PSYCH 261 - Section 001 - Fall 2022

Physiological Psychology

Lecture 2

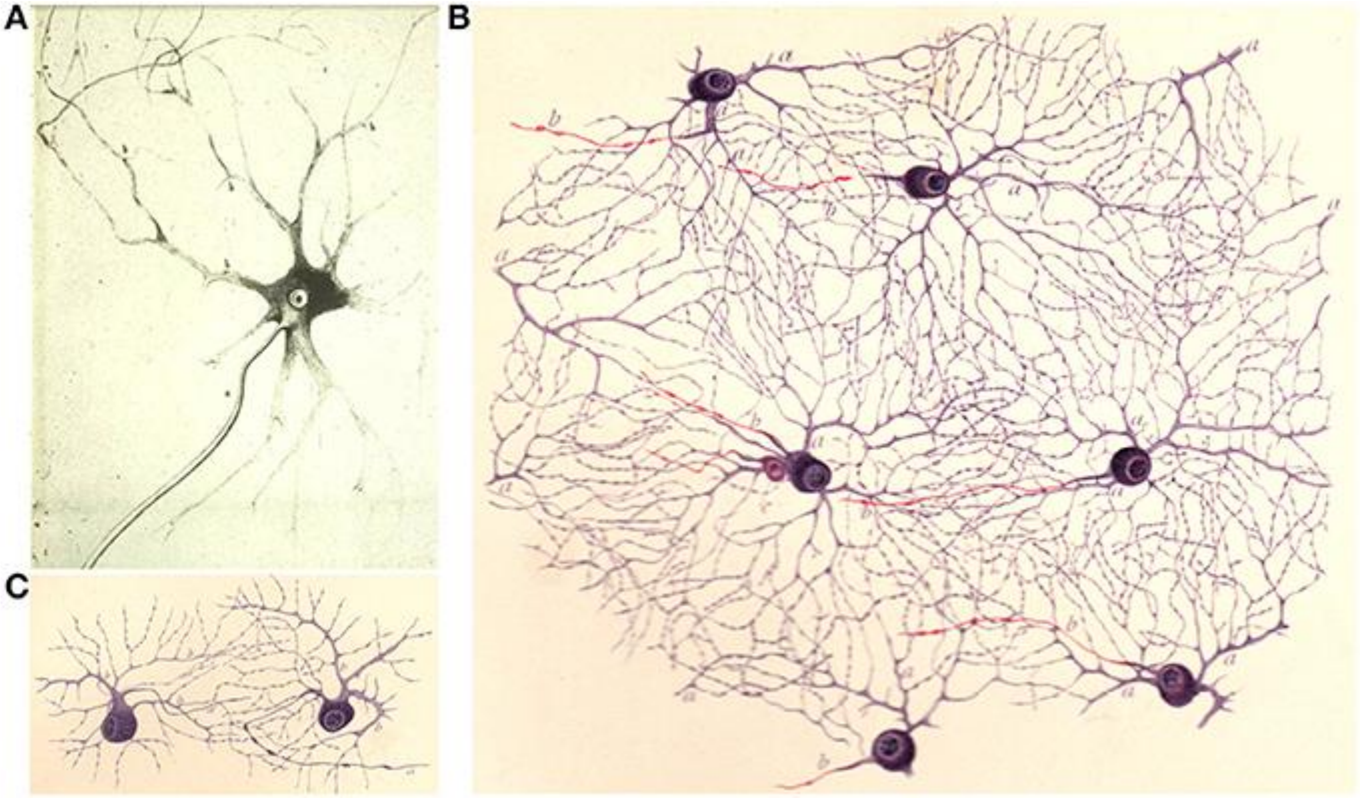
Neurons & Glia

Today's Agenda

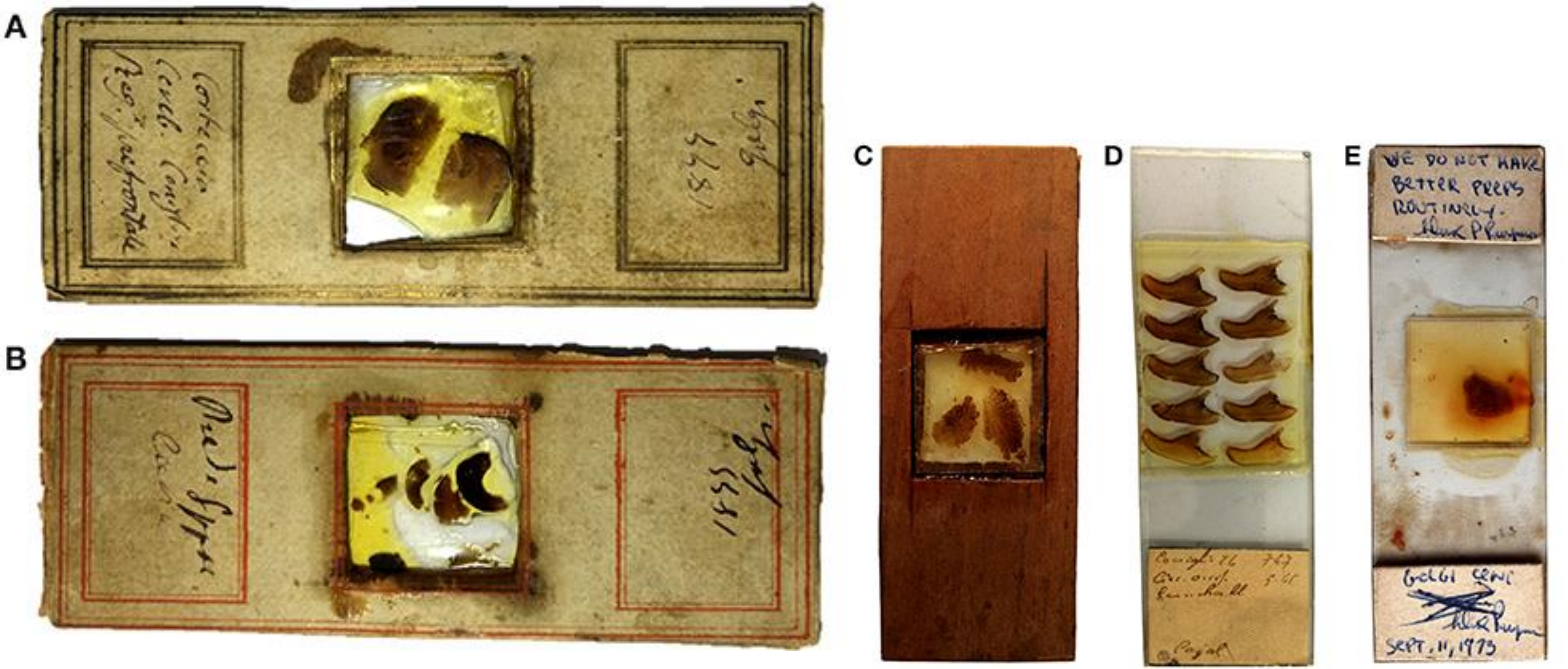
1) Cellular makeup of the brain
2) Neurons
   - Axons, dendrites, and more!
3) Glial cells
   - 6 different types!

Camillo Golgi

Golgi Method

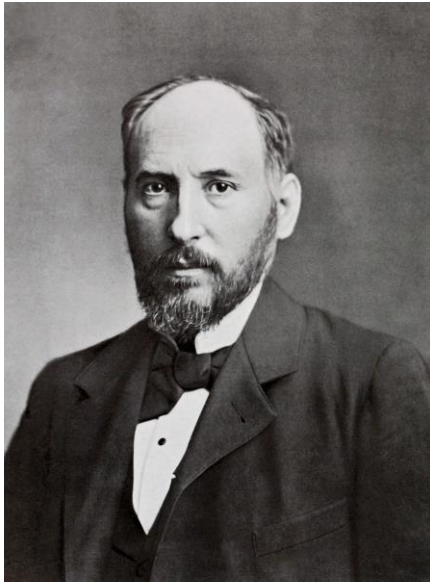


Golgi Method

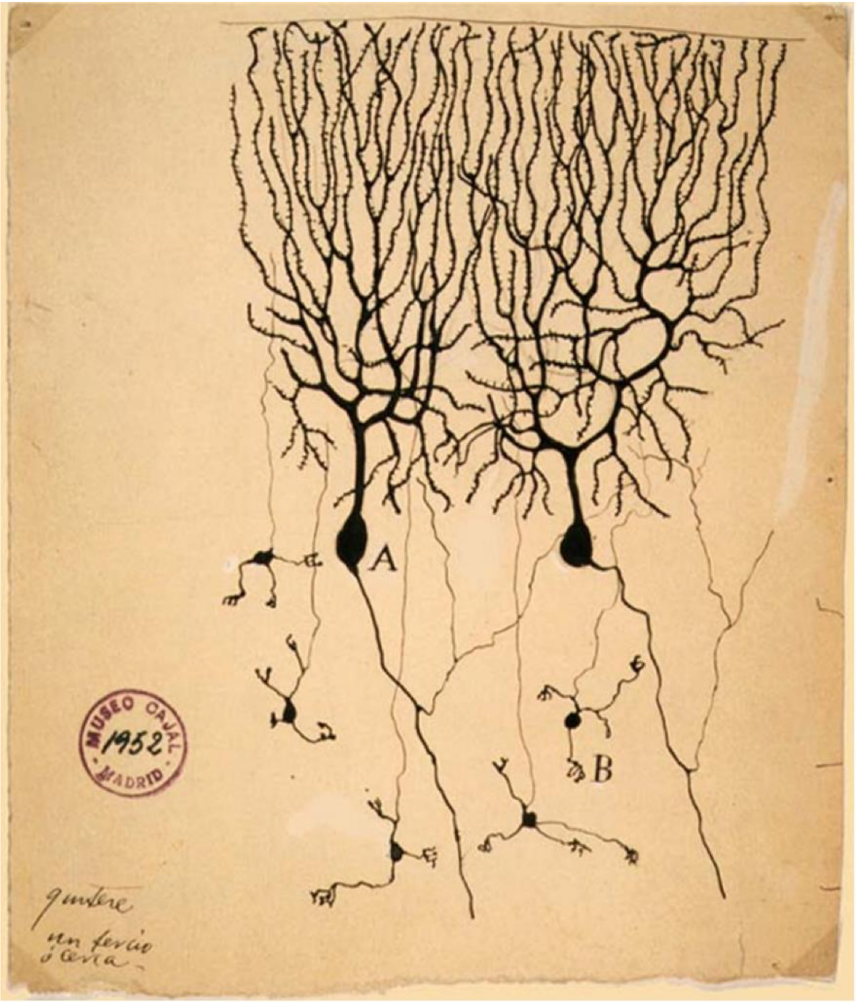


Santiago Ramon y Cajal

(1852-1934 CE)

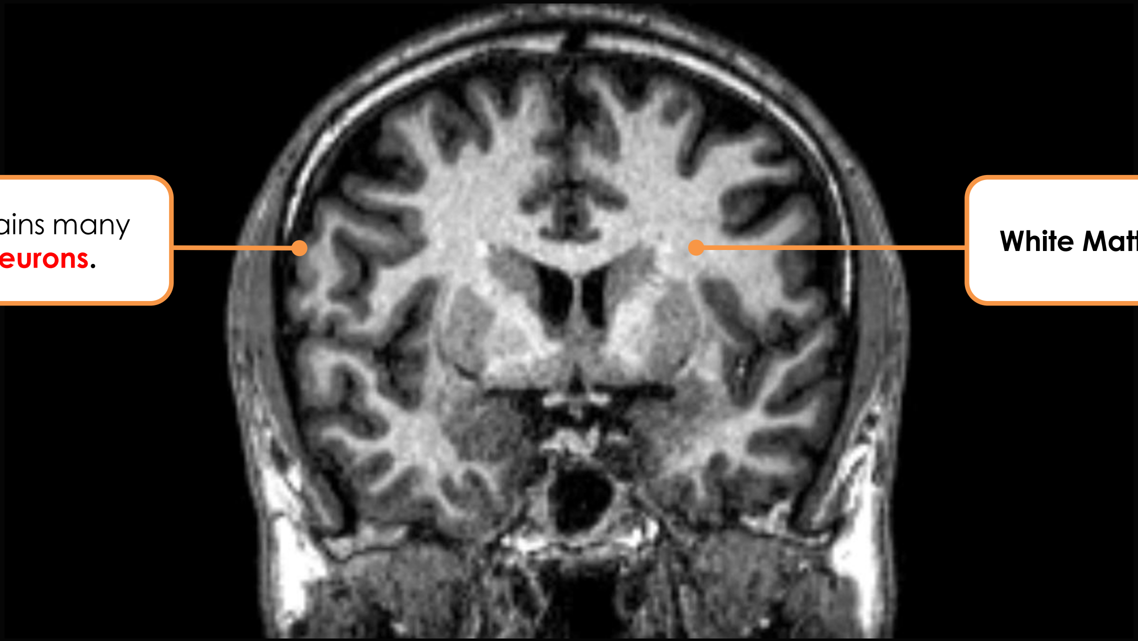


https://en.wikipedia.org/wiki/Santiago_Ram%C3%B3n_y_Cajal#/media/File:Cajal-Restored.jpg



commons.wikimedia.org/ wiki/File:PurkinjeCell.jpg

Types of Cells



Grey Matter contains many cell bodies of **neurons.**

White Matter contains many **glia.**

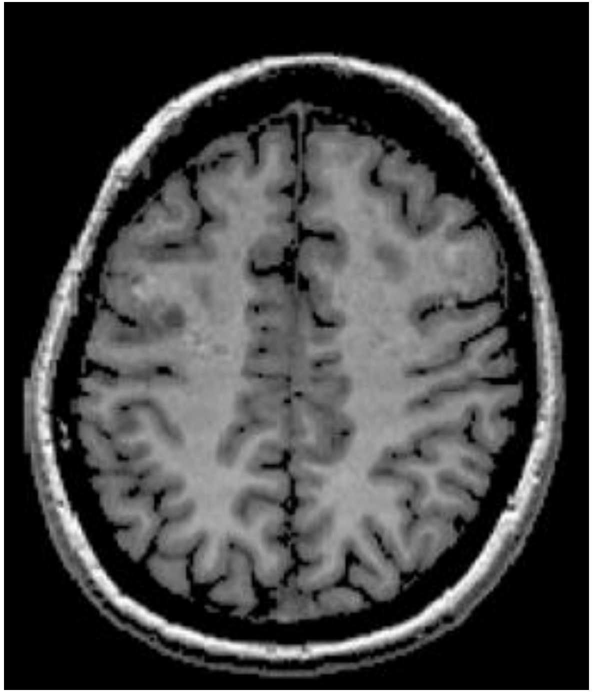
Types of Cells

Neurons

- Transmit electrical signals and are primary determinants of cognition and behaviour
- Many individual cells separated by small gaps
- "Gray matter"

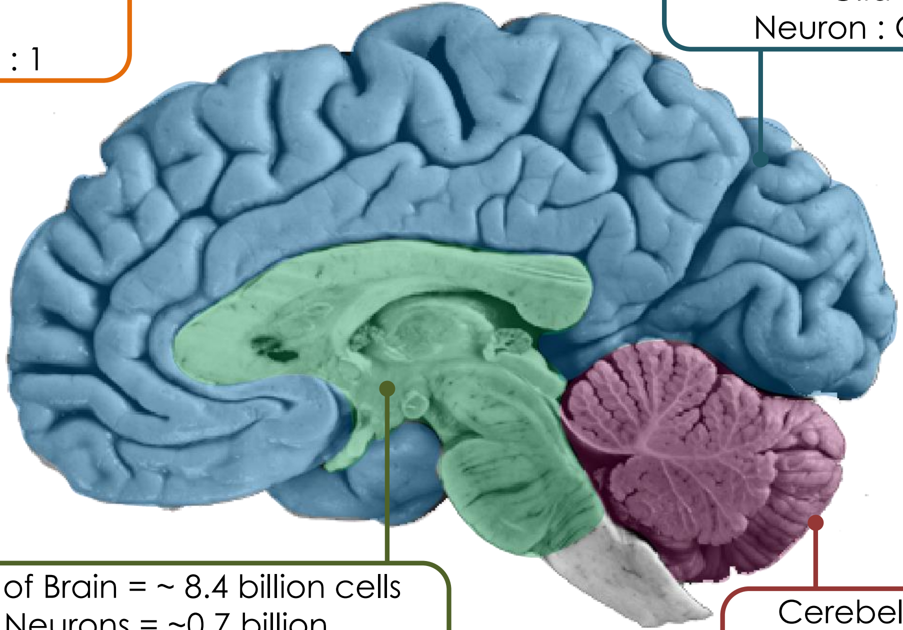
Glia

- Play a supportive role
- Different types in central and peripheral nervous system
- "White matter"



Whole Brain = ~170 billion cells
Neurons = ~86 billion
Glia = ~84 billion
Neuron : Glia ratio = ~ 1 : 1

Cerebral Cortex = ~77 billion cells
Neurons = ~16 billion
Glia = ~61 billion
Neuron : Glia ratio = ~1 : 4

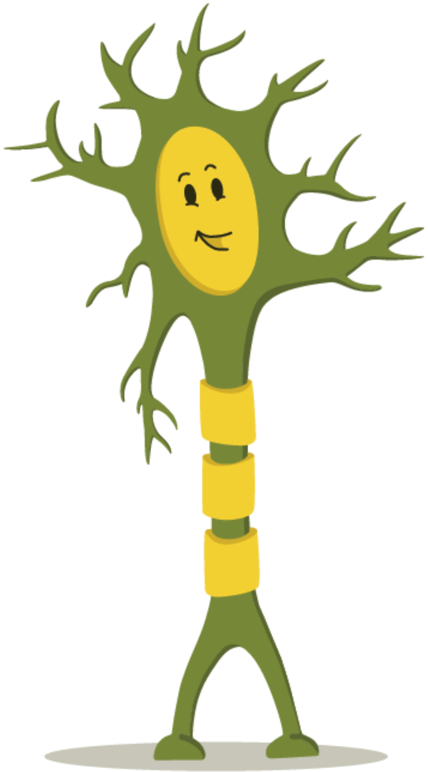


Rest of Brain = ~ 8.4 billion cells
Neurons = ~0.7 billion
Glia = ~7.7 billion
Neuron : Glia ratio = ~ 1 : 11

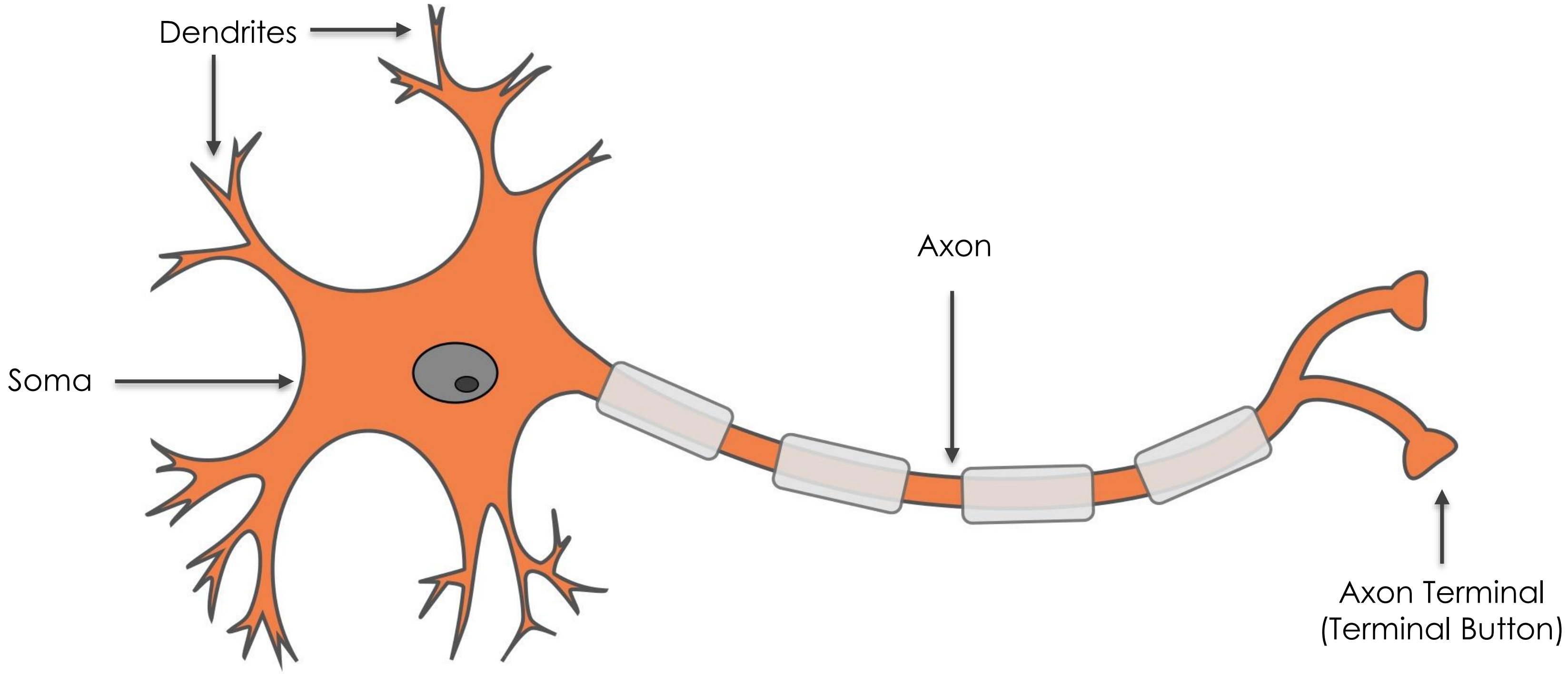
Cerebellum = ~ 85 billion cells
Neurons = ~69 billion
Glia = ~16 billion
Neuron : Glia ratio = ~4 : 1

Azevedo, F. A. C., Carvalho, L. R. B., Grinberg, L. T., Farfel, J. M., Ferretti, R. E. L., Leite, R. E. P., Filho, W. J., Lent, R., & Herculano-Houzel, S. (2009). Equal numbers of neuronal and nonneuronal cells make the human brain an isometrically scaled-up primate brain. *Journal of Comparative Neurology*, *513*(5), 532–541. Figure 2, p. 536.

