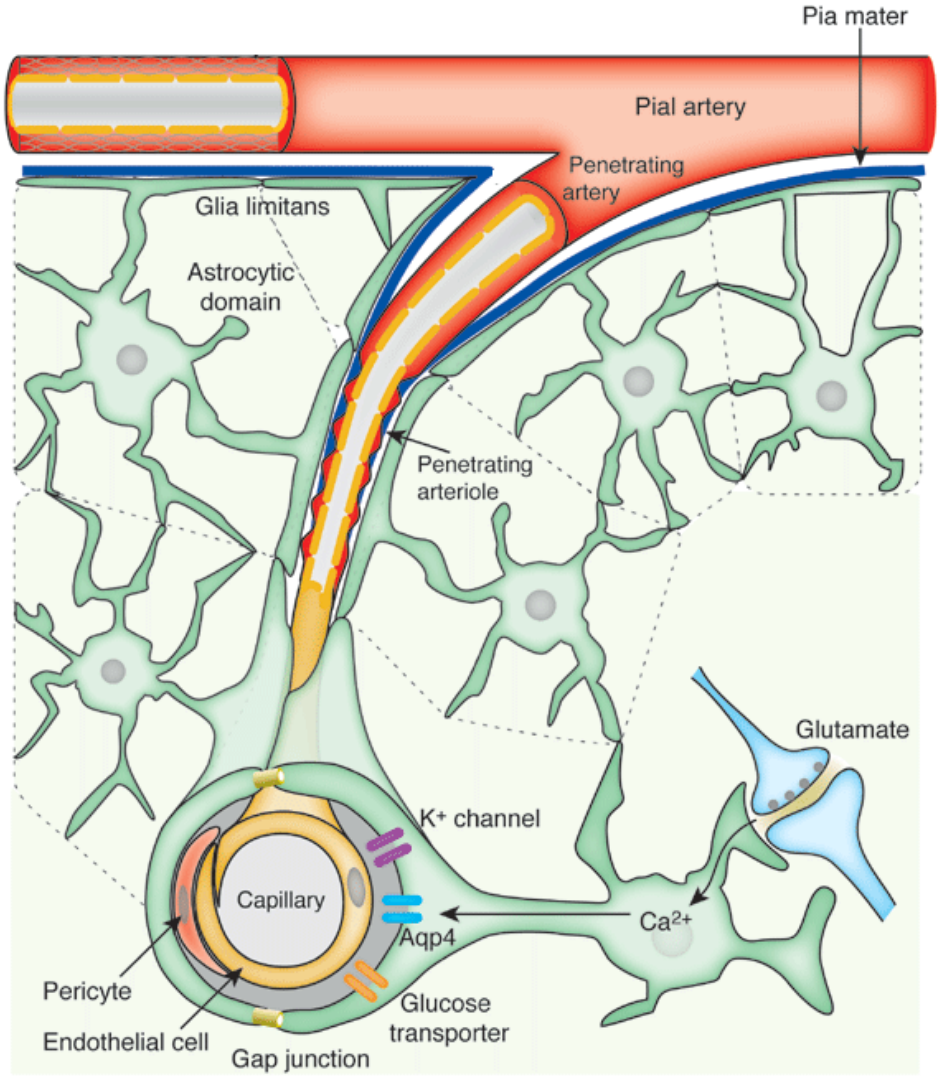
Functions of astrocytes:

- Contribute to the cellular scaffolding
- Secrete extracellular matrix molecules
- Provide trophic support for neurons
- Form the external limiting membrane of the brain & spinal cord
- During development, serve as progenitor cells & guide cell migration
- Following injury or disease, phagocytize cellular debris & a form glial scar

