PSYCH 260/BBH 203

Cellular neuroscience

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2022-02-01 09:22:37

Prelude

(bbscottvids, 2009)

How to play EyeWire (03:56)

http://eyewire.org

Announcements

- Exam 1 next Thursday, 2/10
  - 40 questions
- Complete 1 “component/section” in EyeWire, earn 2 extra credit points.
  - Take screen shot, email to Iris via Canvas
  - Due before Friday, 2/11

Today's Topics

- Cells of the nervous system
  - *Glia*
  - *Neurons*
- How do these cells communicate?

Cells of the nervous system

We are human

- ~ 37 trillion (10^9) (Roy & Conroy, 2018) cells
- 10-100 trillion non-human cells (gut, skin/hair, bloodstream, etc.)

How many neurons and glia?

- Old “lore”: ~100 billion neurons
- New estimate (Azevedo et al., 2009)
  - ~86 +/- 8 billion neurons
  - ~85 +/- 9 billion glia
- 100-500 trillion synapses, 1 billion/mm^3

Could you count to 170 billion?

- How many years to count to 170 billion?
- 60 s/min x 60 min/hr x 24 hrs/day x 365 days/ yr = 31,536,000 s/yr
- 1.7e11/31,536,000 = 5,390 years

Mass, Neurons, Non-Neurons

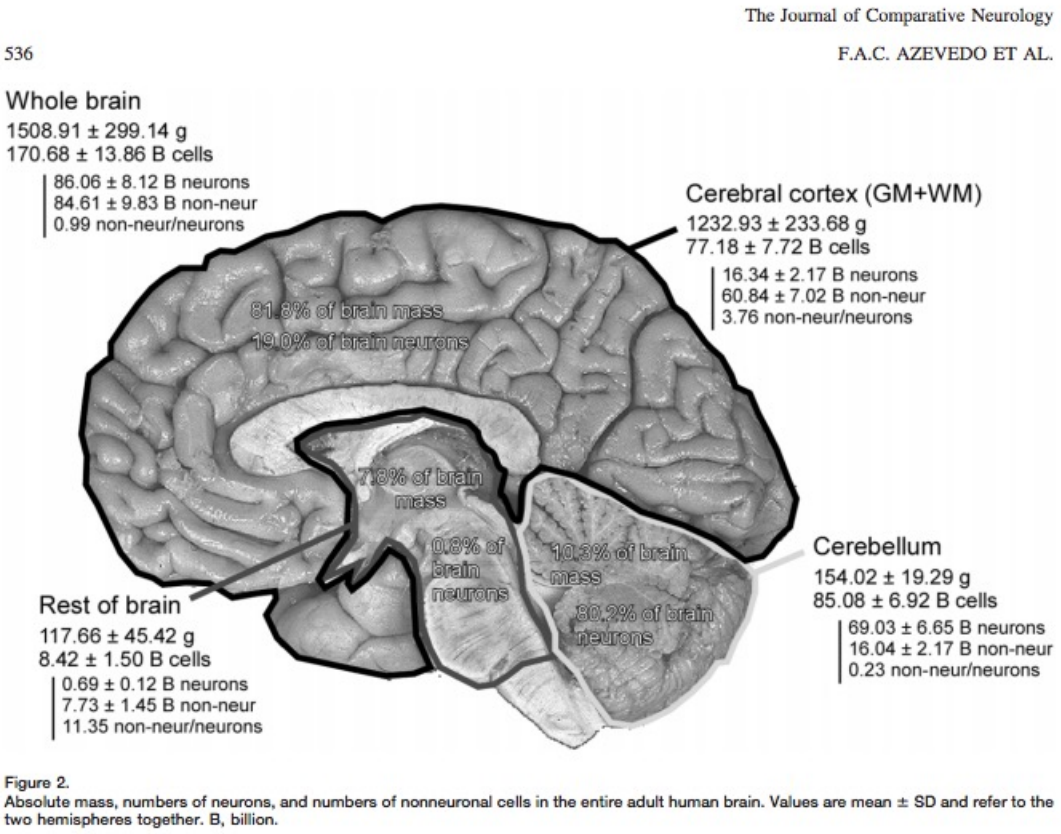
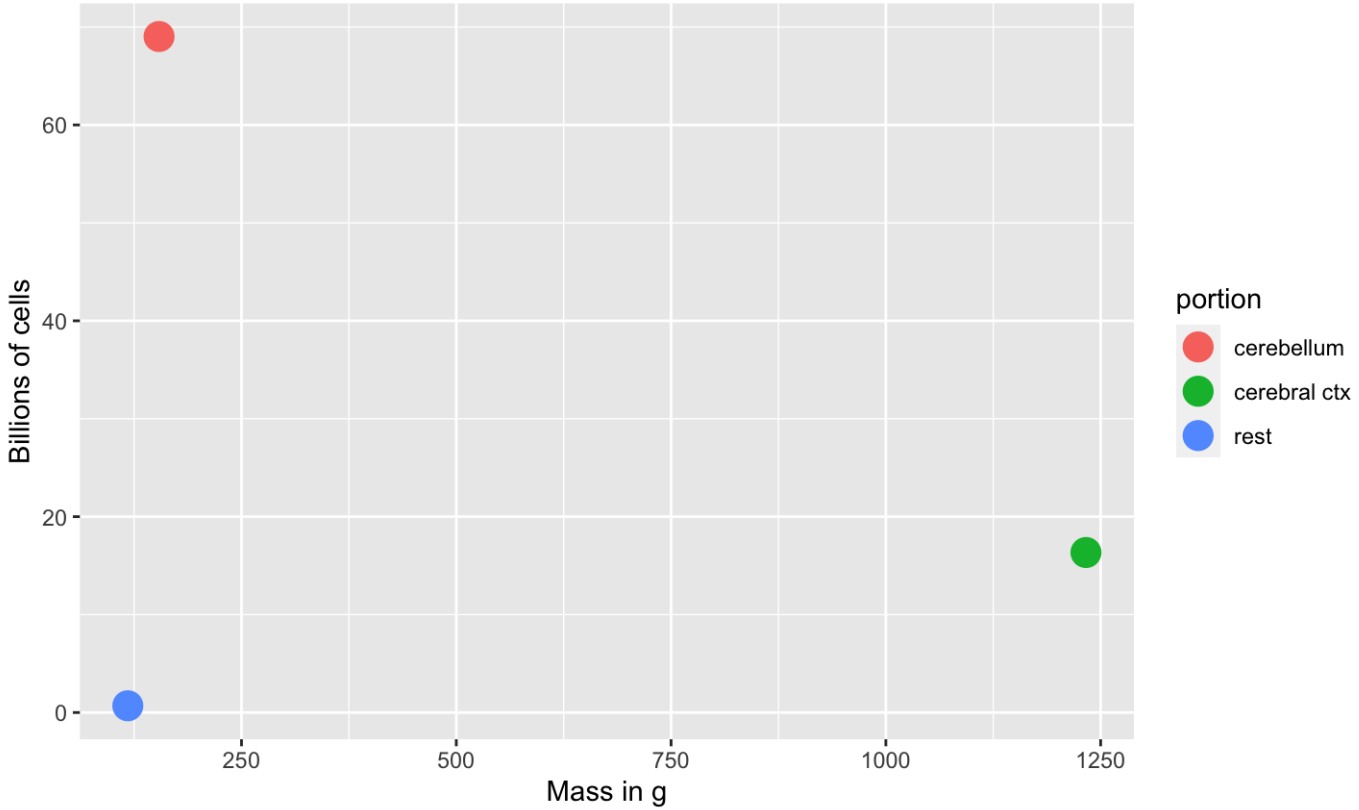