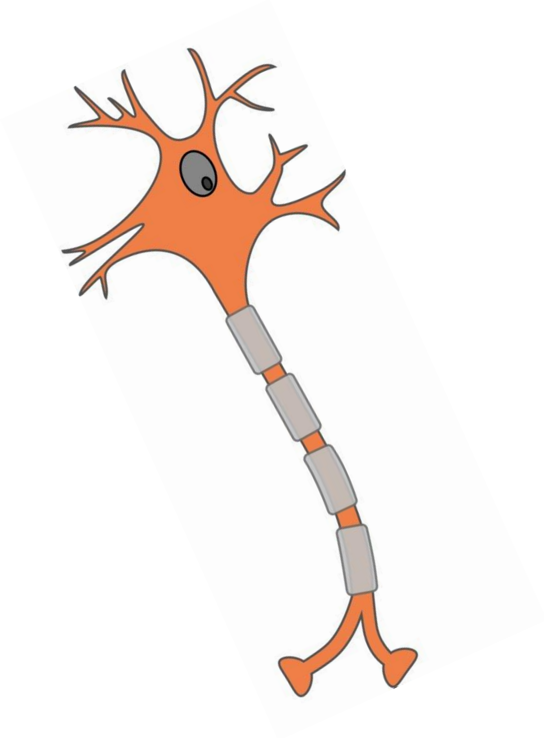
Neurons



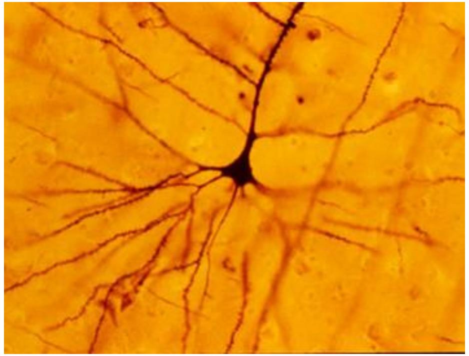
The Neuron



Multipolar Neuron

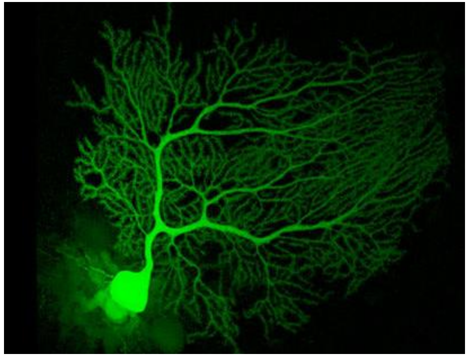


Pyramidal Neuron



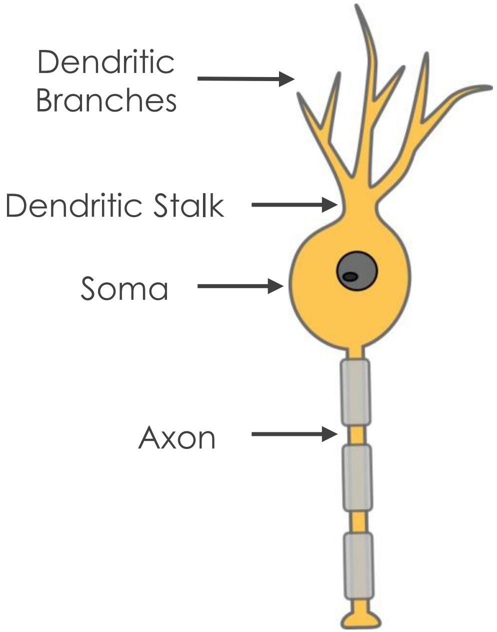
http://commons.wikimedia.org/wiki/File:GolgiStainedPyramidalCell.jpg

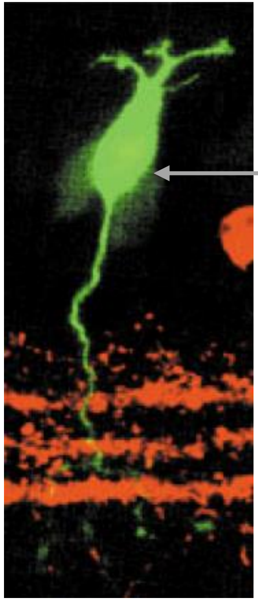
Purkinje Neuron



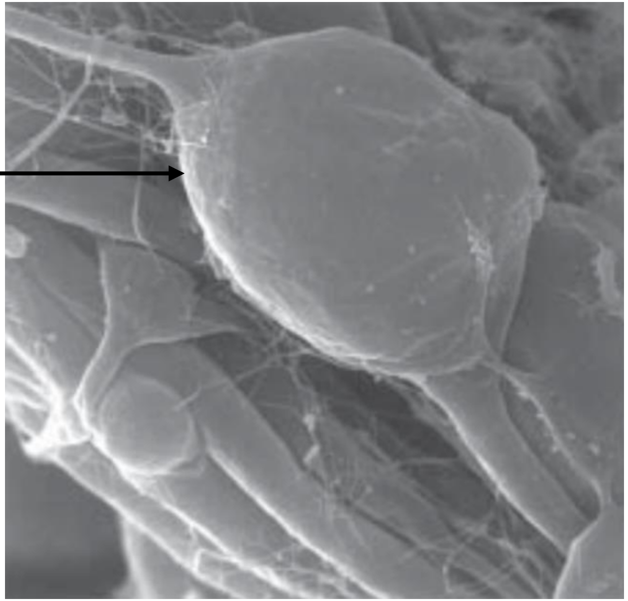
http://commons.wikimedia.org/wiki/File:3_recon_512x512.jpg

Bipolar Neuron



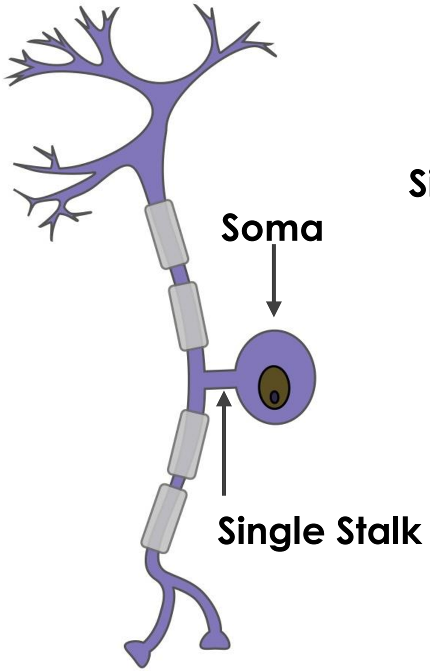


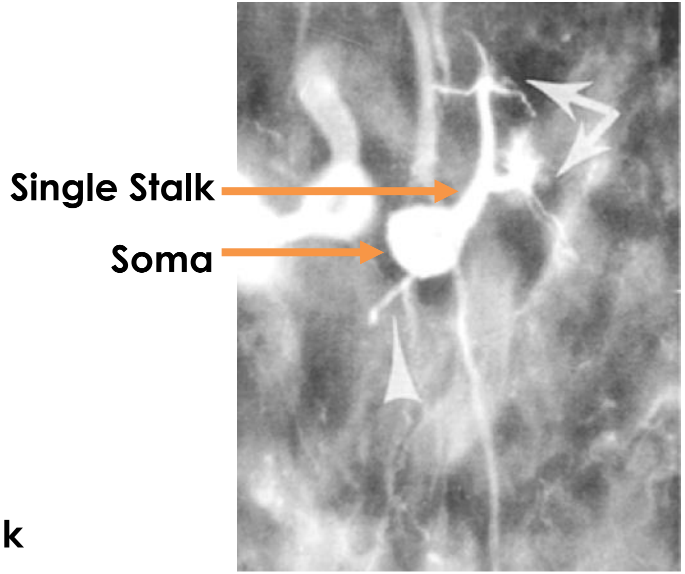
Ghosh, K. K., Bujan, S., Haverkamp, S., Feigenspan, A., & Wässle, H. (2004). Types of bipolar cells in the mouse retina. Journal of Comparative Neurology, 469(1), 70-82. Figure 2B and Figure 3.



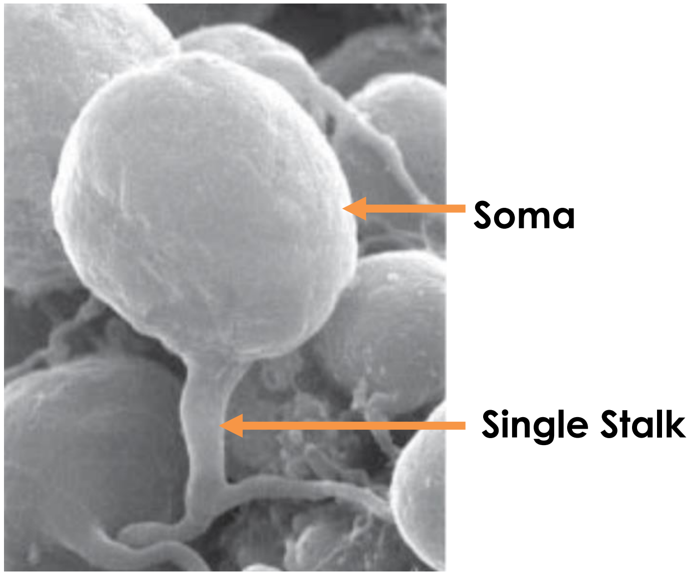
Matsuda, S., Kobayashi, N., Wakisaka, H., Saito, S., Saito, K., Miyawaki, K., ... & Fujiwara, T. (2000). Morphological transformation of sensory ganglion neurons and satellite cells. *Biomedical Reviews*, *11*, 39-52. Figure 1h, p. 41.

Unipolar Neuron



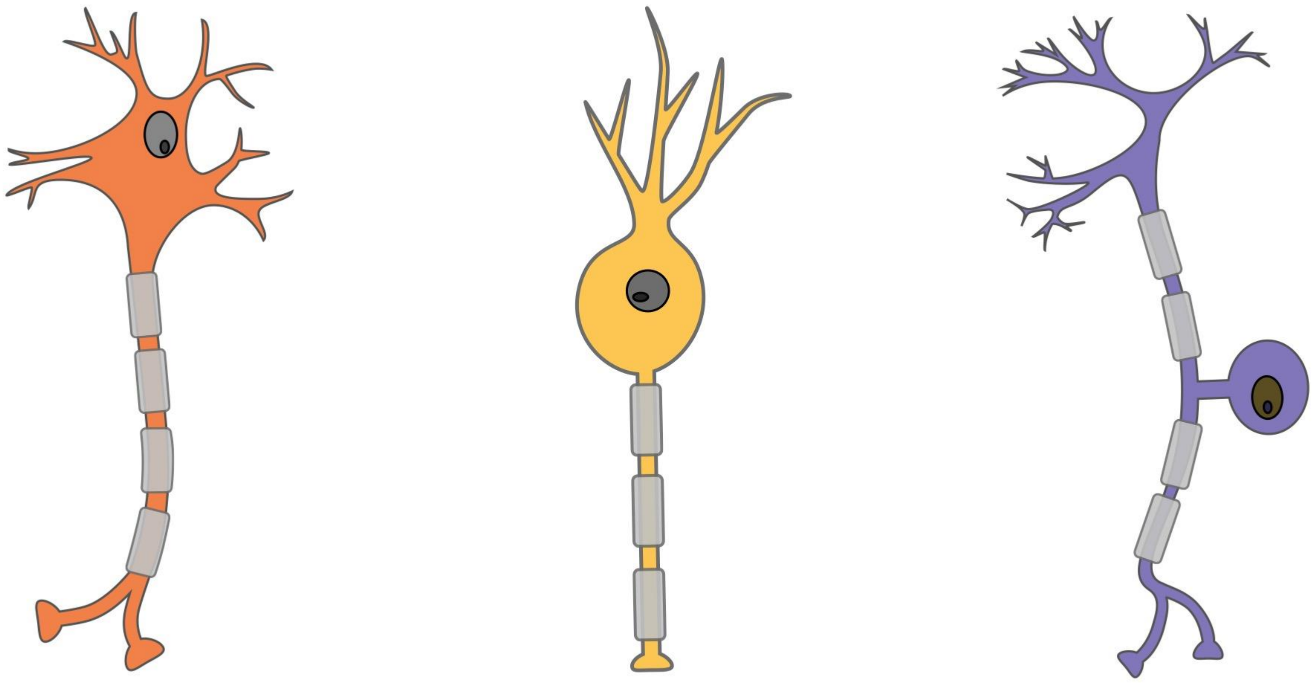


Harris, J., Moreno, S., Shaw, G., & Mugnaini, E. (1993). Unusual neurofilament composition in cerebellar unipolar brush neurons. Journal of Neurocytology, 22(12), 1039-1059. Figures 1 and 3.



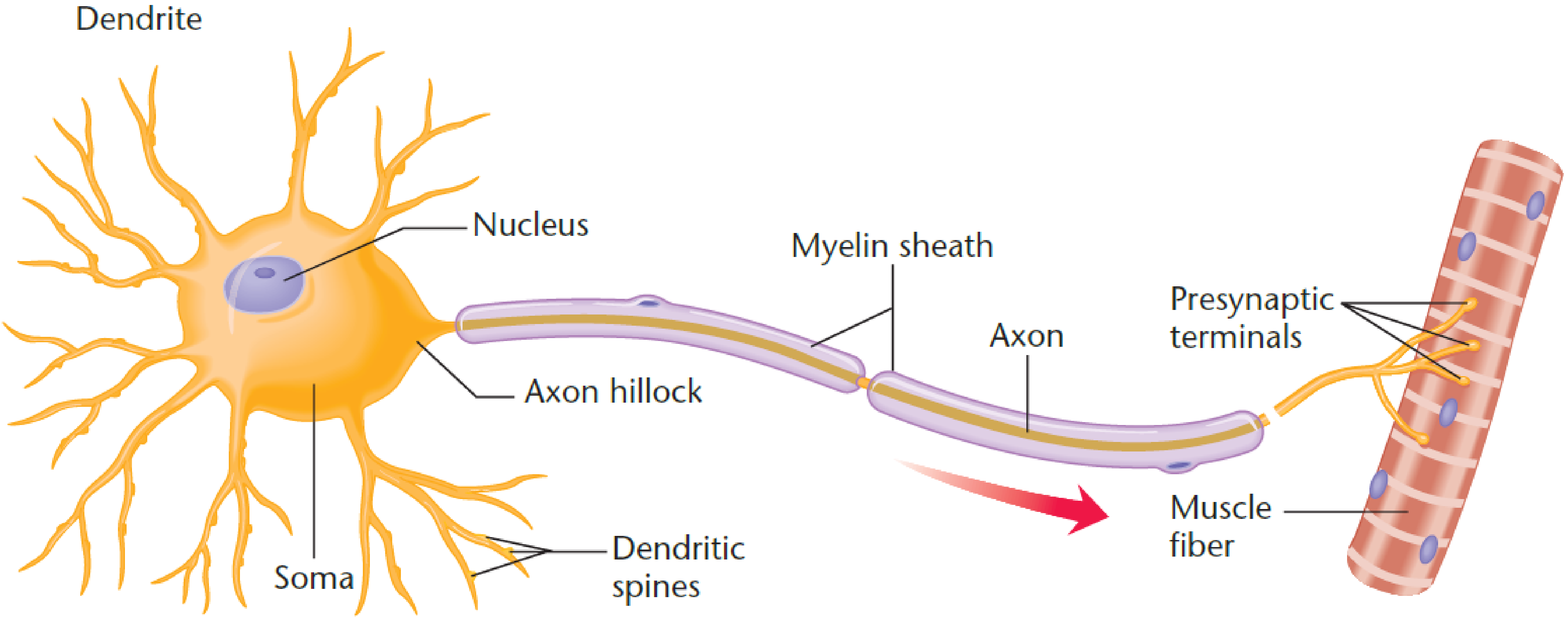
Matsuda, S., Kobayashi, N., Wakisaka, H., Saito, S., Saito, K., Miyawaki, K., ... & Fujiwara, T. (2000). Morphological transformation of sensory ganglion neurons and satellite cells. *Biomedical Reviews*, *11*, 39-52. Figure 1h, p. 41.