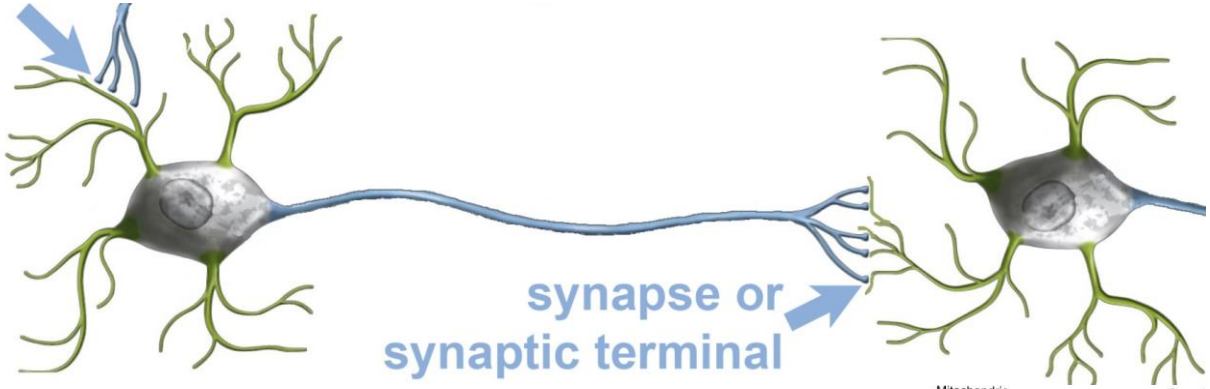


Astrocytes

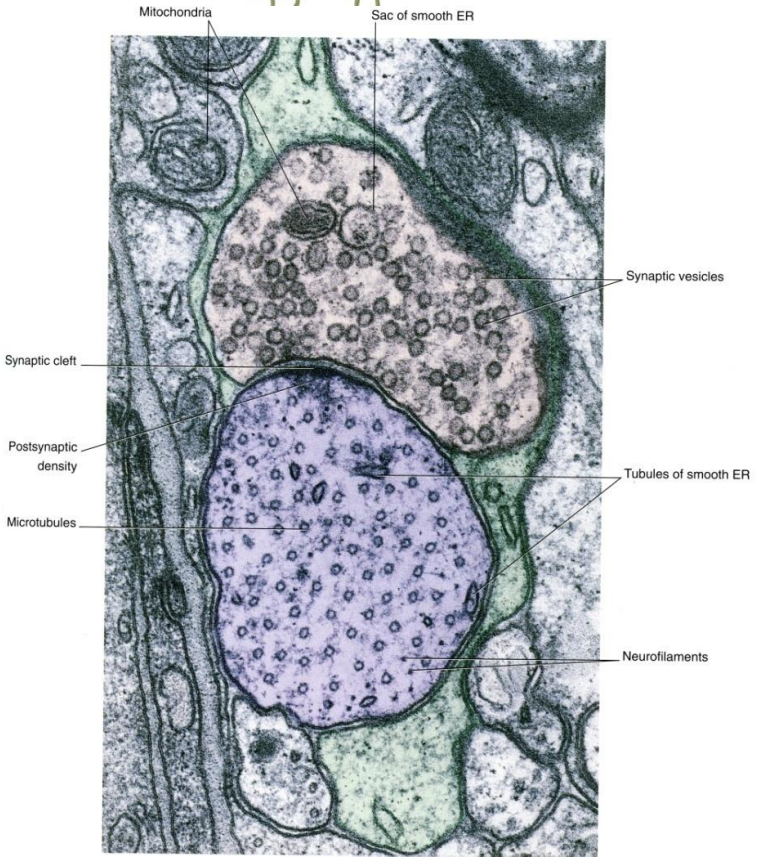
- Mediate exchange between capillaries and neurons; contribute to the blood-brain barrier
- Regulate local blood flow
- Contribute to neuronal metabolism via lactate shuttle & storing glucose as glycogen



Astrocytes



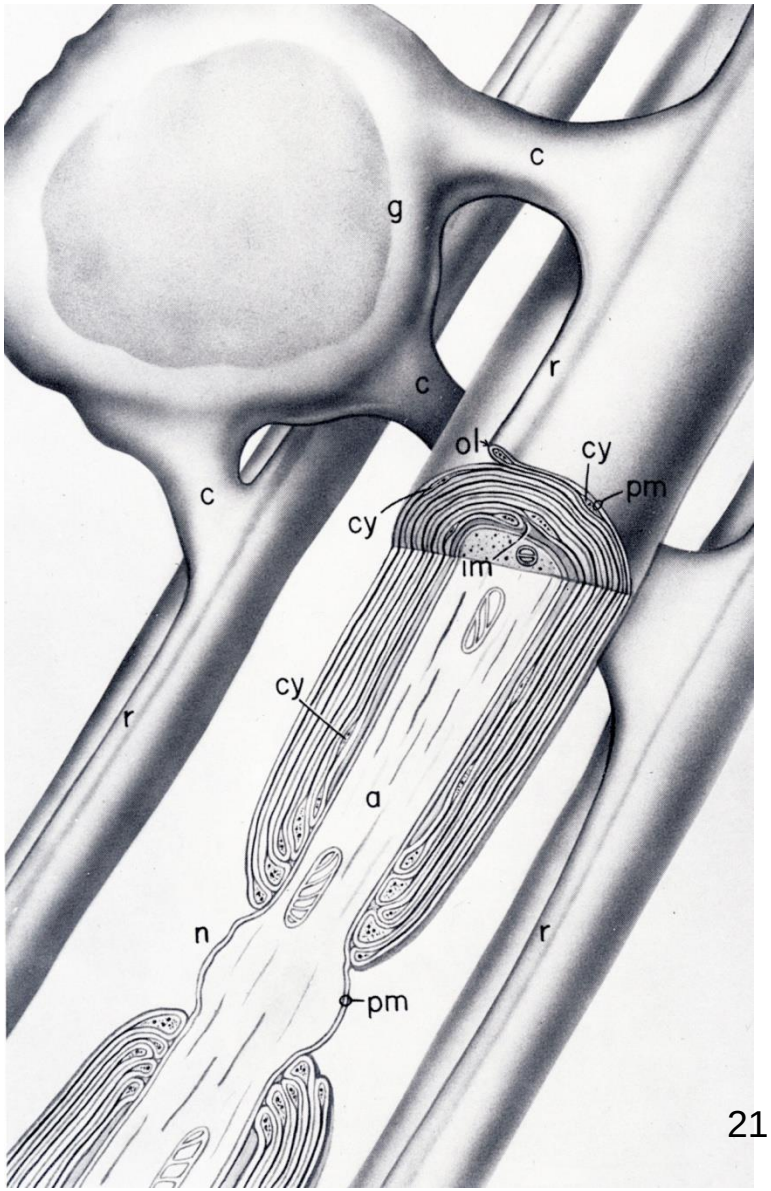
- Regulate the extracellular ionic environment, which modulates synaptic transmission & plasticity
- Remove & recycle neurotransmitter
- ‘Insulate’ synapses (i.e. prevent transmitter spillover)