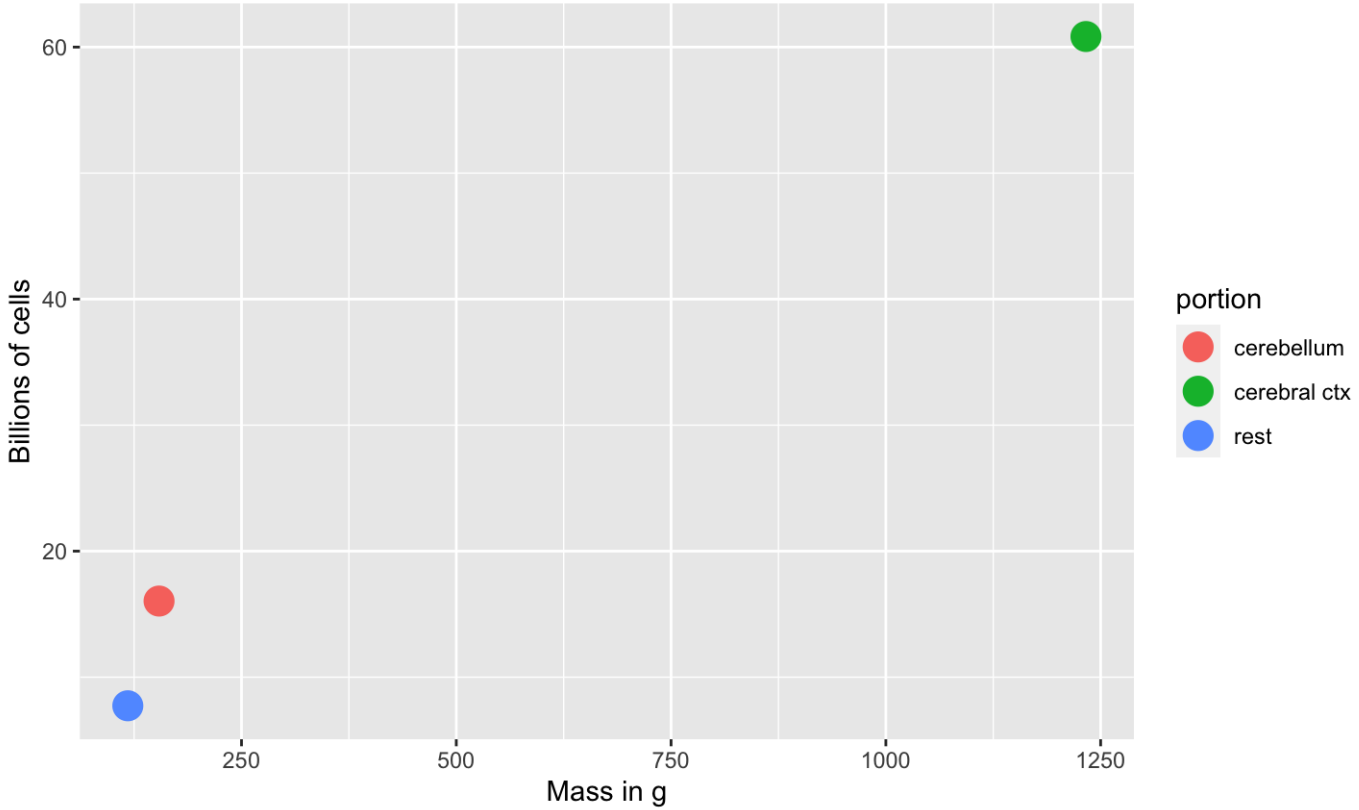
Figure 2.
Absolute mass, numbers of neurons, and numbers of nonneuronal cells in the entire adult human brain. Values are mean ± SD and refer to the two hemispheres together. B, billion.

(Azevedo et al., 2009)

Neurons by brain mass



Non-neuronal cells by brain mass



Summary

neurons doesn’t scale with brain size/mass (most neurons in cerebellum)

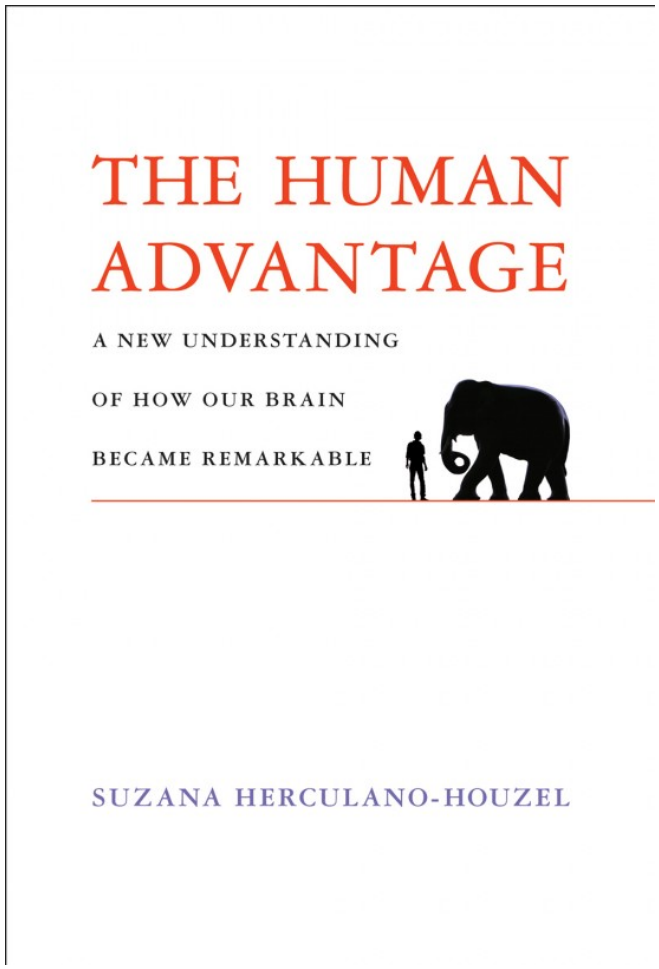
glia+ cells scales with brain size/mass

How many neurons and glia?

“These findings challenge the common view that humans stand out from other primates in their brain composition and indicate that, with regard to numbers of neuronal and nonneuronal cells, the human brain is an isometrically scaled-up primate brain.”

(Azevedo et al., 2009)

The Human Advantage



Glia (neuroglia)

- “Glia” means glue
- Functions
  - Structural support
  - Metabolic support
  - Brain development
  - Neural plasticity?