Neuron Functions

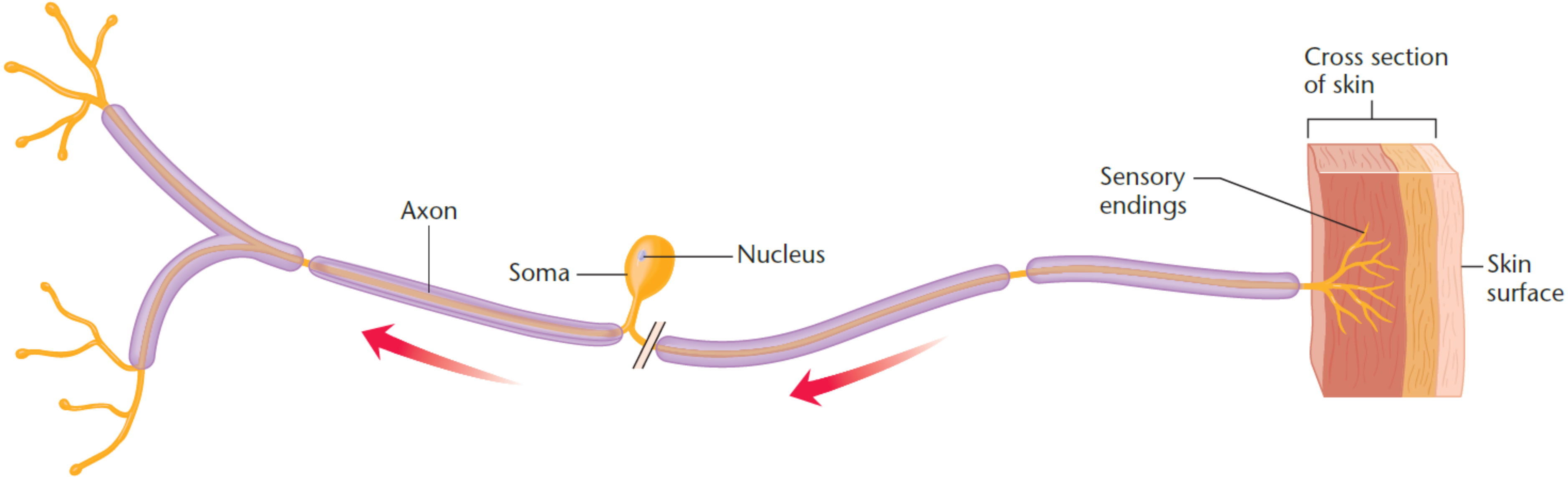


Motor Interneuron Sensory

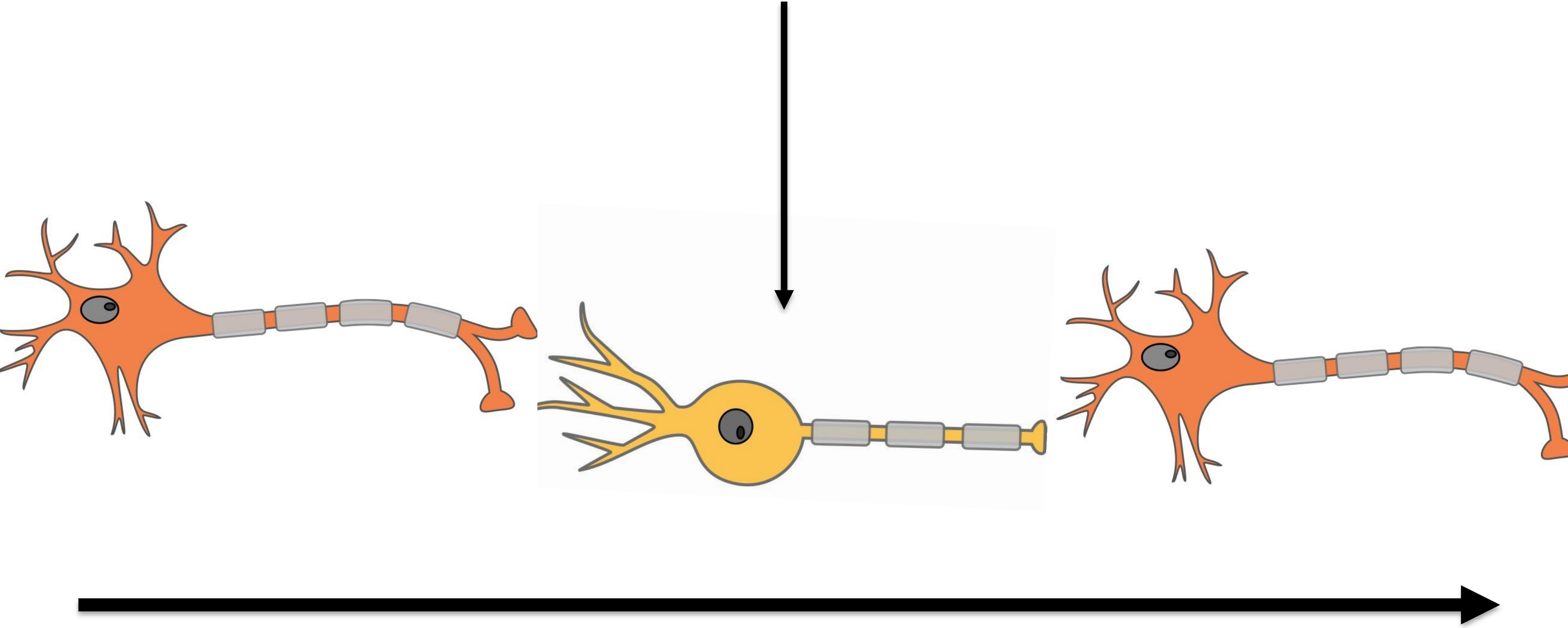
Motor Neurons



Sensory Neurons

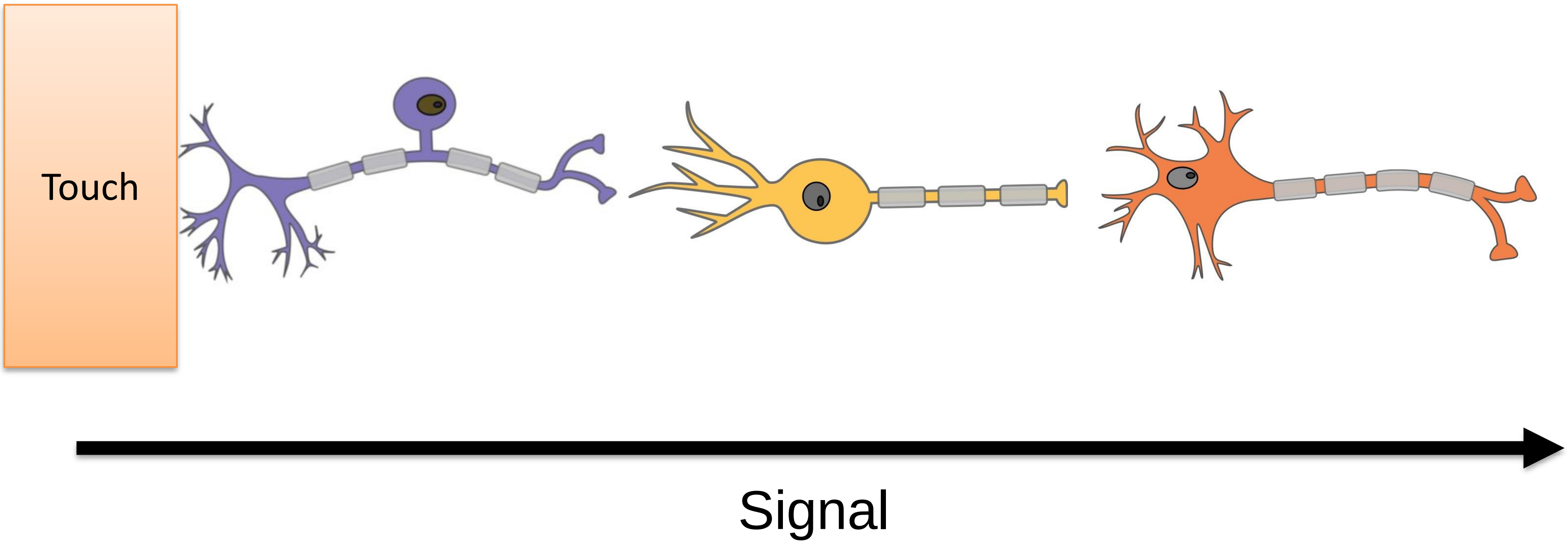


Interneurons

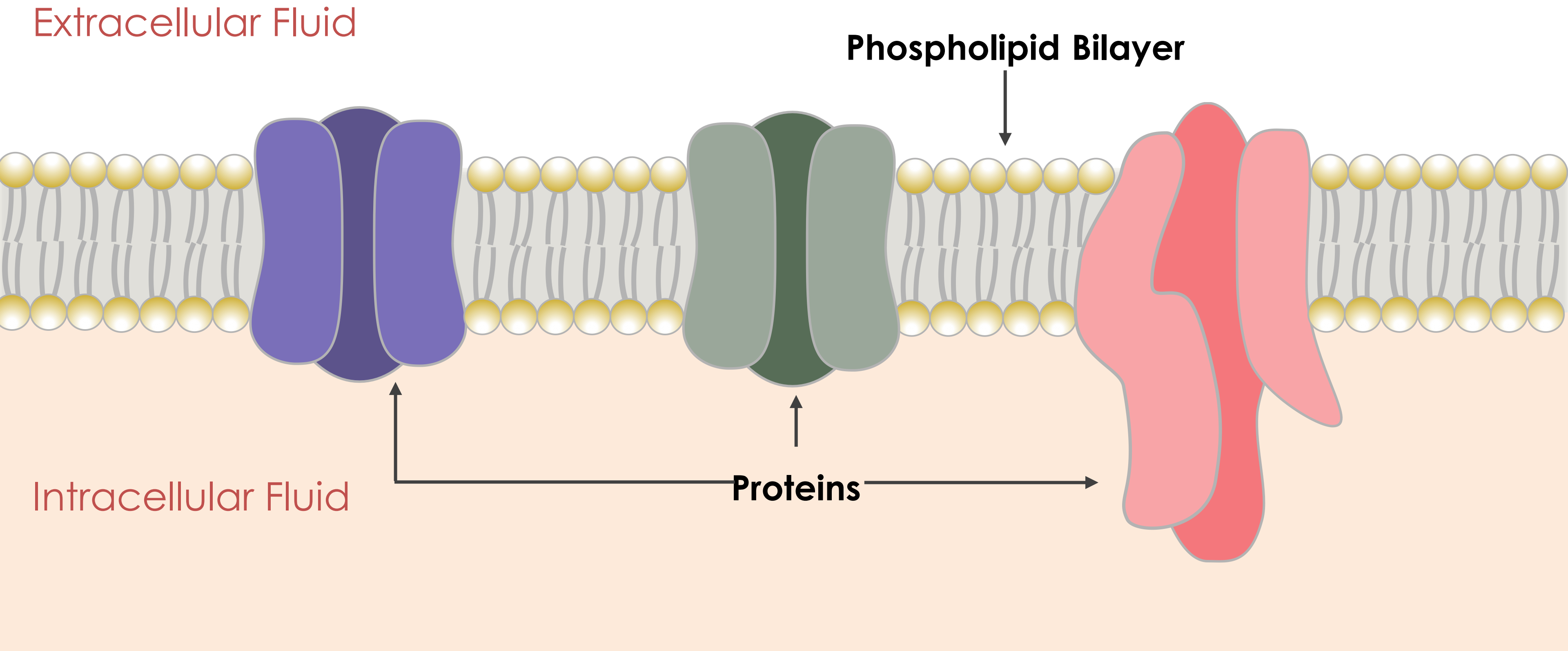


Signal

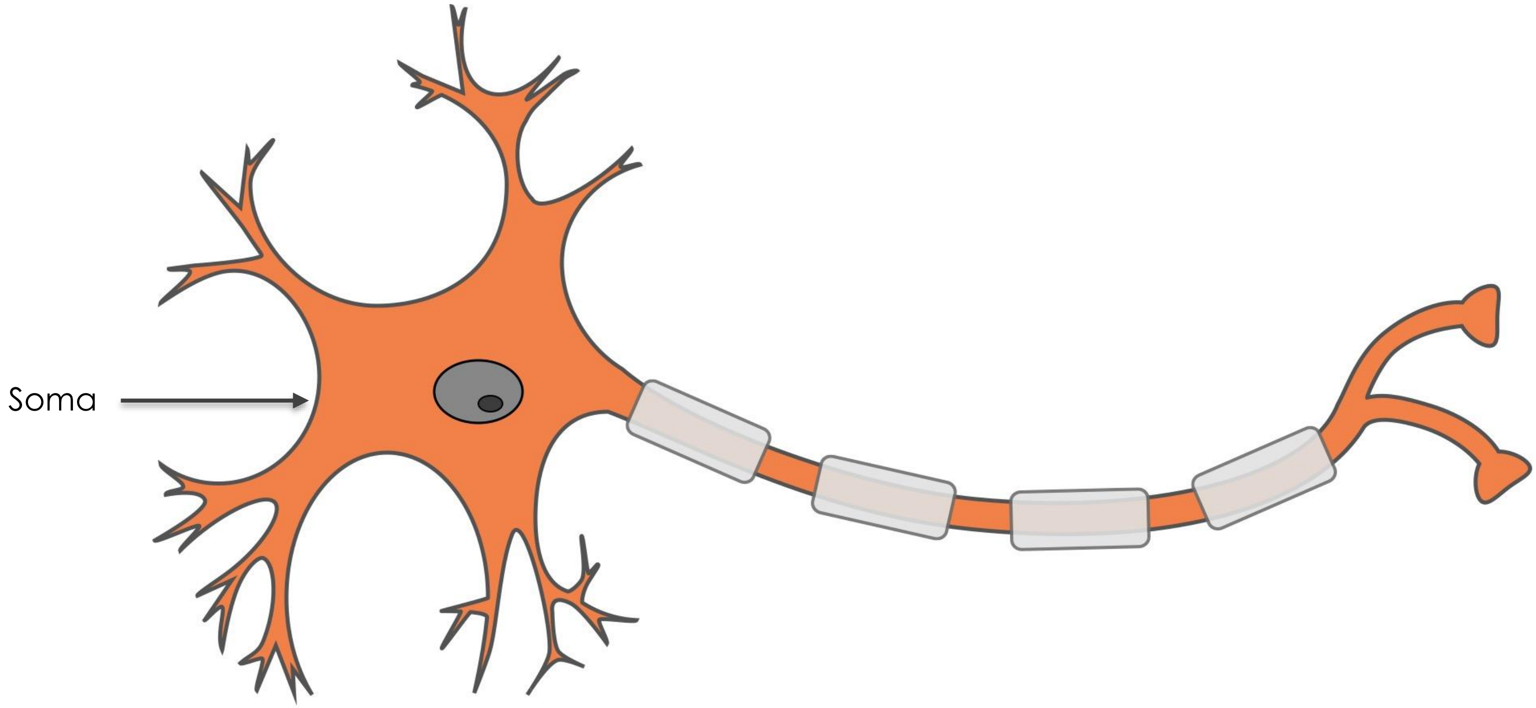
Example: Reflexes

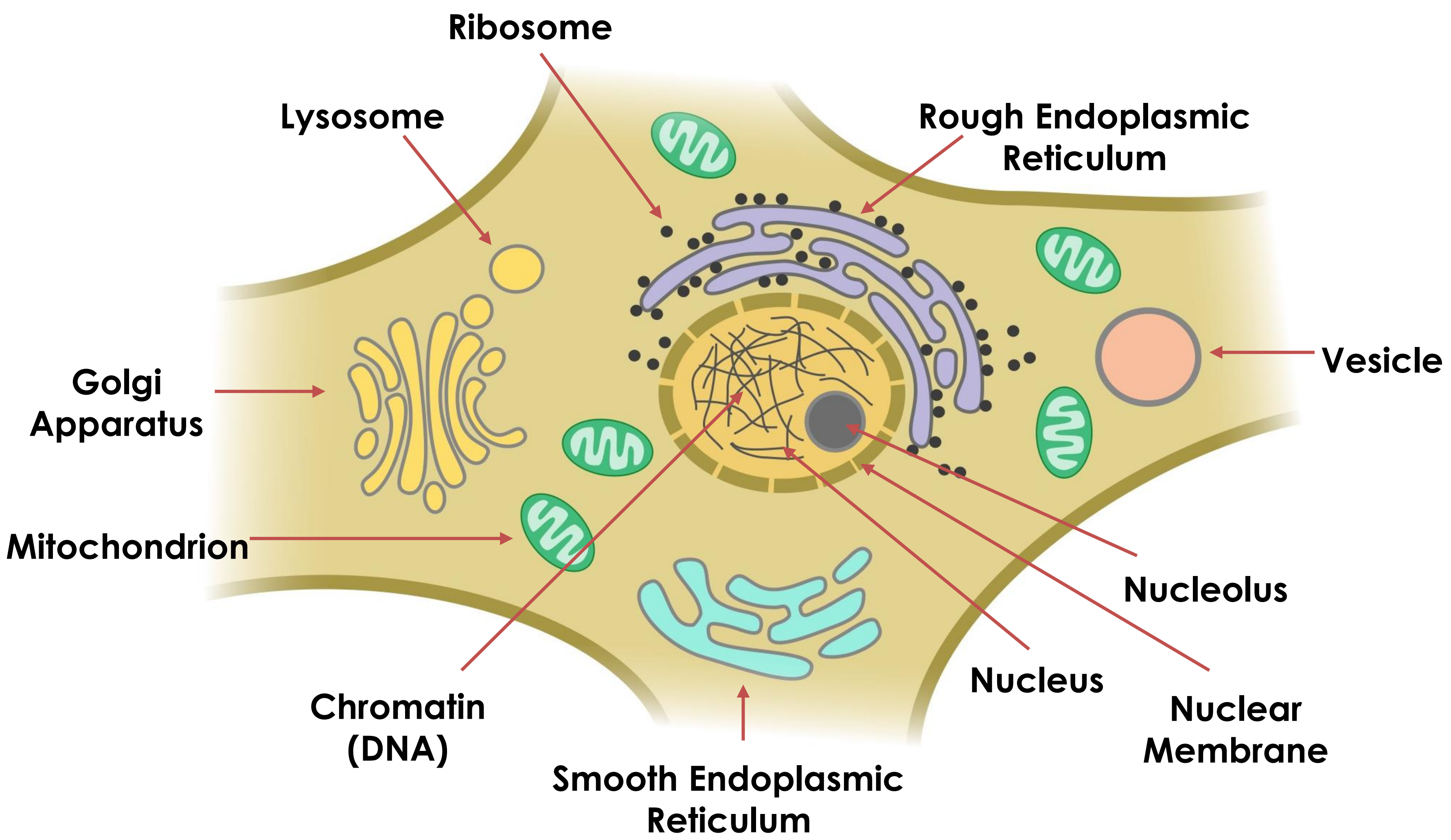


The Semipermeable Membrane

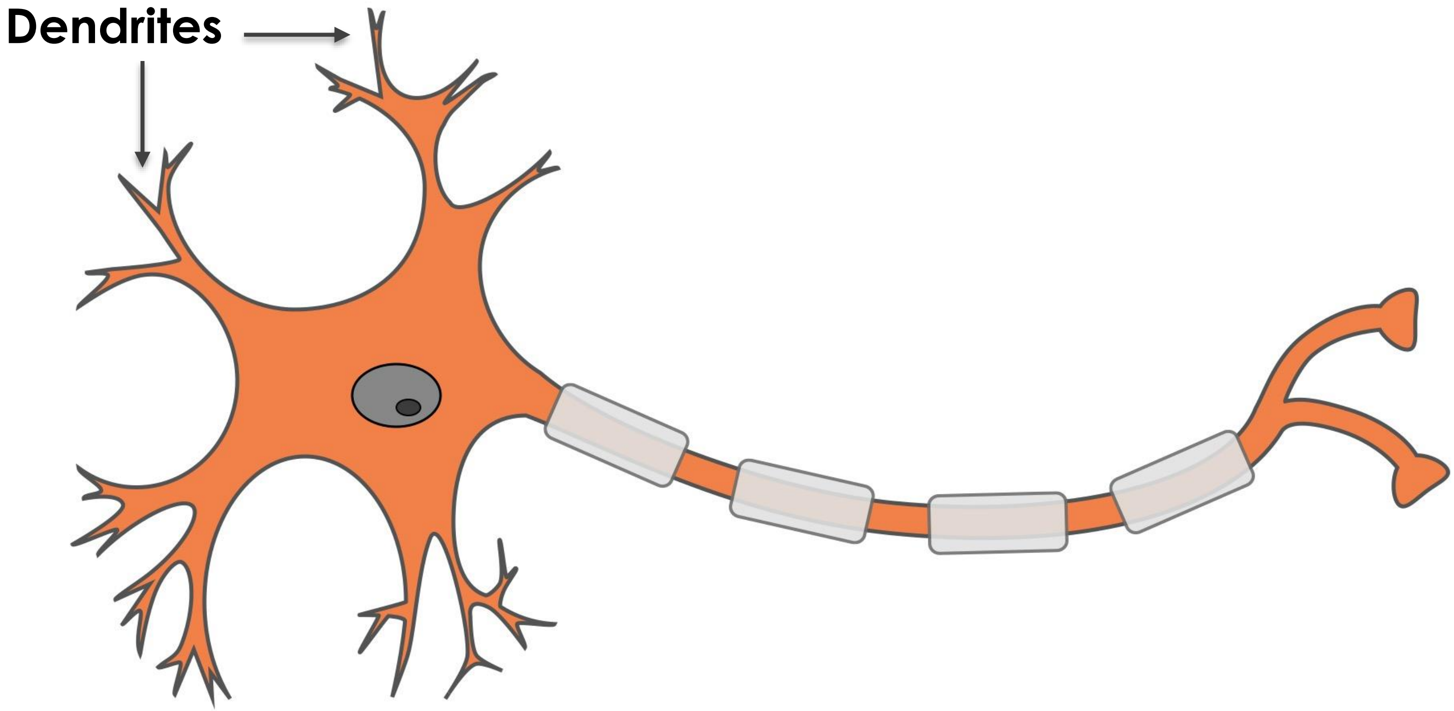


The Soma

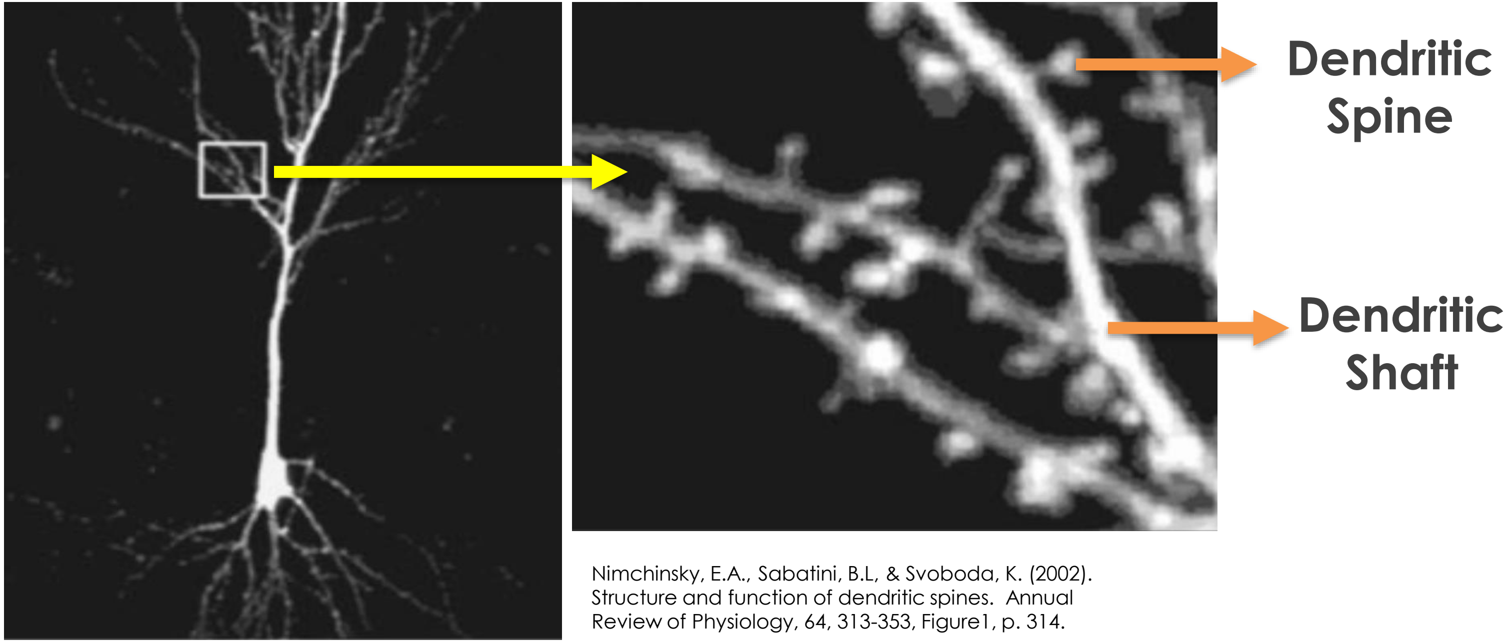



Ribosome
Lysosome
Rough Endoplasmic Reticulum
Golgi Apparatus
Vesicle
Mitochondrion
Nucleolus
Chromatin (DNA)
Nucleus
Nuclear Membrane
Smooth Endoplasmic Reticulum

The Dendrites



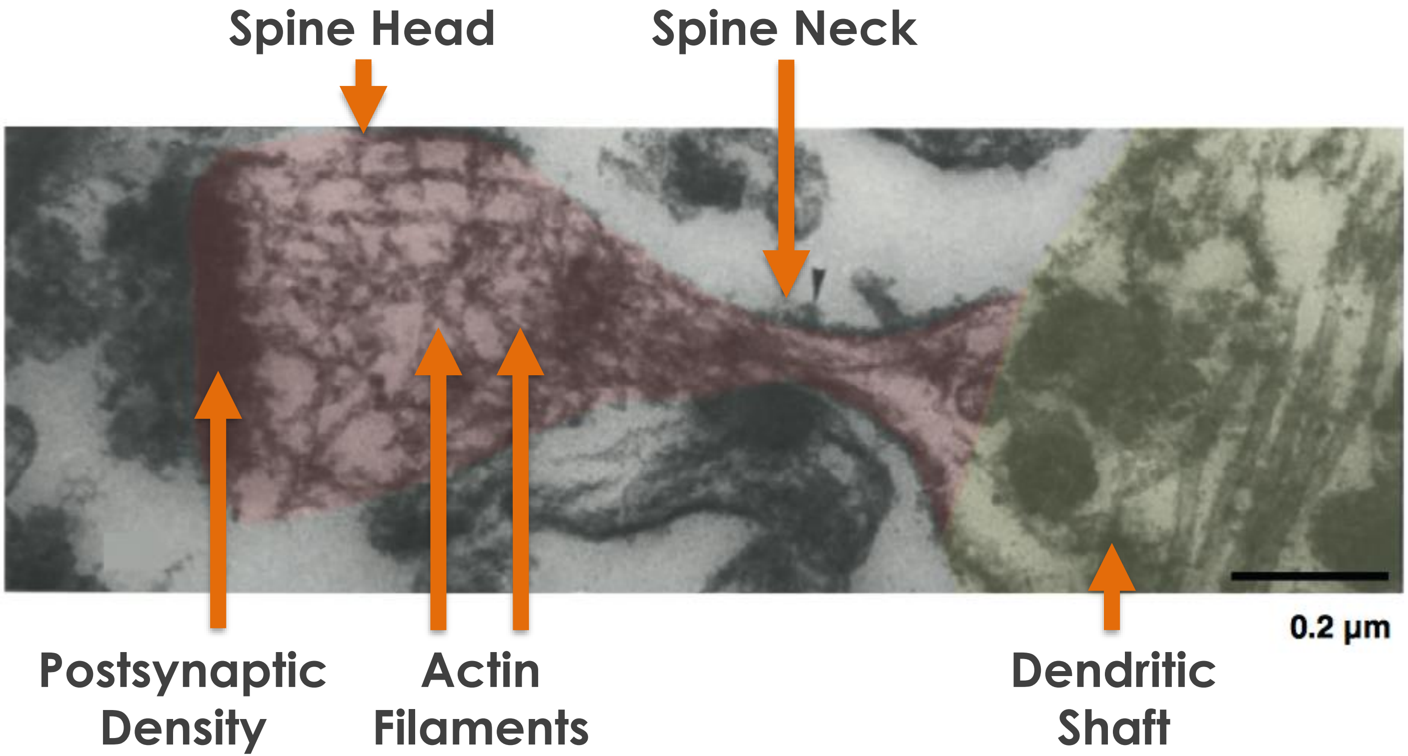
Dendritic Spines



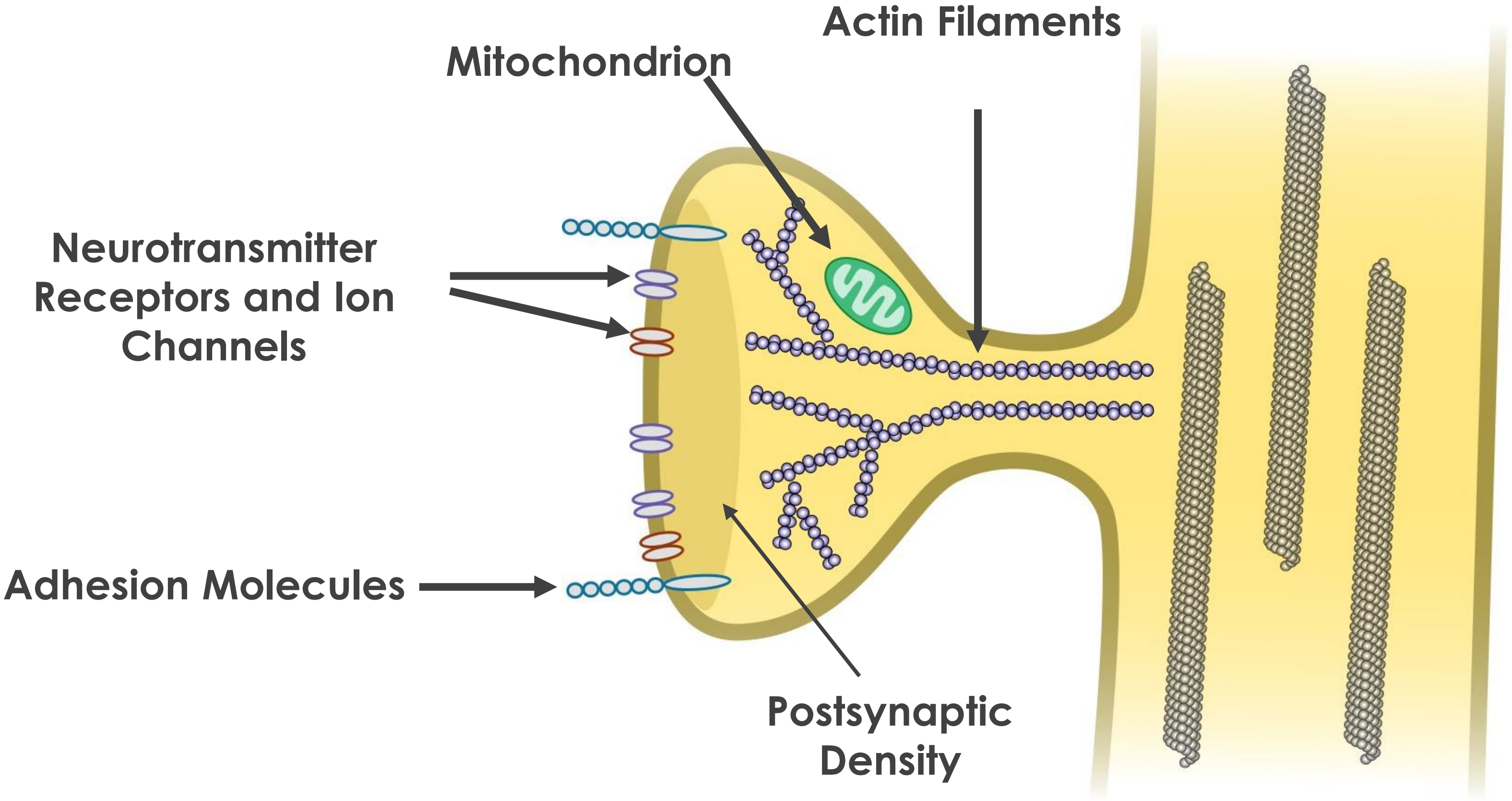
Nimchinsky, E.A., Sabatini, B.L, & Svoboda, K. (2002). Structure and function of dendritic spines. Annual Review of Physiology, 64, 313-353, Figure1, p. 314.

Hippocampal Neuron

Dendritic Spines

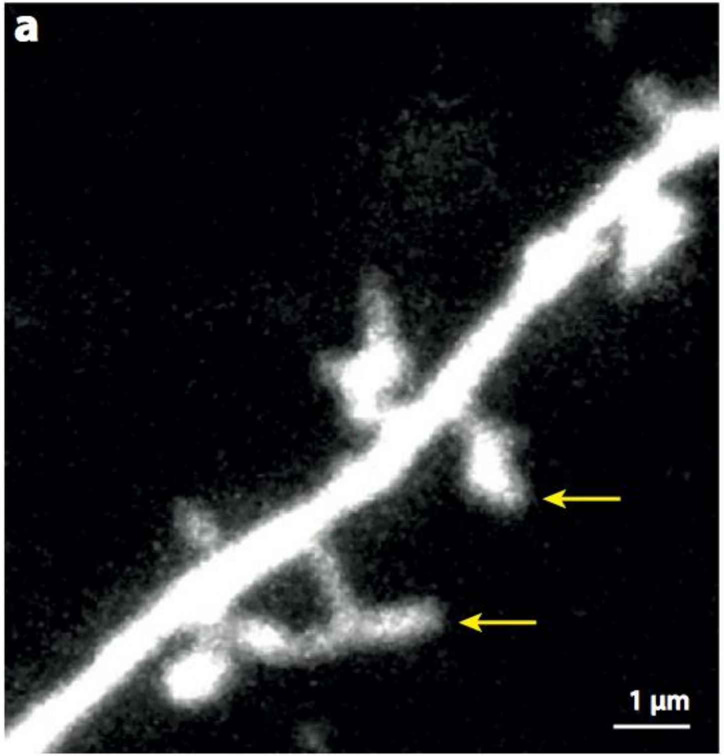


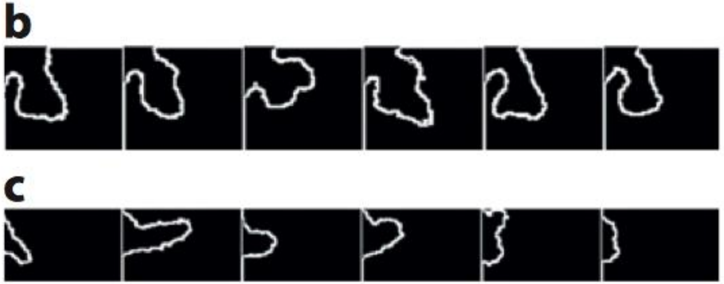
Bosch, M., & Hayashi, Y. (2012). Structural plasticity of dendritic spines. Current Opinion in Neurobiology, 22, 383-388, Figure 1, p. 385.



Base on Figure 1 from Fortin, D.A., Srivastava, T., & Soderling, T.R. (2012). Structural modulation of dendritic spines during synaptic plasticity. The Neuroscientist, 18, 326-341. See also Figure 1 from Brigidi, S.G., & Bamji, S.X. (2011). Current Opinion in Neurobiology, 21, 208-214.

