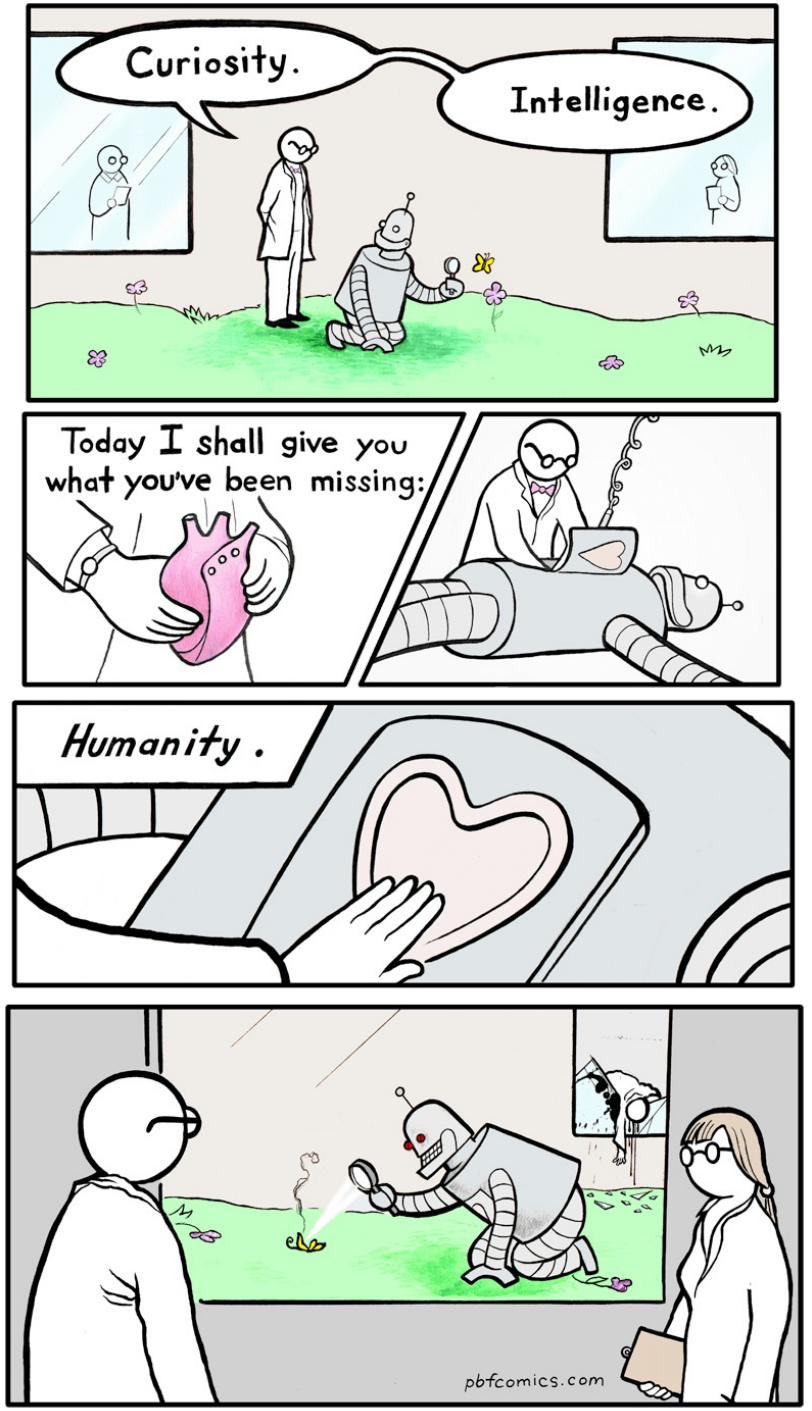
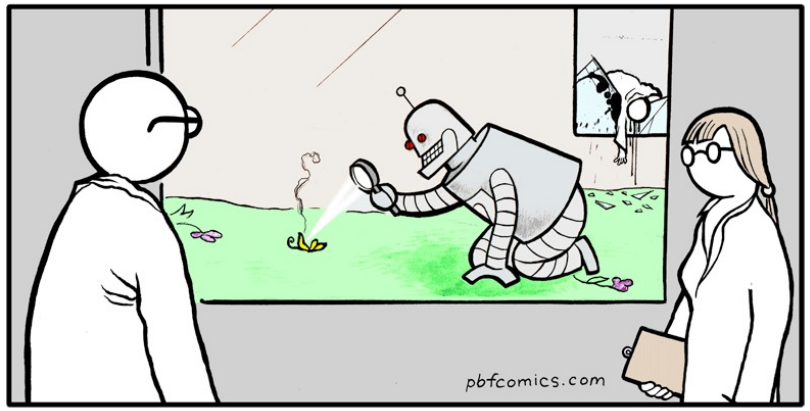
PSYC304: Brain basics

Jay Hosking, PhD



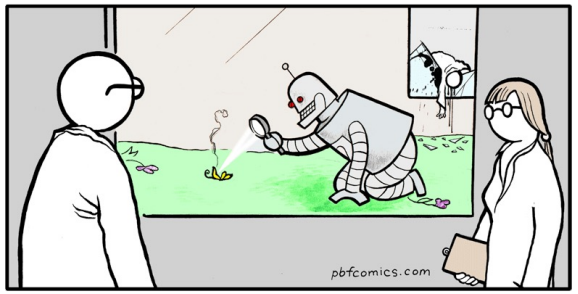
Overview

A. A brief history of neuroscience
B. Brain basics
C. Brain cell basics



Learning objectives

1. Describe how we have used, and continue to use, metaphors to describe brain function. In what ways are these beneficial? In what ways are they limiting?
2. Name two theories of neuron function. Which one was shown to be predominantly correct?
3. Have a foundational understanding of basic brain facts. What aspect of the human brain is most clearly, mechanistically related to our intelligence?
4. Name and describe two general types of cells within the nervous system.
5. Identify three types of staining and the use case for each.
6. Name four types of glial cells and describe some functional roles for each.
7. Explain what is meant by a “tripartite synapse.”
8. Draw, label, and define the major features of a neuron.
9. Describe the central dogma of molecular biology.
10. Name and describe the function of some key cellular structures.



Phineas Gage: “Doctor, here is business for you.”

From

“…the most efficient and capable foreman in their employ… a shrewd, sharp businessman, very energetic and persistent in executing all his plans of operation”

To

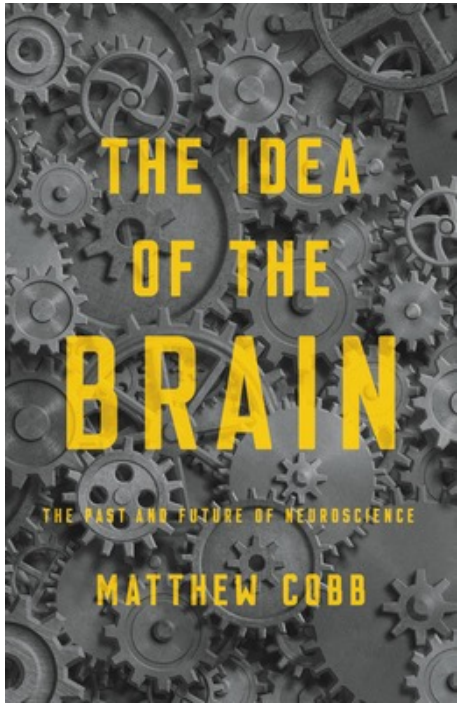
“He is fitful, irreverent, indulging at times in the grossest profanity…, impatient of restraint or advice when it conflicts with his desires…, devising many plans of future operations, which are no sooner arranged than they are abandoned… radically changed, so decidedly that his friends and acquaintances said he was ‘no longer Gage.’”

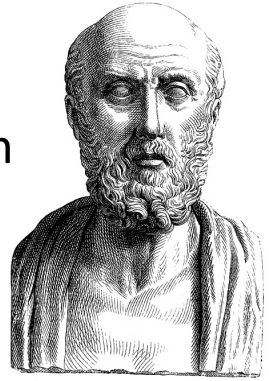
Undoubtedly distorted tale, partial temporary effects, but still…

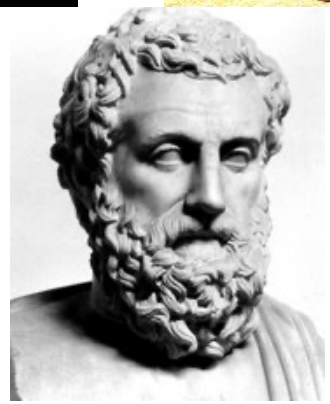
History

Antiquity

- Guiding principle: metaphors
- Schools of thought: doctors and philosophers
- Prehistory
- Egypt
- Greeks
  - Hippocrates
  - Aristotle
- Romans
  - Galen
  - Cerebrum & cerebellum
  - Ventricles, nerves
  - **Humours**



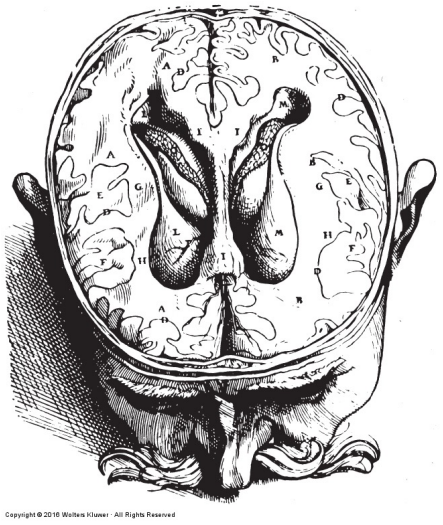


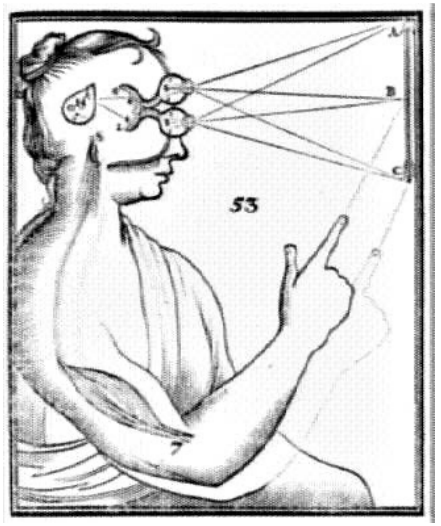


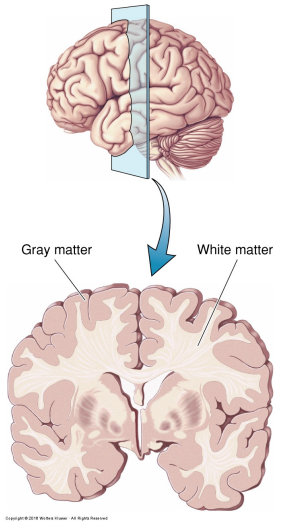
History

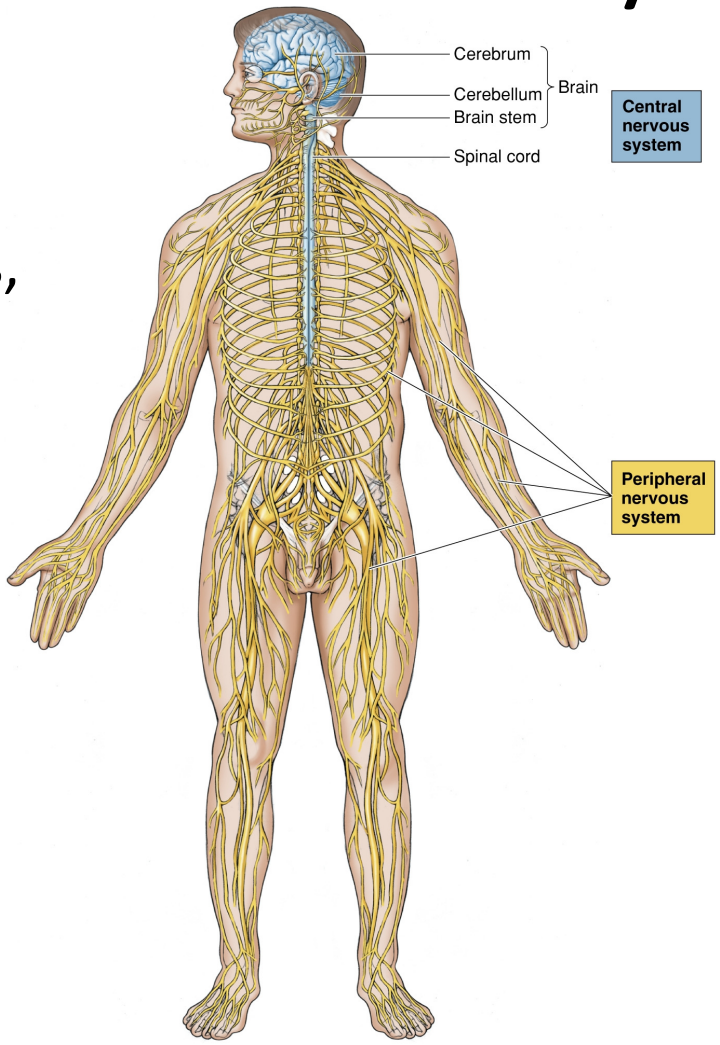
Renaissance to the 18th Century

- **Hydraulics**: Vesalius, Descartes
- Aside: materialism in science
- Birth of white / grey matter anatomical maps, gyri and sulci



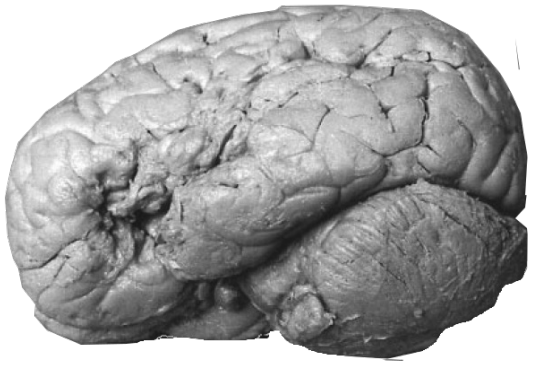


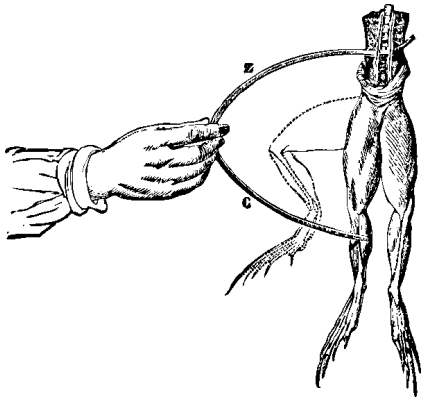


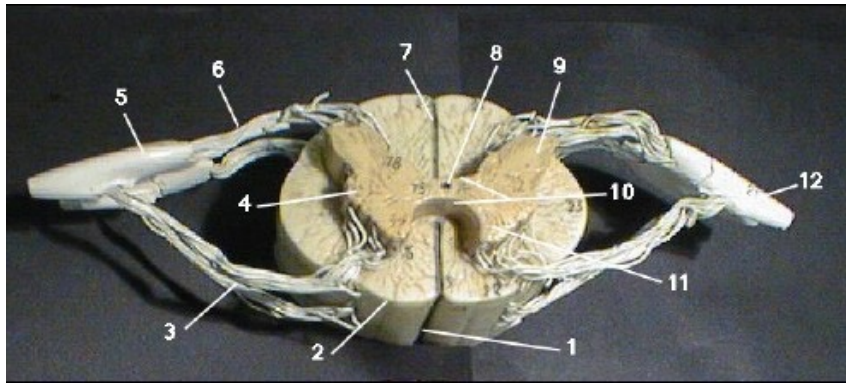


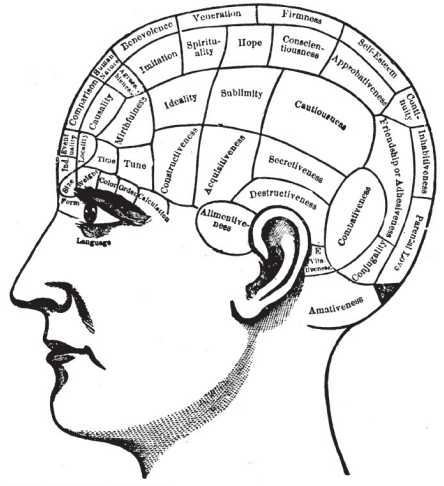
19th Century

- **Wires/electricity**: Galvani & du Bois-Reymond
- Dorsal/ventral: Bell & Magendie
- Localization of function: Fluorens, Gall, Broca