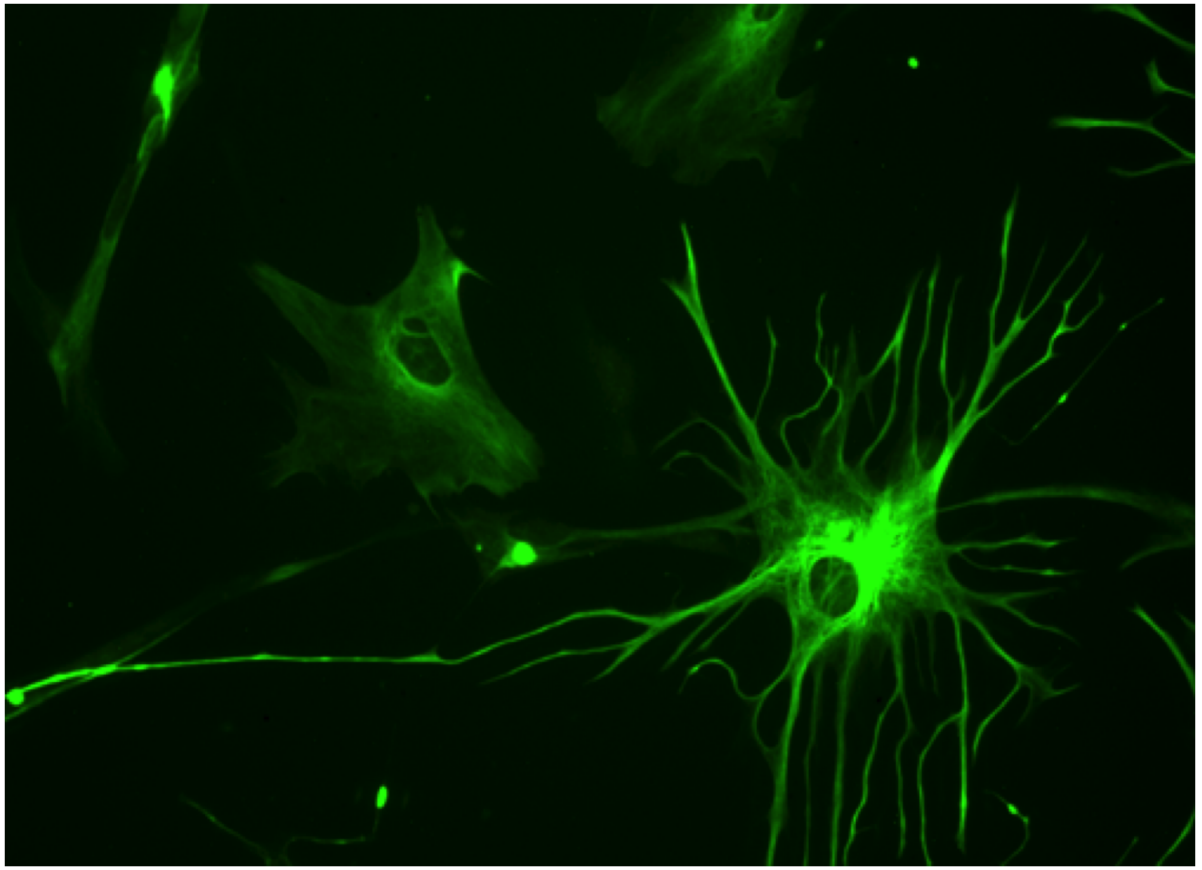
Astrocytes

- “Star-shaped”
- Physical and metabolic support
  - Blood/brain barrier
  - Regulate concentration of key ions (Ca++/K+) for neural communication
  - Regulate concentration of key neurotransmitters (e.g., glutamate)

Astrocytes

- Shape brain development, synaptic plasticity
- Regulate local blood flow (part of fMRI's blood oxygen-dependent BOLD response)
- Regulate/influence communication between neurons, (Bazargani & Attwell, 2016)
- Disruption linked to cognitive impairment, disease (Chung, Welsh, Barres, & Stevens, 2015)

Astrocytes



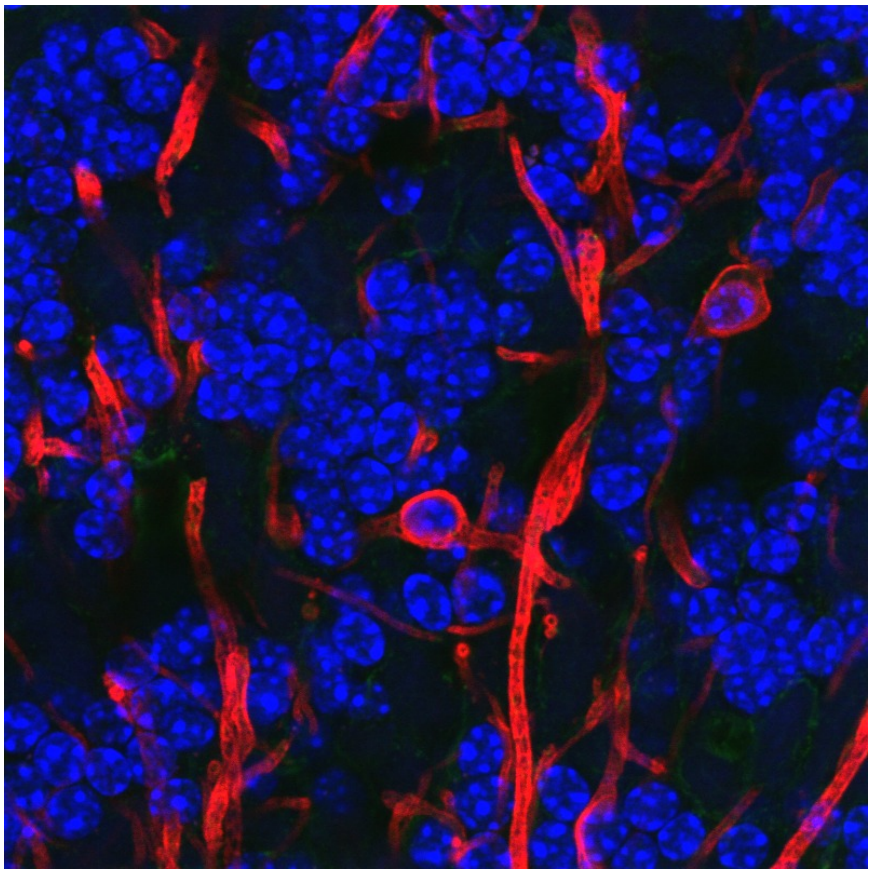
Myelinating cells

- Produce myelin or myelin sheath
  - White, fatty substance
  - Surrounds many neurons
  - The “white” in white matter
- Provide electrical/chemical insulation
- Make neuronal messages faster, less susceptible to noise