Dendritic Spine Motility

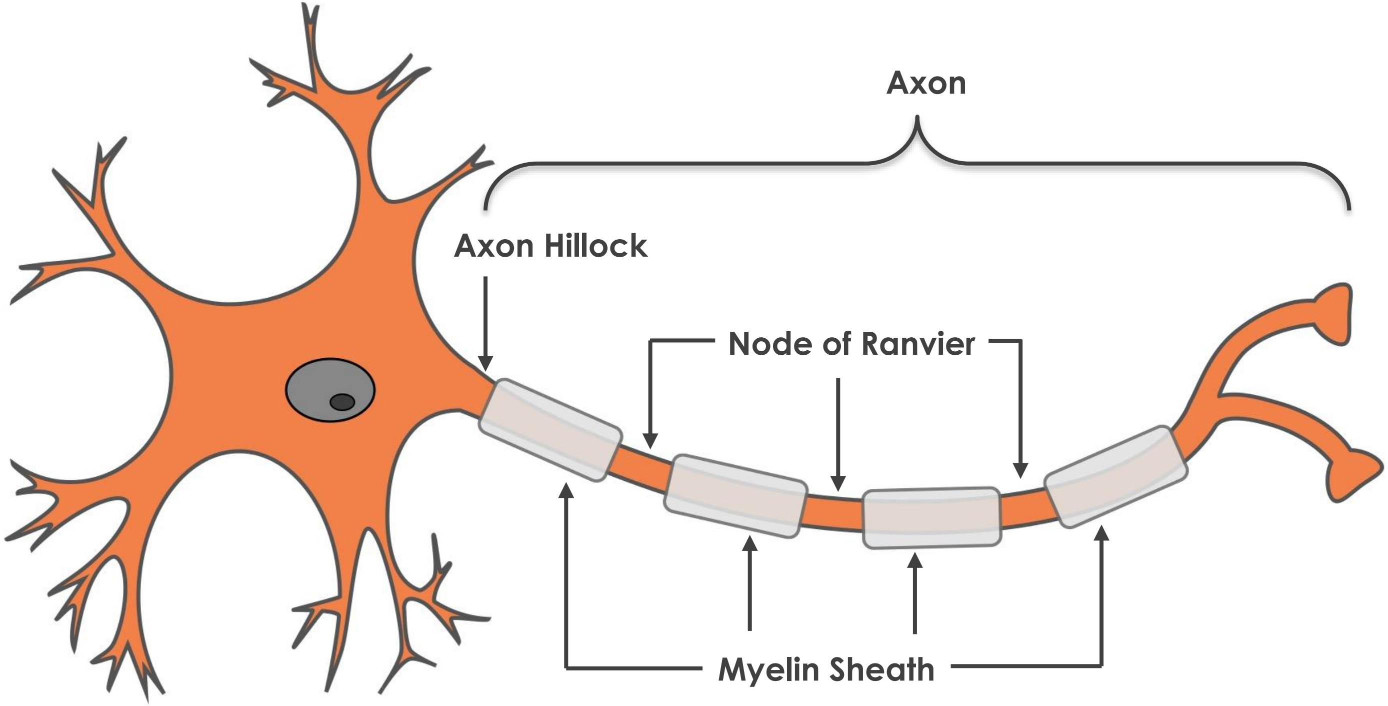


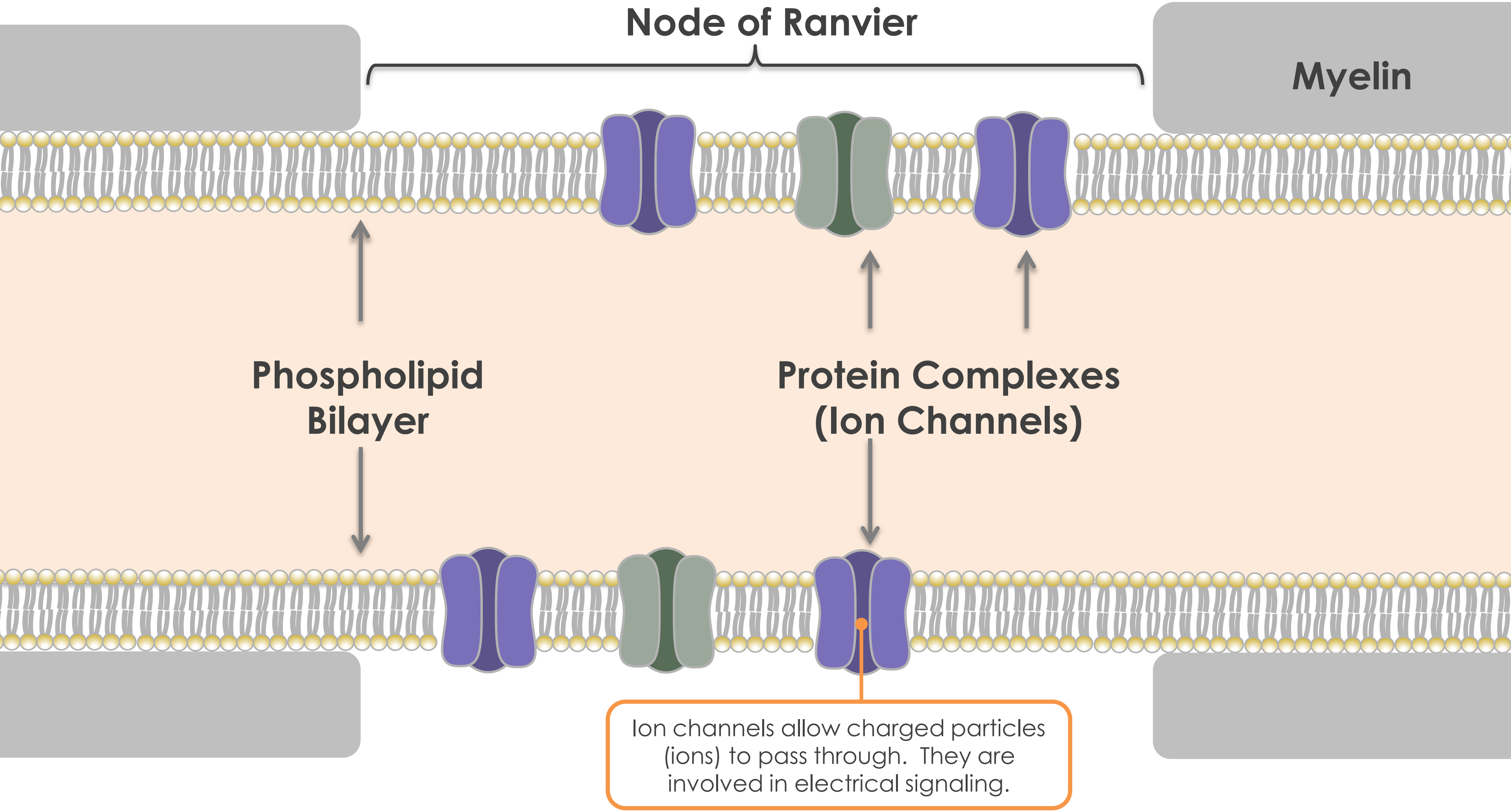


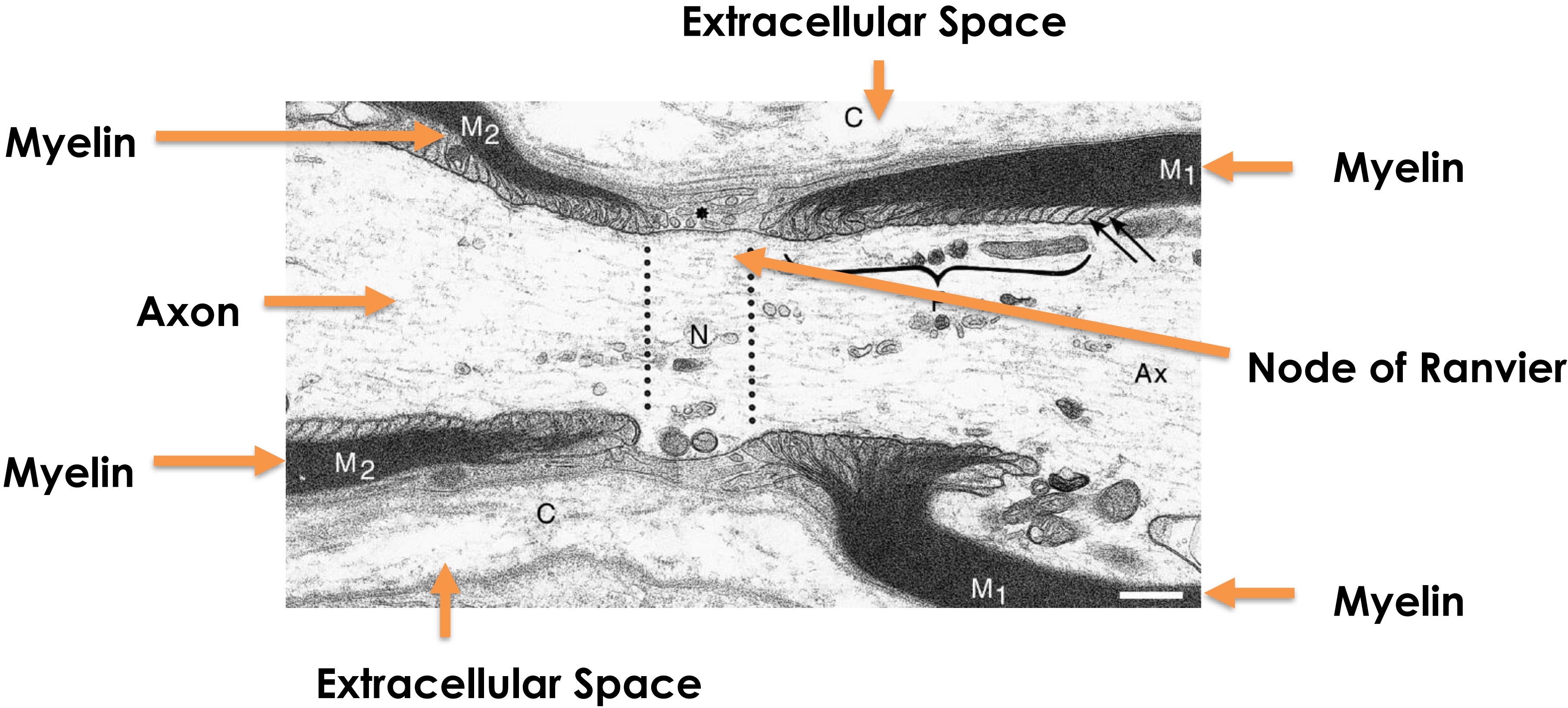
Time
(Each image taken 2.5-min apart)

Yuste, R. (2013). Electrical compartmentalization in dendritic spines. Annual Review of Neuroscience, 36, 429-449, Figure 10, p. 441.

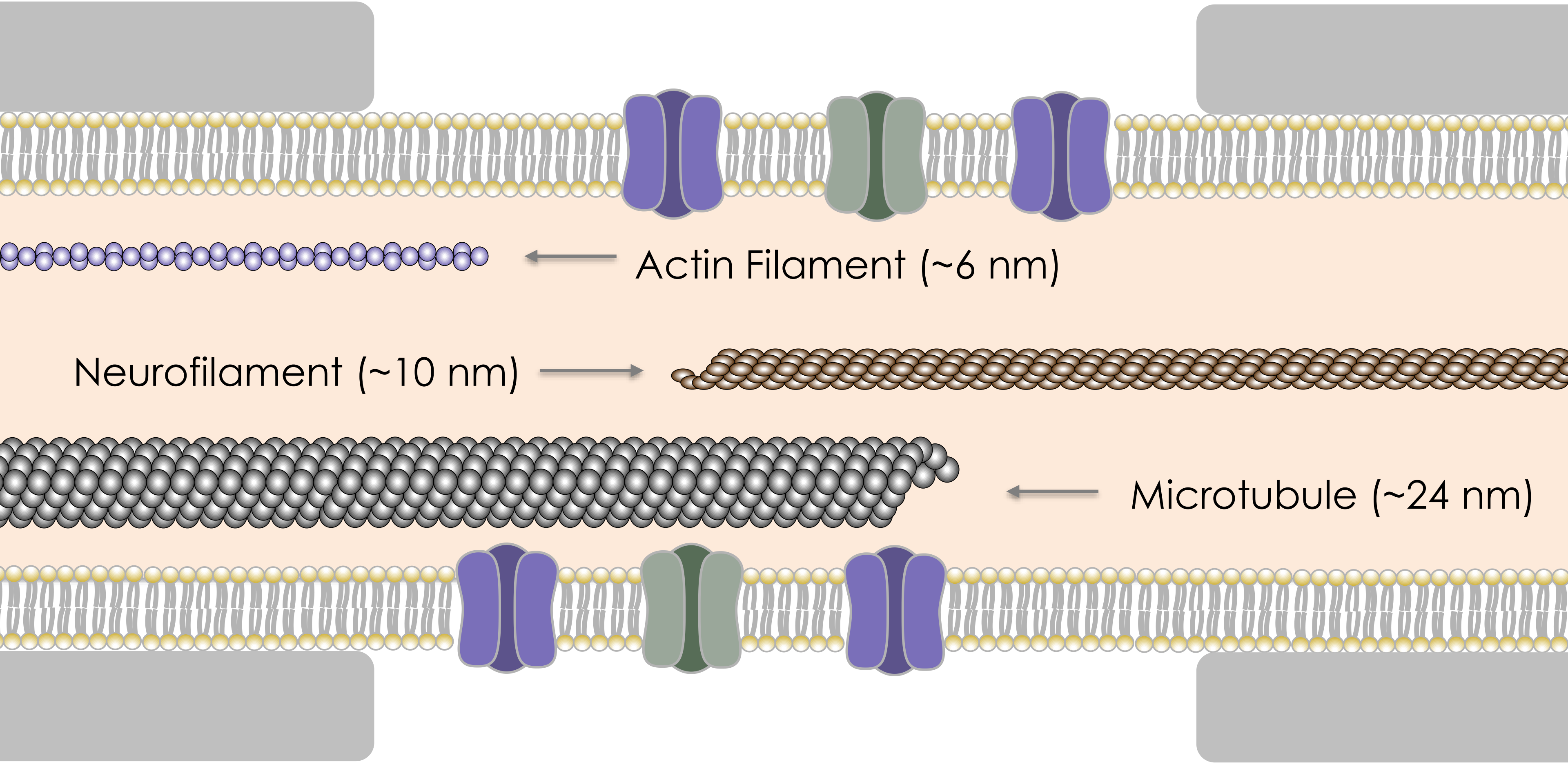
The Axon



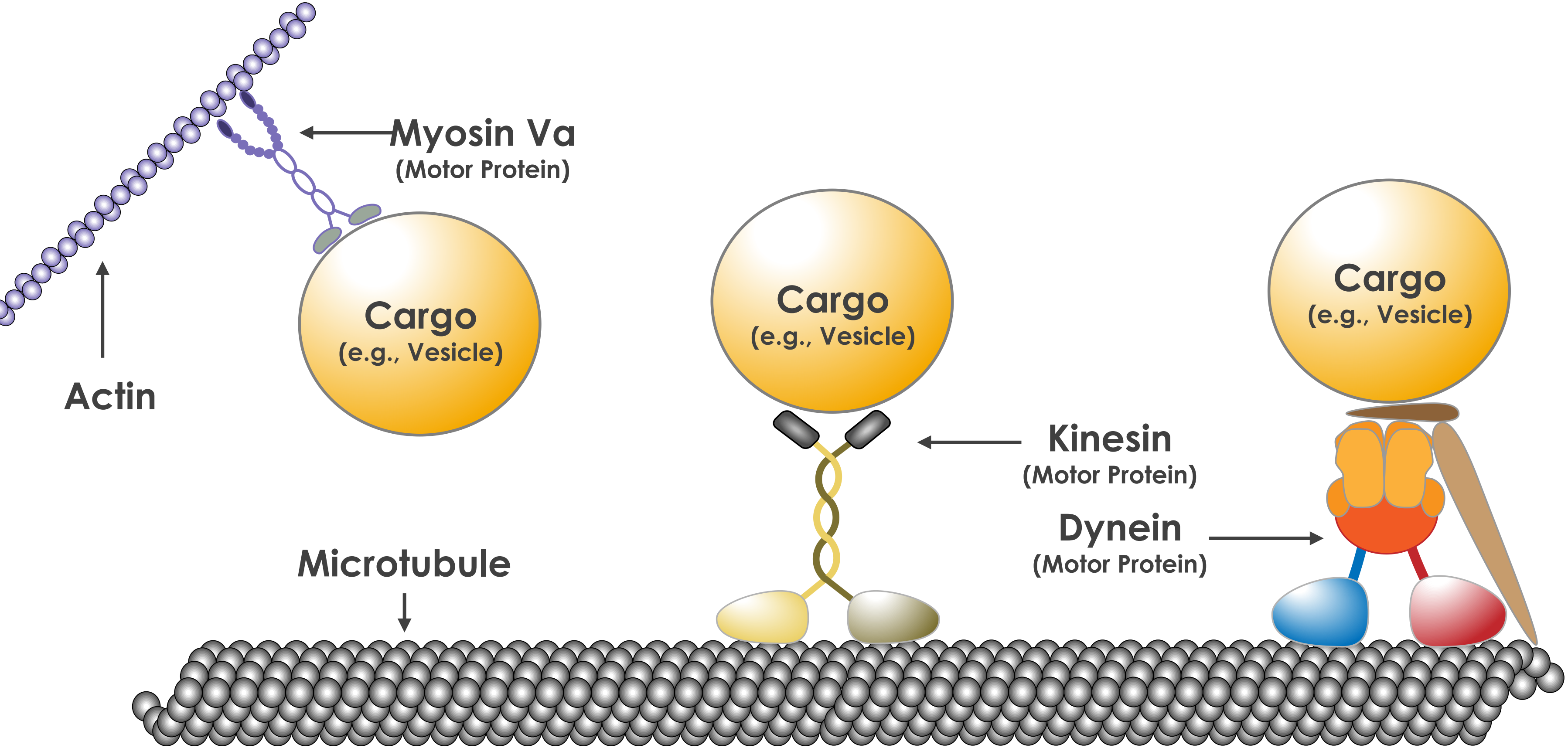

Node of Ranvier
Myelin
Phospholipid Bilayer
Protein Complexes (Ion Channels)
Ion channels allow charged particles (ions) to pass through. They are involved in electrical signaling.



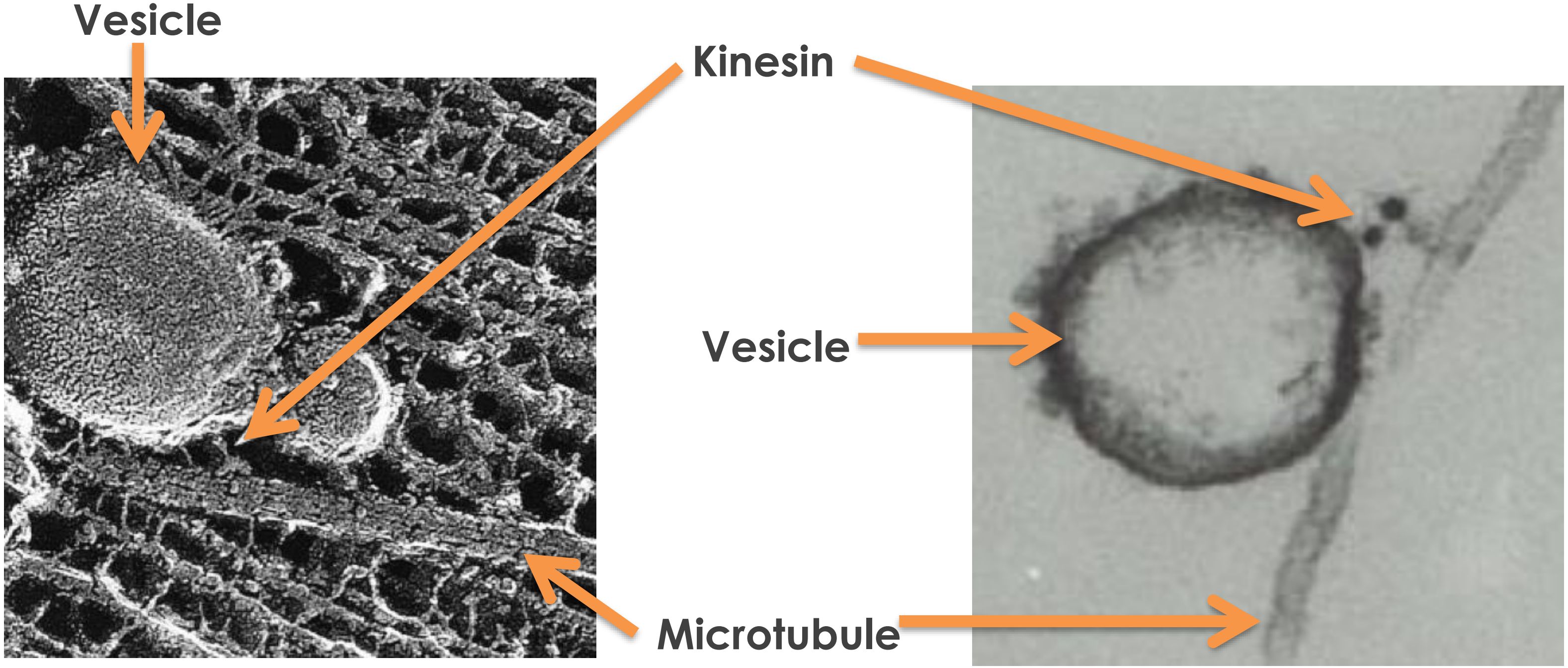
Jessen, K. R., & Mirsky, R. (1999). Schwann cells and their precursors emerge as major regulators of nerve development. Trends in neurosciences, 22(9), 402-410. Figure 5.


Actin Filament (~6 nm)
Neurofilament (~10 nm)
Microtubule (~24 nm)