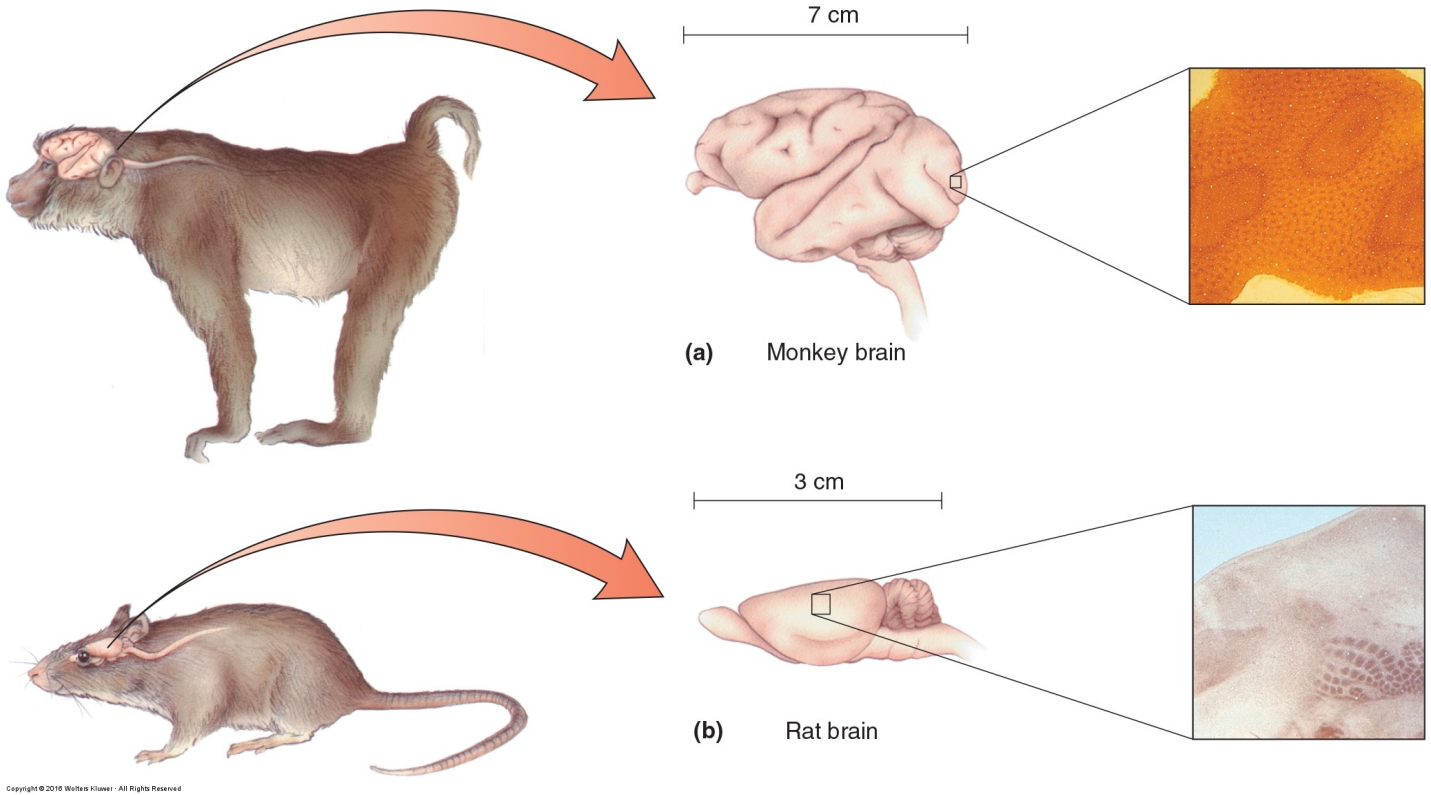
3. Results

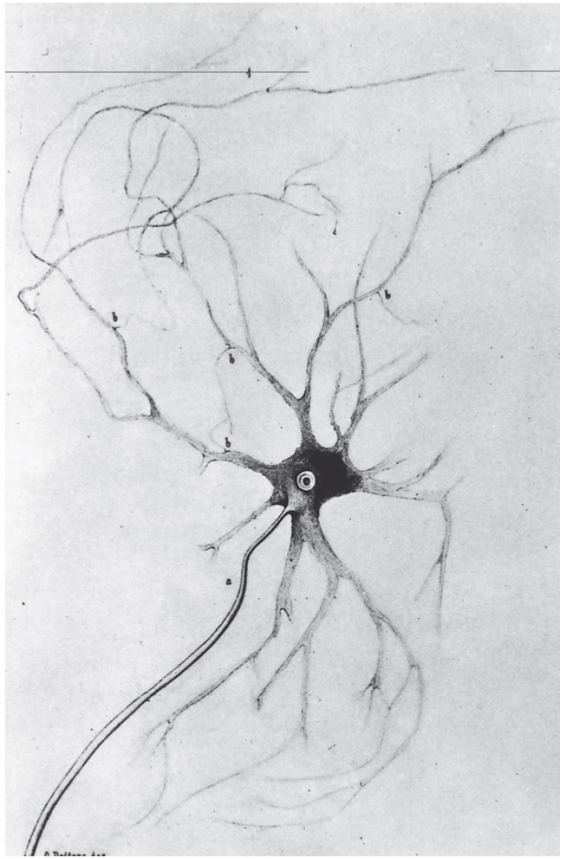
The phrenological analyses produced no statistically significant or meaningful effects.

O. Parker Jones *et al*. 2018

19th Century, continued

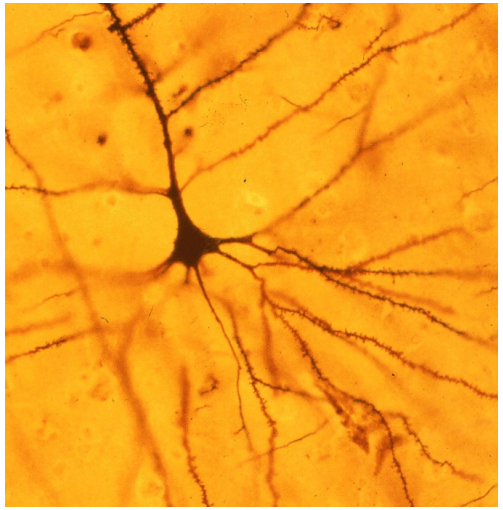
- Evolution: Darwin, animal models
- Cellular theory: Schwann

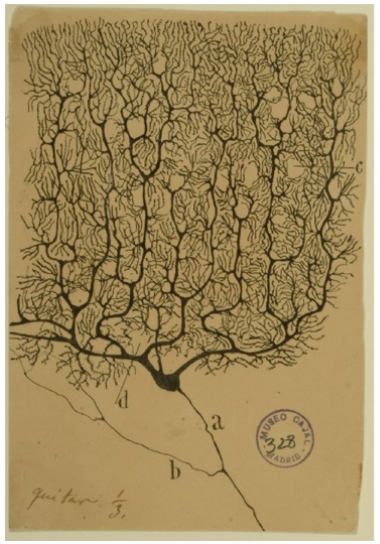


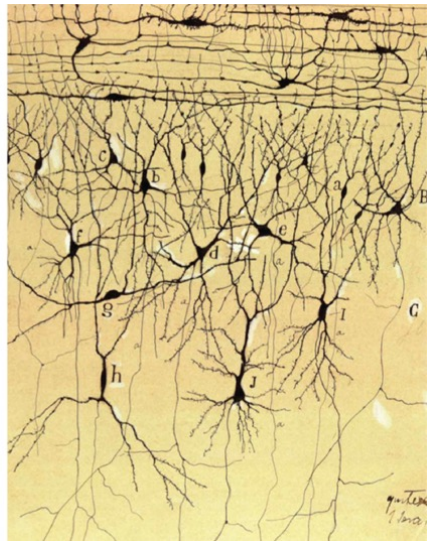


Golgi vs. Ramon y Cajal

- Late 19th, early 20th c.
- Golgi's stain
- Ramon y Cajal's drawings
- Golgi: reticular theory
- Ramon y Cajal: neuron doctrine
- Shared Nobel prize
- Bitter rivals to the end
- Ramon y Cajal vindicated
- BUT Golgi not entirely wrong

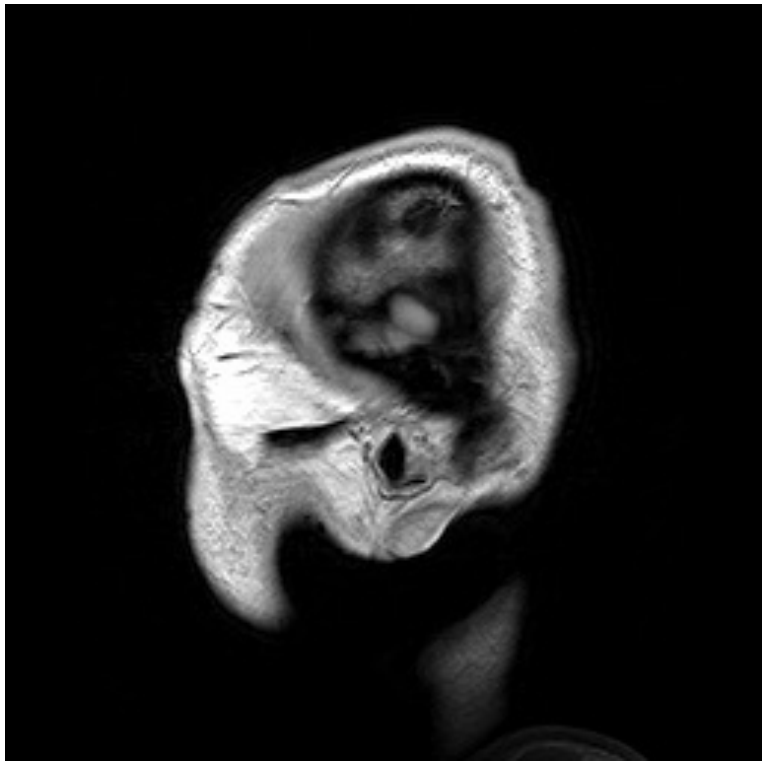


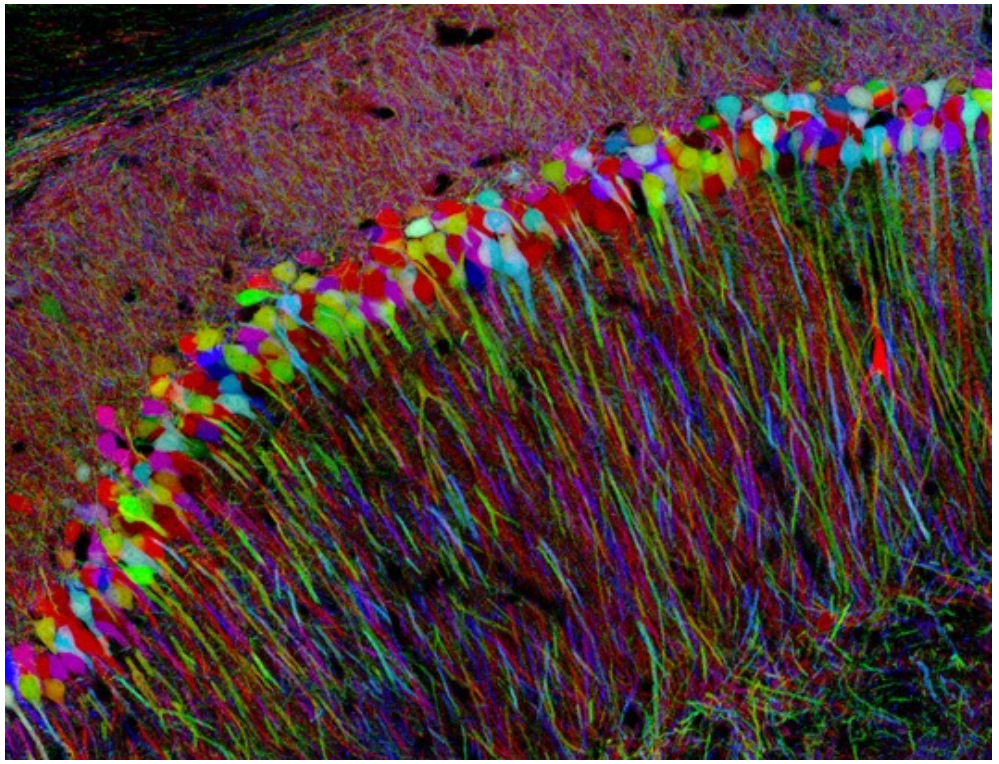




20th century: SO MUCH

- Really when modern neuroscience was born
- What we'll be studying here, mostly
- 1990s onward: **the brain as computer** (problem?)

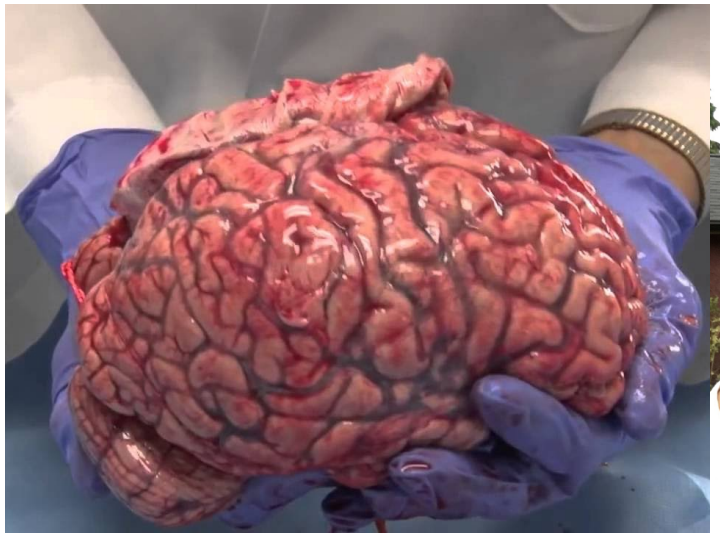




This one is from UBC!
Courtesy of Dr. Kurt Haas

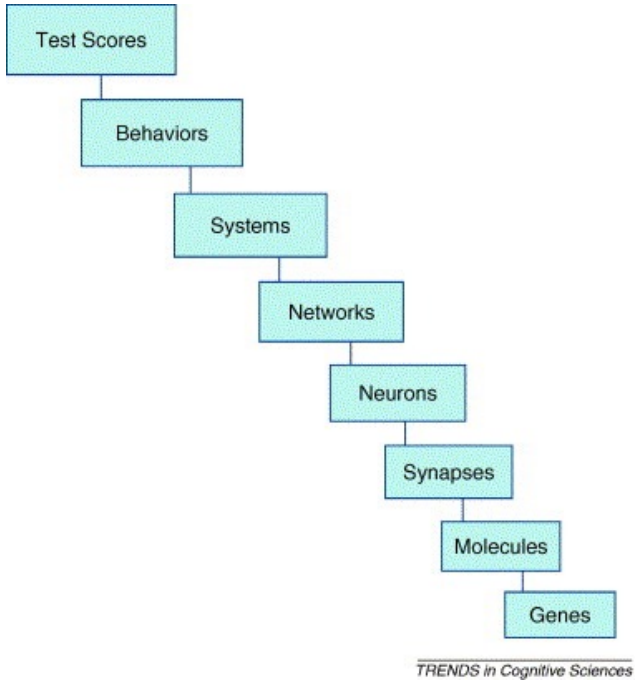
Neuroscience: what it means to be you

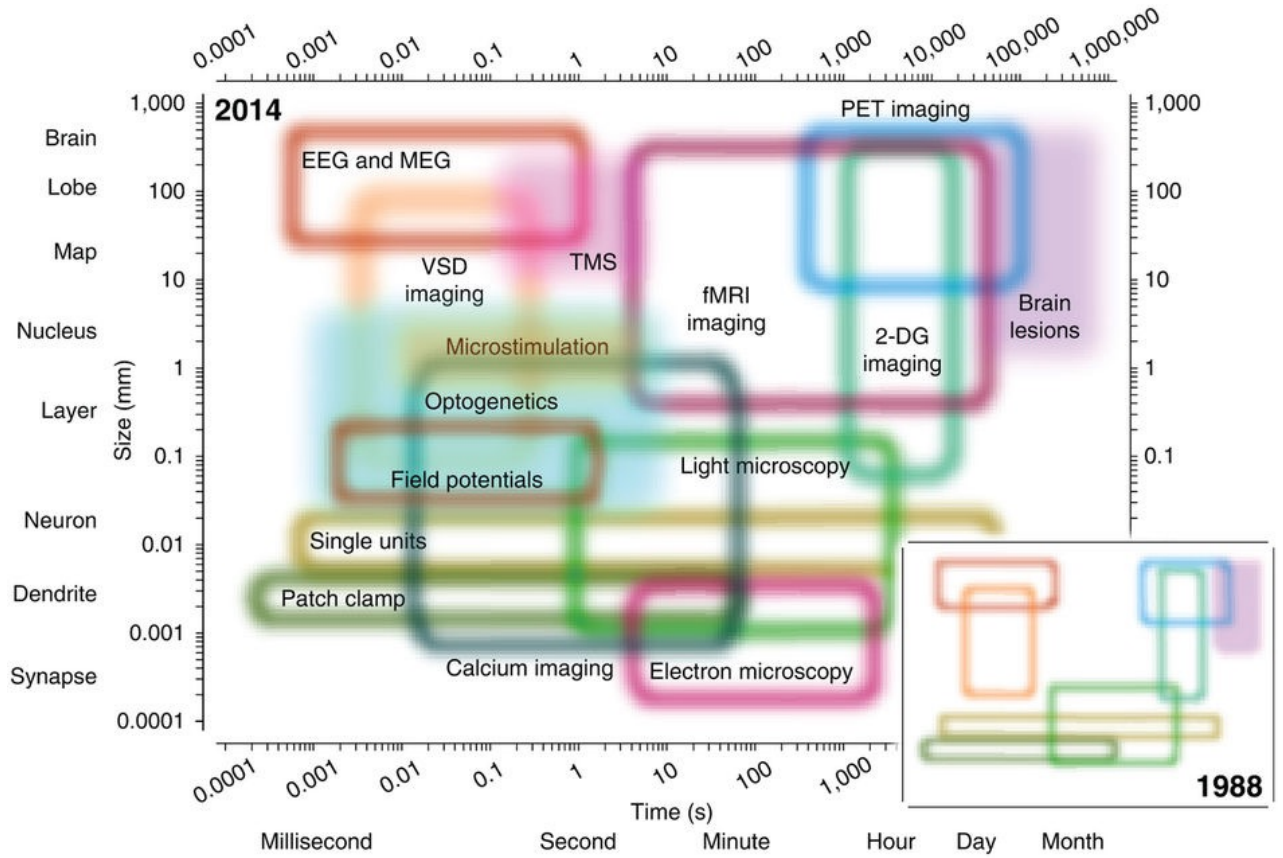
- Ostensibly the study of the nervous system
- Very much the study of human nature
- The goal: learn how the NS functions, and how it's related to mind



Levels of analysis

- Molecular neuroscience
- Cellular neuroscience
- Systems neuroscience
- Behavioural neuroscience
- Cognitive neuroscience