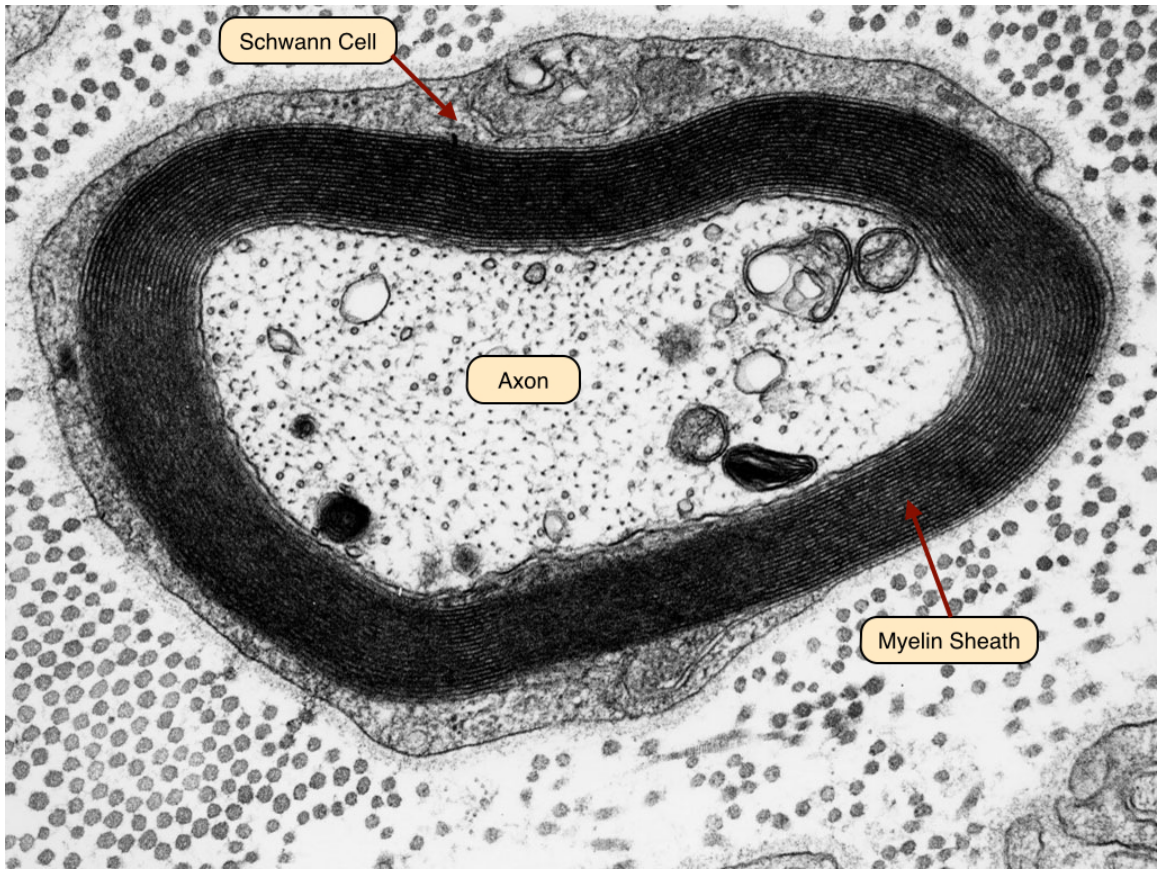
Types of myelin-producing cells

- Oligodendrocytes
  - In brain and spinal cord (CNS)
  - 1:many neurons
- Schwann cells
  - In PNS
  - 1:1 neuron
  - Facilitate neuro-regeneration
- Mnemonics: COPS/SPOC