Fast Axonal Transport

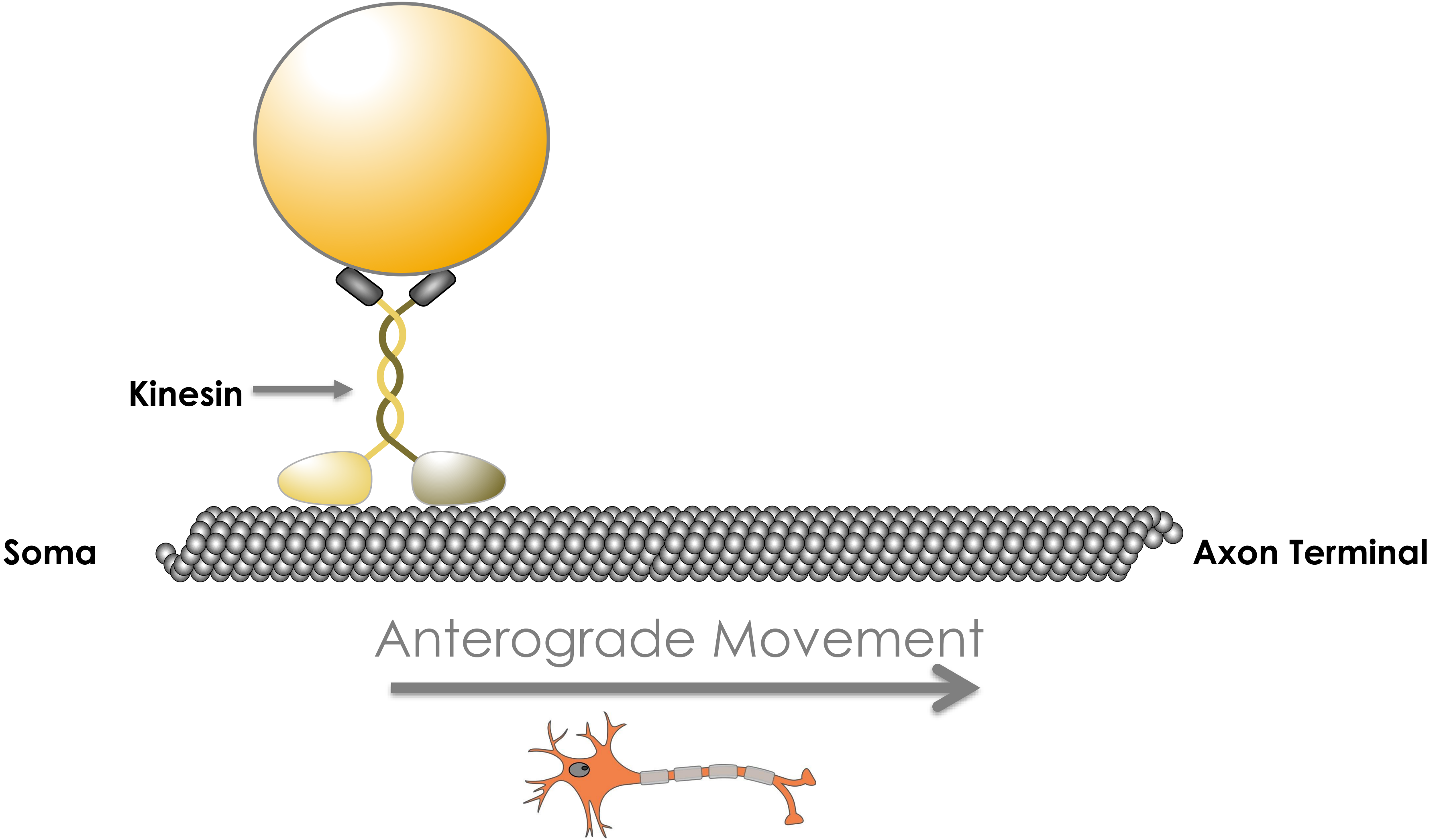


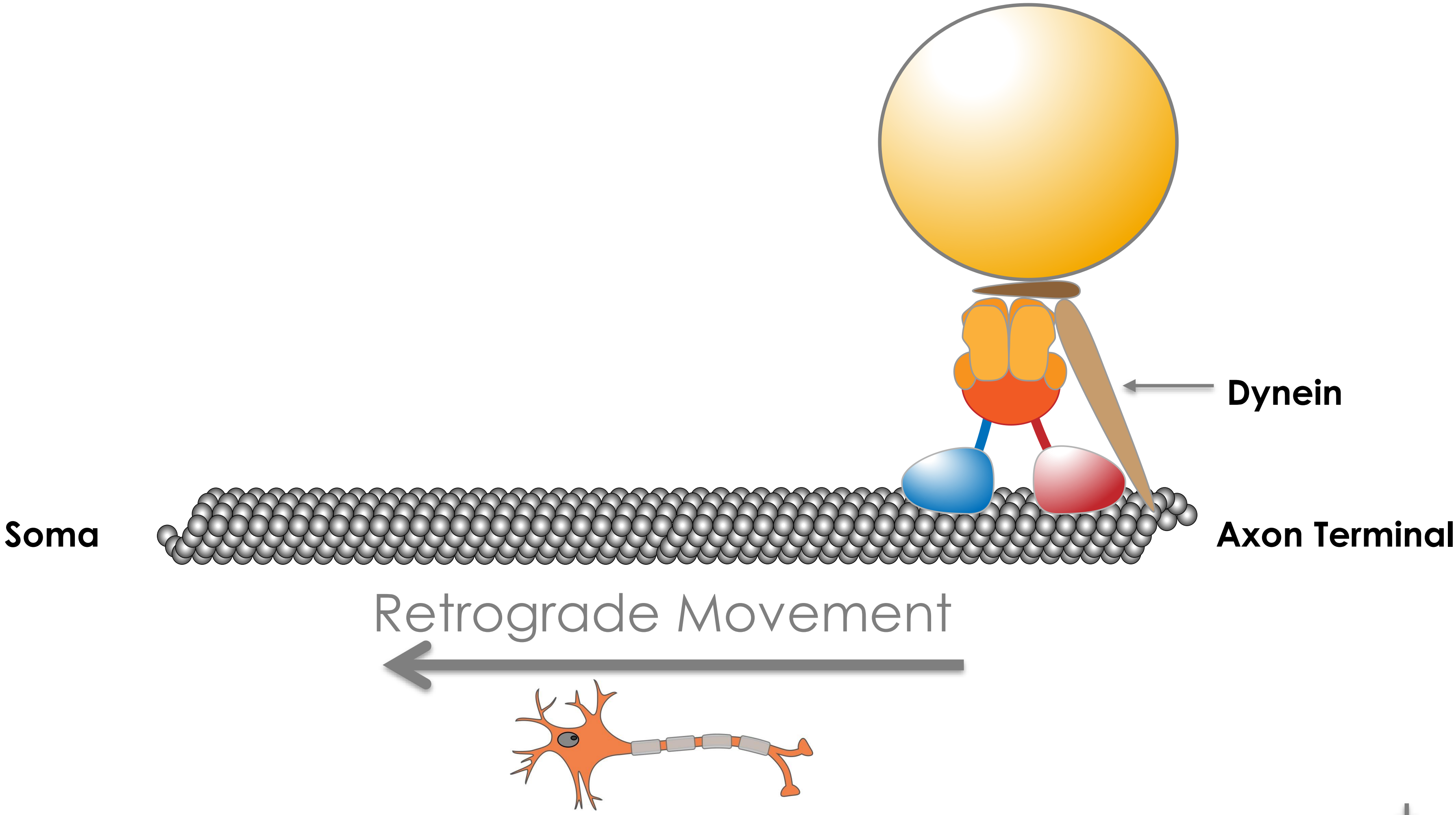
Fast Axonal Transport

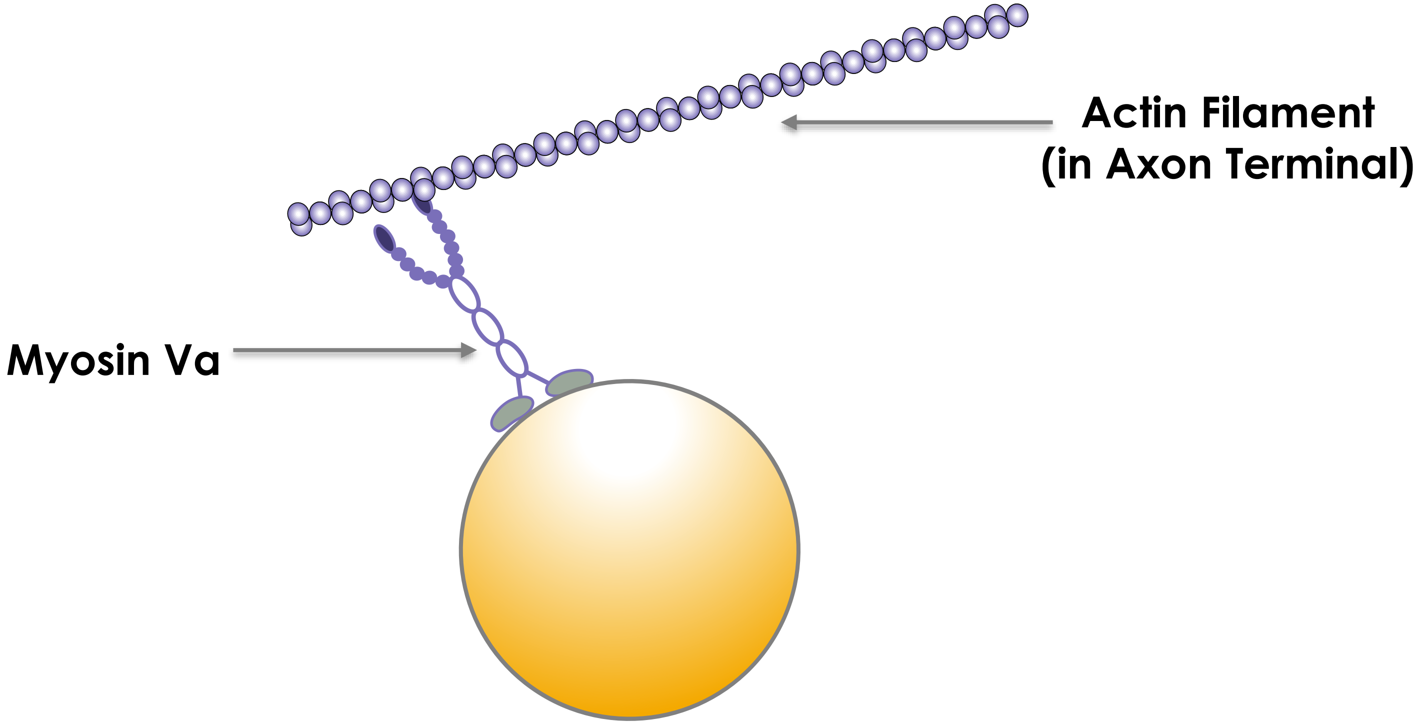


Hirokawa, N. (1998). Kinesin and dynein superfamily proteins and the mechanism of organelle transport, Science, 279, 519-526, Figure 1, p. 519.

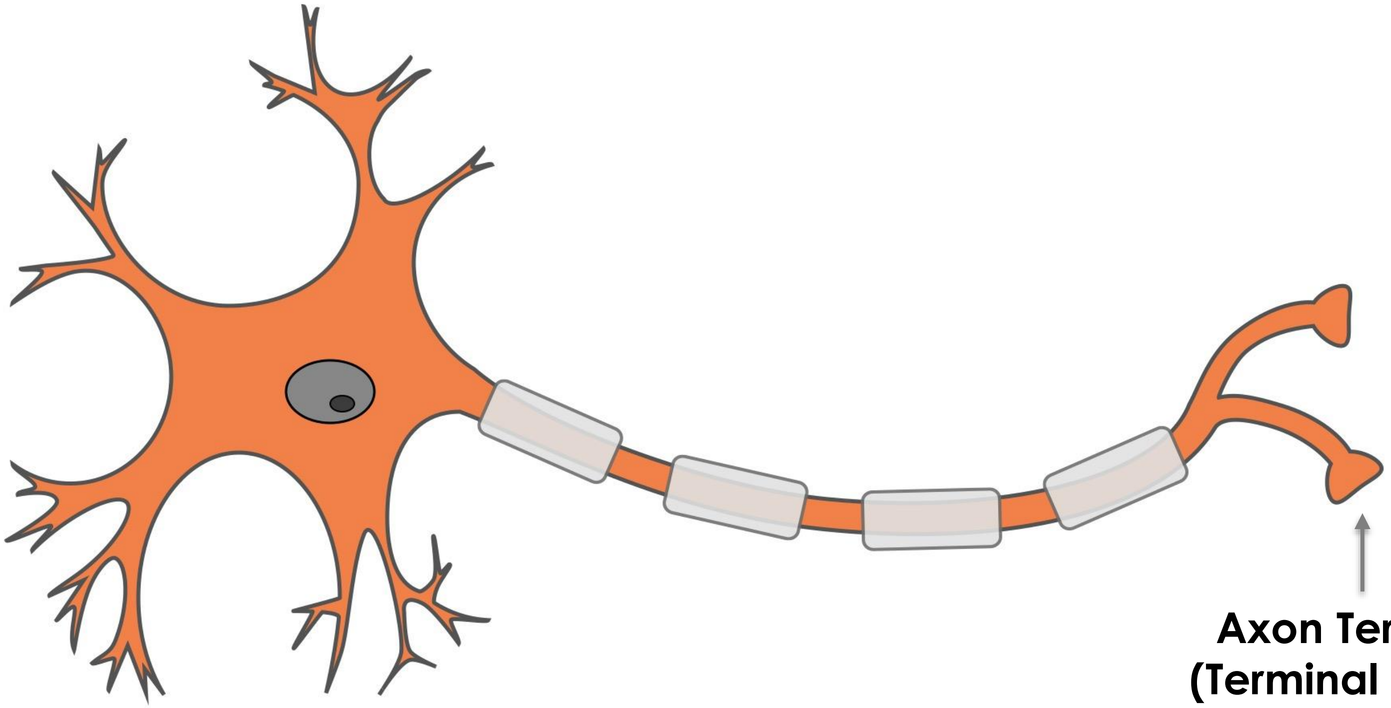
Setou, M., Nakagawa, T., Seog, D., & Hirokawa, N. (2000). Kinesin superfamily motors protein KIF17 and mLin-10 in NMDA receptor-containing vesicle transport. Science, 288, 1796-1800, Figure 7, p. 1800.