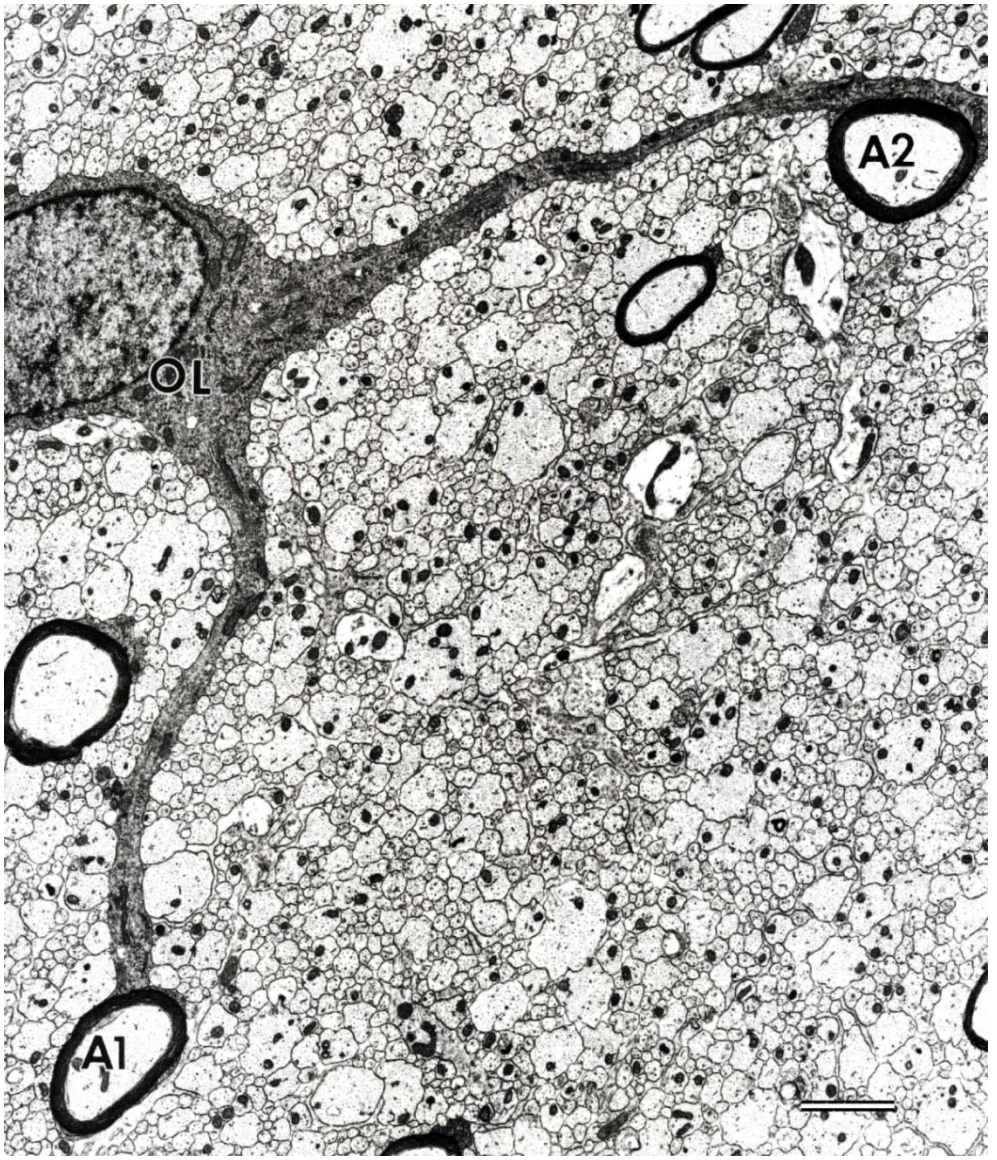
Myelin

Myelin or a wrapping of glial cell membranes around axons is formed by:

- Schwann cells in the PNS
- Oligodendrocytes in the CNS



Myelin



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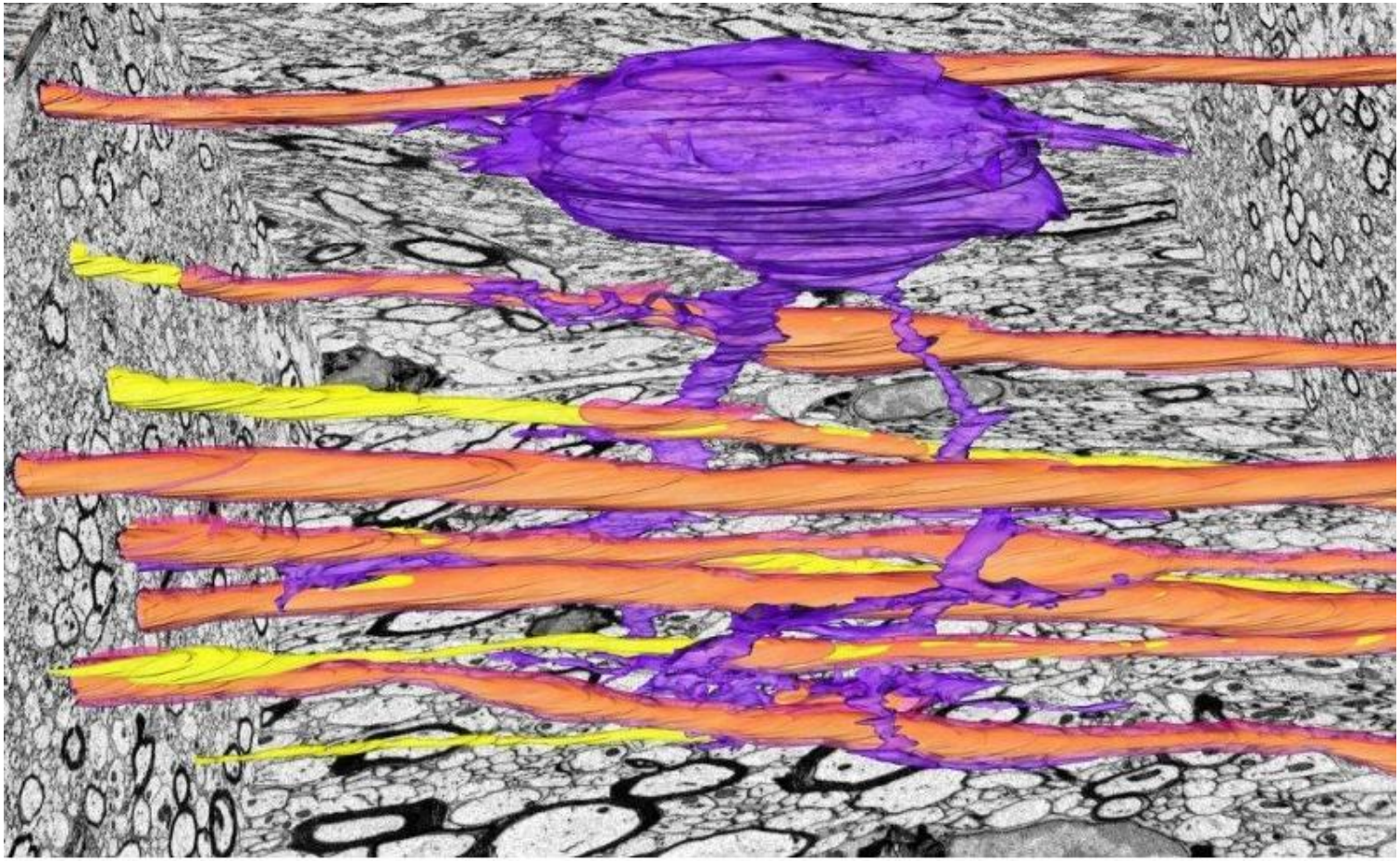
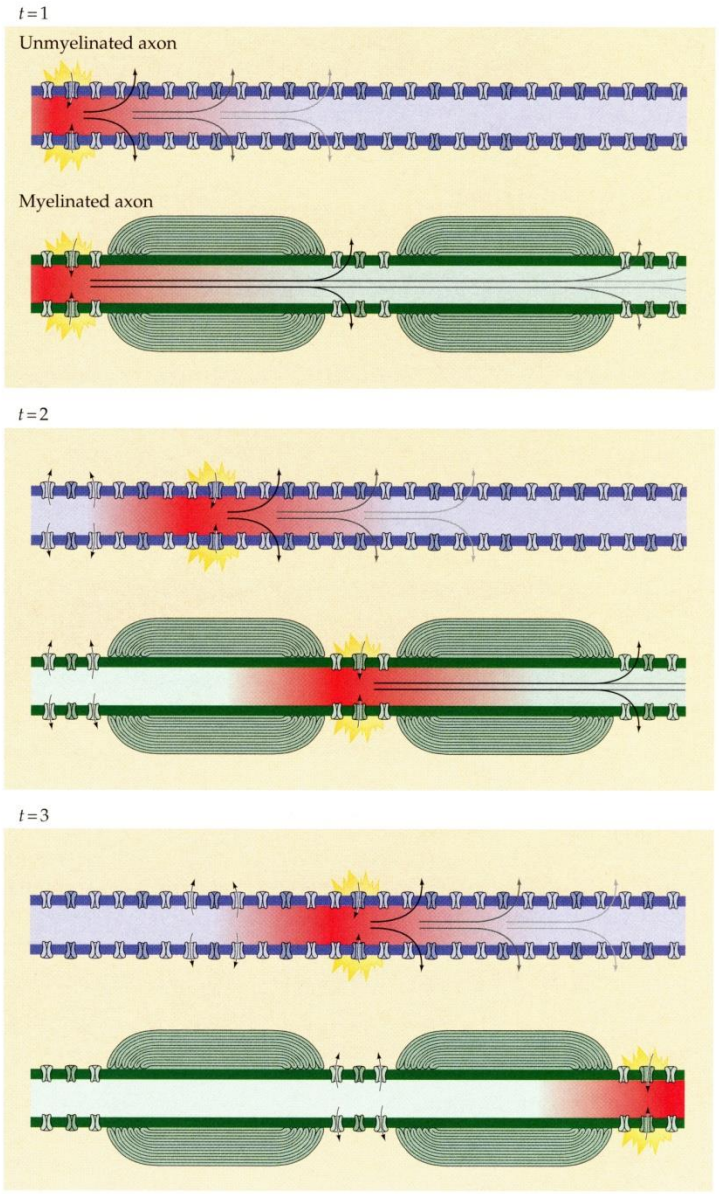


Oligodendrocytes are glial cells that exclusively provide axonal myelin sheaths in the central nervous system (CNS). Using a serial block face scanning EM, the three-dimensional morphology of a oligodendrocyte in the corpus callosum is visualized to understand the characteristics of a remyelinating oligodendrocyte. The mice were subject to a 12 week toxic demyelination, followed by a recovery period of 3 weeks. The segmented oligodendrocyte comes into direct contact with 14 myelinated (10 depicted in view) axons with the surrounding 21296.7µm3 of tissue. Myelin is depicted as transparent red, axons are yellow and the oligodendrocyte is purple. In the study we also evaluated metrics including; g-ratios, internodal lengths and axonal degeneration. -Renova Neural Inc.