Oligodendrocytes



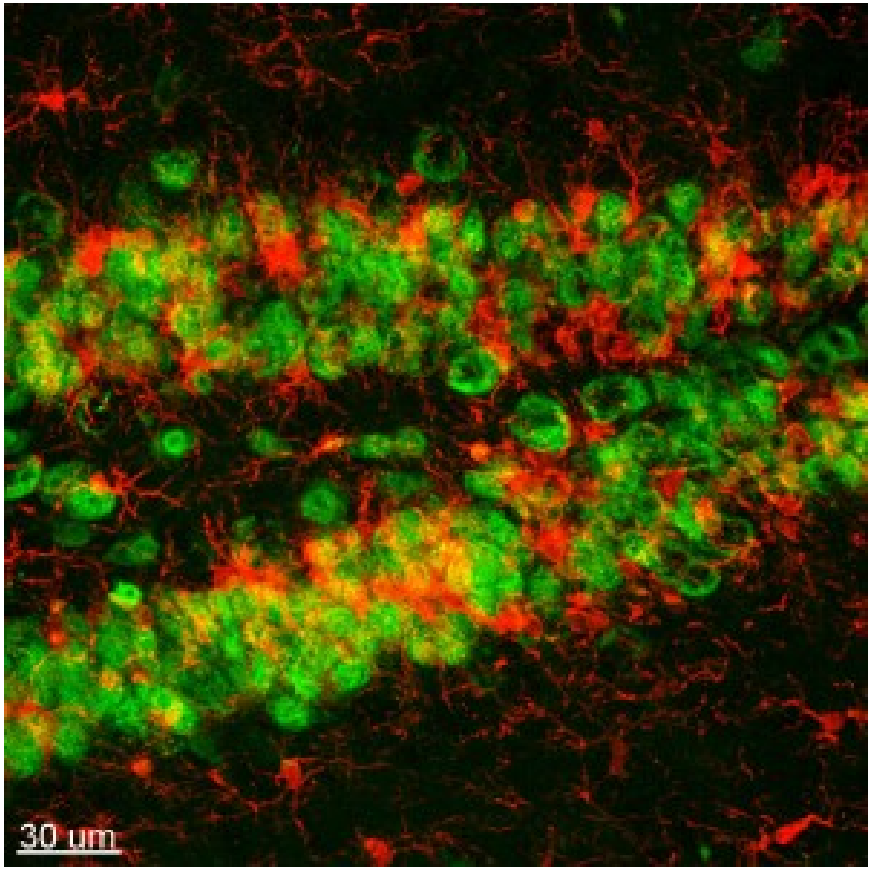
Schwann Cells



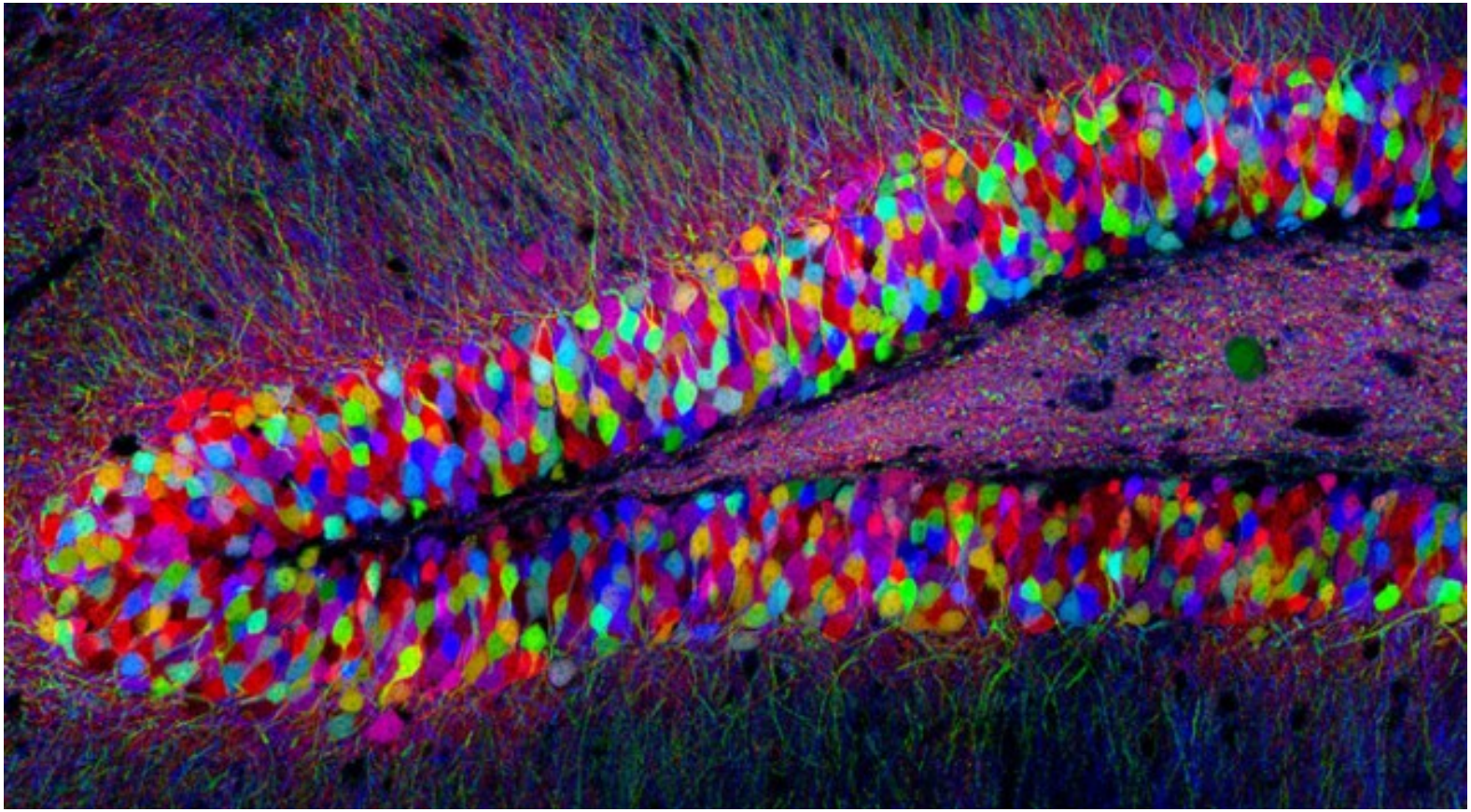
Microglia

- Phagocytosis
- Clean-up damaged, dead tissue
- Prune synapses in normal development and disease
- Disruptions in microglia pruning -> impaired functional brain connectivity and social behavior, (Zhan et al., 2014)

Microglia



Neurons



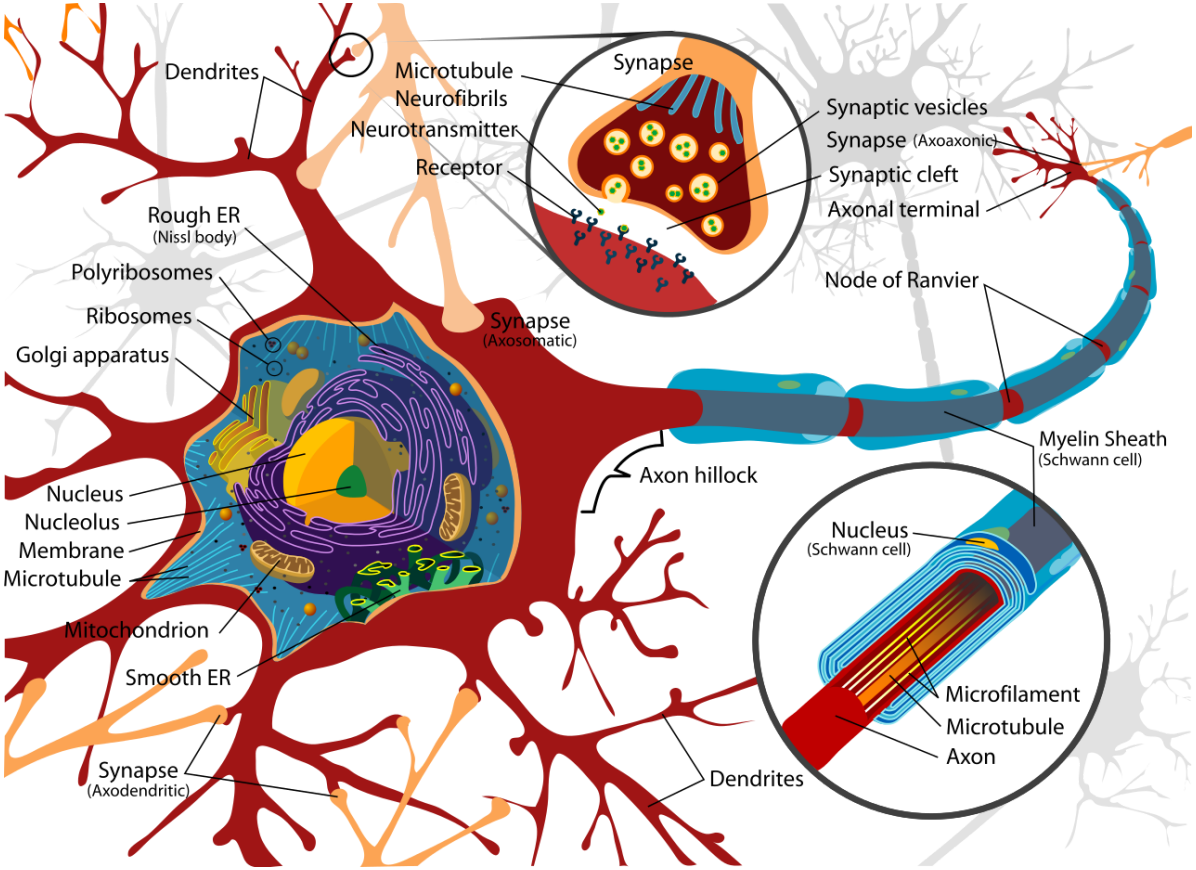
Fun facts about neurons

- Specialized for electrical & chemical communication
- Post-mitotic – don't divide
- Most born early in life, (Bhardwaj et al., 2006)
- Among longest-lived cells in body, may scale with organism lifespan (Magrassi, Leto, & Rossi, 2013)
- Can extend over long distances

Macrostructure of neurons

- Dendrites
- Soma (cell body)
- Axons
- Terminal buttons (boutons)