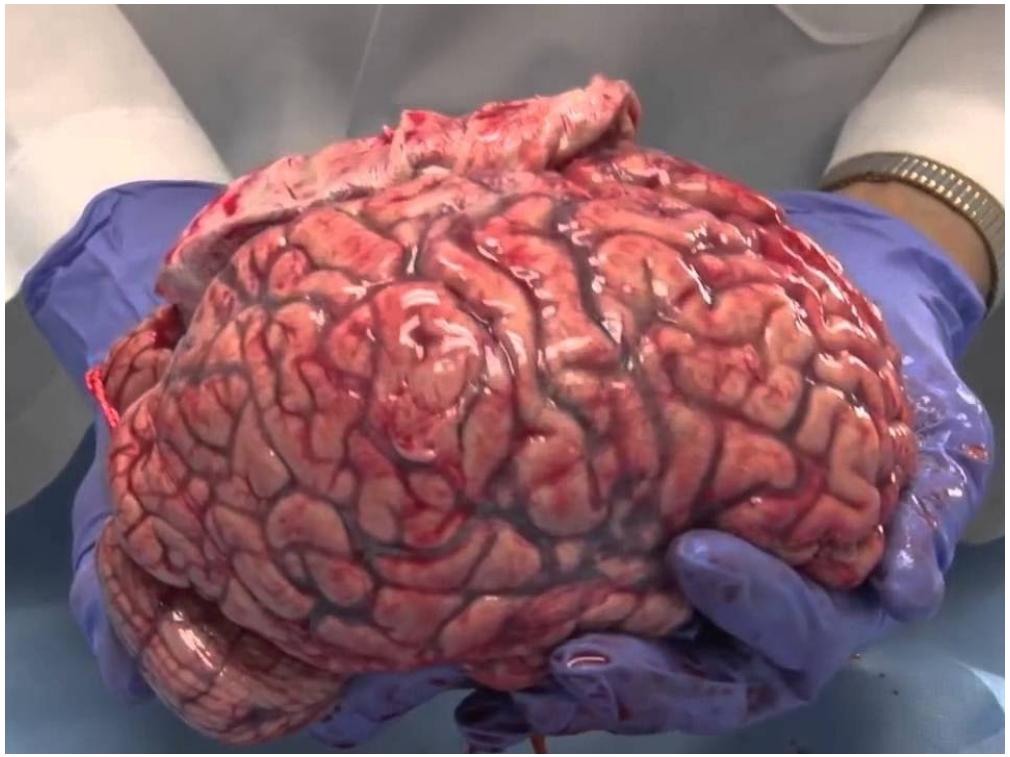




Talking science

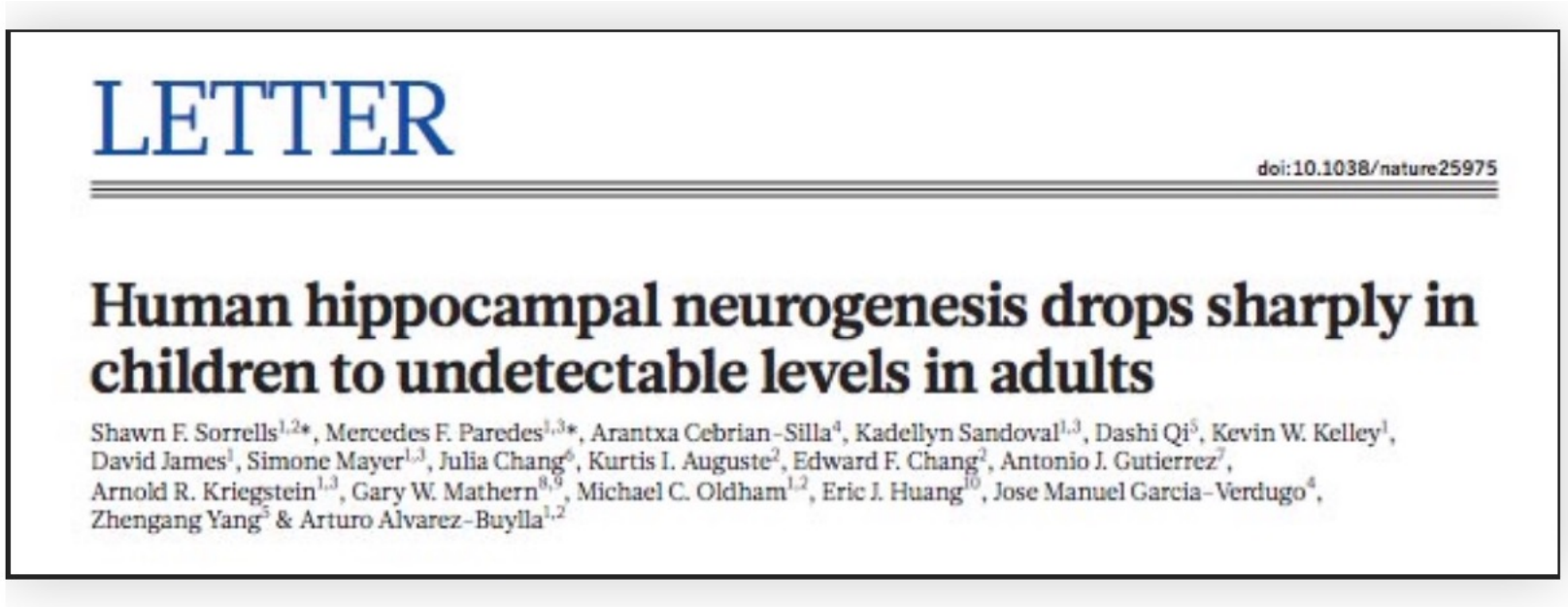
Human brain facts

- 2-3% of body weight, ~3lbs
- Consumes ~20% of your energy!
- Slightly larger in men than women
- Huge individual variation
- Composed of neurons, glia, stem cells, blood vessels
- <100 billion neurons (hard to say), more than half of which are cerebellum
- Consistency of soft tofu (yum)
- Convoluted (wrinkled)
- Cells are not replaced



Adult neurogenesis or no?

- A long history of controversy
- First no, then yes, now no again?



LETTER

doi:10.1038/nature25975

Human hippocampal neurogenesis drops sharply in children to undetectable levels in adults

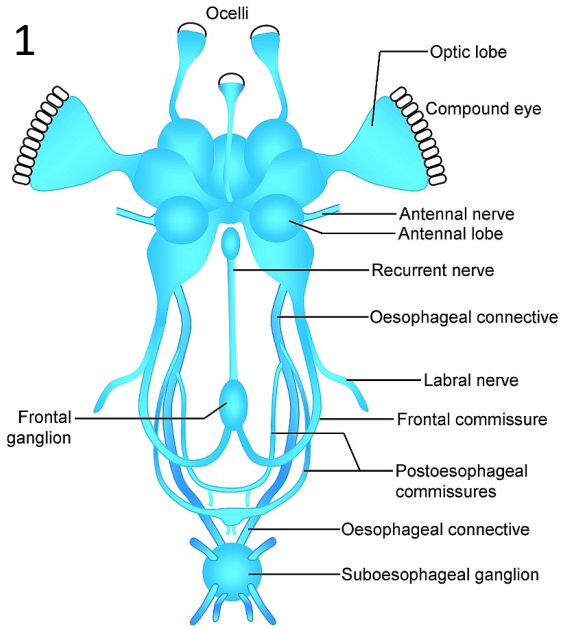
Shawn F. Sorrells[1,2*], Mercedes F. Paredes[1,3*], Arantxa Cebrian-Silla[4], Kadellyn Sandoval[1,3], Dashi Qi[5], Kevin W. Kelley[1], David James[1], Simone Mayer[1,3], Julia Chang[6], Kurtis I. Auguste[2], Edward F. Chang[2], Antonio J. Gutierrez[7], Arnold R. Kriegstein[1,3], Gary W. Mathern[8,9], Michael C. Oldham[1,2], Eric J. Huang[10], Jose Manuel Garcia-Verdugo[4], Zhengang Yang[5] & Arturo Alvarez-Buylla[1,2]

Sorrells *et al.* 2018

See Professor Jason Snyder's excellent piece on this: http://snyderlab.com/2018/03/07/wtf-no-neurogenesis-in-humans/
See a great review on the state of neurogenesis in humans here: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8967762/

Types of brains (not to scale)

1



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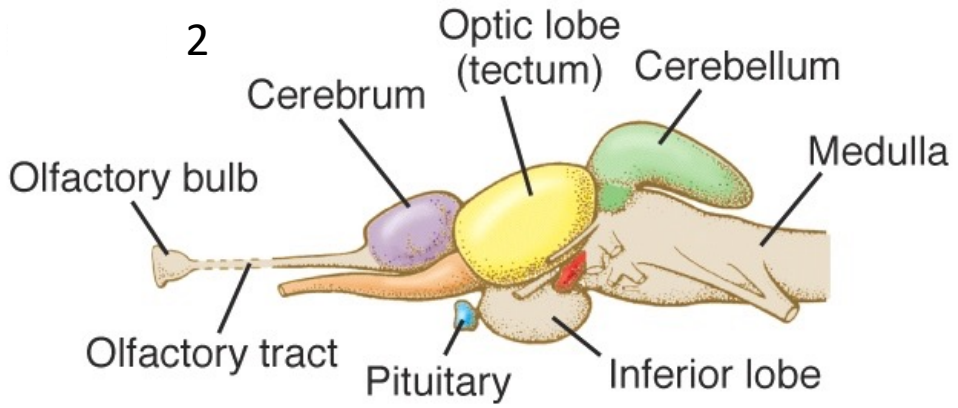

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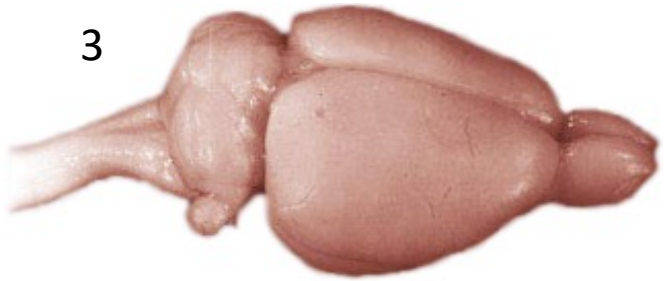
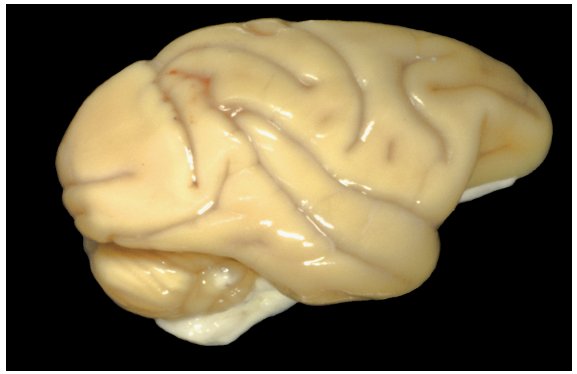


4

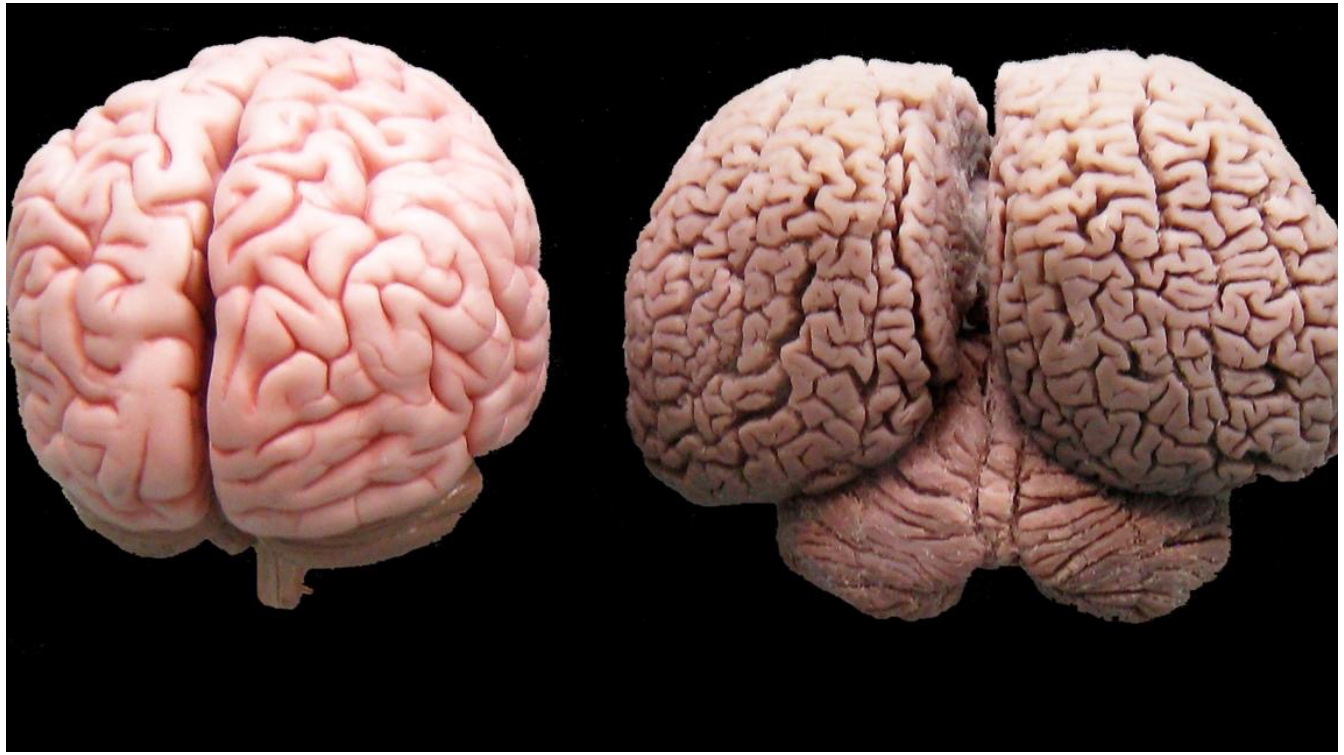
5

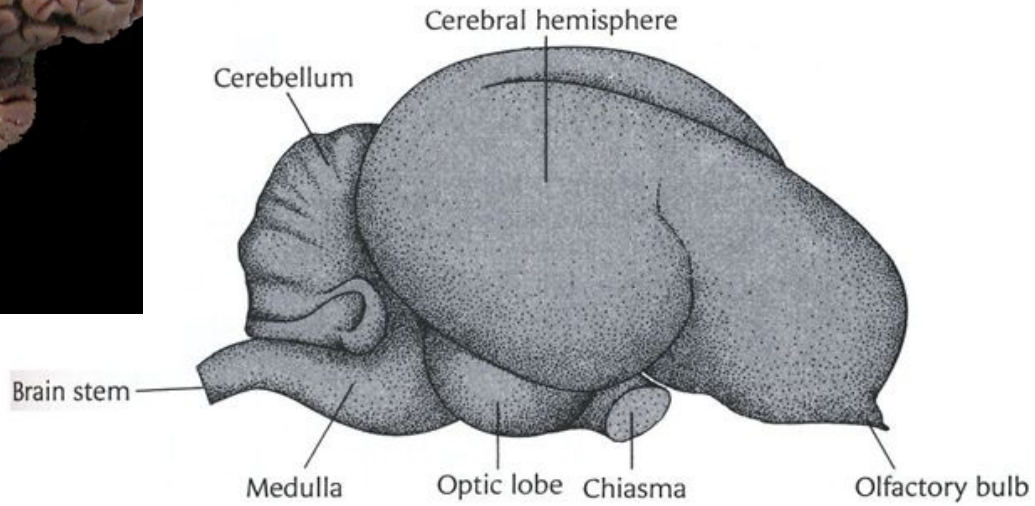


6

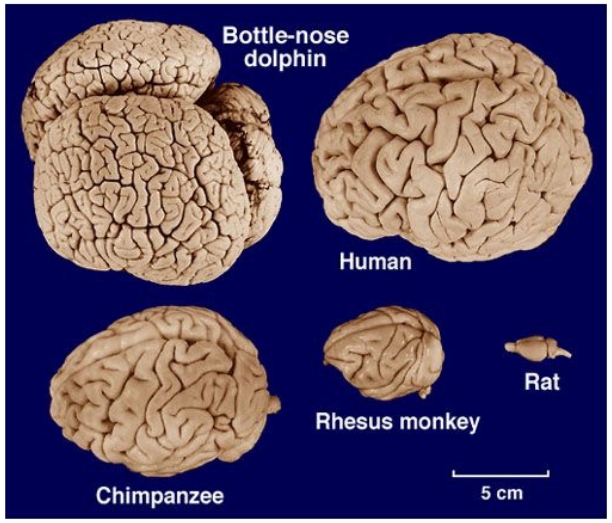
- Pattern?