Kinesin
Soma
Axon Terminal
Anterograde Movement

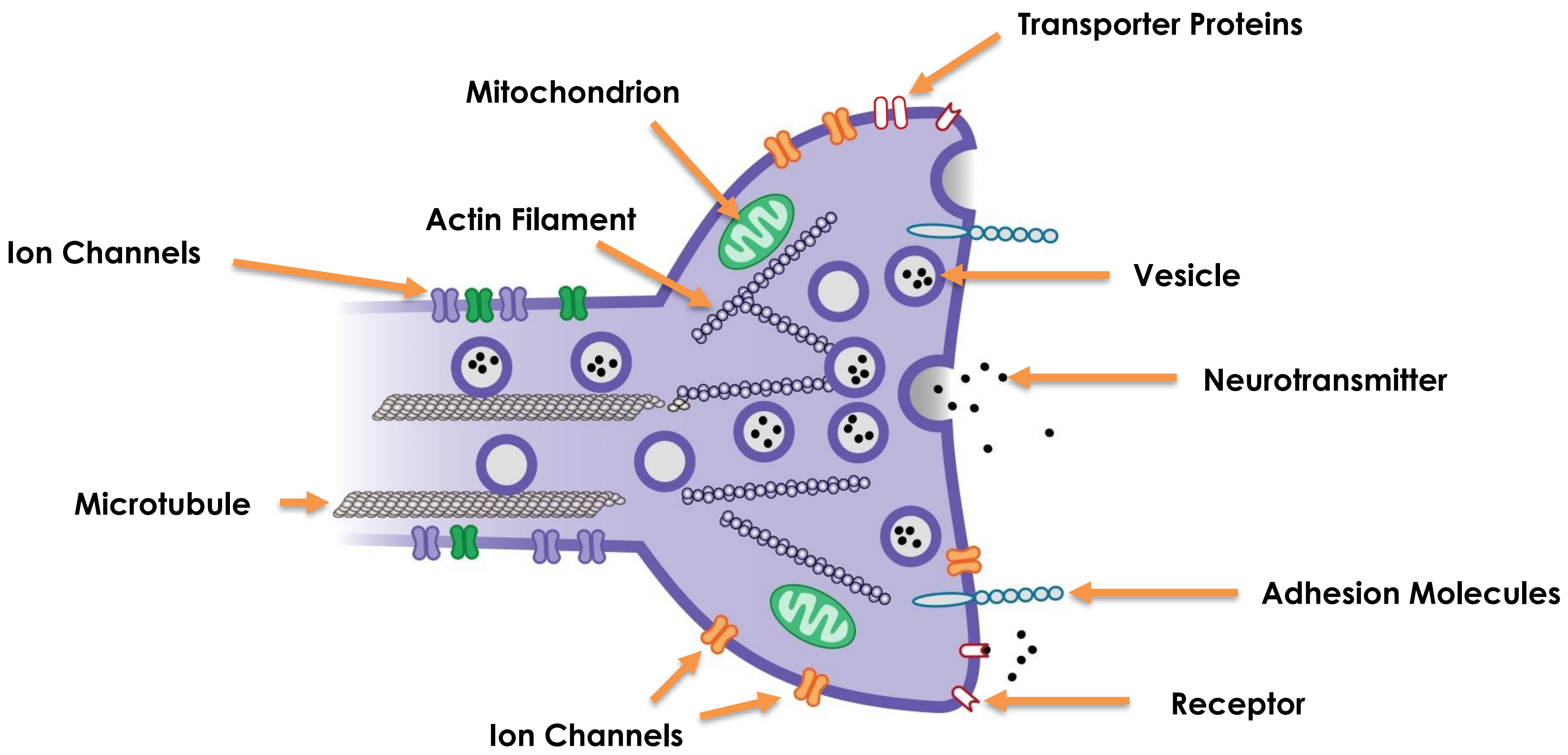

Dynein
Soma
Axon Terminal
Retrograde Movement


Actin Filament
(in Axon Terminal)
Myosin Va

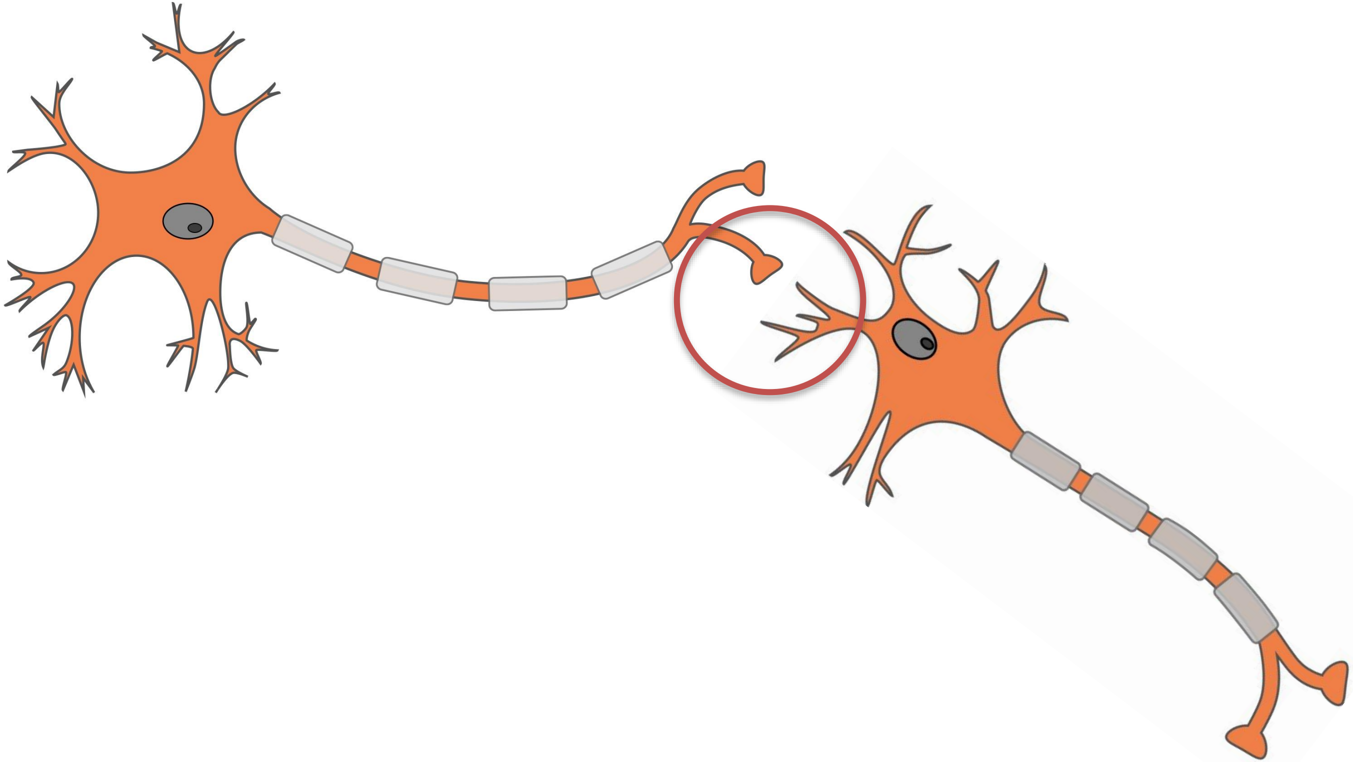
Axon Terminals



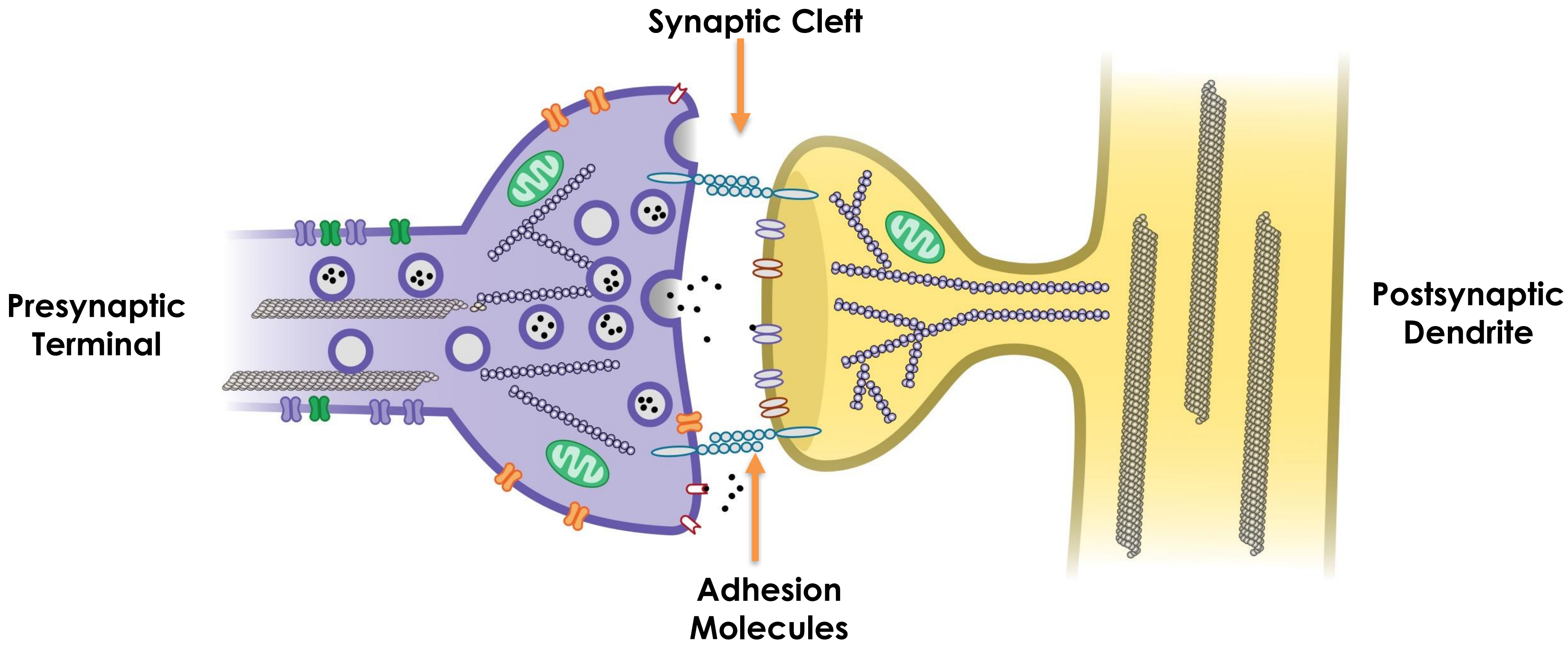
Axon Terminal



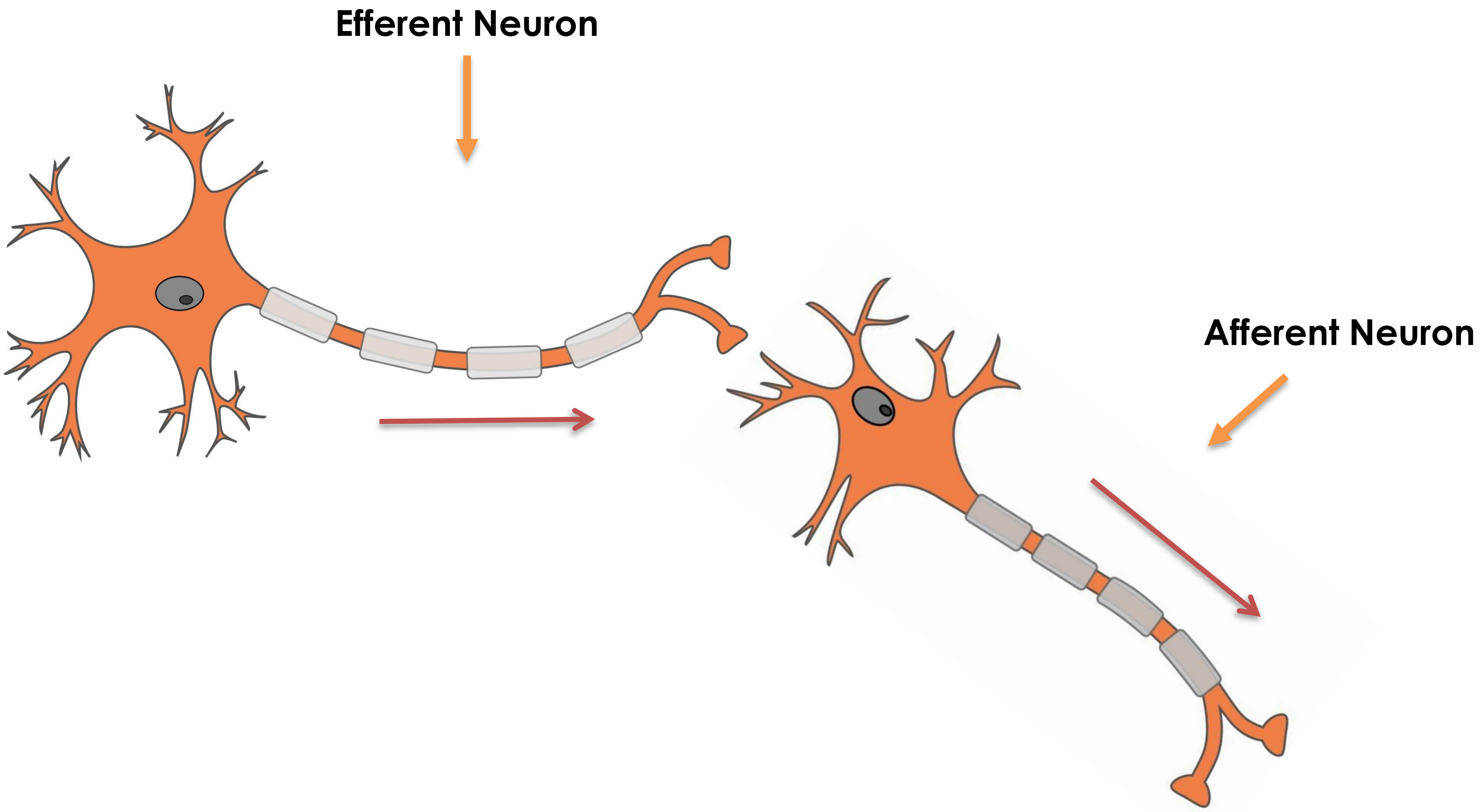
The Synapse



The Synapse

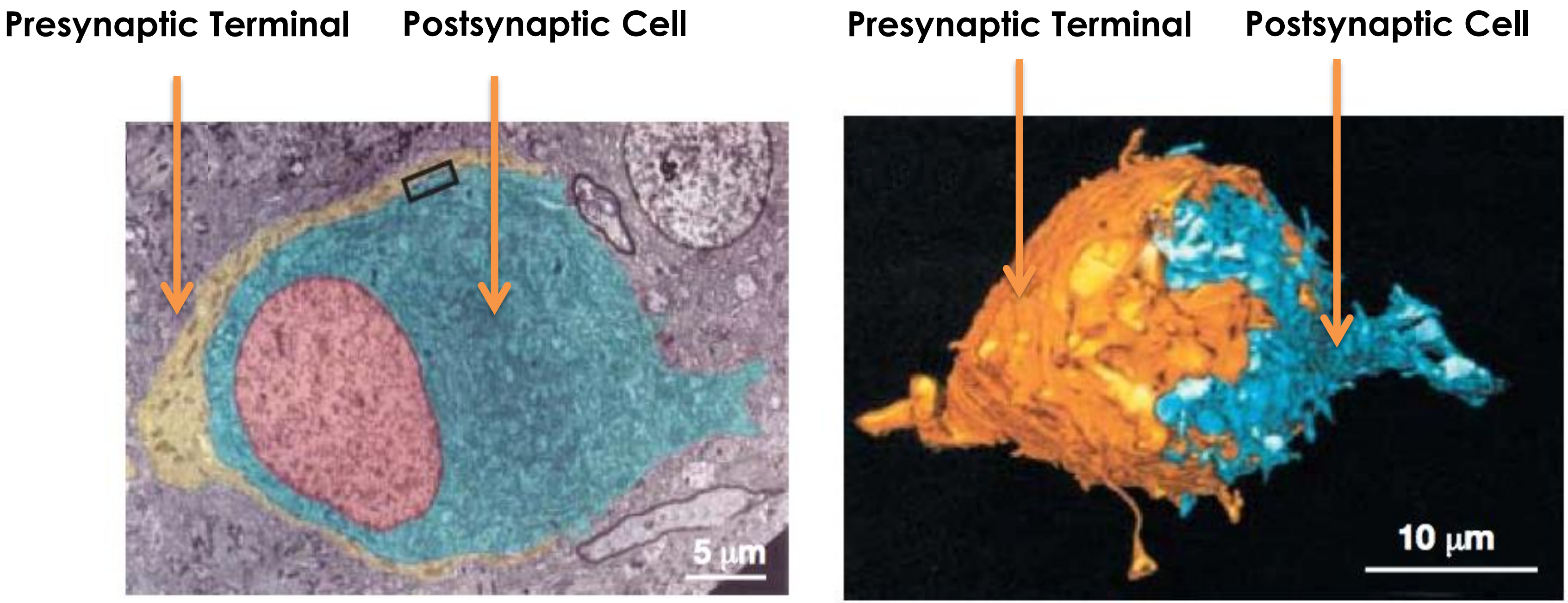


Synaptic Cleft
Presynaptic Terminal
Postsynaptic Dendrite
Adhesion Molecules



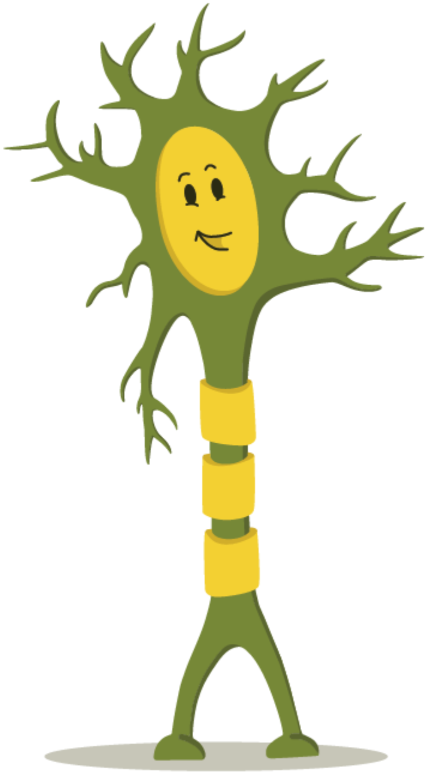
Efferent Neuron
Afferent Neuron

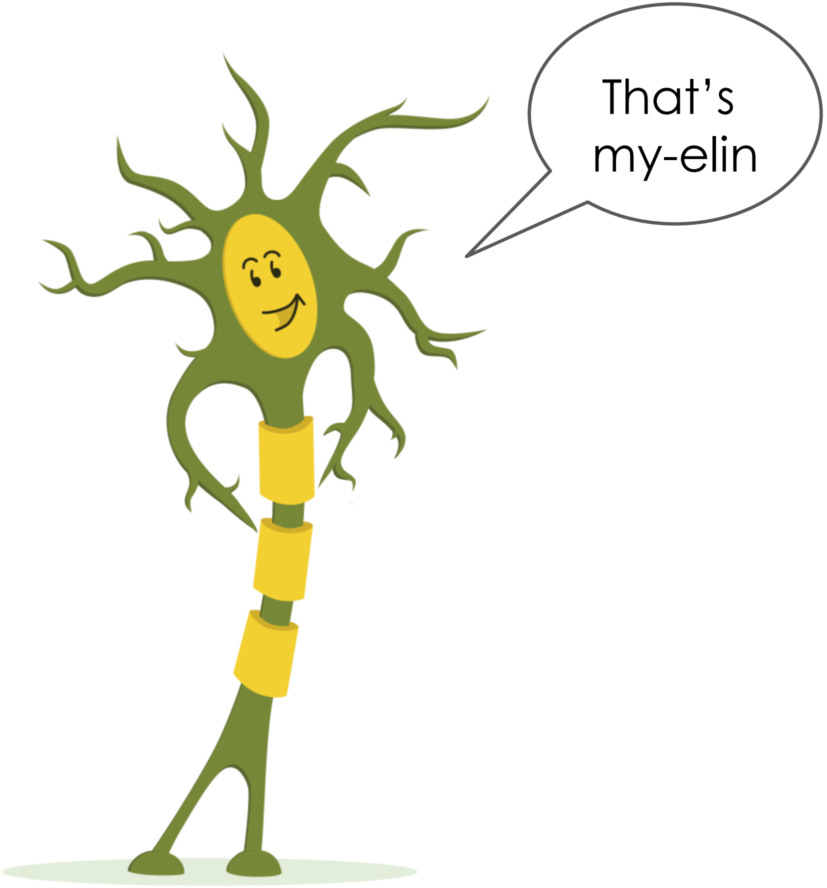
The Synapse



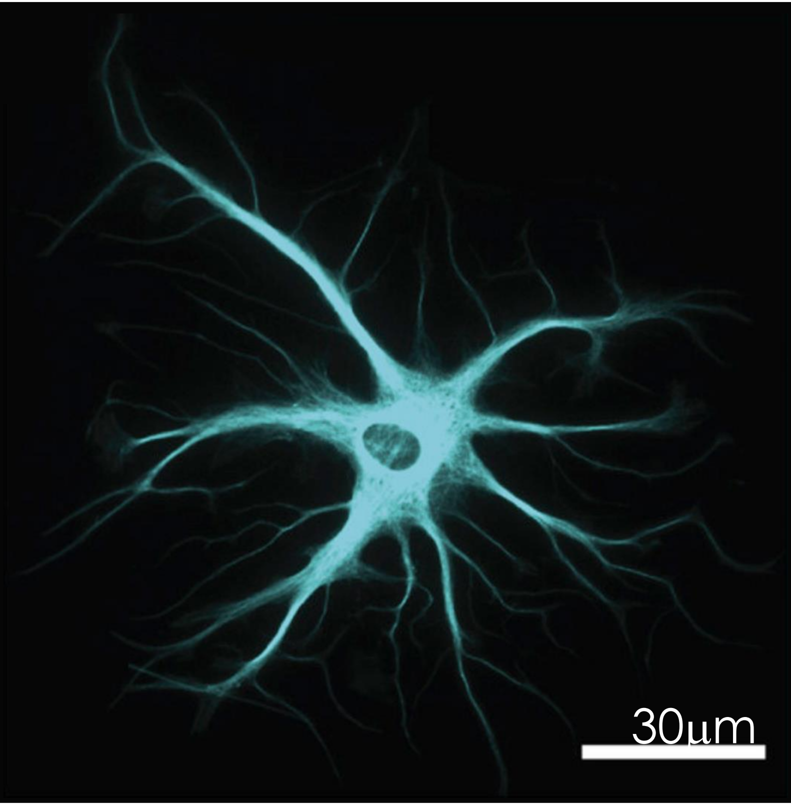
Rizzoli, S.O., & Betz, W. (2005). Synaptic vesicle pools. Nature Reviews Neuroscience, 6, 57-69. Figure 5.

Glia



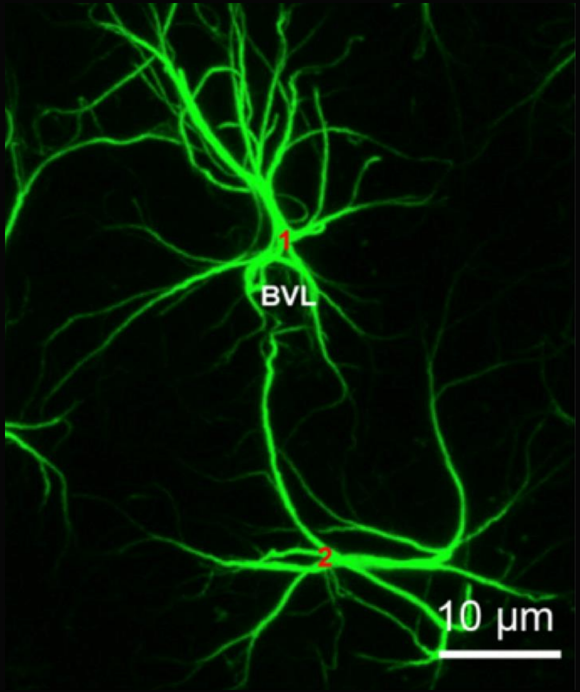

That's
my-elin

Astrocytes



Sloan, S. A., Darmanis, S., Huber, N., Khan, T. A., Birey, F., Caneda, C., Reimer, R., Quake, S. R., Barres, B. A., & Paşca, S. P. (2017). Human Astrocyte Maturation Captured in 3D Cerebral Cortical Spheroids Derived from Pluripotent Stem Cells. *Neuron*, *95*(4), 779-790.e6. Fig 1C, p. 780.

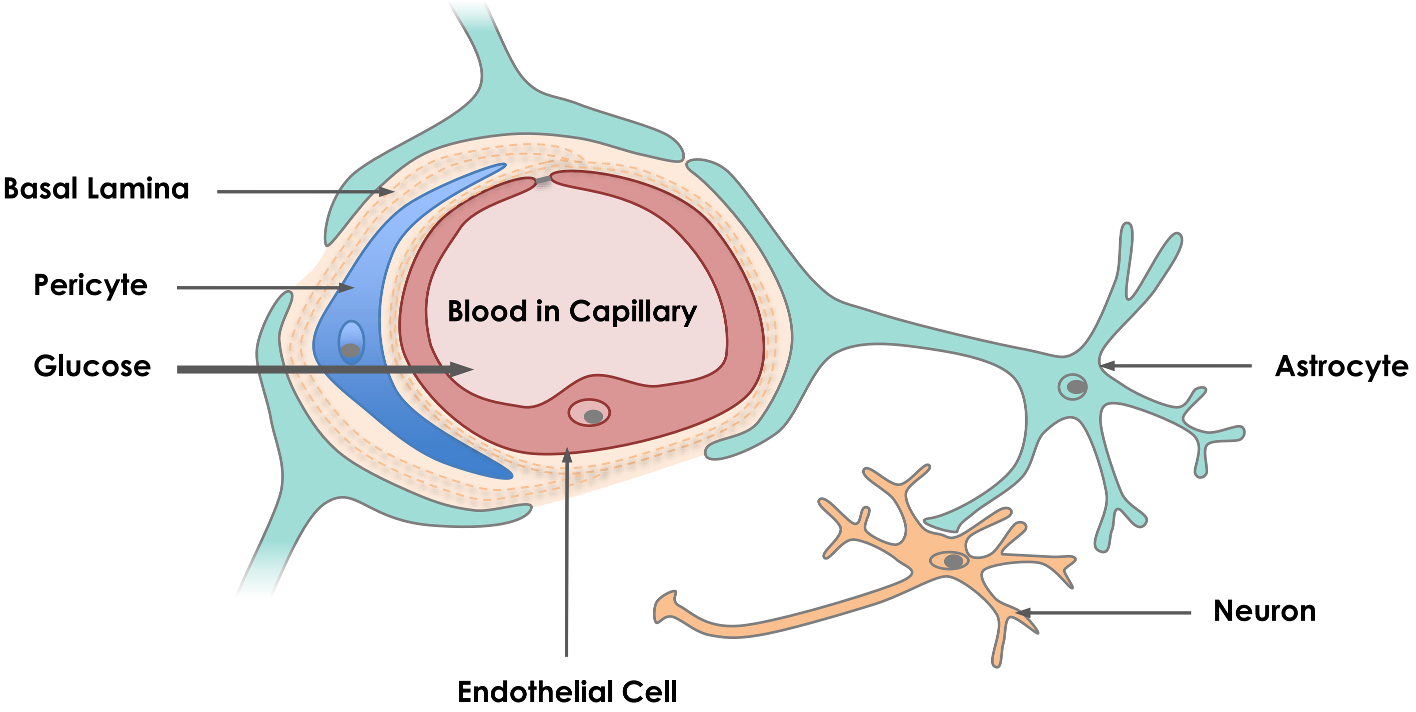
Astrocytes Forming a Blood-Brain Barrier



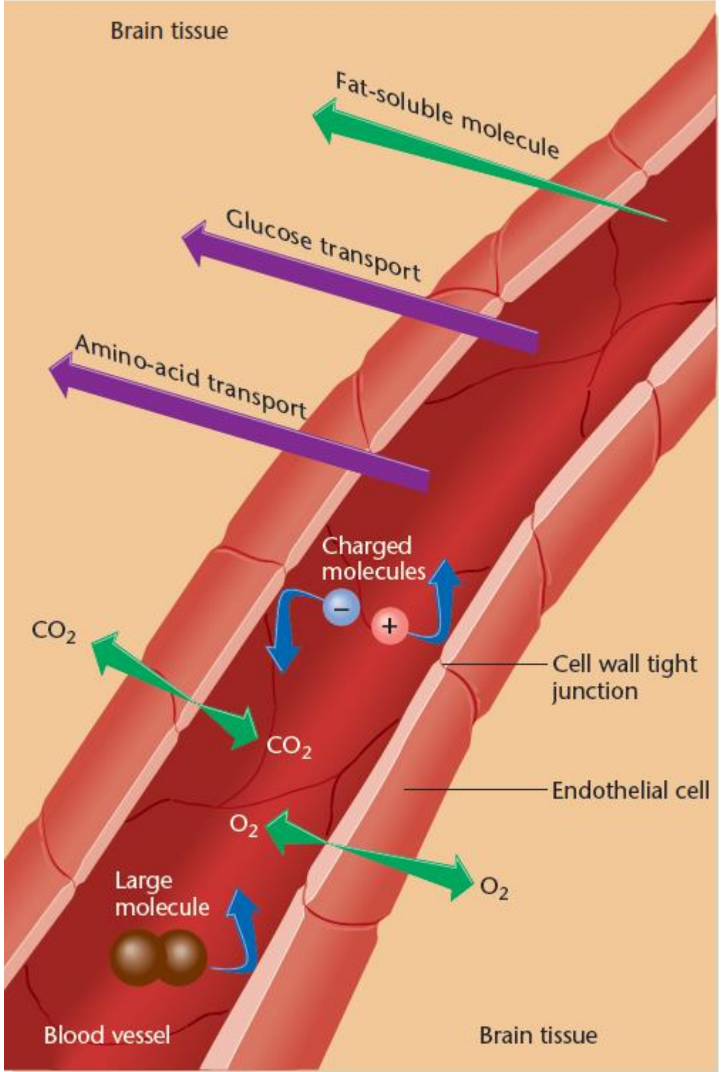
BVL = Blood Vessel

Heneka, M. T., Rodríguez, J. J., & Verkhratsky, A. (2010). Neuroglia in neurodegeneration. Brain research reviews, 63(1), 189-211. Figure 3.

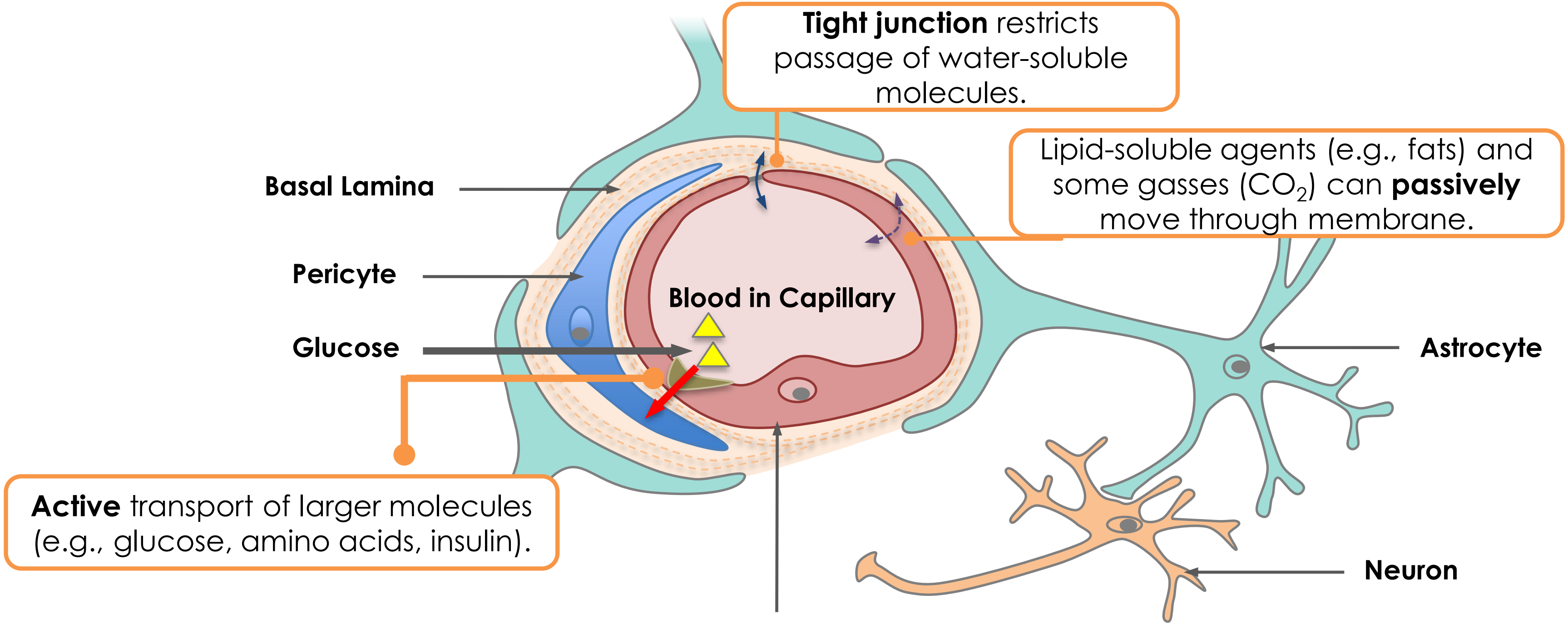
The Blood-Brain Barrier



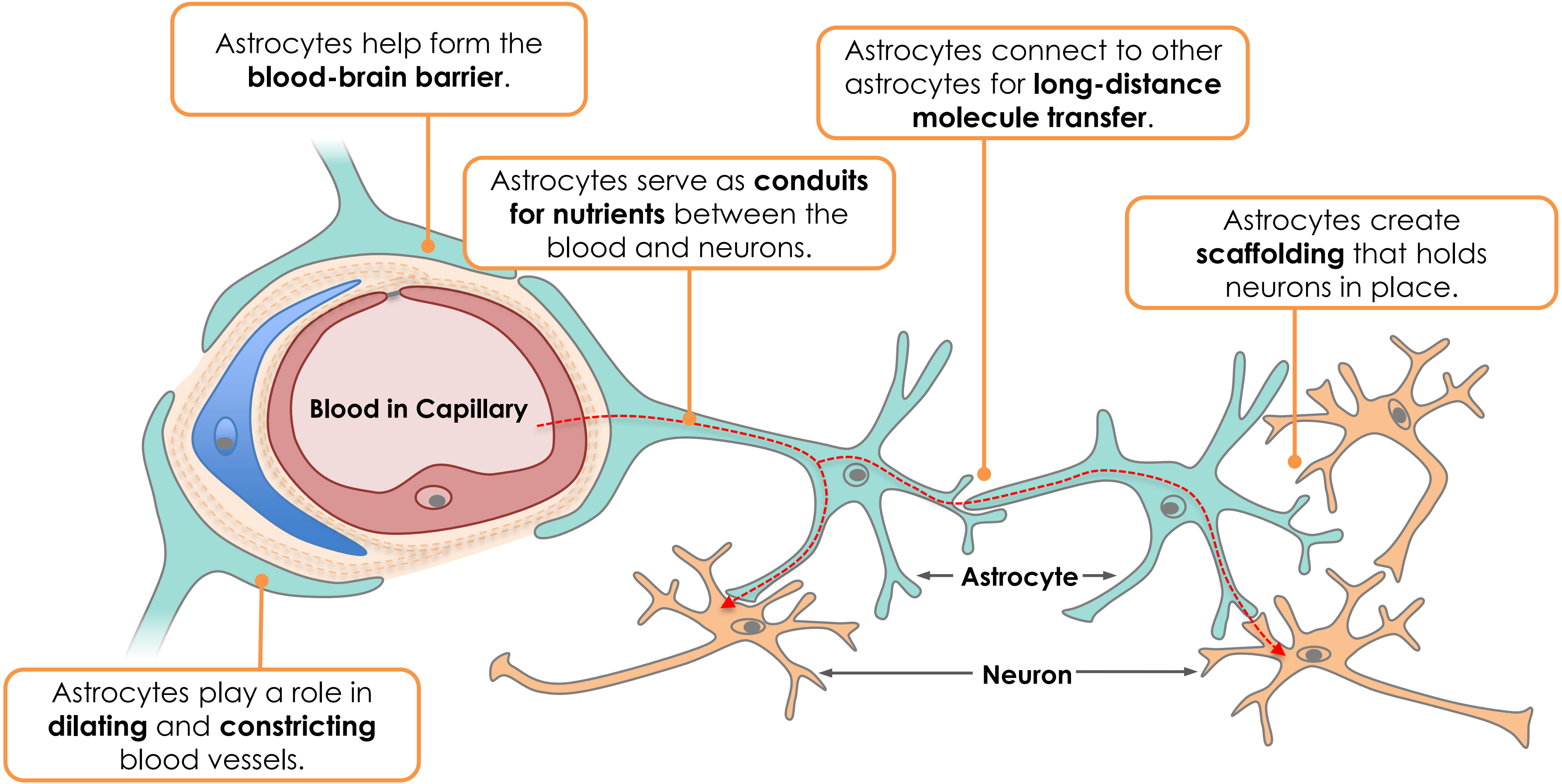
Based on: Abbott, N. J., Rönnbäck, L., & Hansson, E. (2006). Astrocyte–endothelial interactions at the blood–brain barrier. *Nature reviews neuroscience*, *7*(1), 41. Fig 2 & 3, p. 43 & 44.


Brain tissue
Fat-soluble molecule
Glucose transport
Amino-acid transport
Charged molecules
−
+
CO_2
CO_2
Cell wall tight junction
Endothelial cell
O_2
O_2
Large molecule
Blood vessel
Brain tissue

The Blood-Brain Barrier



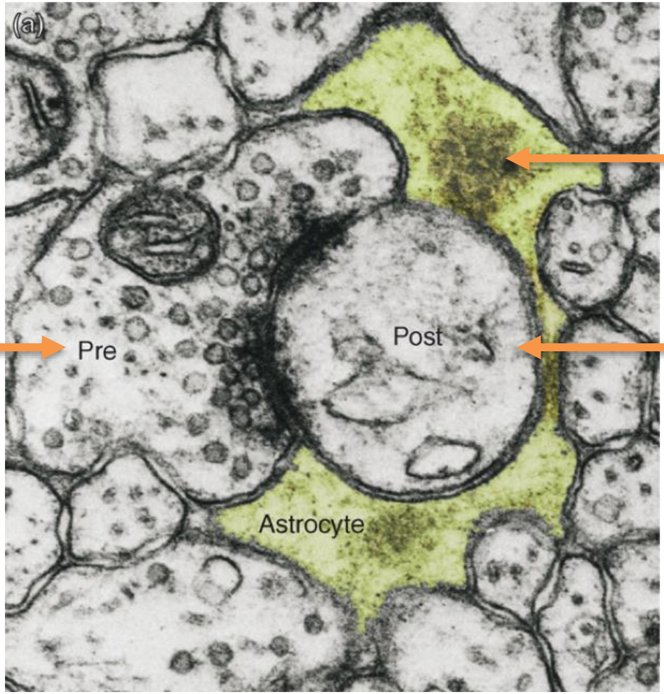
Based on: Abbott, N. J., Rönnbäck, L., & Hansson, E. (2006). Astrocyte–endothelial interactions at the blood–brain barrier. *Nature reviews neuroscience*, *7*(1), 41. Fig 2 & 3, p. 43 & 44.



Astrocytes help form the **blood-brain barrier**.
Astrocytes serve as **conduits for nutrients** between the blood and neurons.
Astrocytes connect to other astrocytes for **long-distance molecule transfer**.
Astrocytes create **scaffolding** that holds neurons in place.
Blood in Capillary
Astrocyte
Neuron
Astrocytes play a role in **dilating** and **constricting** blood vessels.