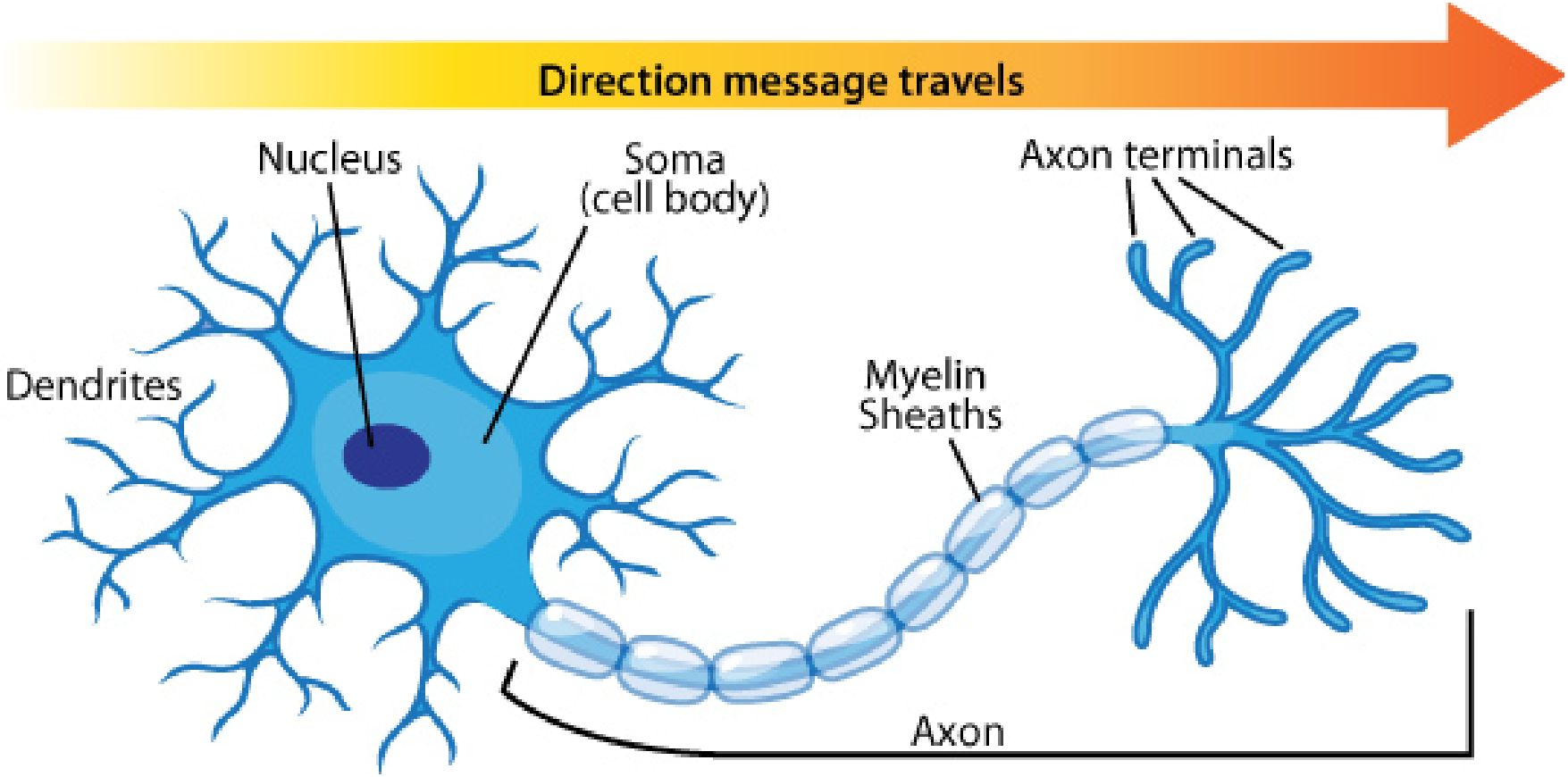
Structure of neurons



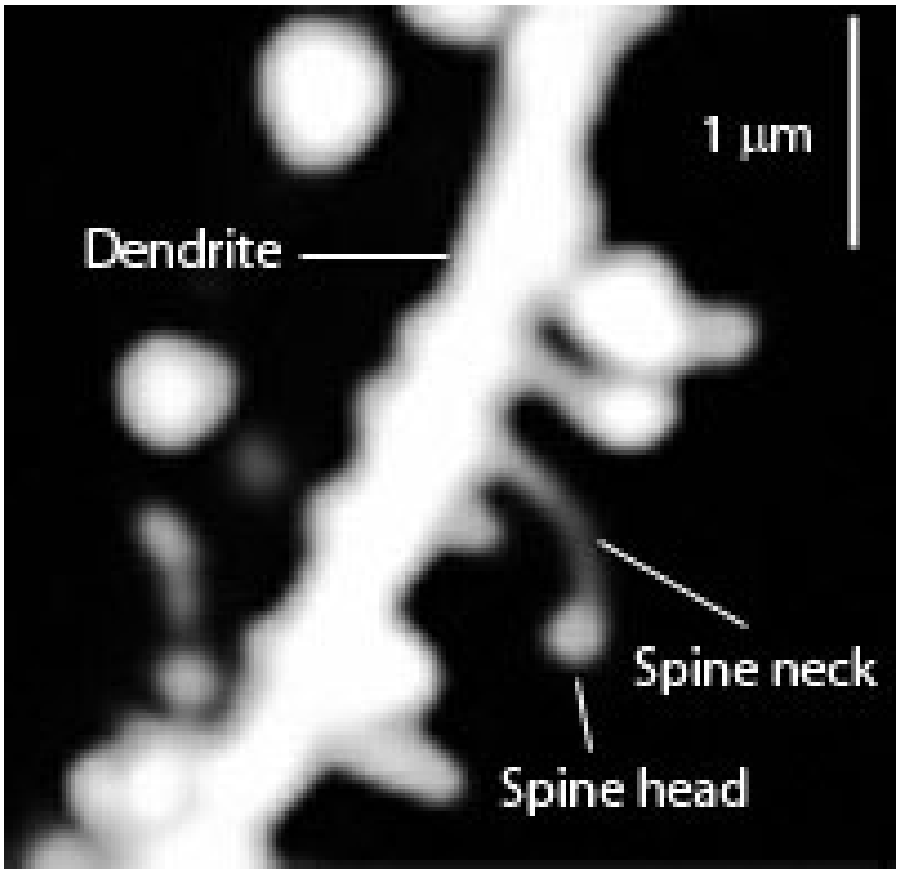
Dendrites

- Branch-like “extrusions” from cell body
- Majority of input to neuron
- Cluster close to cell body/soma
- Usually receive info
- Passive (do not regenerate electrical signal) vs. active (regenerate signal)
- Spines

Dendrites


Direction message travels
Nucleus
Soma
(cell body)
Axon terminals
Dendrites
Myelin
Sheaths
Axon

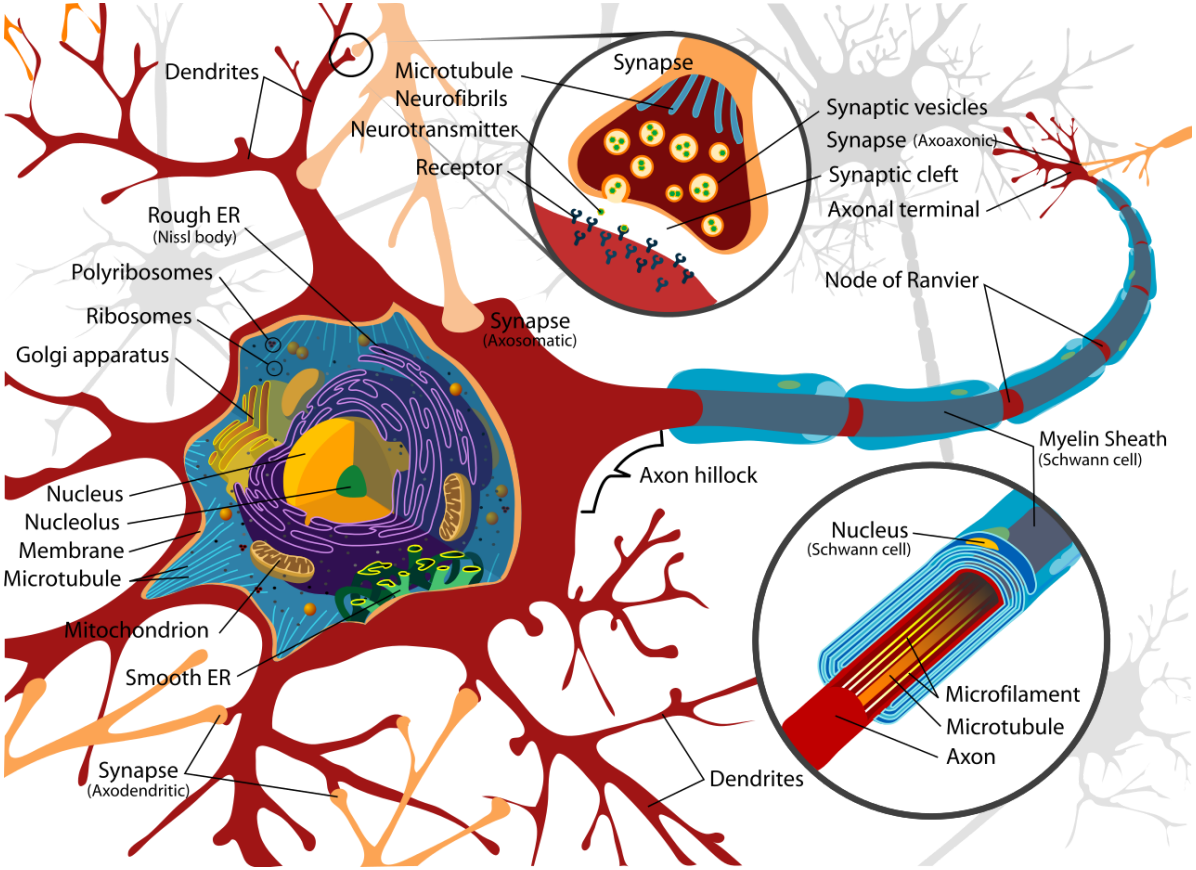
Dendritic Spines



Soma (cell body)