Exceptions to the “rules”

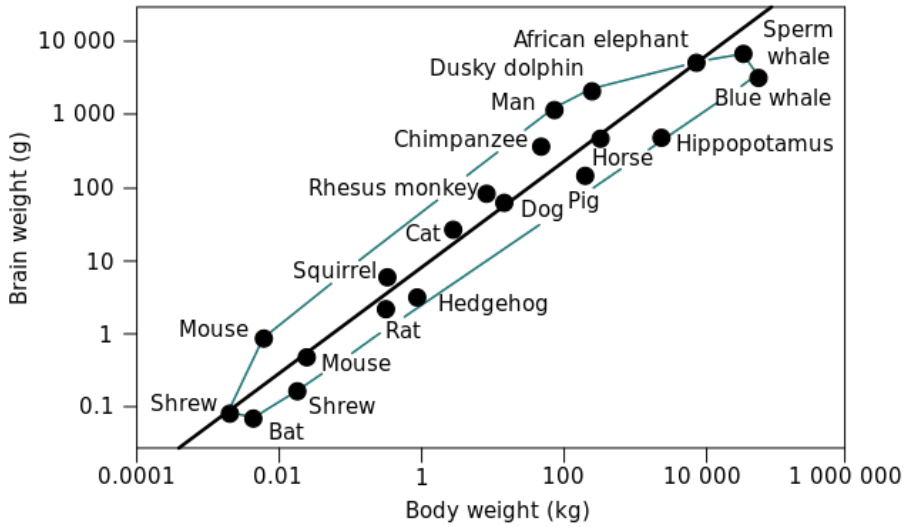


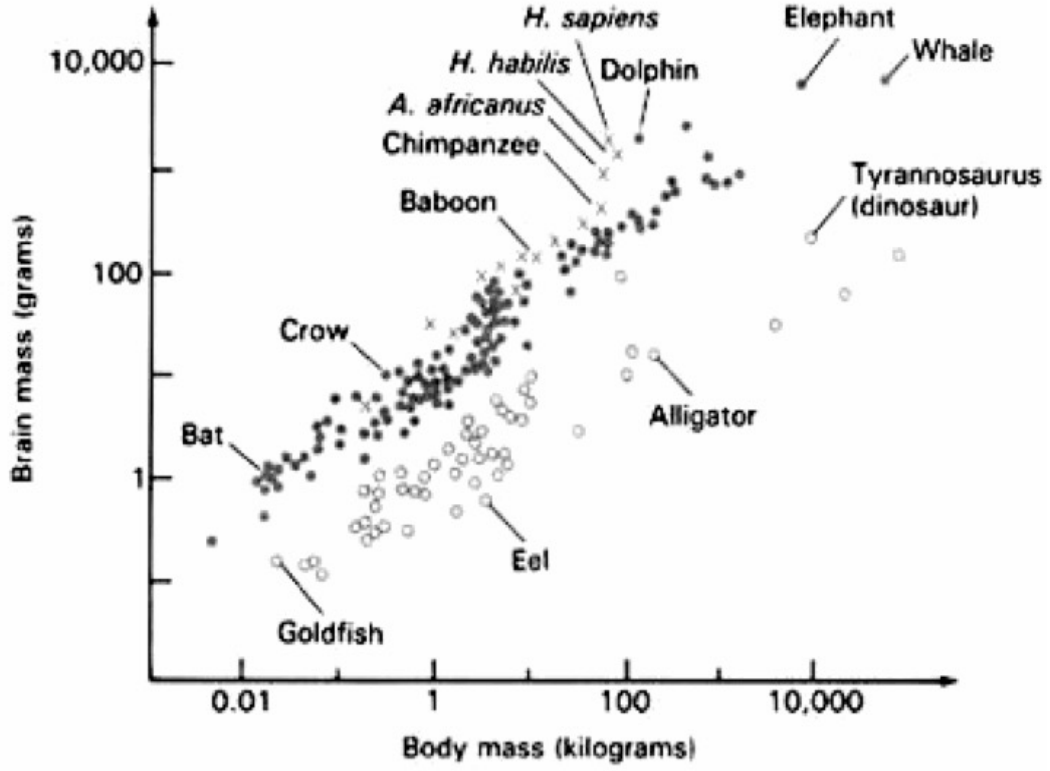


It’s not the size that counts



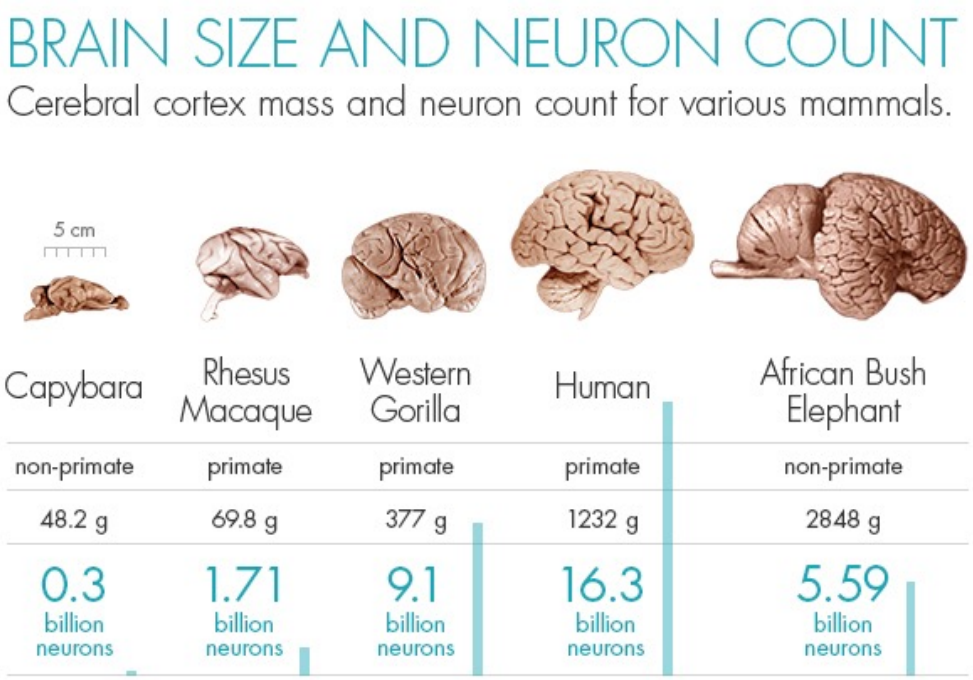
Species	Adult Brain Weight (grams)
Chimpanzee	450
Human	1,350
Bottlenosed dolphin	1,600
African elephant	6,075
Fin whale	7,200
Sperm Whale	9,200

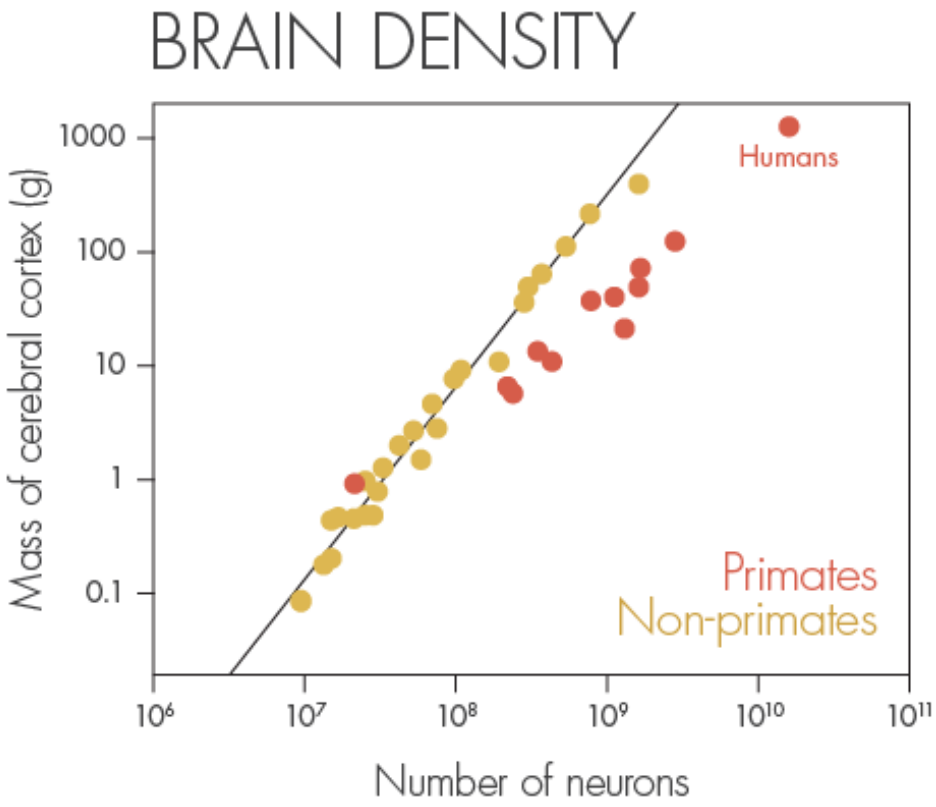




Still doesn’t give us a mechanism, though

Brain Cell Density

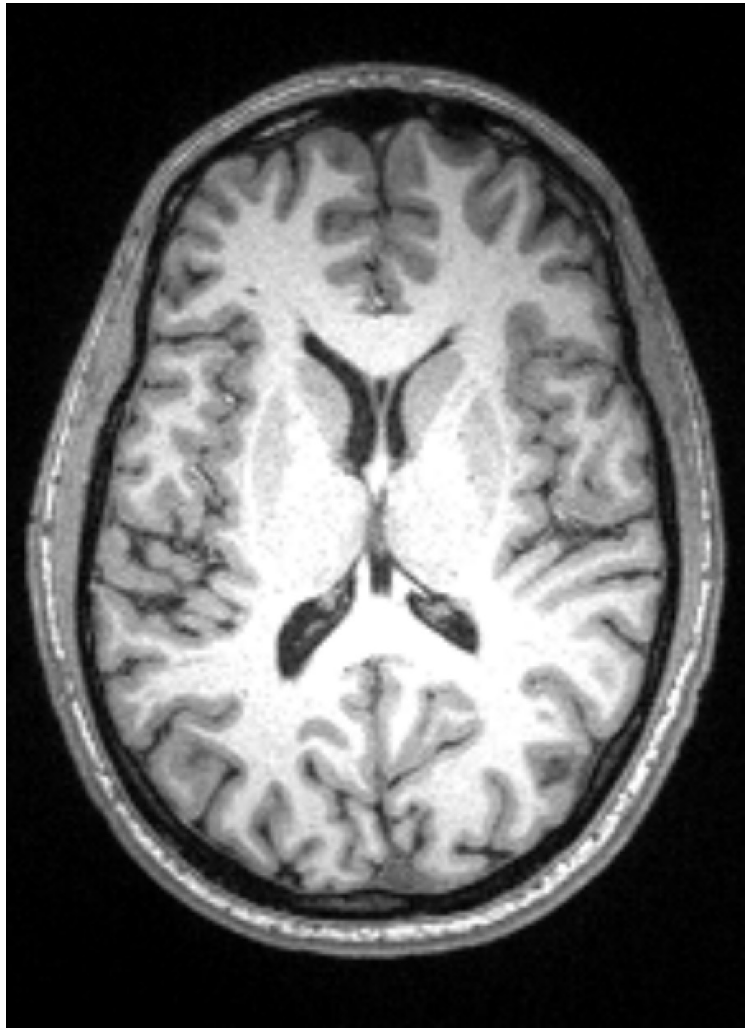




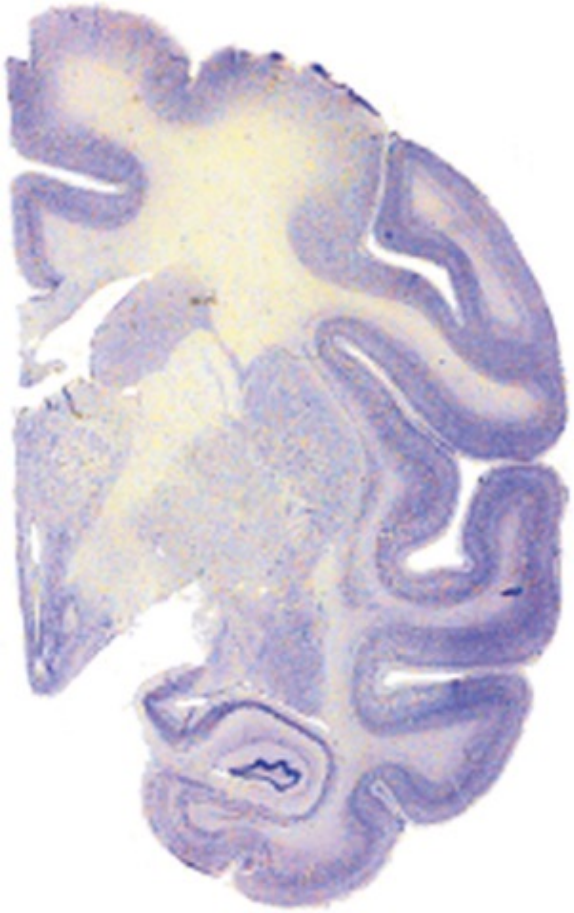
- Intelligence also correlates with sophistication of cellular connections (i.e. wiring)

“Matter”

- Gray Matter
- White Matter



Staining reveals “matter”

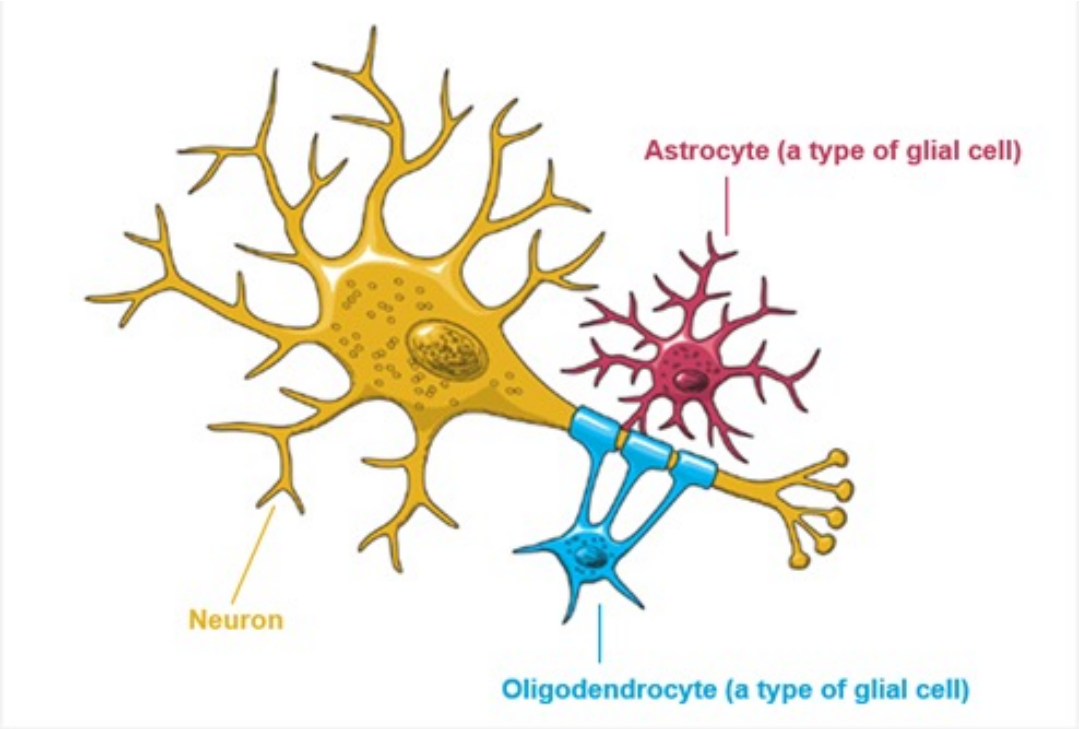


Nissl-stained (cresyl violet) gray matter of monkey

Fiber stain of white matter: staining insulating glia cells

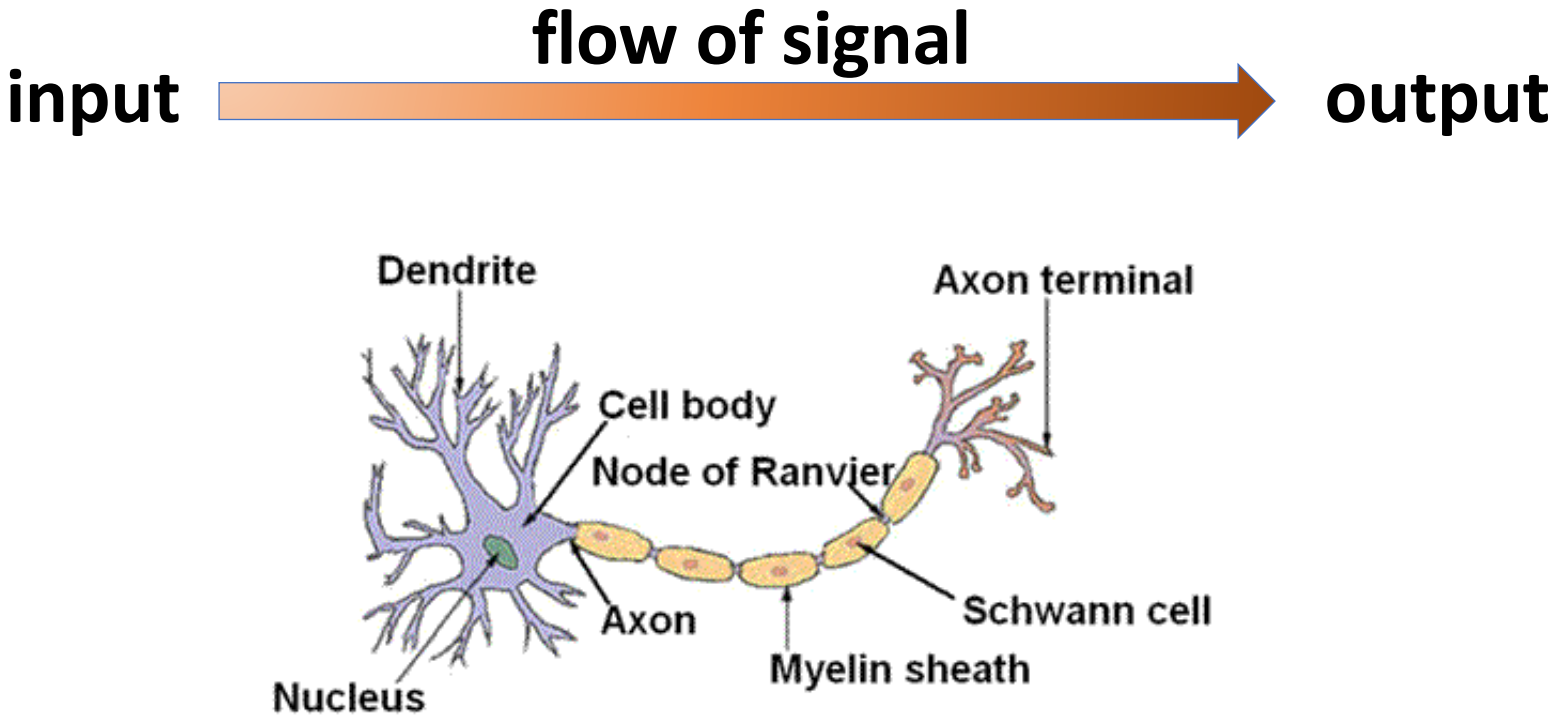
Two basic cell types

- Neurons
- Glia



The neuron

- Many types, but similar design
- Dendrite → soma → axon → terminals



The neuron

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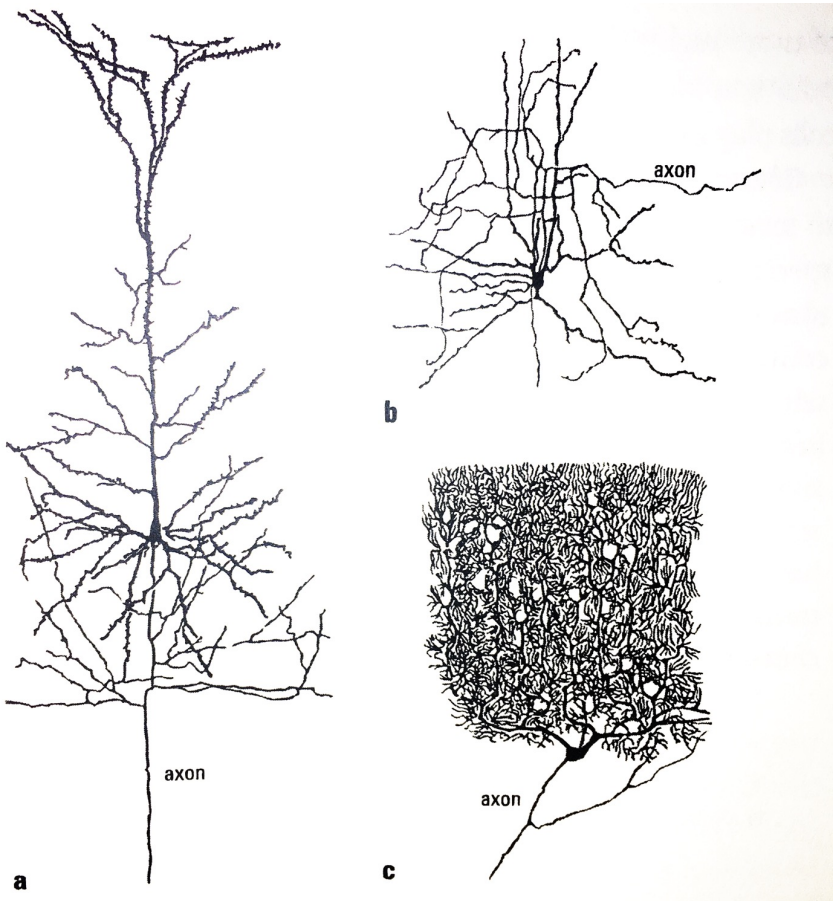
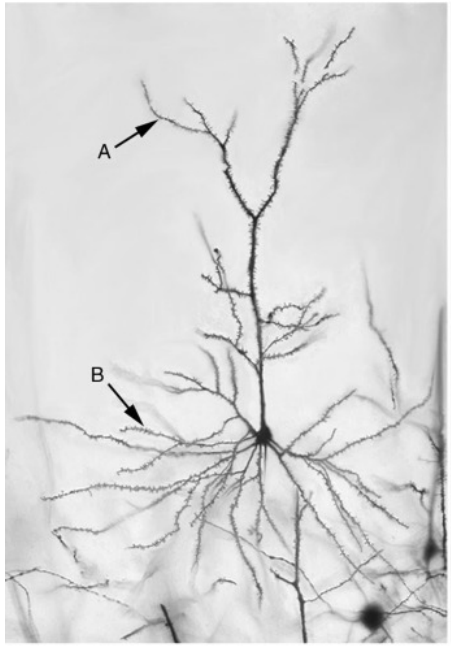
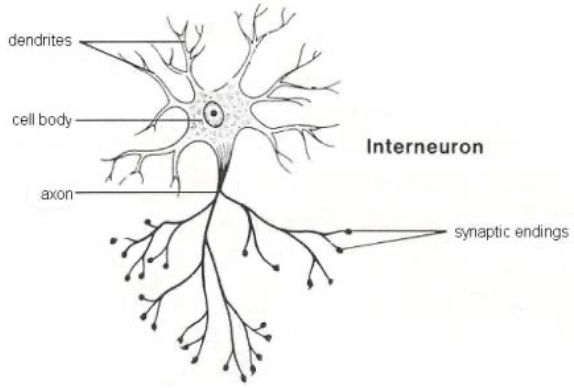