The Tripartite Synapse

Presynaptic
Axon Terminal



Astrocyte

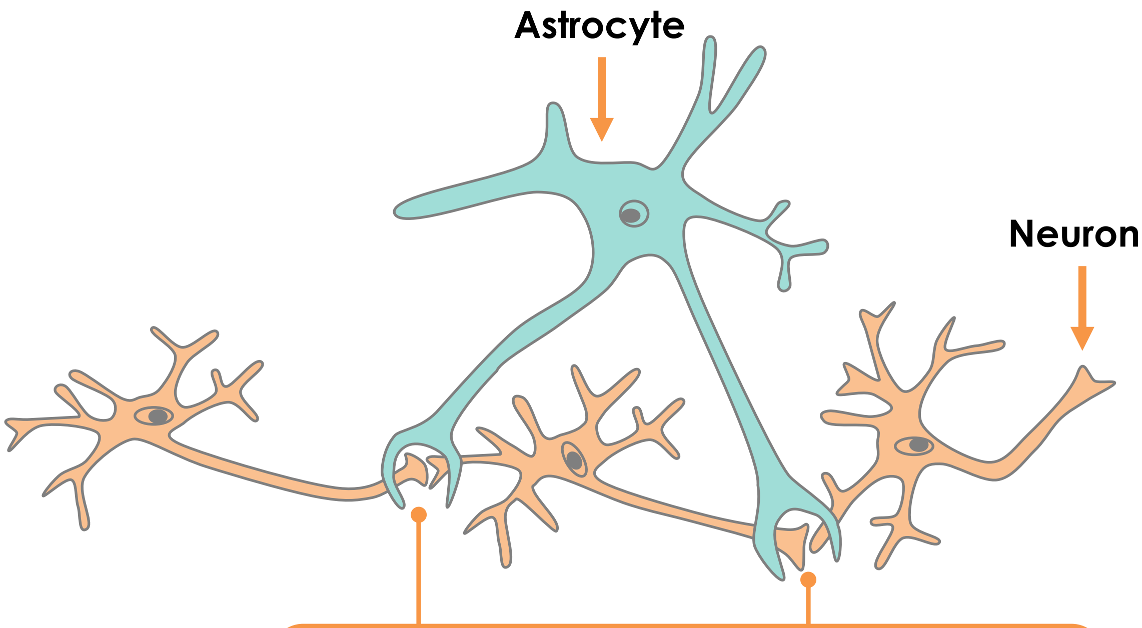
Postsynaptic
Dendritic Spine

Halassa, M. M., Fellin, T., & Haydon, P. G. (2007). The tripartite synapse: roles for gliotransmission in health and disease. Trends in molecular medicine, 13(2), 54-63. Figure 1, p. 55.

“. . . glutamate, despite being the main excitatory neurotransmitter in the [central nervous system], is the most powerful neurotoxin, and every excess of glutamate in the extracellular spaces triggers . . . neuronal death.”

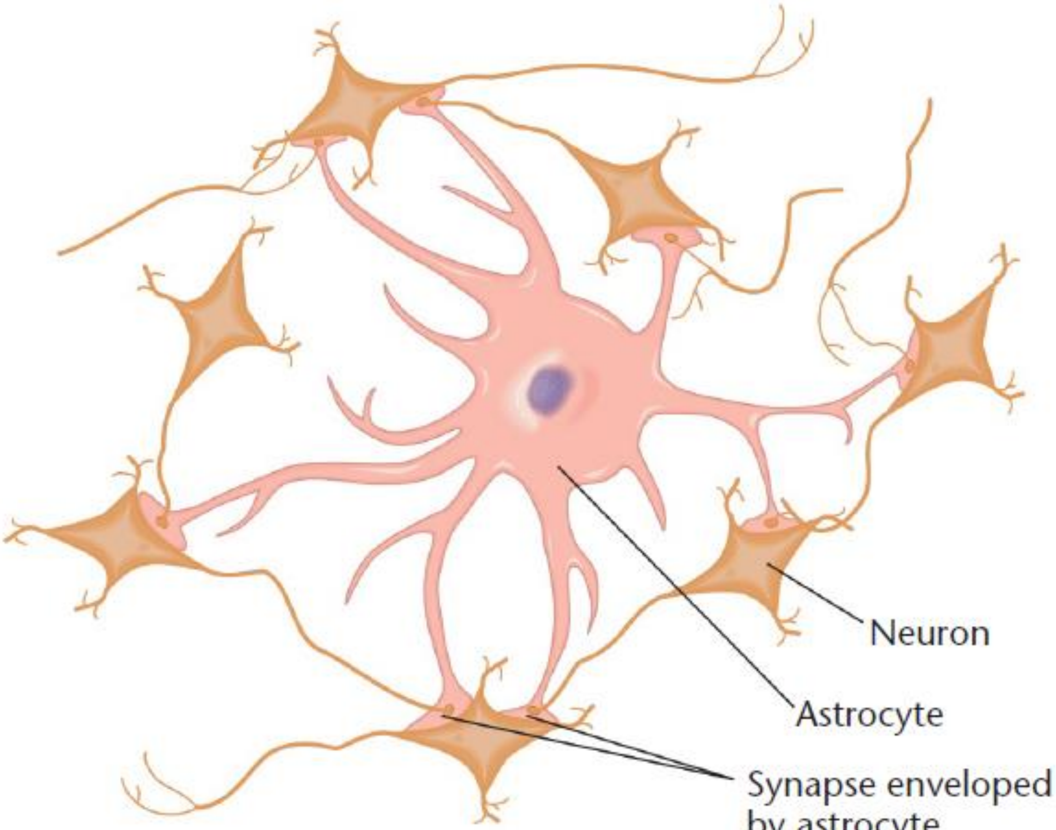
Heneka et al. (2010, p. 191)

Synchronization of Multiple Synapses

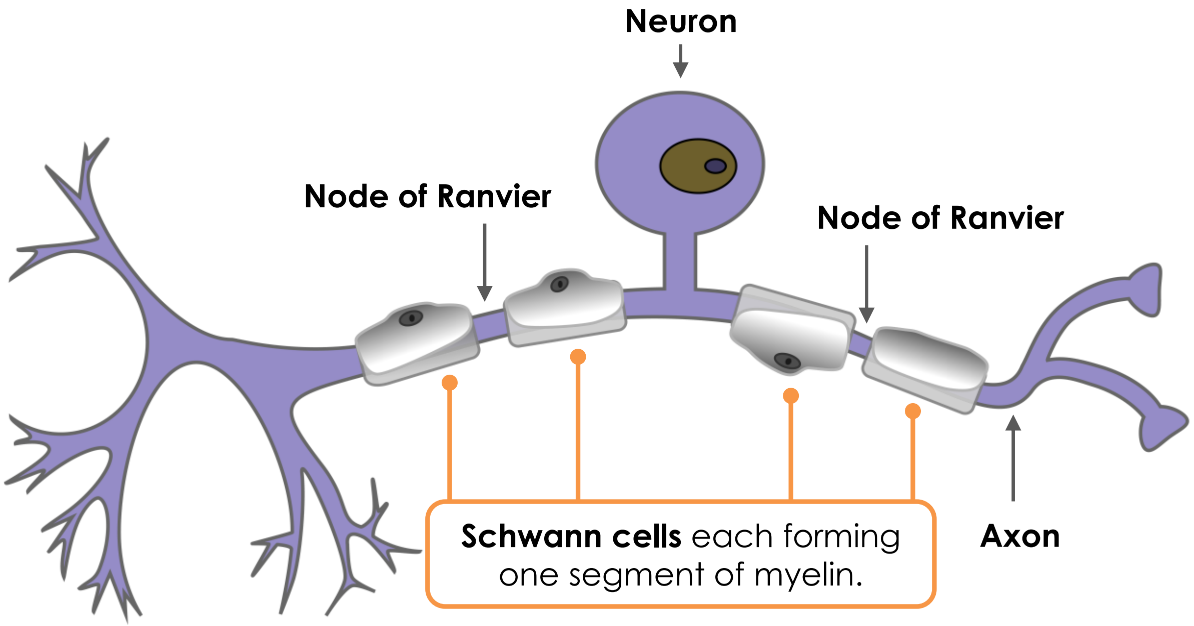


Astrocyte envelopes multiple synapses (i.e., forming multiple tripartite synapses) and **synchronizes** activity at the synapses.

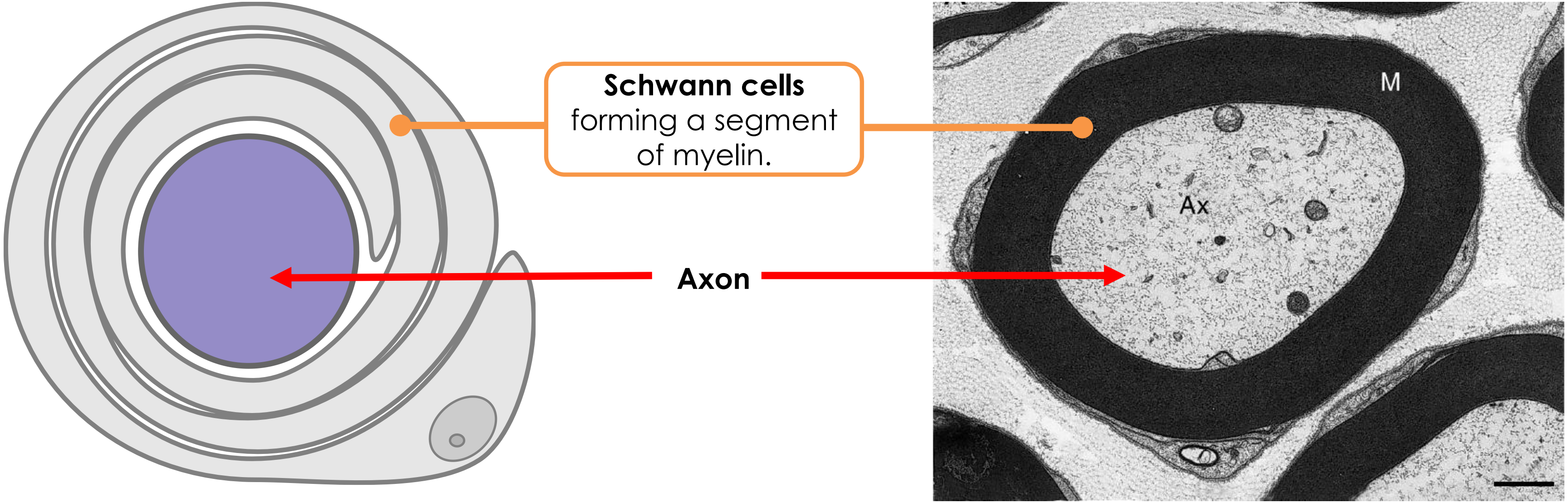
Synchronization of Multiple Synapses



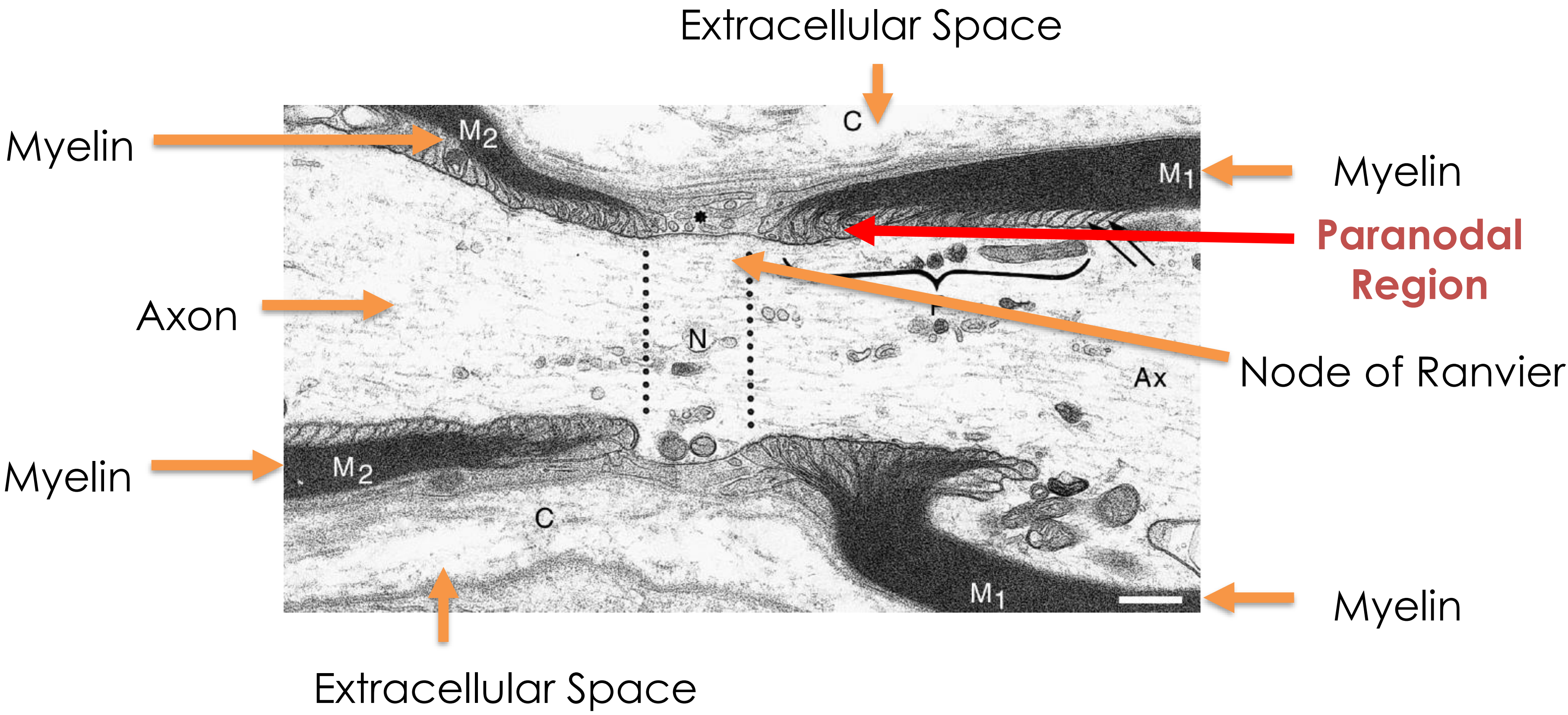
Schwann Cells



Schwann Cells

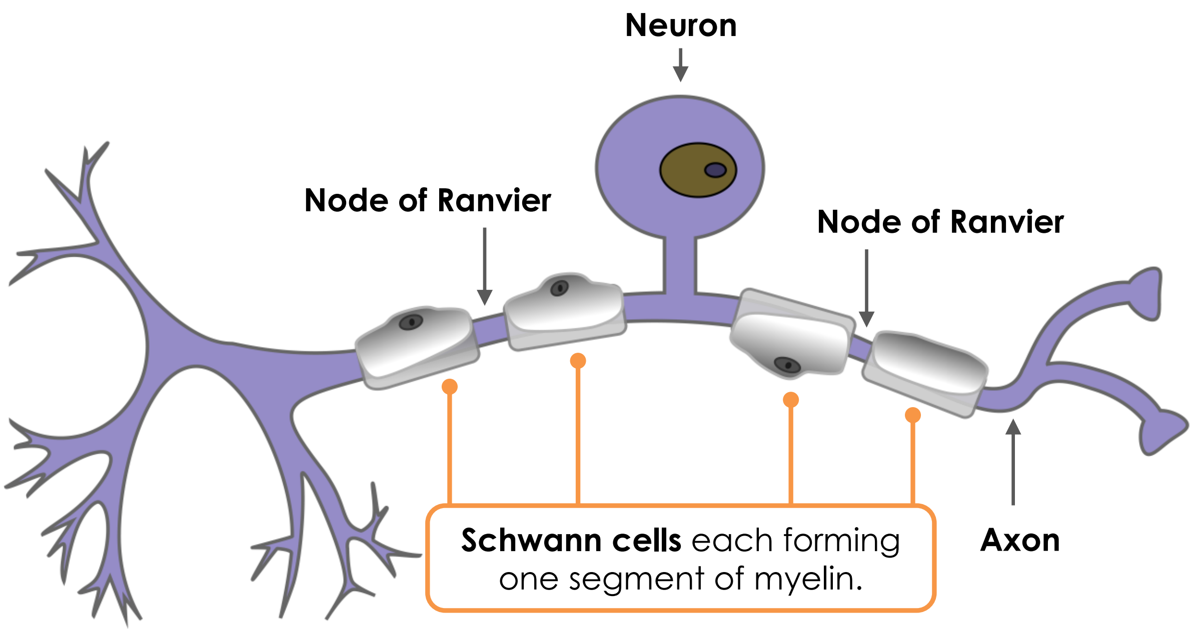


Jessen, K. R., & Mirsky, R. (1999). Schwann cells and their precursors emerge as major regulators of nerve development. Trends in neurosciences, 22(9), 402-410. Figure 5.

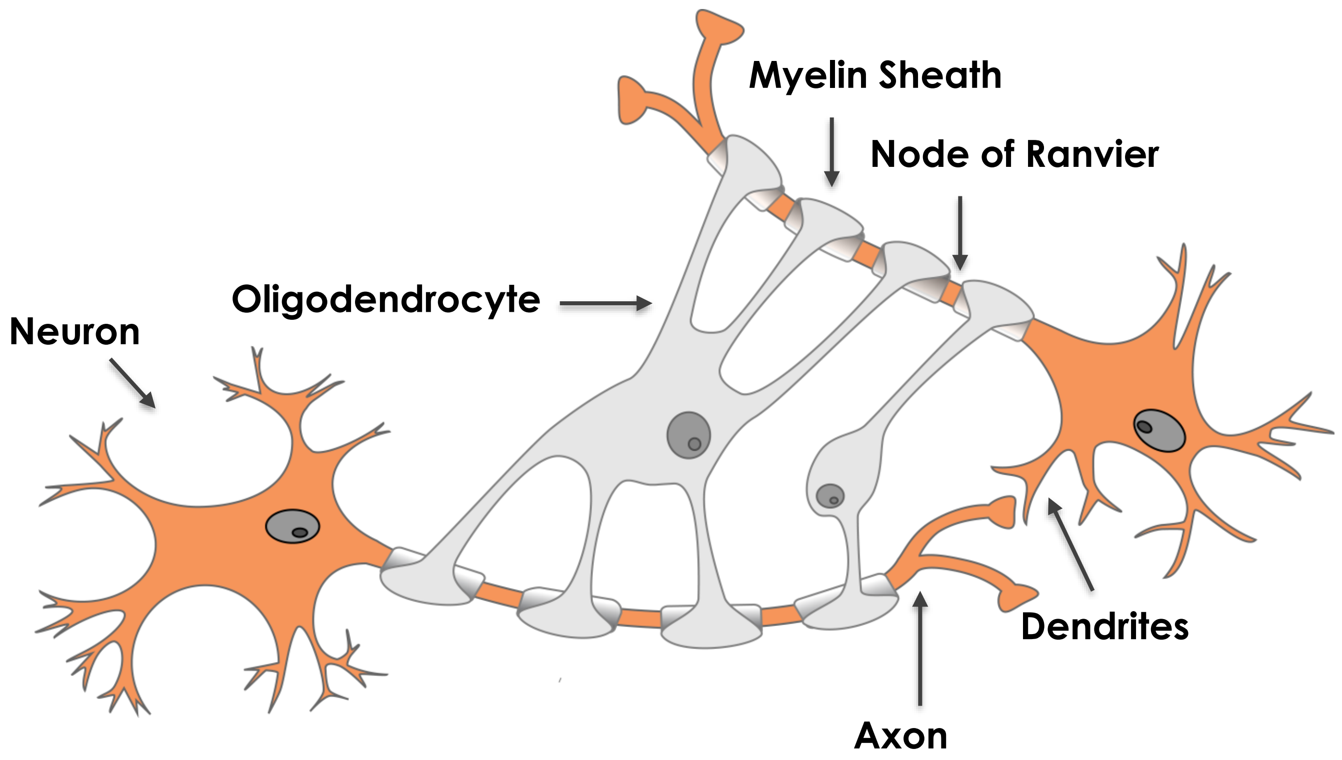


Jessen, K. R., & Mirsky, R. (1999). Schwann cells and their precursors emerge as major regulators of nerve development. Trends in neurosciences, 22(9), 402-410. Figure 5.

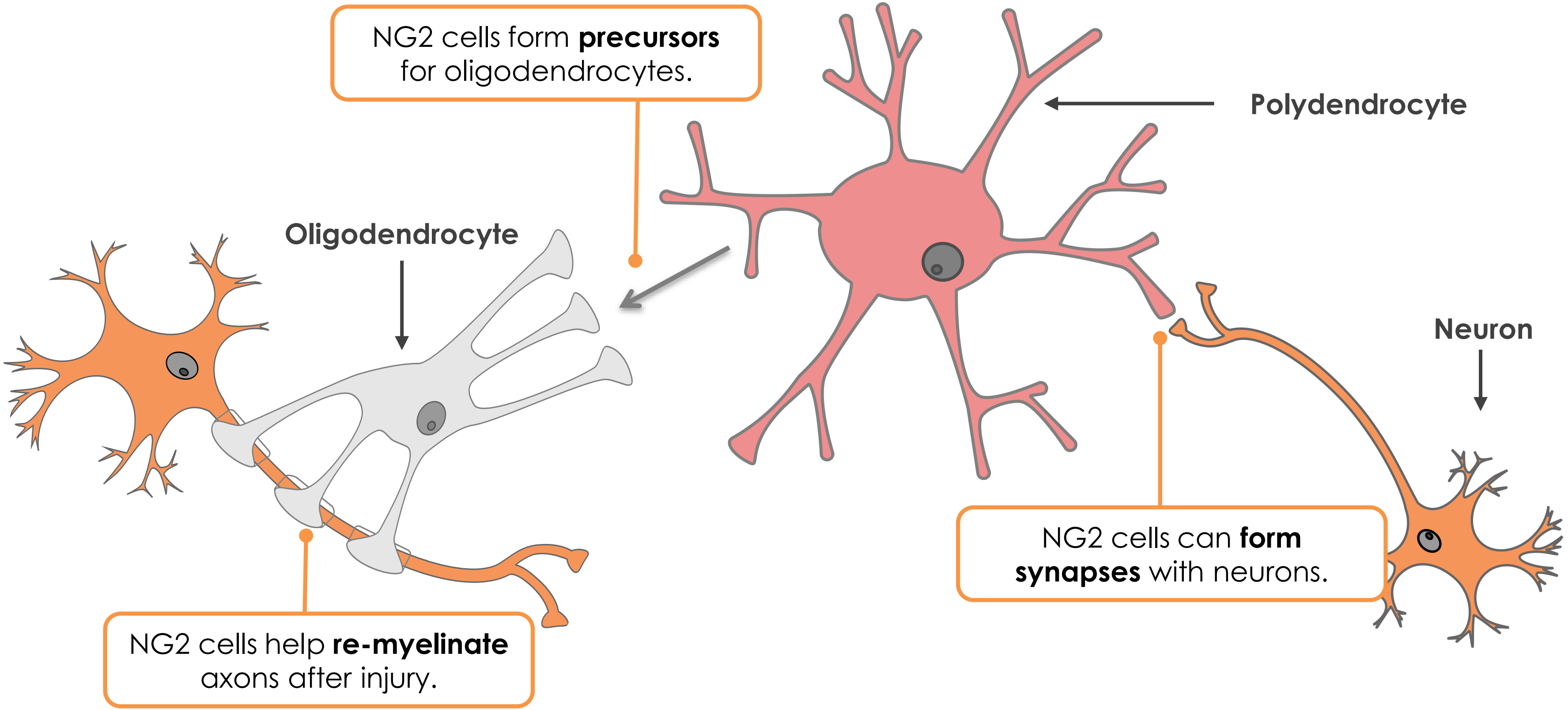
Schwann Cells



Oligodendrocytes



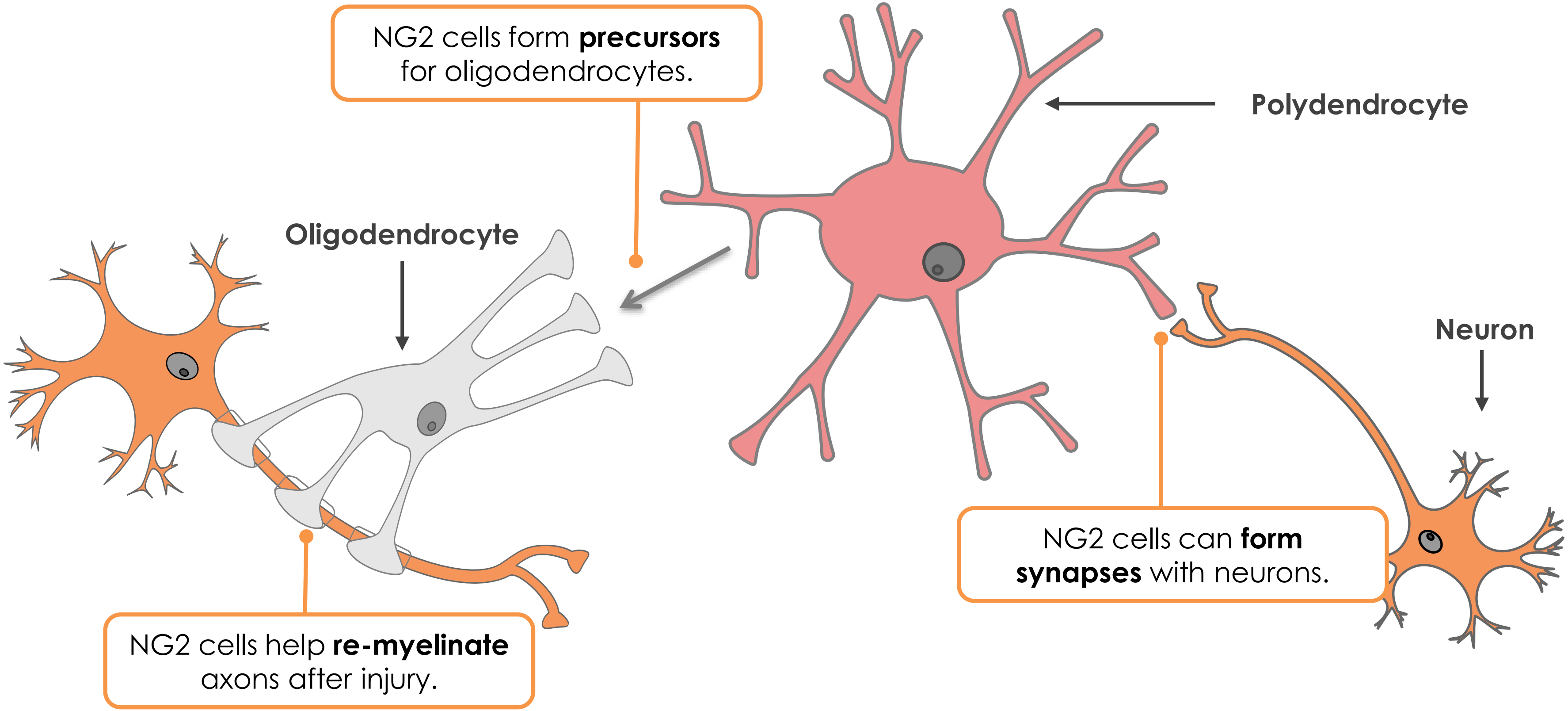
Polydendrocytes (NG2 Cells)



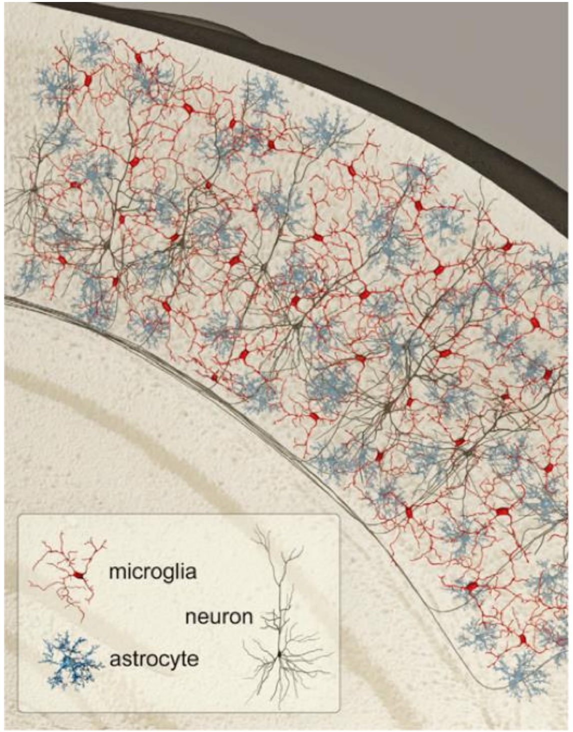
Polydendrocytes “may be important for integration in the brain because their processes pass through several neuronal layers and traverse grey and white matter.”