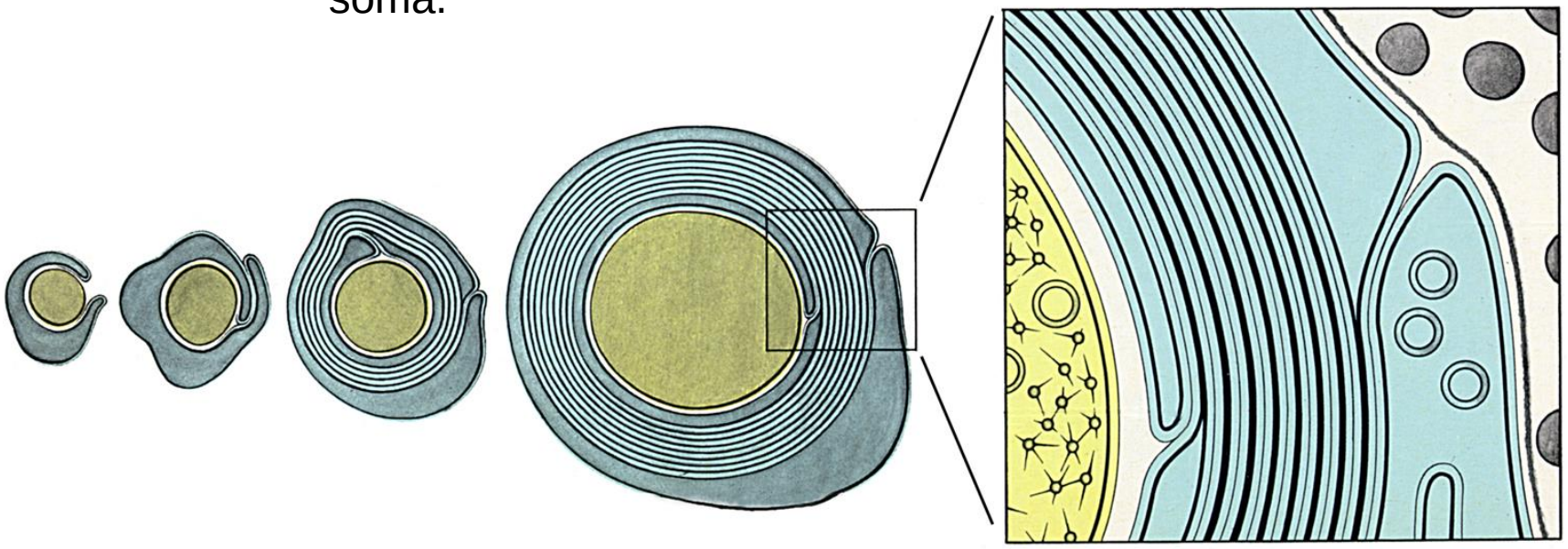
Myelin

- Myelin allows saltatory conduction or rapid advance of the action potential down the axon.



Development of Myelin

- Glial cells wrap around the axons, synthesize the molecules associated with myelin-type membrane, and exclude cytoplasm from all but the mesaxon and soma.



Development of Myelin

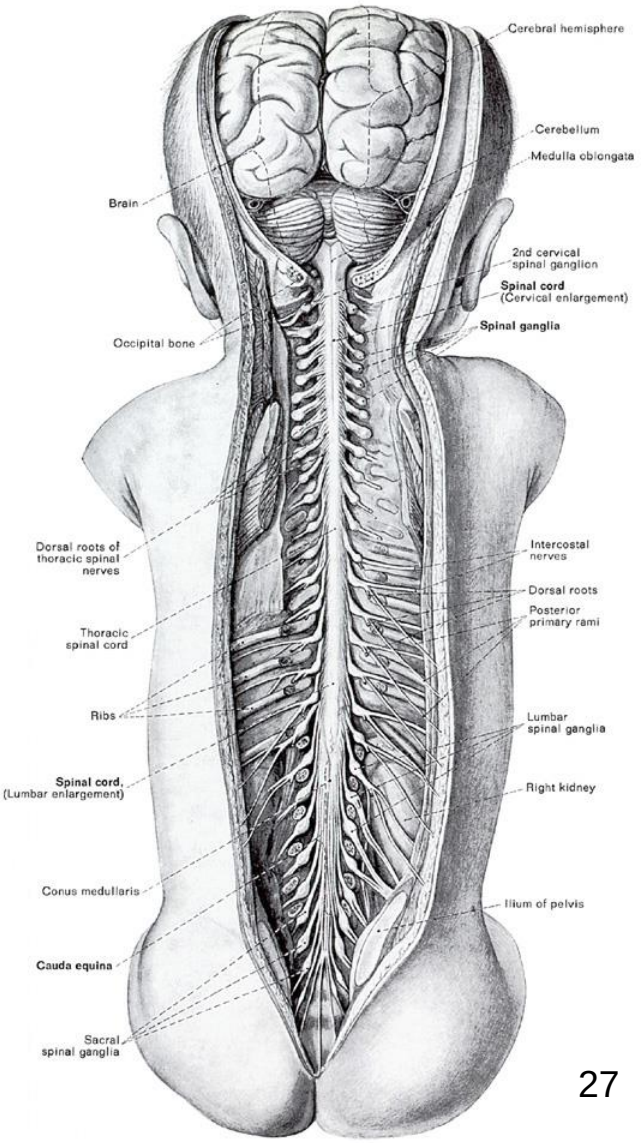
- Some tracts myelinate as early as 14wks of gestation; myelination continues until mid-adolescence.

- Babinski sign is present in newborns and disappears as pyramidal tract myelinates (4mos – 2yrs of age); also associated with upper motor neuron disease in adults.

- Many factors can delay myelination including poor nutrition.

Nervous System Organization

- Peripheral nervous system (PNS) includes nerves and ganglia.
  - Nerves are bundles of axons.
  - Nerves connect to the brain (cranial nerves) or to the spinal cord (spinal nerves).
  - Ganglia are collections of neuronal cell bodies.
- Central nervous system (CNS) includes the brain, spinal cord and retina.
  - Tracts are bundles of axons (white matter).
  - Neuronal cell bodies are in nuclei or layered structures (grey matter).