a. Pyramidal
b. Stellate
c. Purkinje

Two basic types of neurons

- Projection neurons
- Interneurons



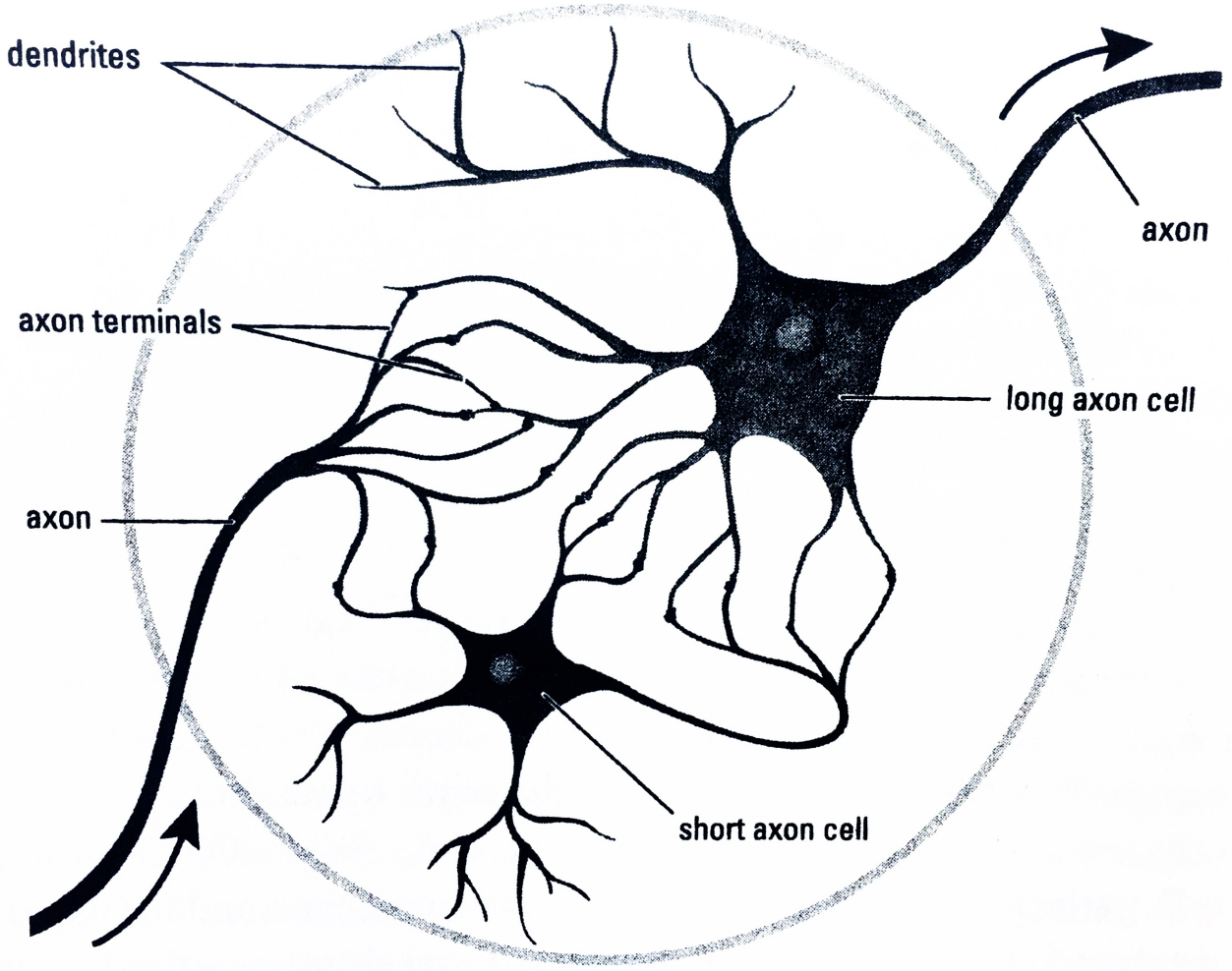


Medium Spiny Projection Neurons (**MSNs**) 96%

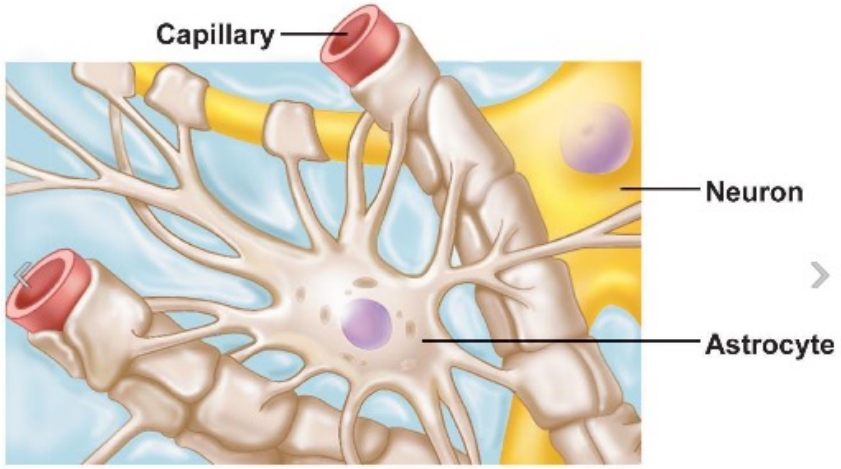
GABA Interneurons 2%

TANs - Cholinergic Interneurons 2%

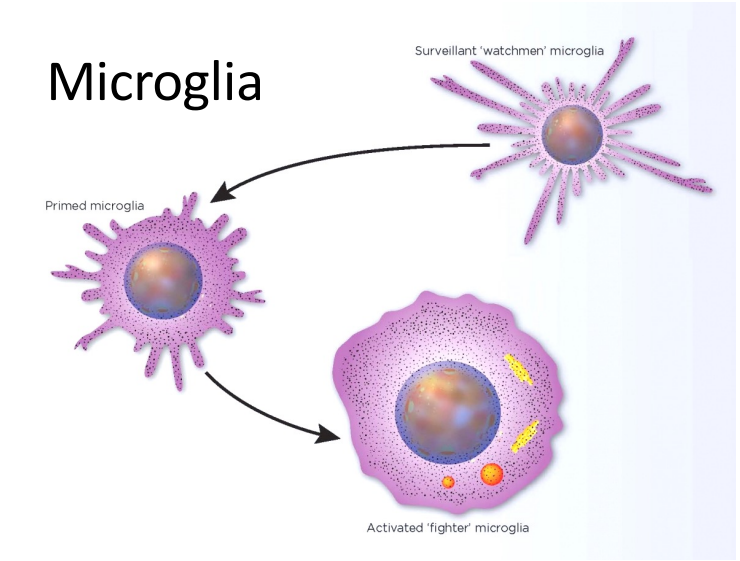
Two basic types of neurons

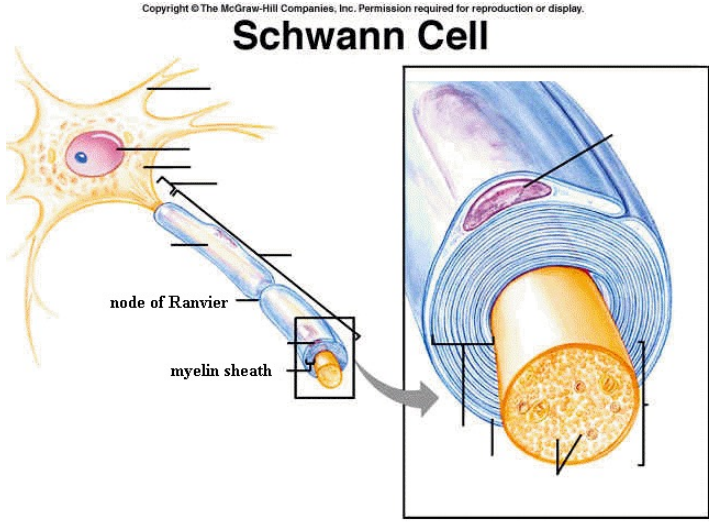


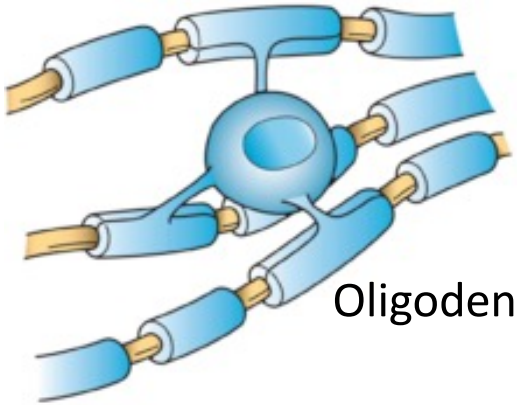
Glial Cells



(a) Astrocytes are the most abundant CNS neuroglia.

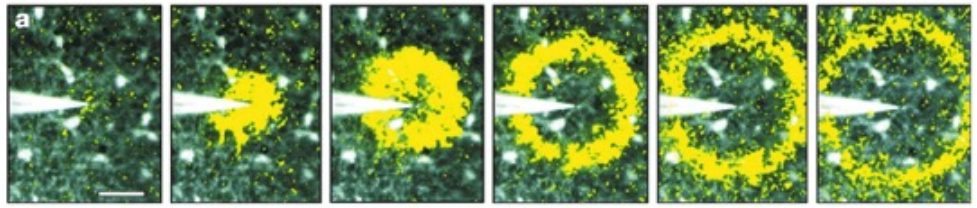


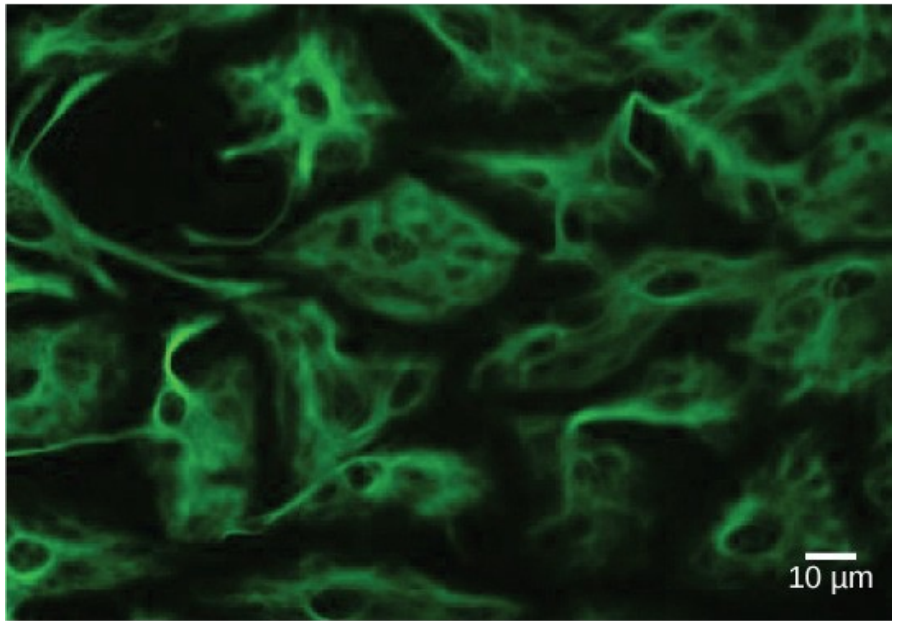


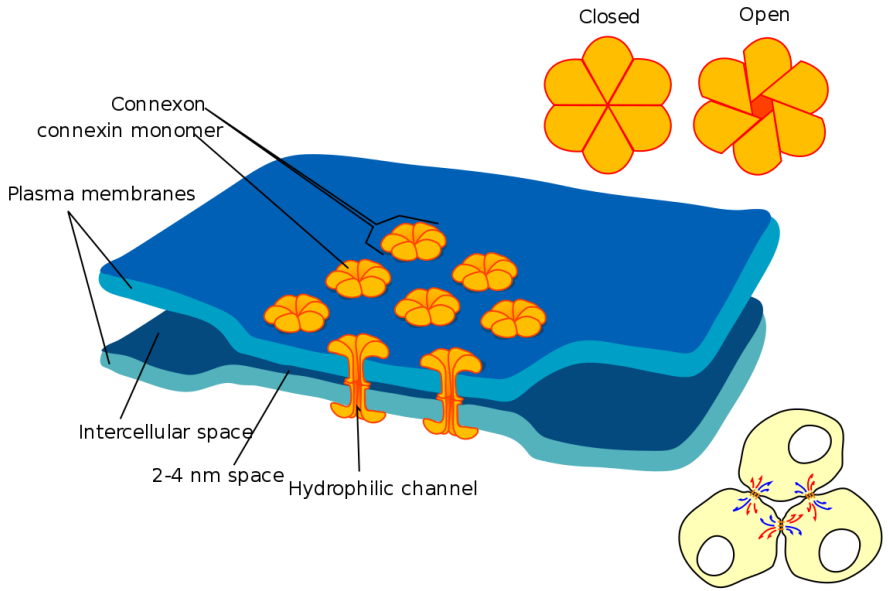


Glial networks (astrocytes)

- Gap junctions
- Reticular theory, revisited

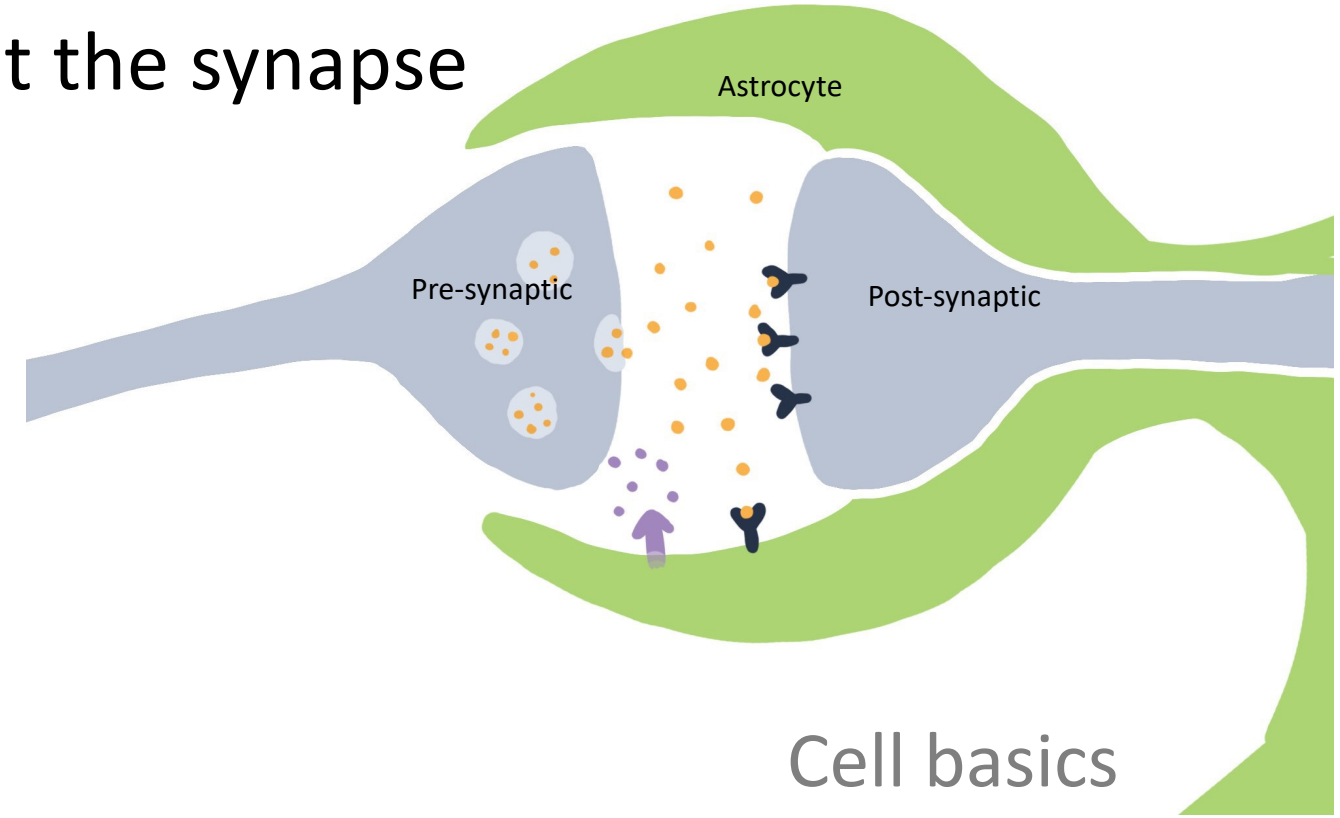




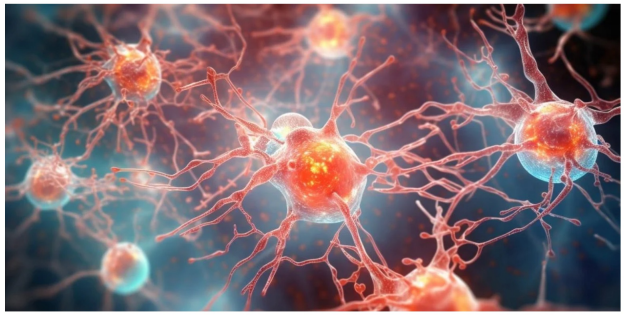


The tripartite synapse

- A conversation of three
- Glia have receptors, transmitters
- Glia shape conditions at the synapse



Ripped from the headlines



Featured Neuroscience Psychology · June 5, 2023 · 6 min read

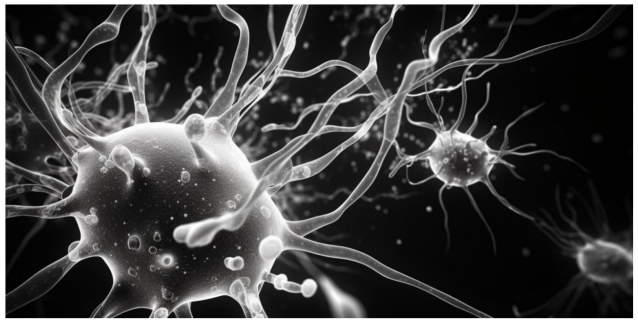
Microglia's Role in Controlling Anxiety and OCD

A new study reveals how microglia can regulate anxiety and obsessive-compulsive spectrum disorder (OCSD) behaviors. Traditionally overlooked in favor of neurons, specific microglia populations were found to both stimulate and suppress these behaviors, thus acting as both a "brake" and "accelerator".