- Varied shapes
- Nucleus
  - Chromosomes
- Organelles
  - Mitochonrdria
  - Smooth and Rough Endoplasmic reticulum (ER)

Soma


Dendrites
Microtubule
Neurofibrils
Neurotransmitter
Receptor
Synapse
Synaptic vesicles
Synapse (Axoaxonic)
Synaptic cleft
Axonal terminal
Rough ER
(Nissl body)
Polyribosomes
Ribosomes
Golgi apparatus
Synapse
(Axosomatic)
Node of Ranvier
Myelin Sheath
(Schwann cell)
Axon hillock
Nucleus
Nucleolus
Membrane
Microtubule
Mitochondrion
Smooth ER
Nucleus
(Schwann cell)
Microfilament
Microtubule
Axon
Synapse
(Axodendritic)
Dendrites

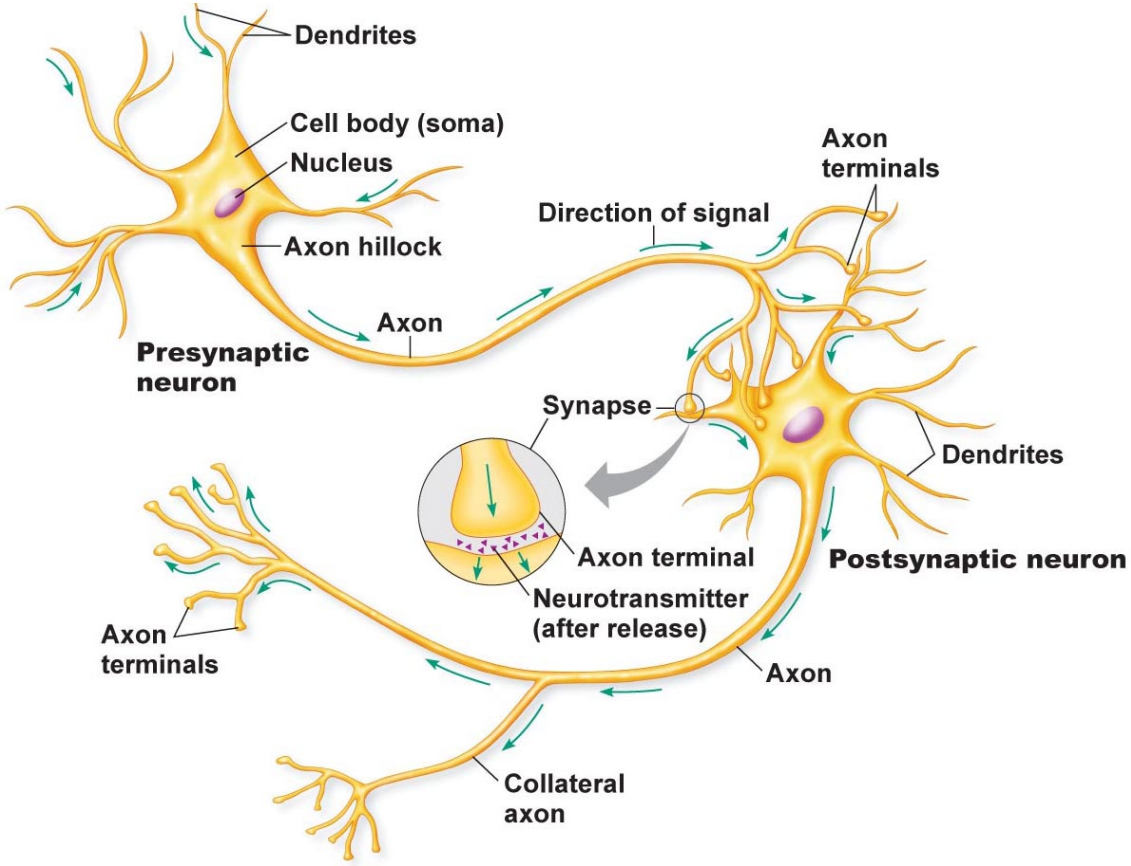
Axons

- Another branch-like “extrusion” from soma
- Extend farther than dendrites
- Usually transmit info

Axons

- Parts
  - **Initial segment** (closest to soma, unmyelinated)
  - **Nodes of Ranvier** (unmyelinated segments along axon)
  - Terminals, axon terminals, terminal buttons, synaptic terminals, synaptic boutons

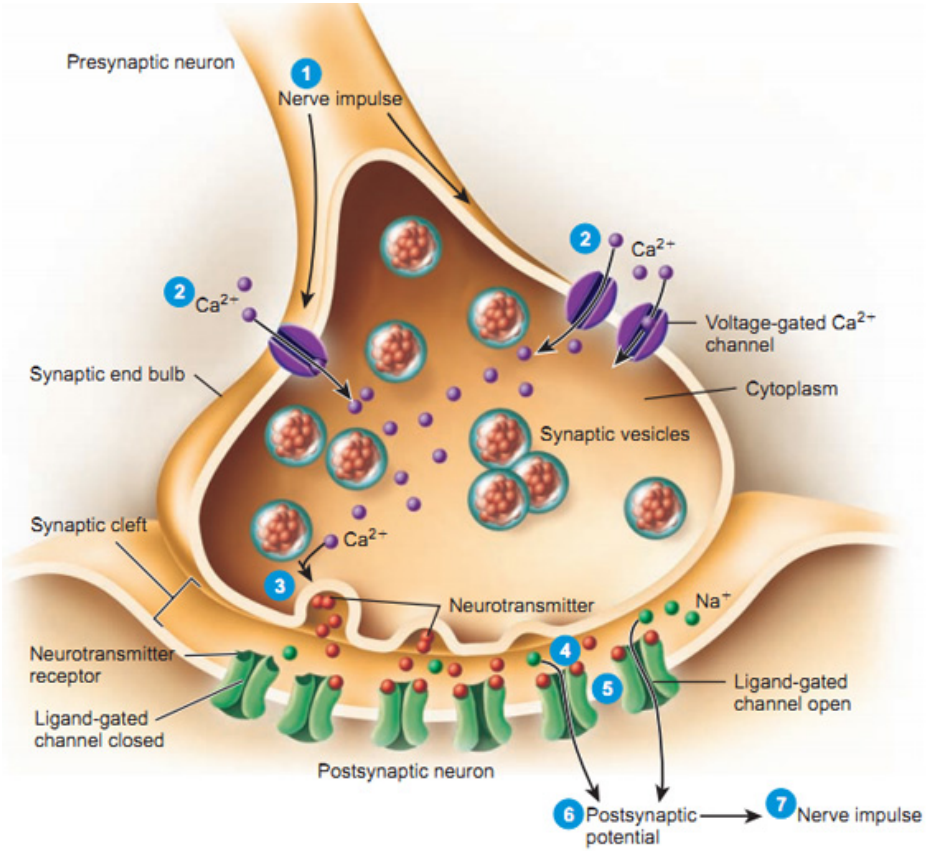
Axons


Dendrites
Cell body (soma)
Nucleus
Axon hillock
Axon
Presynaptic neuron
Direction of signal
Axon terminals
Synapse
Dendrites
Axon terminal
Postsynaptic neuron
Neurotransmitter (after release)
Axon terminals
Axon
Collateral axon