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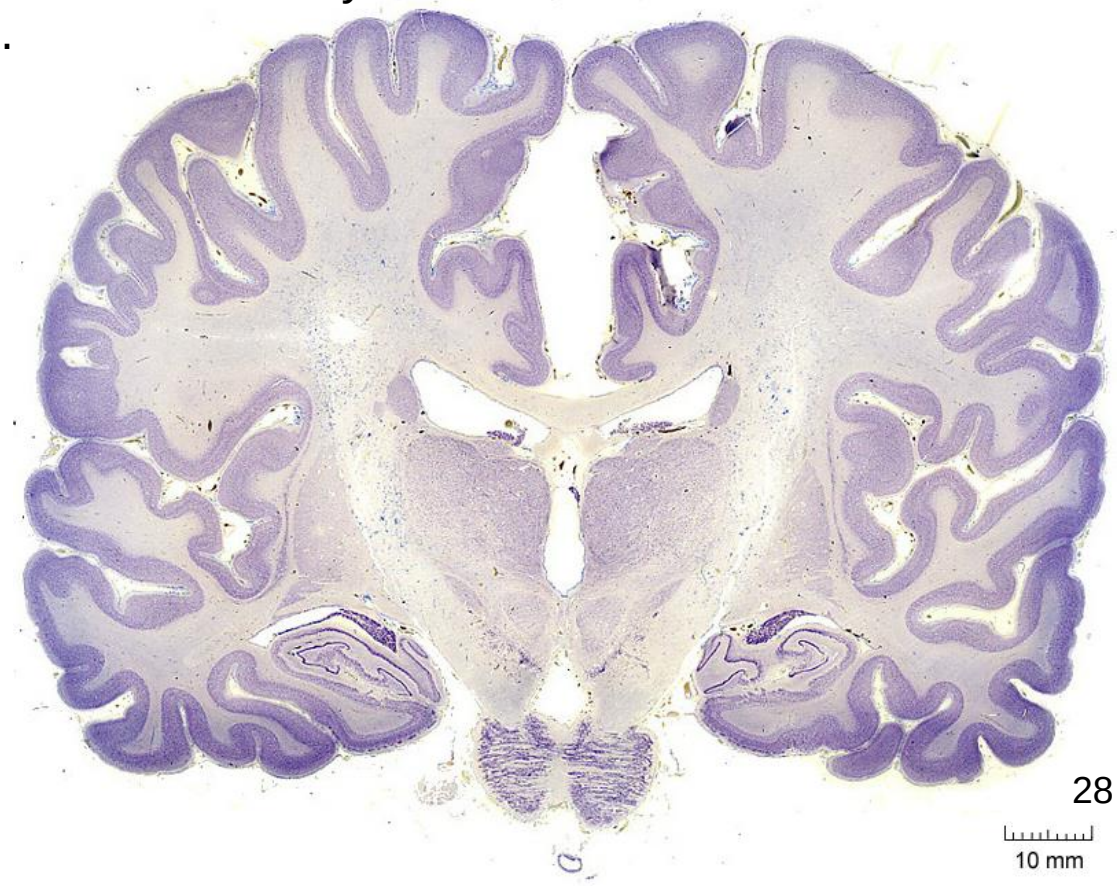
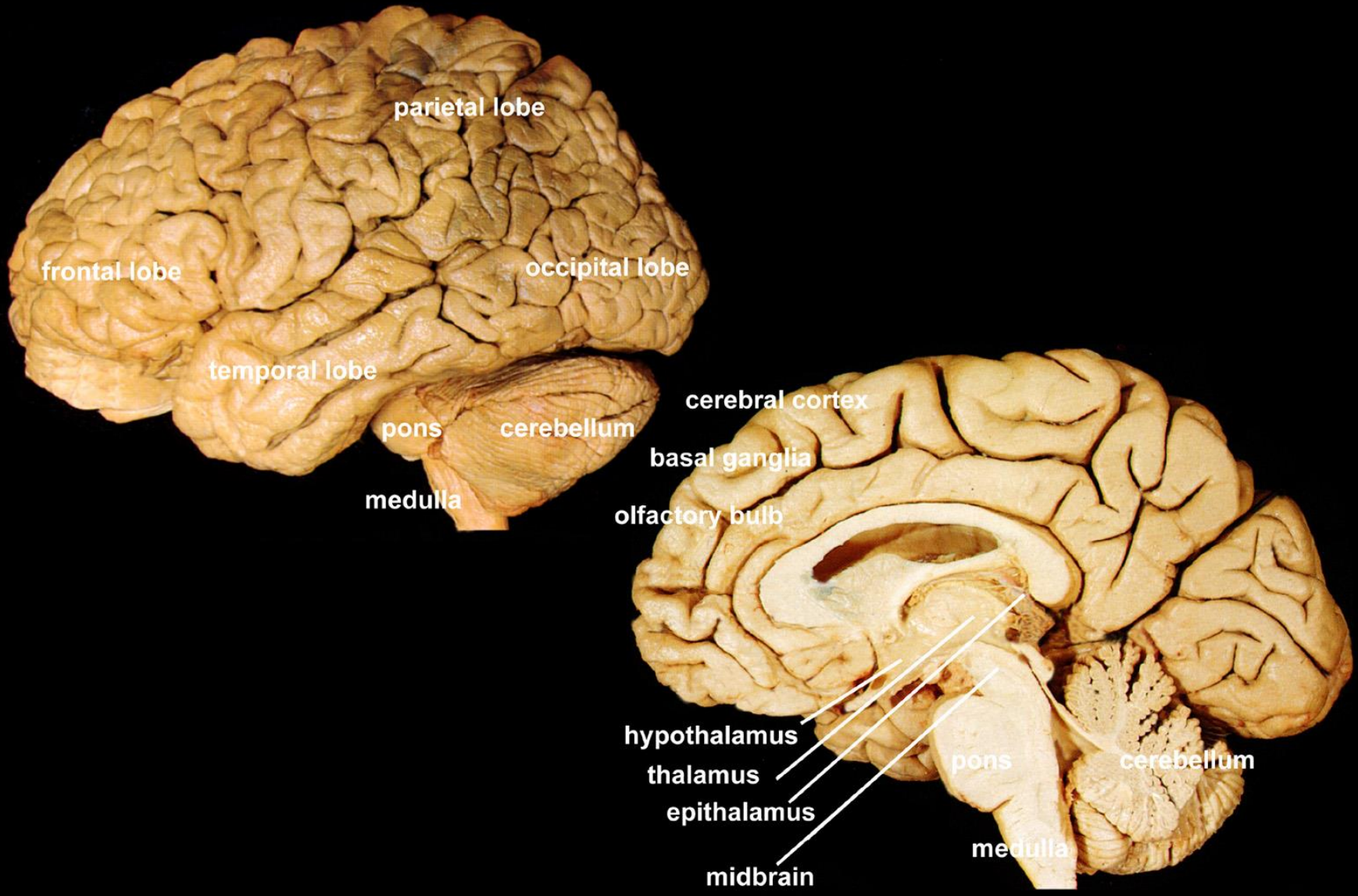
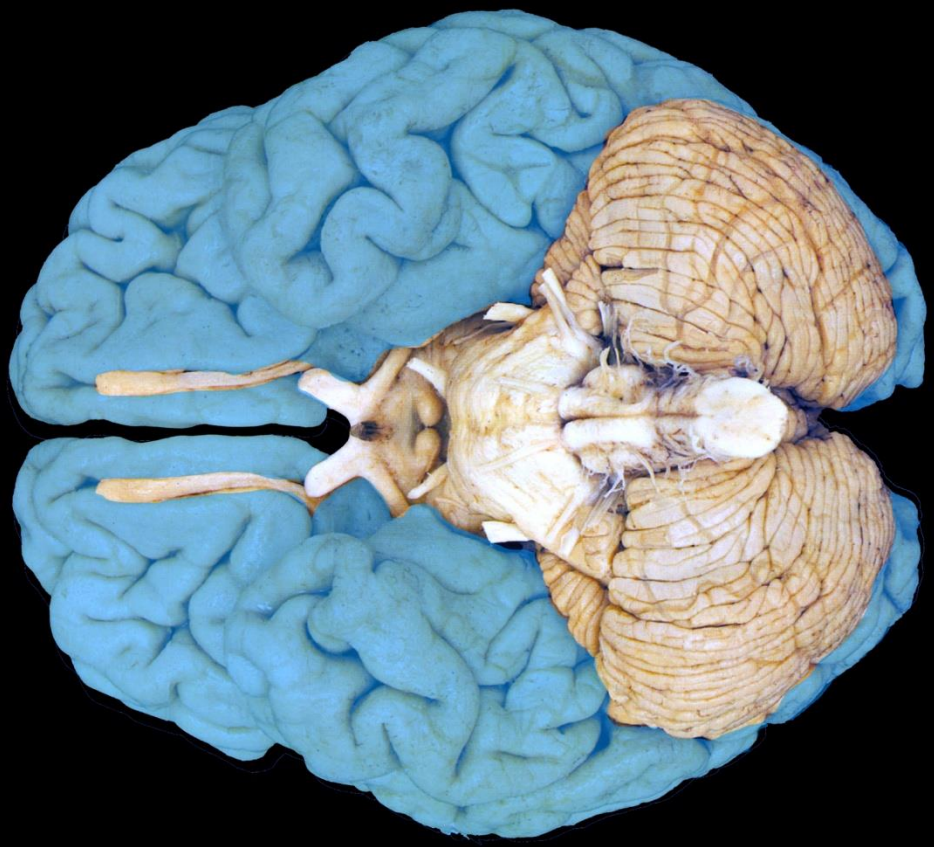