Featured Neuroscience Psychology · May 22, 2023 · 5 min read

Microglia Less Active in Those With Depression

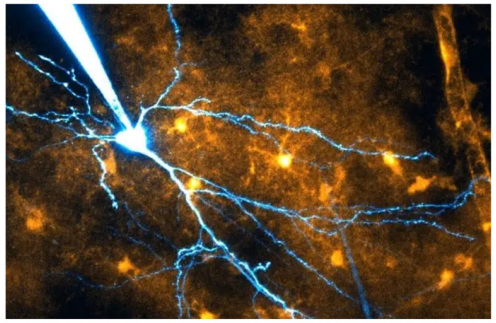
Researchers have uncovered a crucial link between depression and the immune system. A new study reveals microglial cells, a type of immune cell in the brain, are less active in individuals with depression.



Featured Neuroscience · May 15, 2023 · 4 min read

Unique Microglia Subset Crucial for Cognitive Functioning

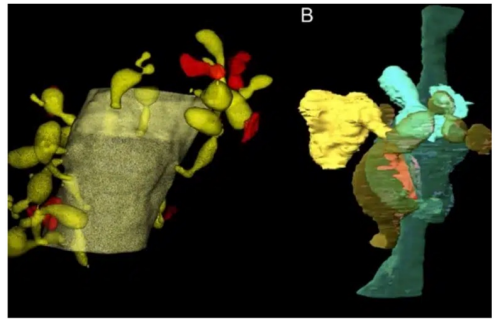
A new study discovered not all microglia are the same, challenging existing beliefs. A unique subset of these cells, the ARG1+microglia, important for proper cognitive functions, were identified in mice, with evidence suggesting a similar subset exists in humans.



Featured Neuroscience · January 10, 2023 · 5 min read

Glial Cells Help Memory Along

Astrocytes play a crucial role in spatial learning, researchers discovered.



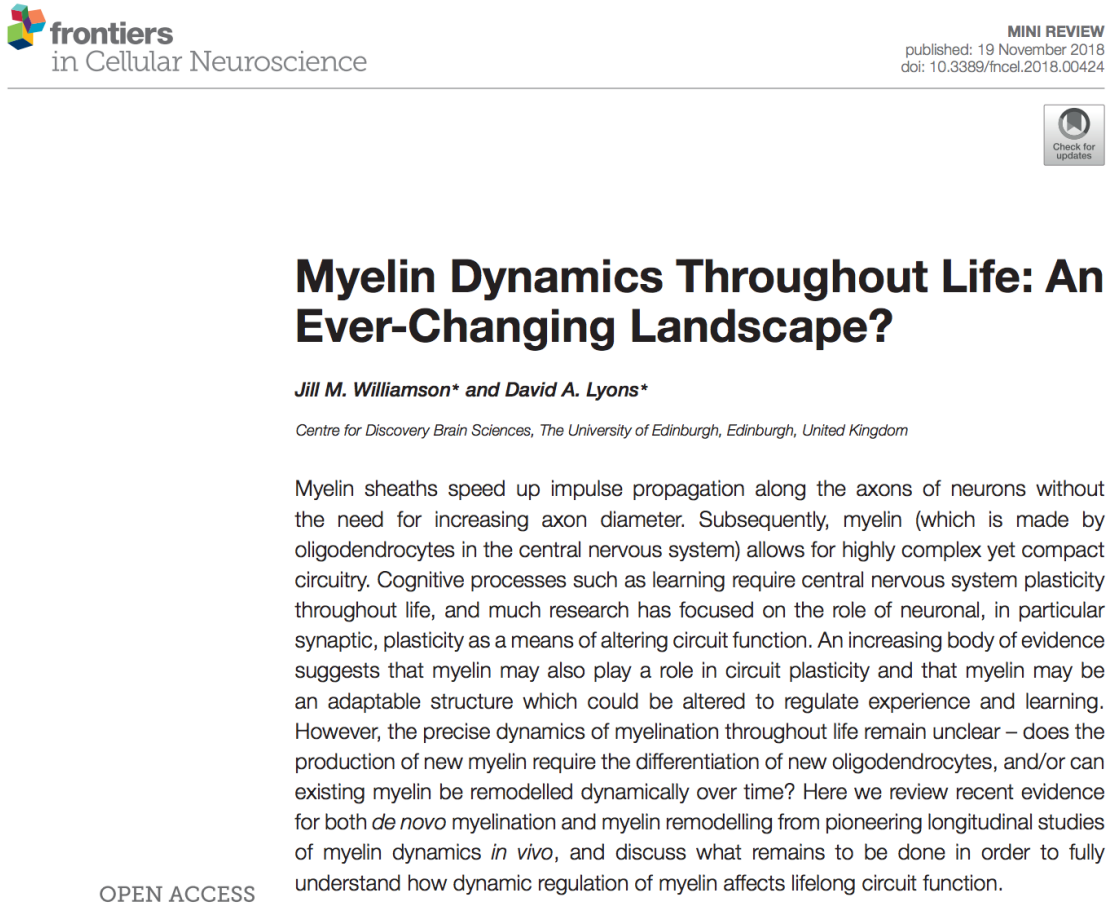
Featured Neuroscience · November 2, 2022 · 4 min read

Glial Cells Eating of Synapses May Enhance Learning and Memory

Bergmann glial cell synaptic engulfing in the cerebellum was enhanced during motor learning in mice.

- Glia play a key role in brain function, and we will hardly talk about them throughout this course

Ripped from the headlines



frontiers in Cellular Neuroscience

MINI REVIEW
published: 19 November 2018
doi: 10.3389/fncel.2018.00424

Check for updates

Myelin Dynamics Throughout Life: An Ever-Changing Landscape?

Jill M. Williamson and David A. Lyons**

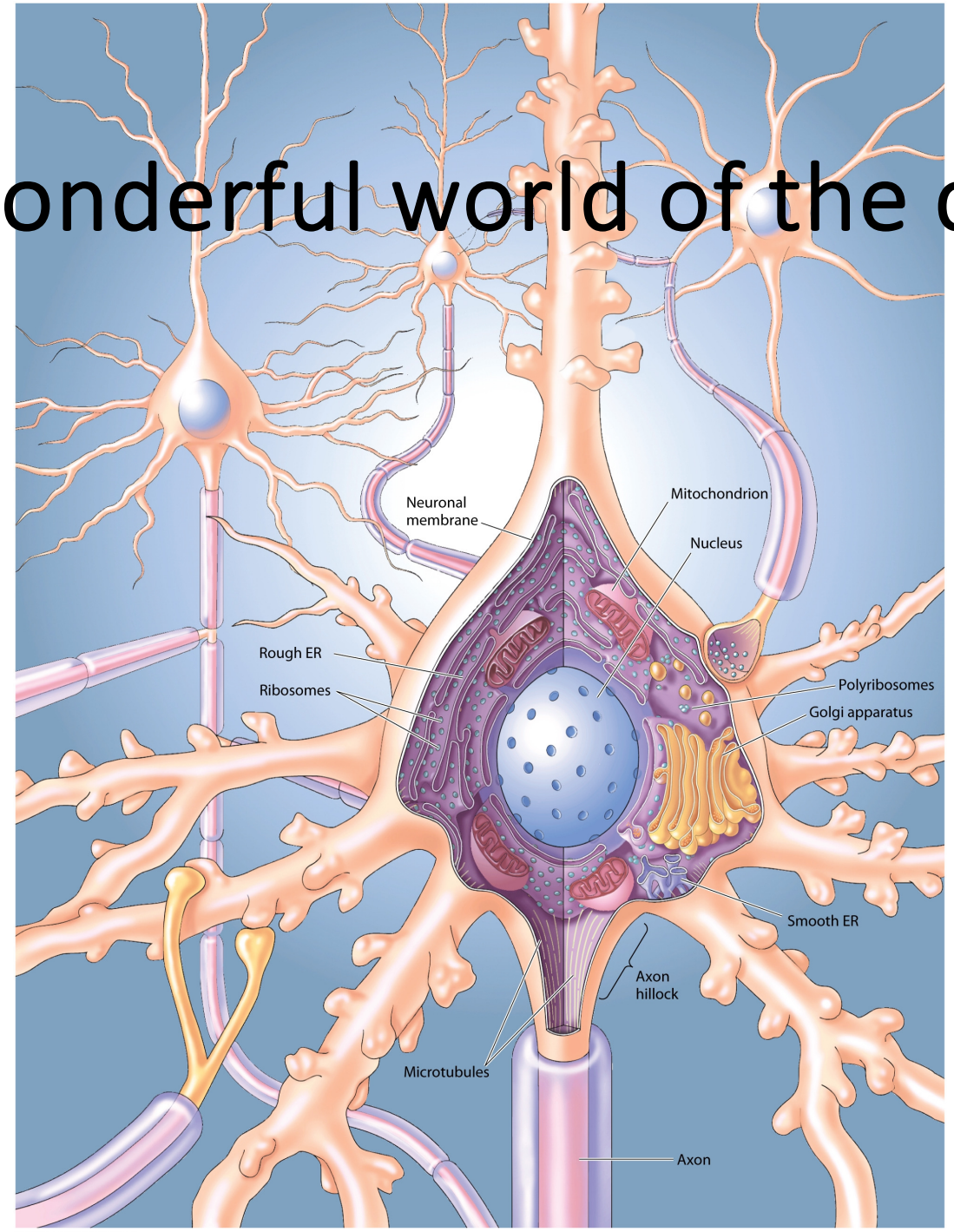
Centre for Discovery Brain Sciences, The University of Edinburgh, Edinburgh, United Kingdom

Myelin sheaths speed up impulse propagation along the axons of neurons without the need for increasing axon diameter. Subsequently, myelin (which is made by oligodendrocytes in the central nervous system) allows for highly complex yet compact circuitry. Cognitive processes such as learning require central nervous system plasticity throughout life, and much research has focused on the role of neuronal, in particular synaptic, plasticity as a means of altering circuit function. An increasing body of evidence suggests that myelin may also play a role in circuit plasticity and that myelin may be an adaptable structure which could be altered to regulate experience and learning. However, the precise dynamics of myelination throughout life remain unclear – does the production of new myelin require the differentiation of new oligodendrocytes, and/or can existing myelin be remodelled dynamically over time? Here we review recent evidence for both *de novo* myelination and myelin remodelling from pioneering longitudinal studies of myelin dynamics *in vivo*, and discuss what remains to be done in order to fully understand how dynamic regulation of myelin affects lifelong circuit function.

OPEN ACCESS

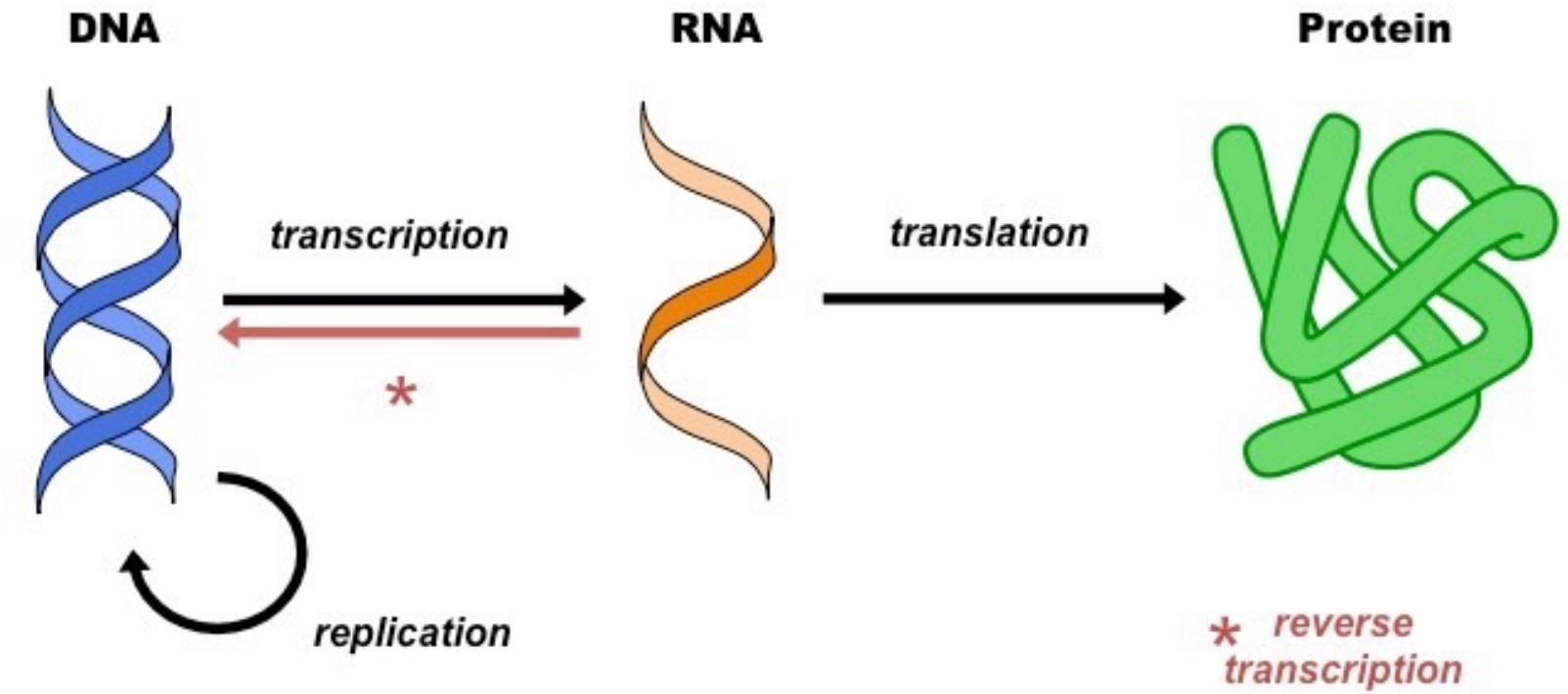
- Glia play a key role in brain function, and yet we will hardly talk about them throughout this course