Synaptic bouton (terminal button)

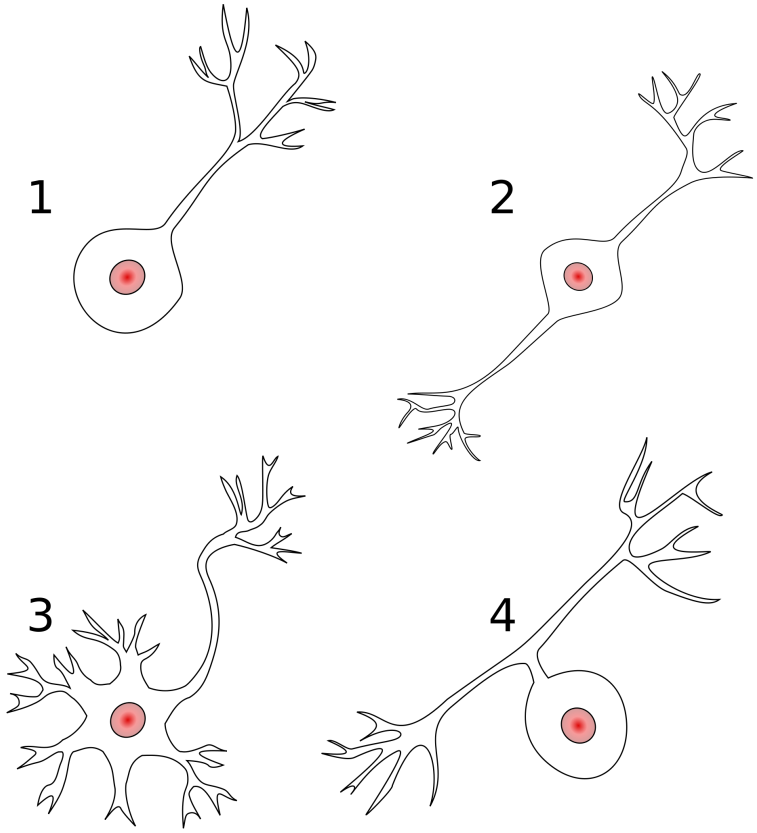
- Synapse (~5-10K per neuron)
- Presynaptic membrane (sending cell) and postsynaptic (receiving cell) membrane
- Synaptic cleft – space between cells
- Synaptic vesicles
    - Pouches of neurotransmitters
- Autoreceptors (detect NTs); transporters (transport NTs across membrane)

Synaptic bouton (terminal button)



Classifying neurons

- Functional role
  - Input (sensory), output (motor/secretory), interneurons
- Anatomy
  - Unipolar
  - Bipolar
  - Multipolar

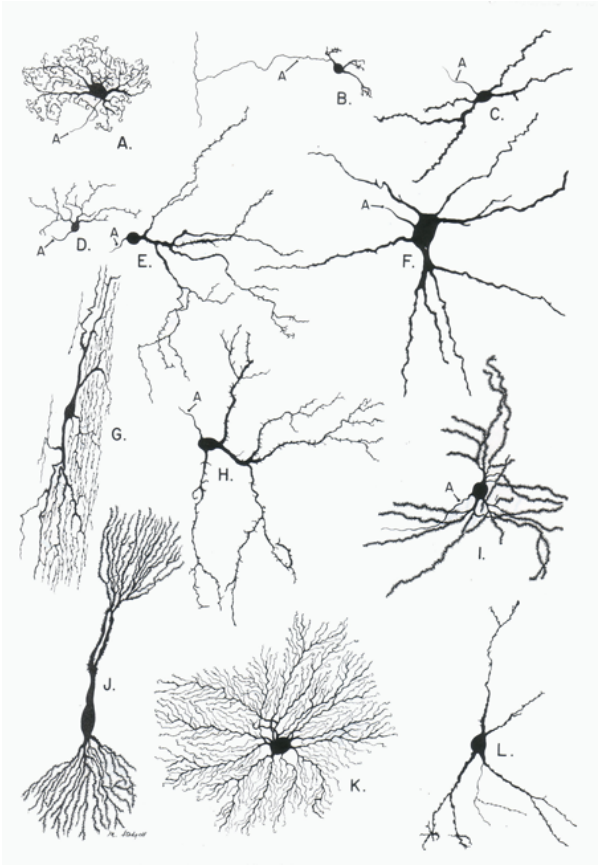


https://upload.wikimedia.org/wikipedia/commons/thumb/9
Neurons_uni_bi_multi_pseudouni.svg.pngg

Classifying neurons

- By specific anatomy
  - Pyramidal cells
  - Stellate cells
  - Purkinje cells
  - Granule cells

Neurons by type



Next time

- How neurons communicate

References

Azevedo, F. A., Carvalho, L. R., Grinberg, L. T., Farfel, J. M., Ferretti, R. E., Leite, R. E., … others. (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.

Bazargani, N., & Attwell, D. (2016). Astrocyte calcium signaling: The third wave. *Nature Neuroscience*, *19*(2), 182–189. https://doi.org/10.1038/nn.4201

bbscottvids. (2009, September). Neuronal migration. Youtube. Retrieved from https://www.youtube.com/watch?v=t-8bxeWqSV4

Bhardwaj, R. D., Curtis, M. A., Spalding, K. L., Buchholz, B. A., Fink, D., Björk-Eriksson, T., … Frisén, J. (2006). Neocortical neurogenesis in humans is restricted to development. *Proceedings of the National Academy of Sciences*, *103*(33), 12564–12568. https://doi.org/10.1073/pnas.0605177103

Chung, W.-S., Welsh, C. A., Barres, B. A., & Stevens, B. (2015). Do glia drive synaptic and cognitive impairment in disease? *Nature Neuroscience*, *18*(11), 1539–1545. https://doi.org/10.1038/nn.4142

Magrassi, L., Leto, K., & Rossi, F. (2013). Lifespan of neurons is uncoupled from organismal lifespan. *Proceedings of the National Academy of Sciences*, *110*(11), 4374–4379. https://doi.org/10.1073/pnas.1217505110

Roy, A. L., & Conroy, R. S. (2018). Toward mapping the human body at a cellular resolution. *Molecular Biology of the Cell*, *29*(15), 1779–1785. https://doi.org/10.1091/mbc.E18-04-0260

Zhan, Y., Paolicelli, R. C., Sforazzini, F., Weinhard, L., Bolasco, G., Pagani, F., … Gross, C. T. (2014). Deficient neuron-microglia signaling results in impaired functional brain connectivity and social behavior. *Nature Neuroscience*, *17*(3), 400–406. https://doi.org/10.1038/nn.3641