Major Brain Regions



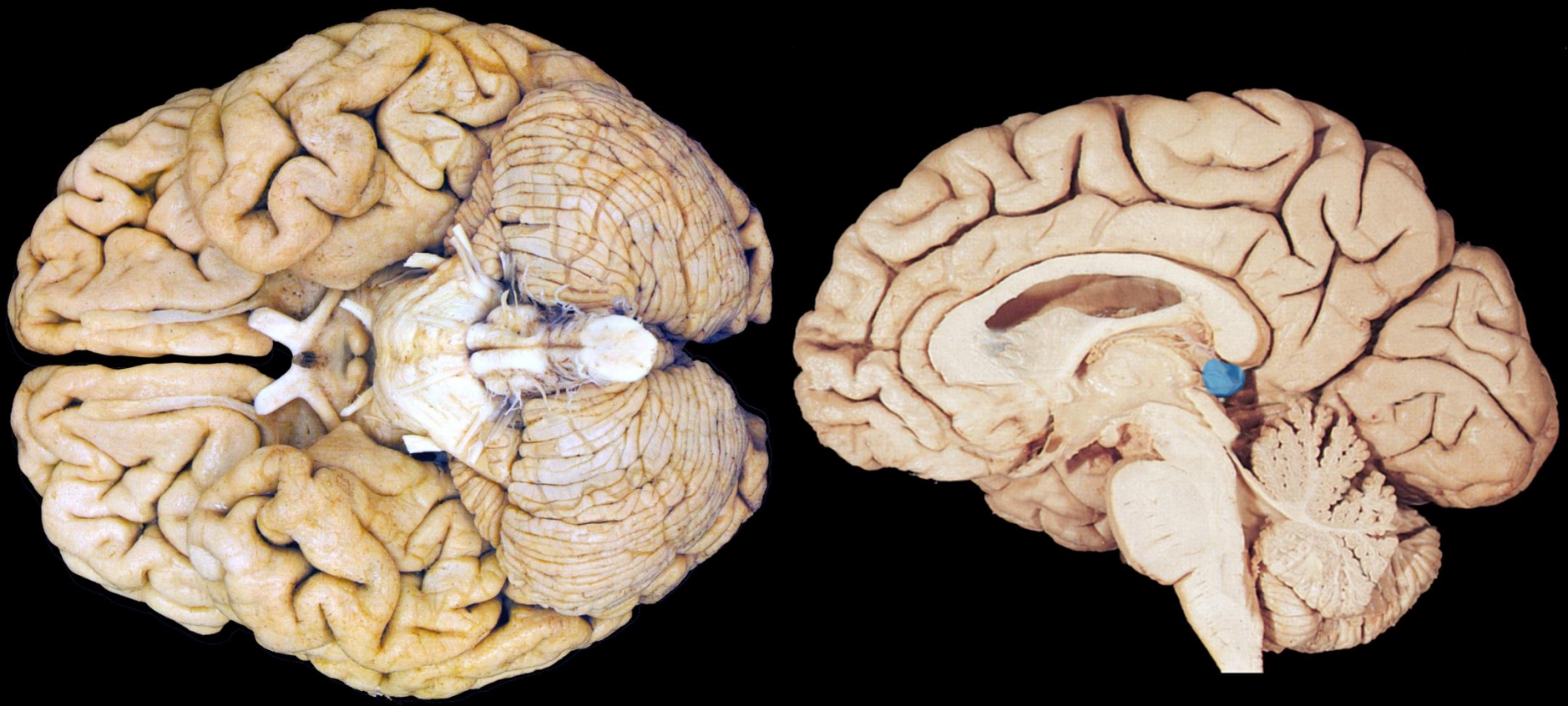
Cerebral Cortex



Hypothalamus

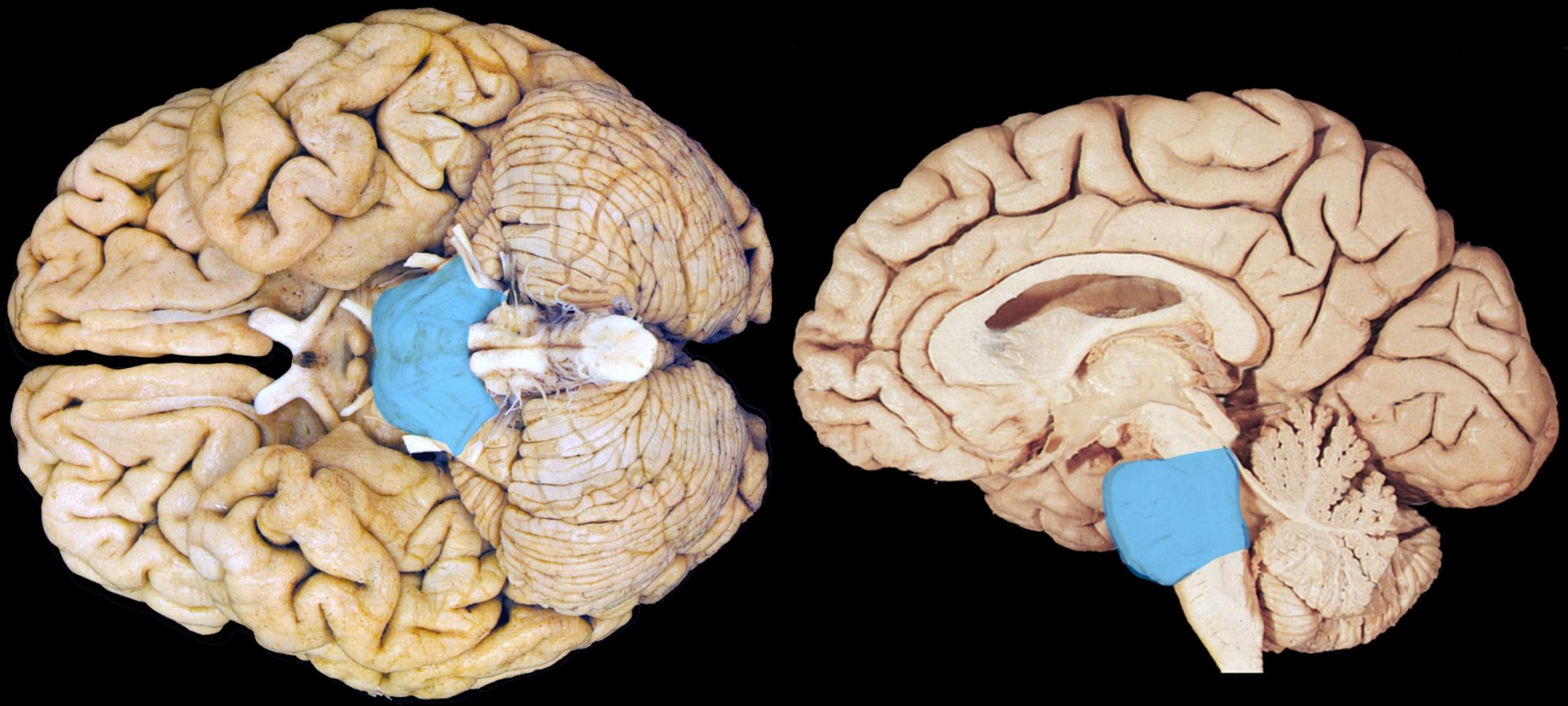