The wonderful world of the cell

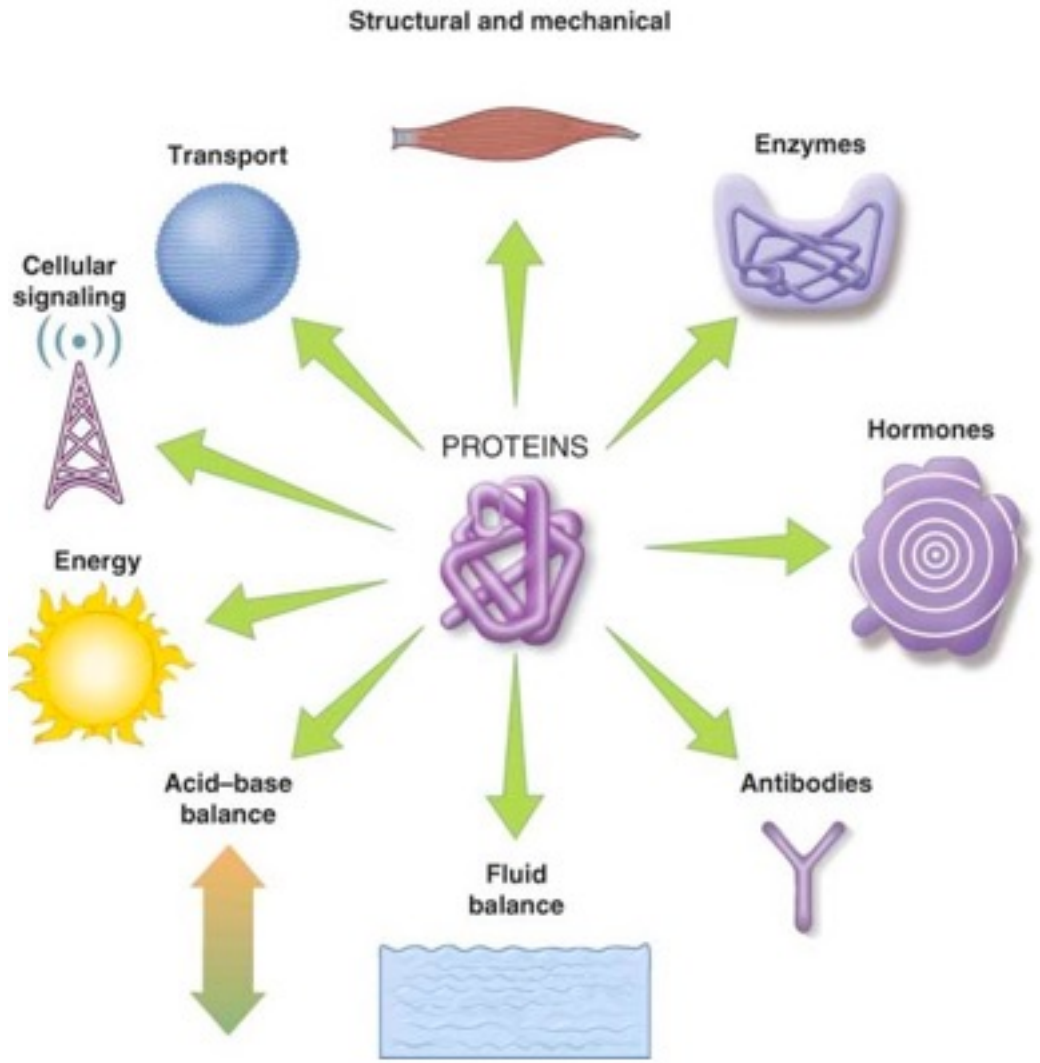


The central dogma of molecular biology:

DNA → mRNA → Protein

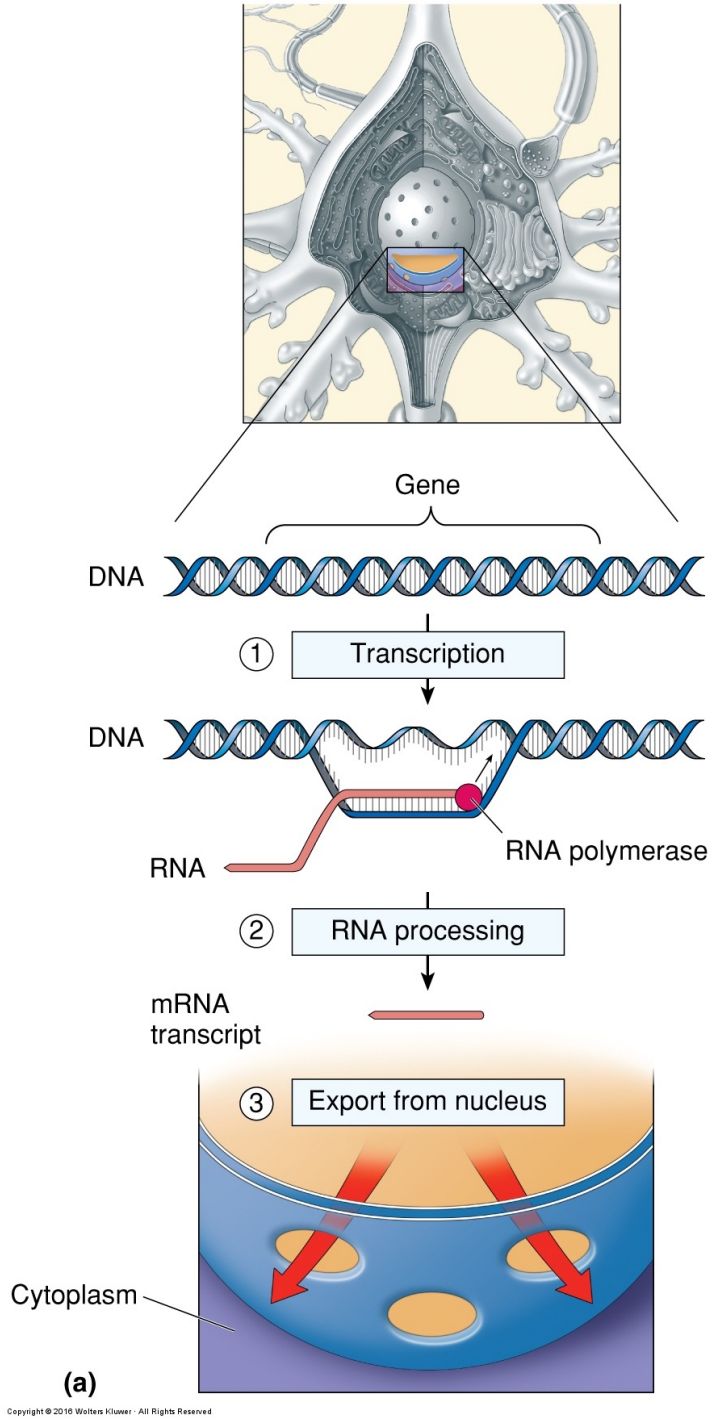


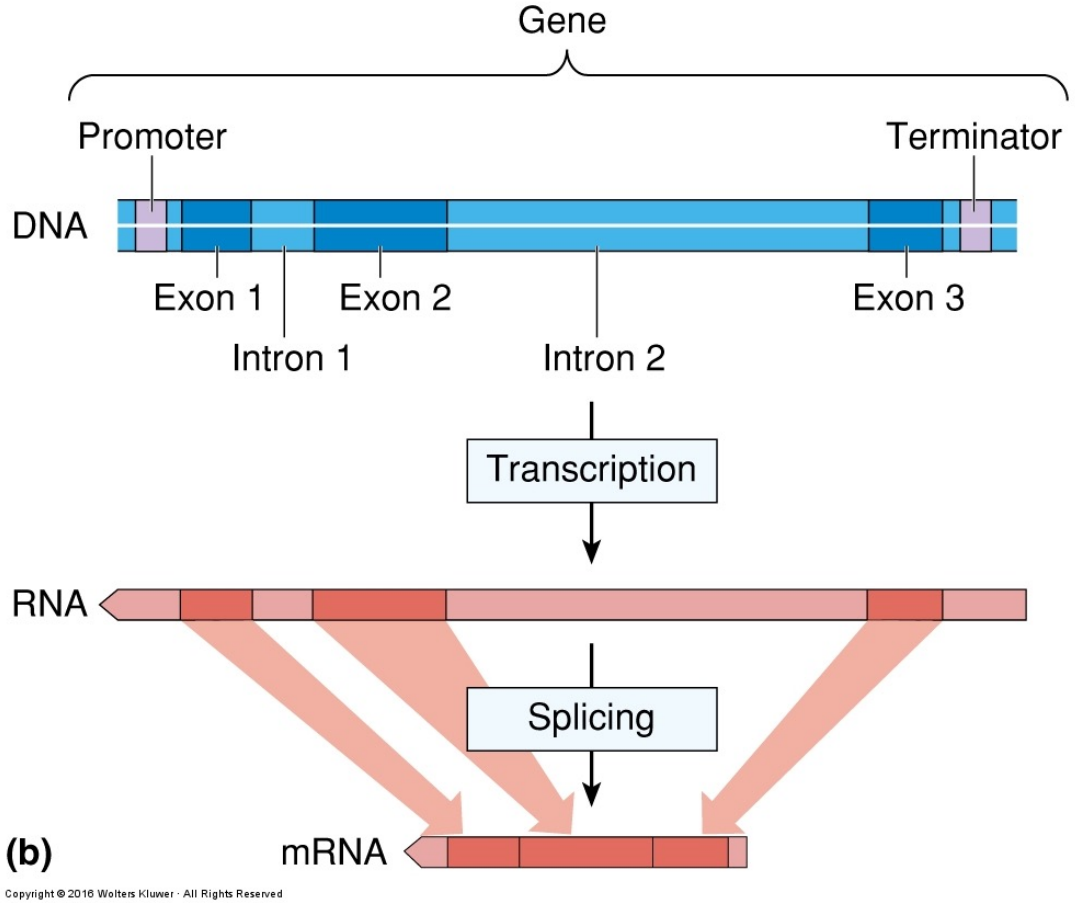
What do proteins do? So much!



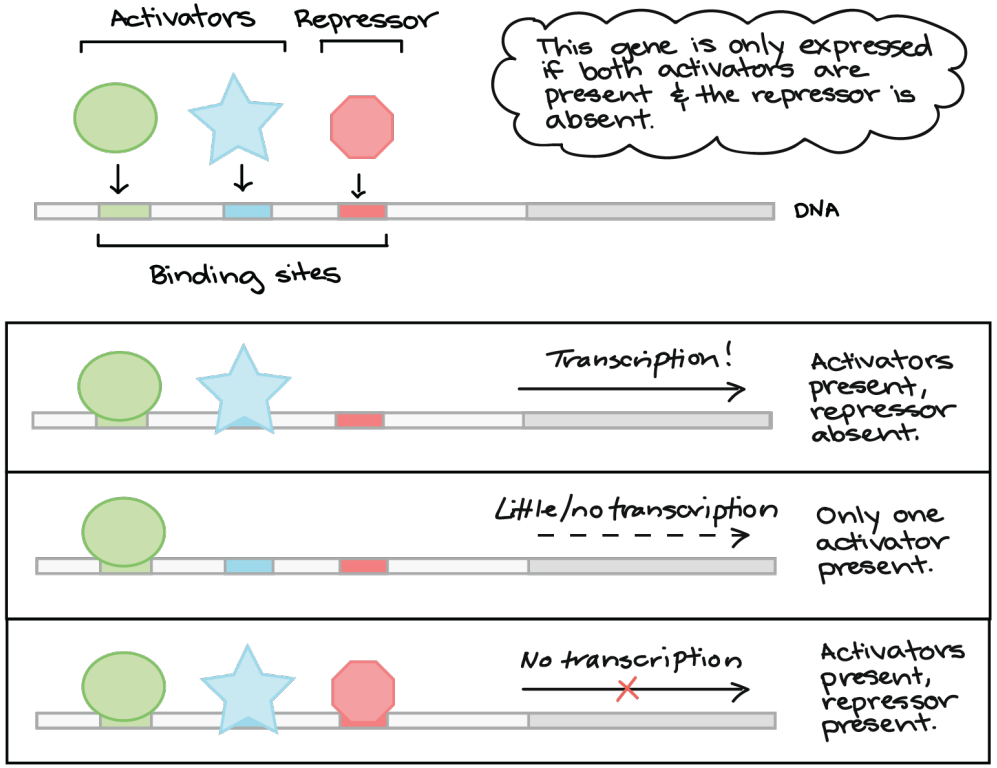
Including being the basis for neuronal function

Soma: nucleus

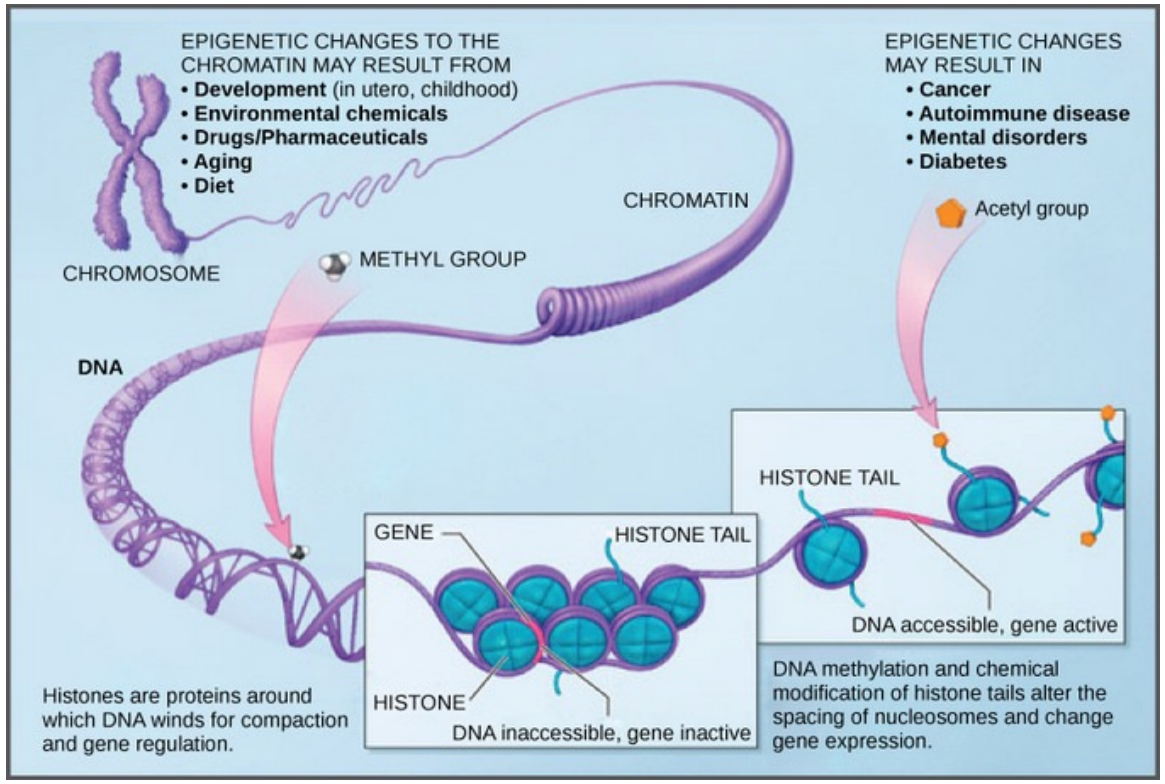




What determines transcription?

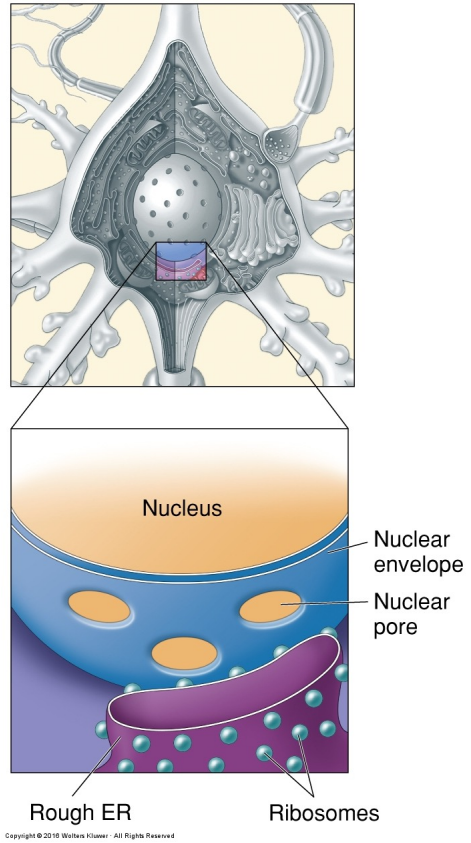


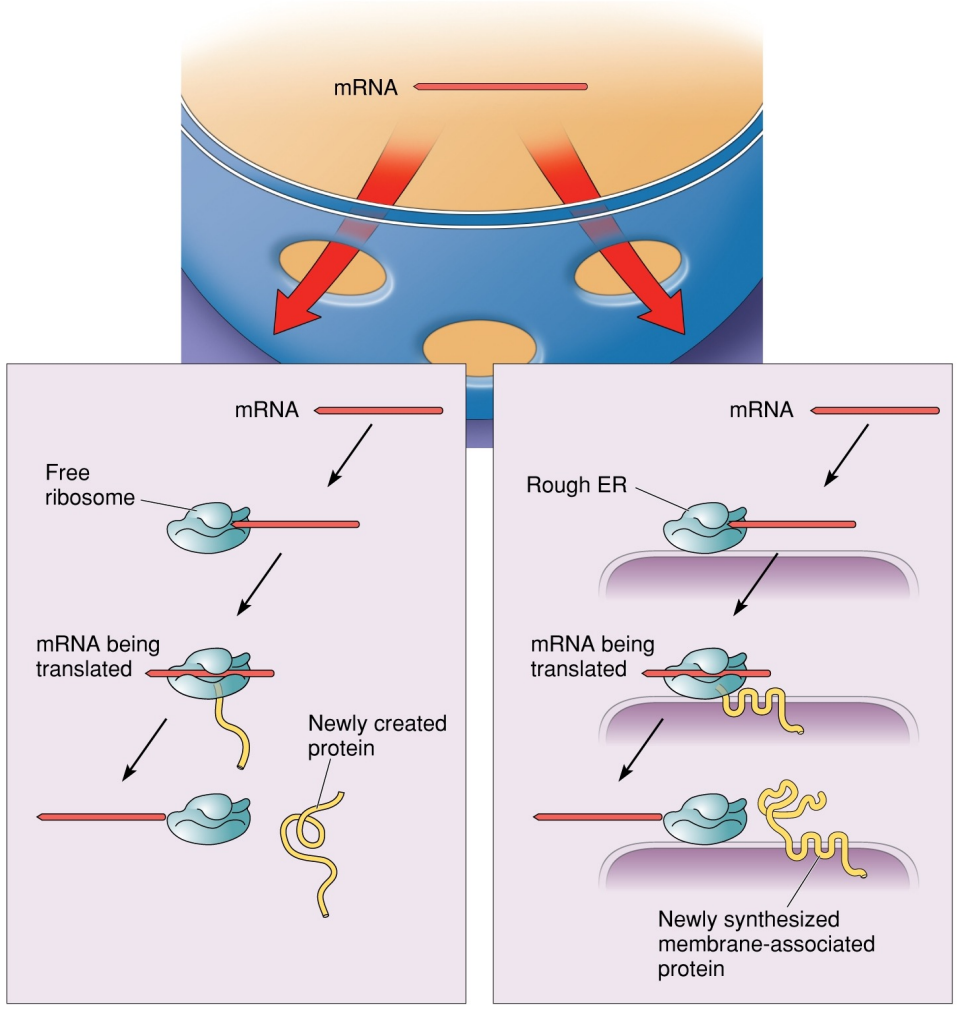
Transcription factors



Histone modification

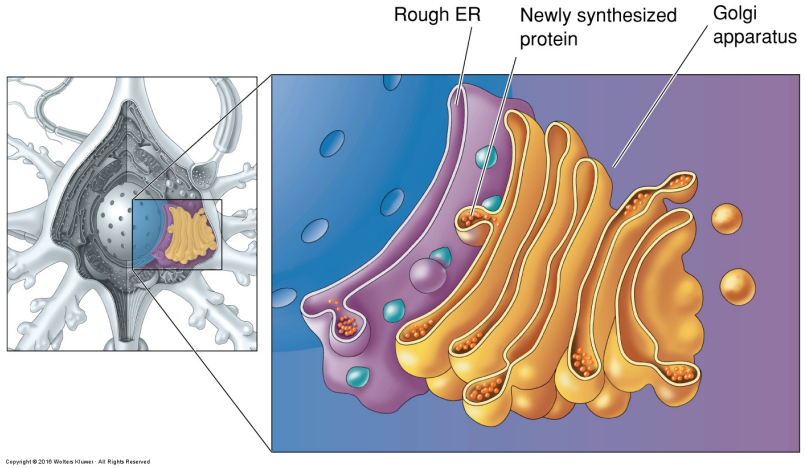
Soma (and elsewhere): ER and Golgi apparatus