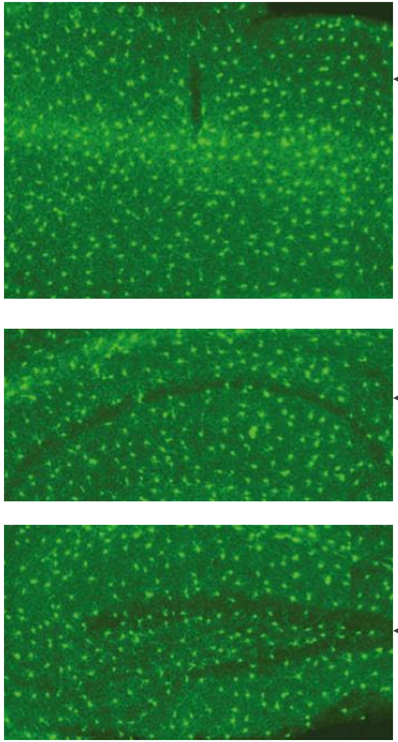
Heneka et. al. (2010, p.193).

Polydendrocytes (NG2 Cells)



Microglia



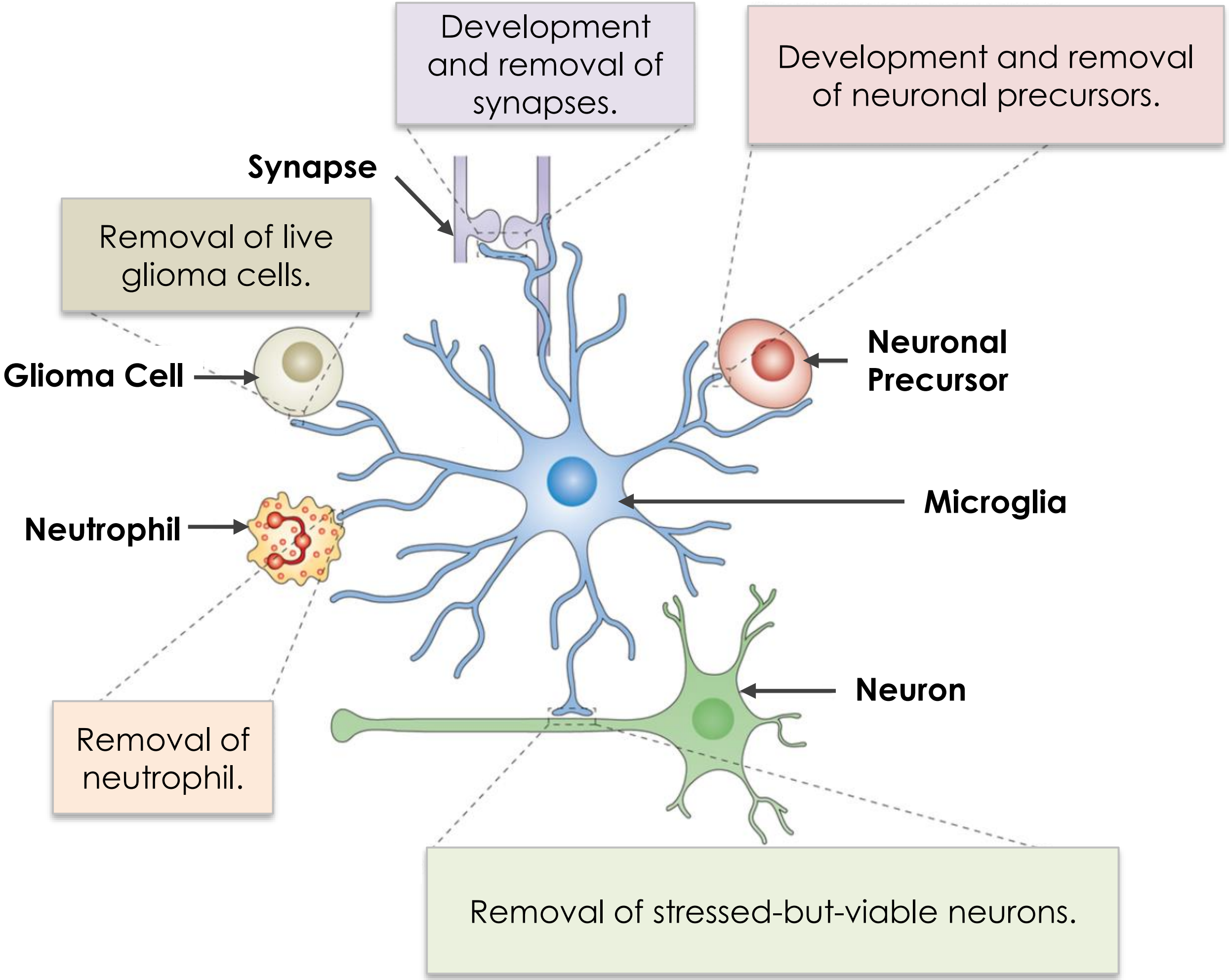


Cortex

Corpus Callosum

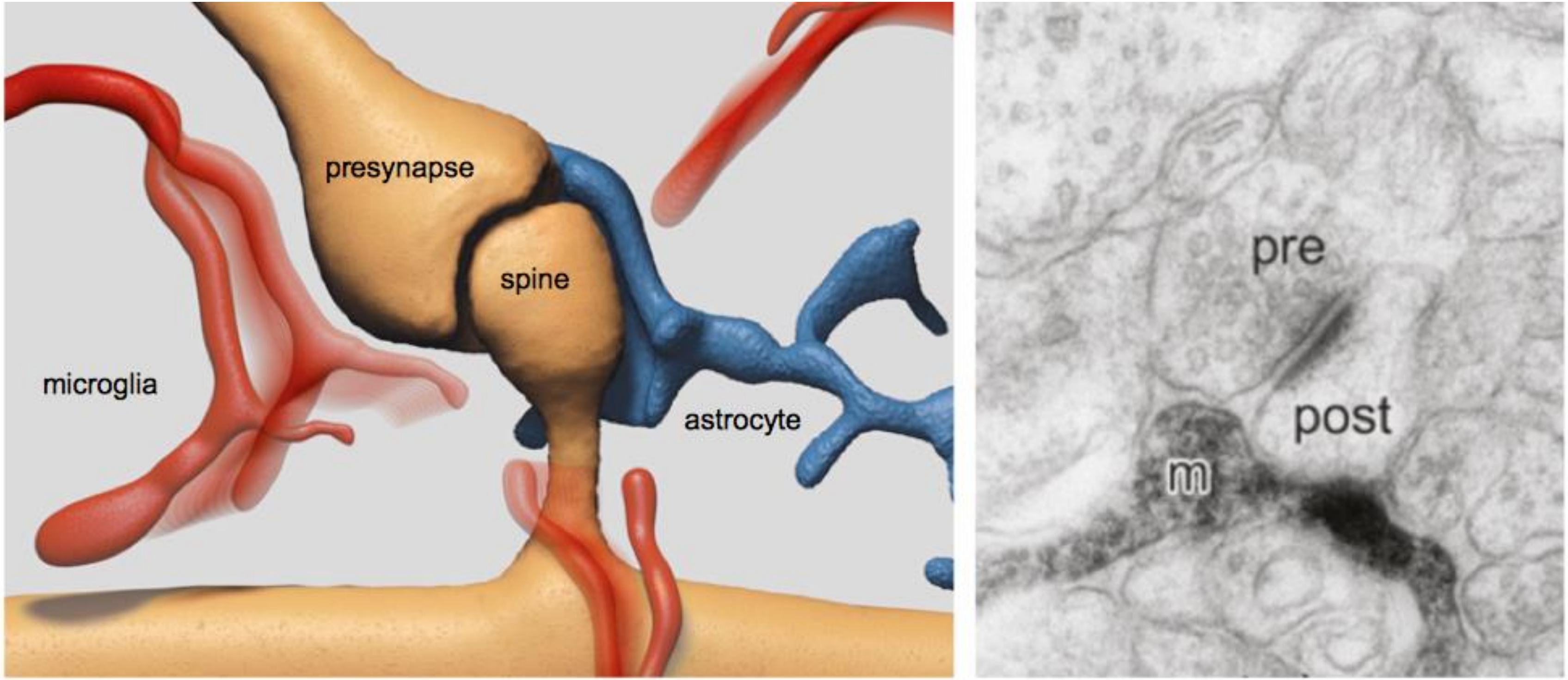
Hippocampus

From: Kettenmann, H., Kirchhoff, F., & Verkhratsky, A. (2013). Microglia: new roles for the synaptic stripper. Neuron, 77(1), 10-18. Figure 1.



Modified from Brown, G. C., & Neher, J. J. (2014). Microglial phagocytosis of live neurons. Nature Reviews Neuroscience, 15(4), 209-216. Figure 2.

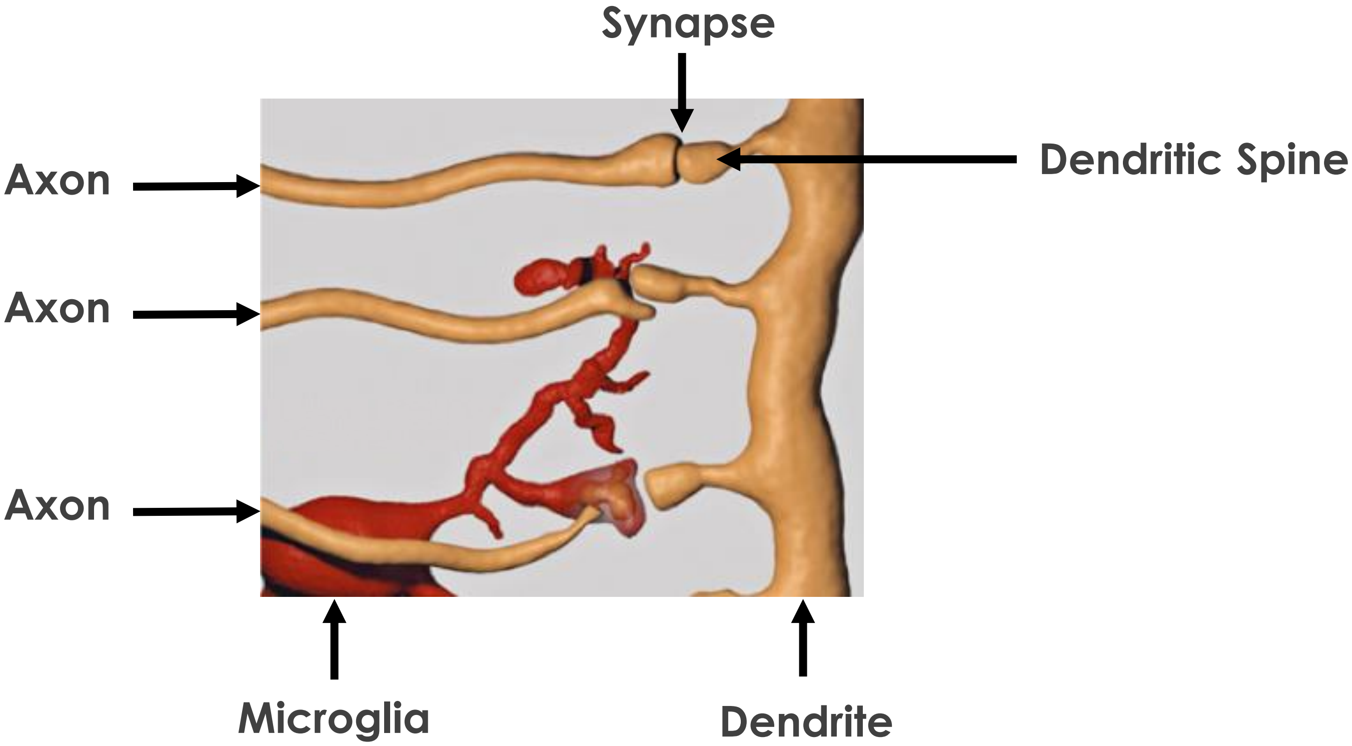
Microglia and the Synapse



Kettenmann, H., Kirchhoff, F., & Verkhratsky, A. (2013). Microglia: new roles for the synaptic stripper. Neuron, 77(1), 10-18. Figure 2.

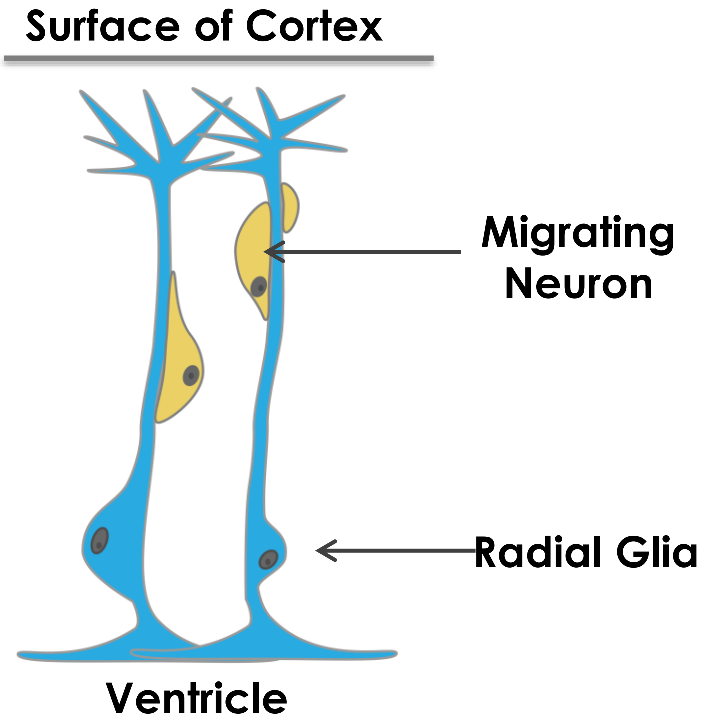
The “Quad-partite” Synapse

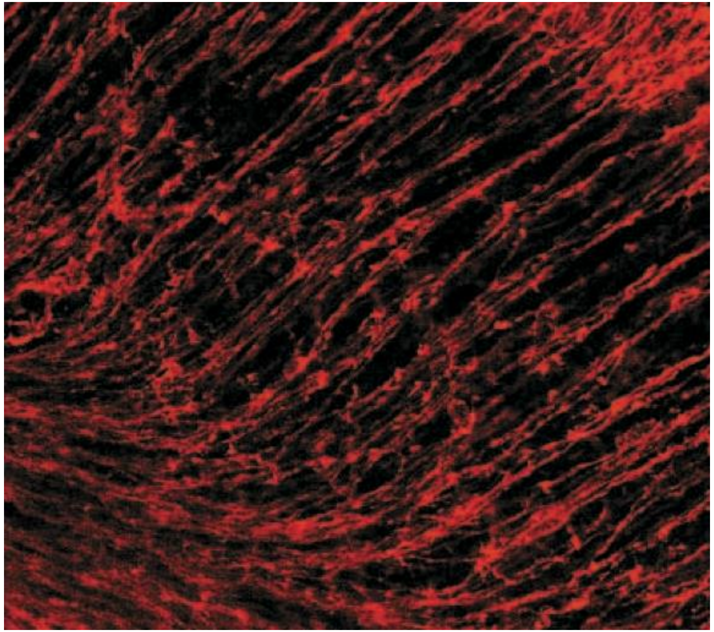
Microglia and Synaptic Pruning



Kettenmann, H., Kirchhoff, F., & Verkhratsky, A. (2013). Microglia: new roles for the synaptic stripper. Neuron, 77(1), 10-18. Figure 3.

Radial Glia

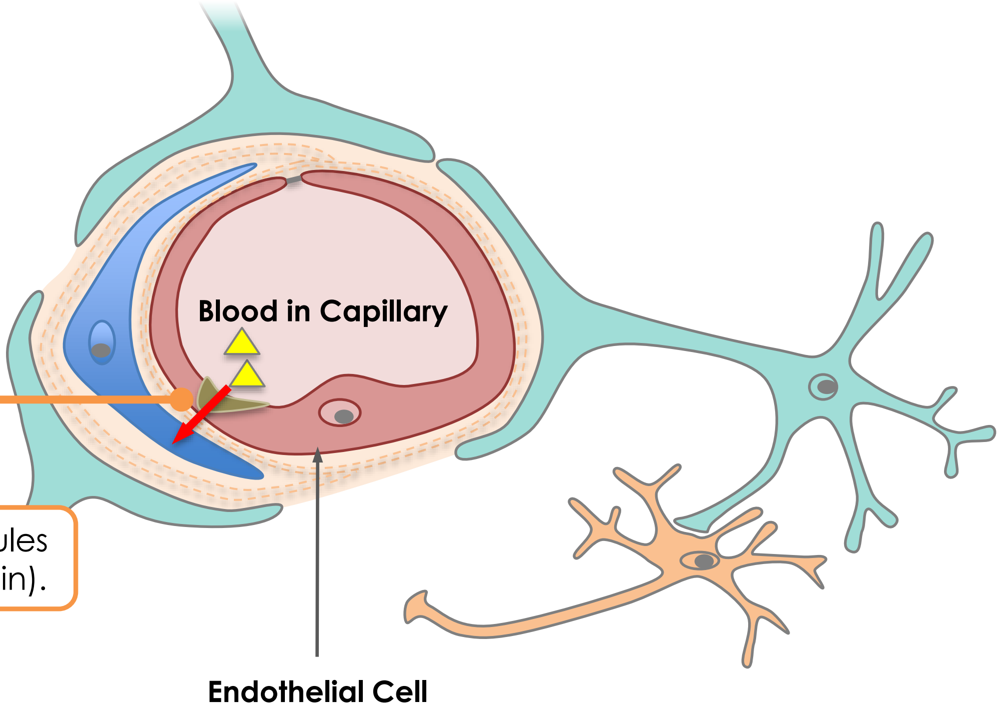




Malatesta, P., Hartfuss, E., & Gotz, M. (2000). Isolation of radial glial cells by fluorescent-activated cell sorting reveals a neuronal lineage. Development, 127(24), 5253-5263. Figure 1B.

Lack of neuronal nutrition: Korsakoff Syndrome

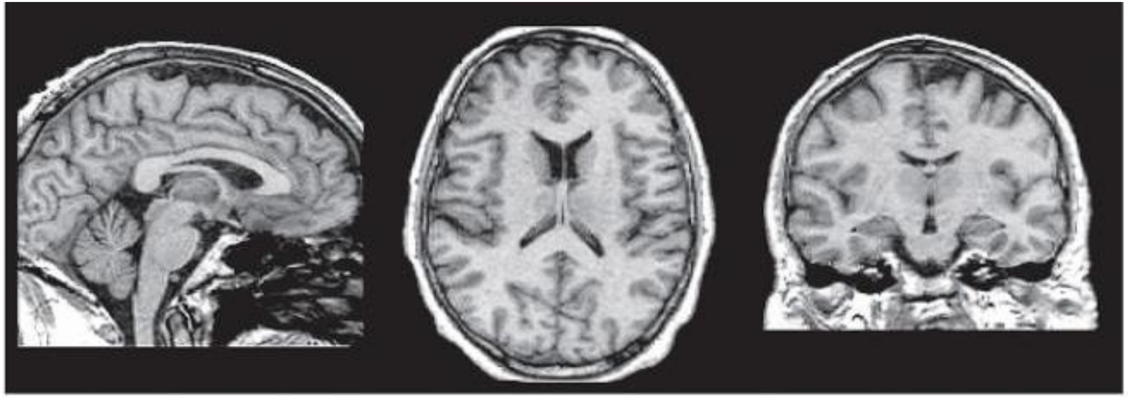
The Blood-Brain Barrier



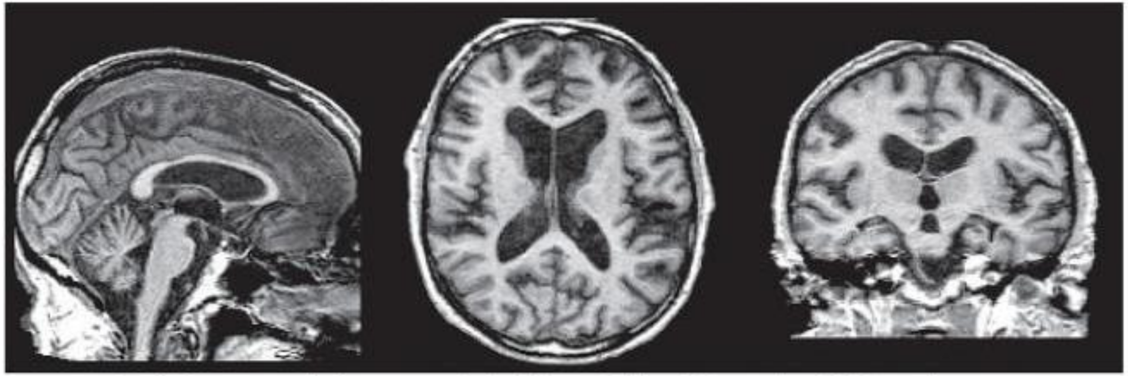
Active transport of larger molecules (e.g., glucose, amino acids, insulin).

Based on: Abbott, N. J., Rönnbäck, L., & Hansson, E. (2006). Astrocyte–endothelial interactions at the blood–brain barrier. *Nature reviews neuroscience*, *7*(1), 41. Fig 2 & 3, p. 43 & 44.

Korsakoff Syndrome



A 63-year-old healthy control male



A 63-year-old man with Wernicke-Korsakoff Syndrome

Today's Summary

- The ratio of glial cells to neurons differs throughout the brain.
- Neurons consist of somas, axons, and dendrites. Neurons are able to generate electrical pulses (more on this next lecture), while most glia do not.
- Glia are the 'support' cells of the brain. There are many different types, but we covered the 6 main ones. Glia provide structure, protection, and cleanup in and around neurons.
- While glia are not traditionally thought to send electrical signals like neurons, new research on Polydendrocytes is starting to challenge this view.