Thalamus

Pineal Body

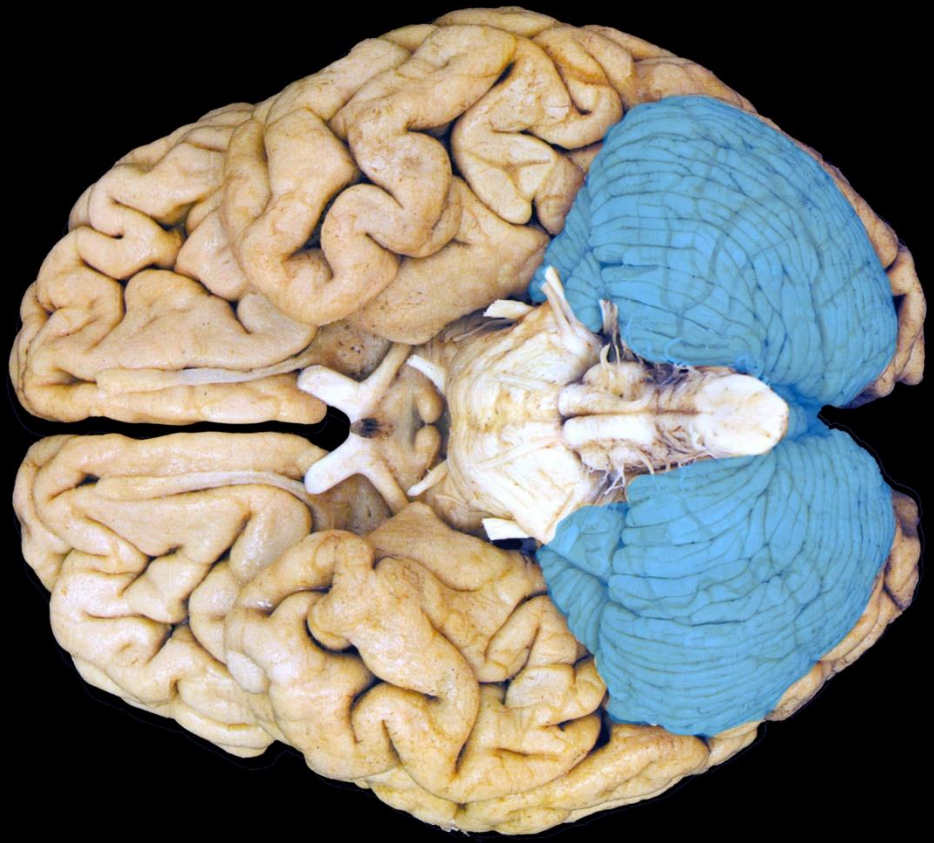


Midbrain

Pons



Cerebellum



Medulla

Spinal Cord