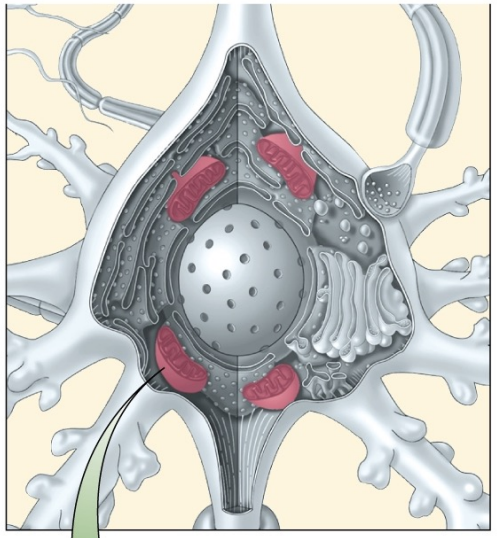


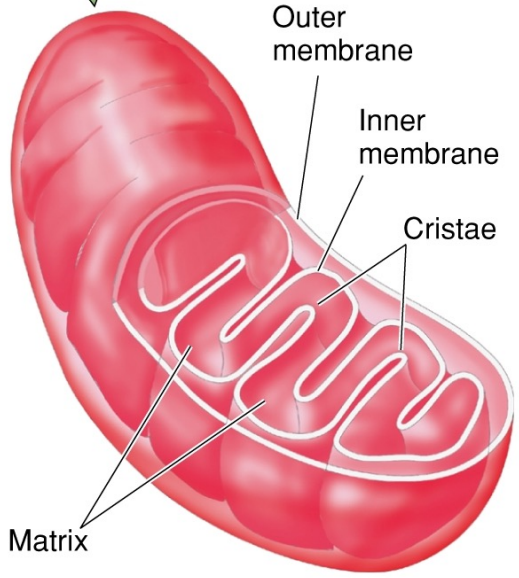
(a) Protein synthesis on a free ribosome

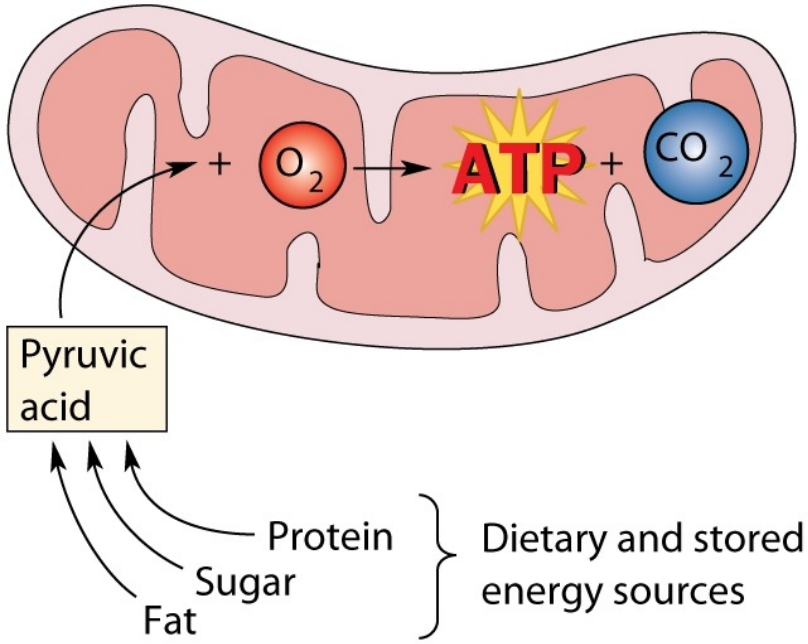
(b) Protein synthesis on rough ER

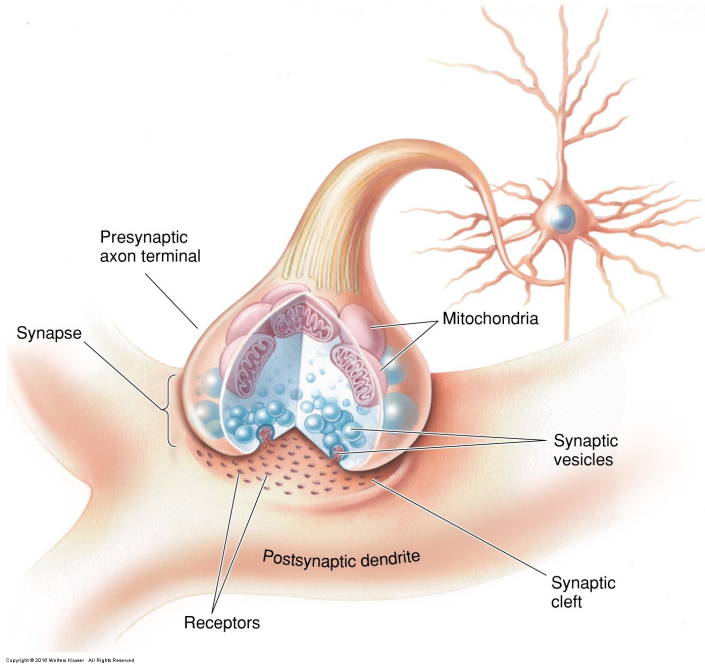


Soma (and elsewhere): Mitochondria



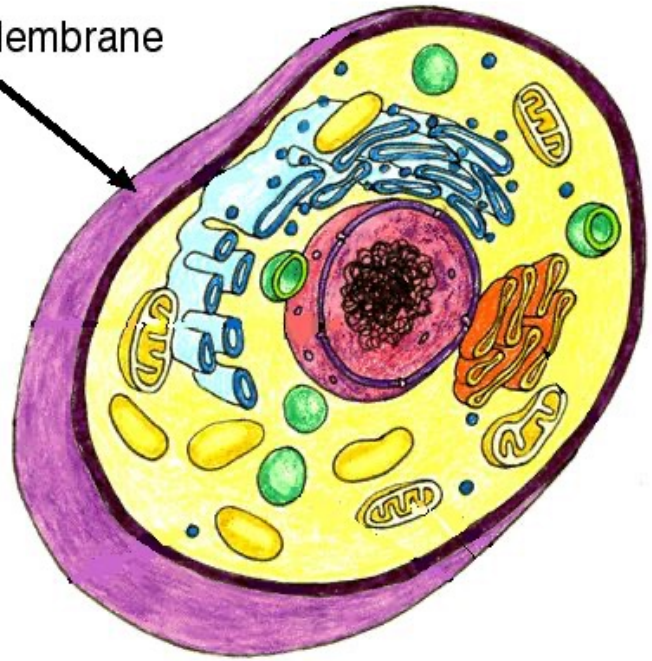


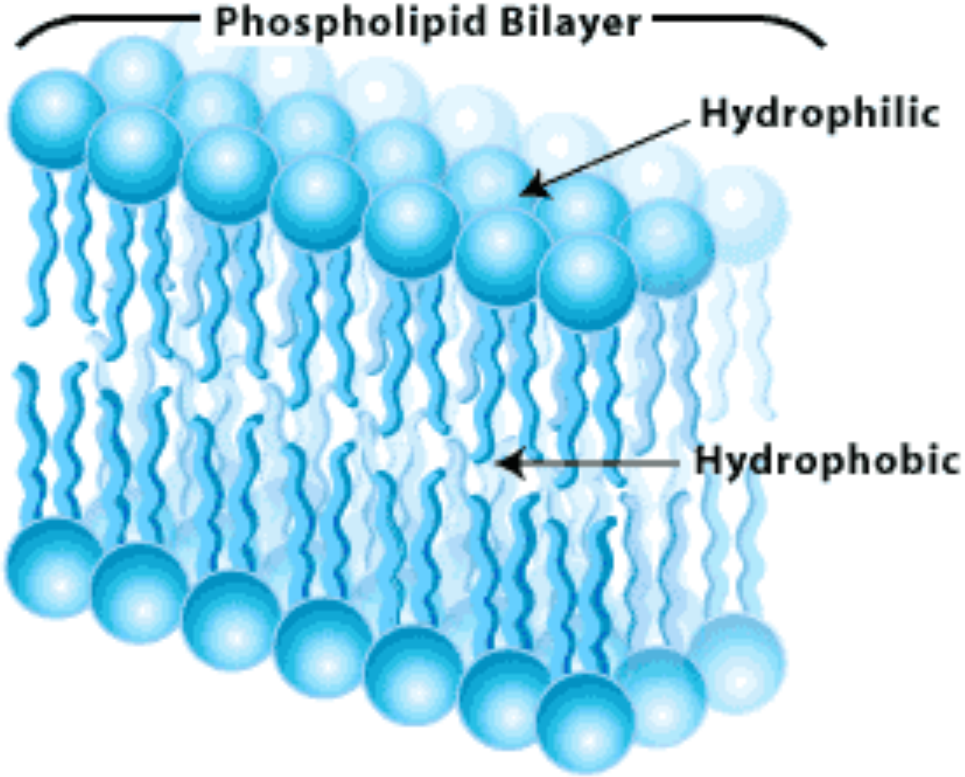


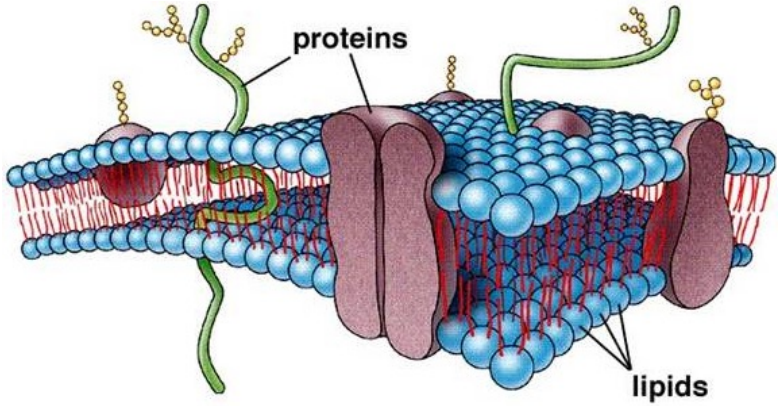


- Engulfed bacteria?
- mtDNA
- Mitochondrial Eve?

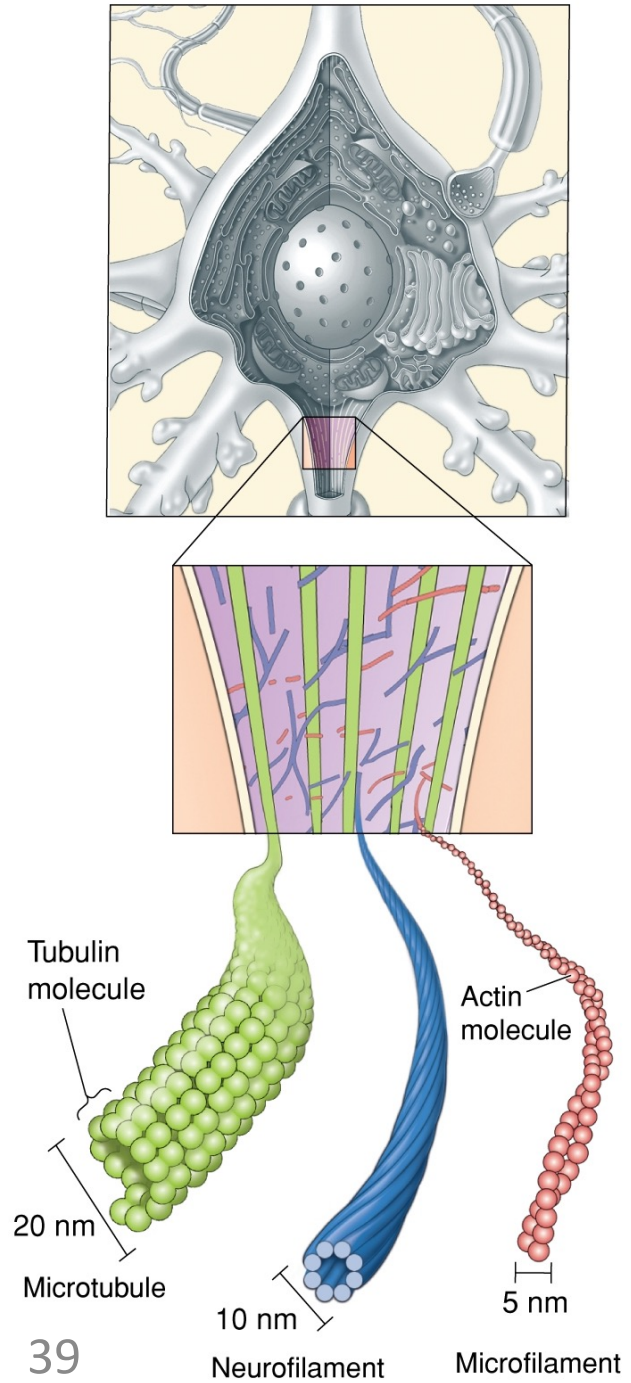
The cell membrane

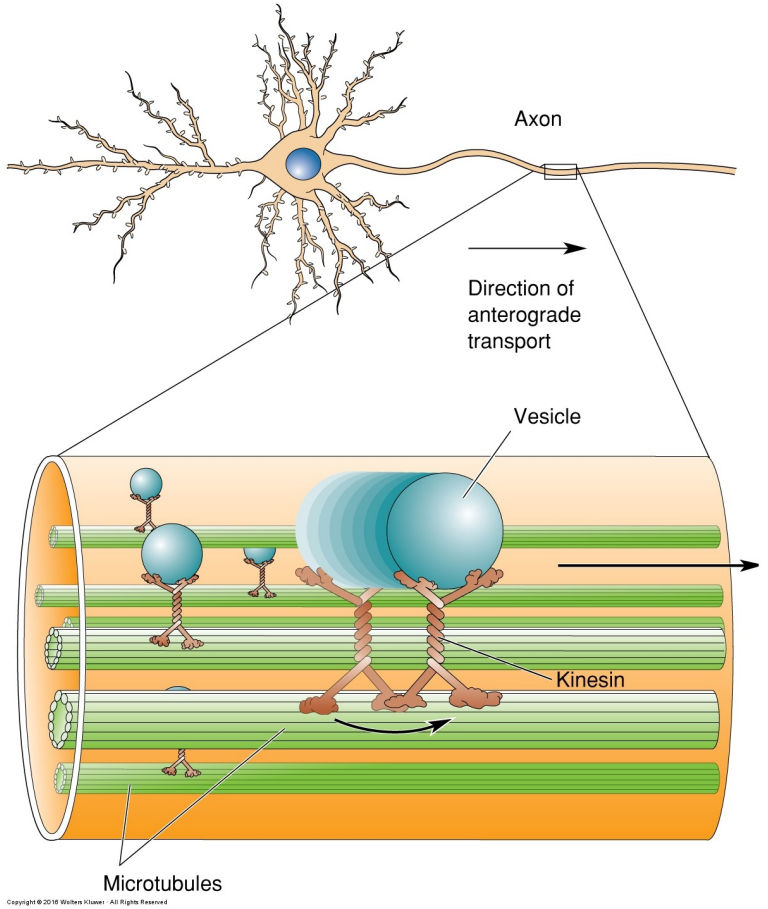






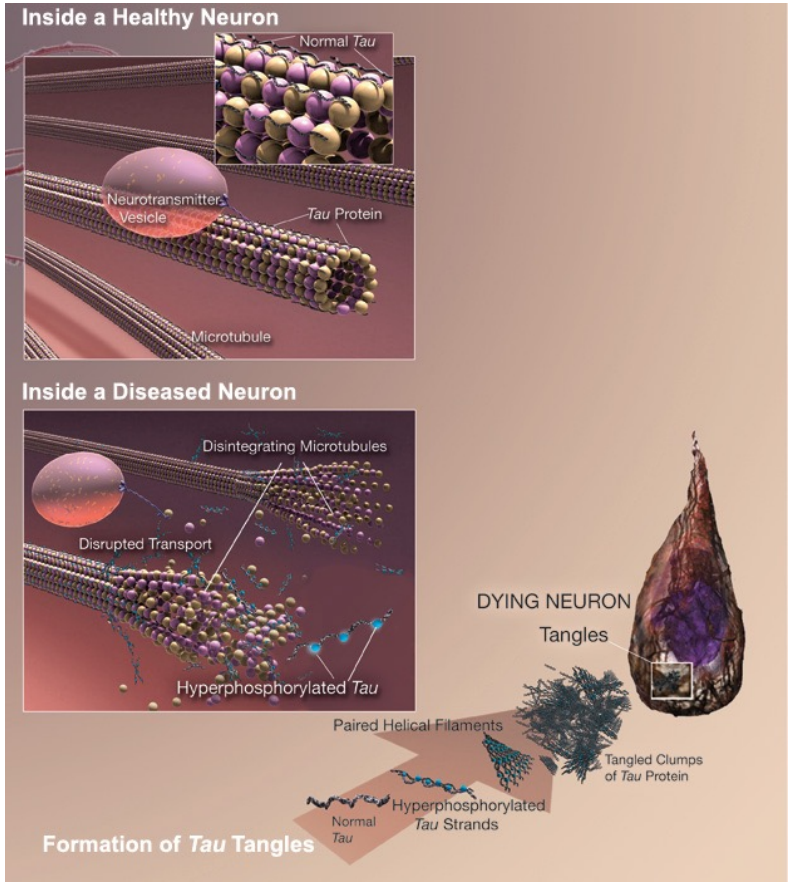
The cytoskeleton



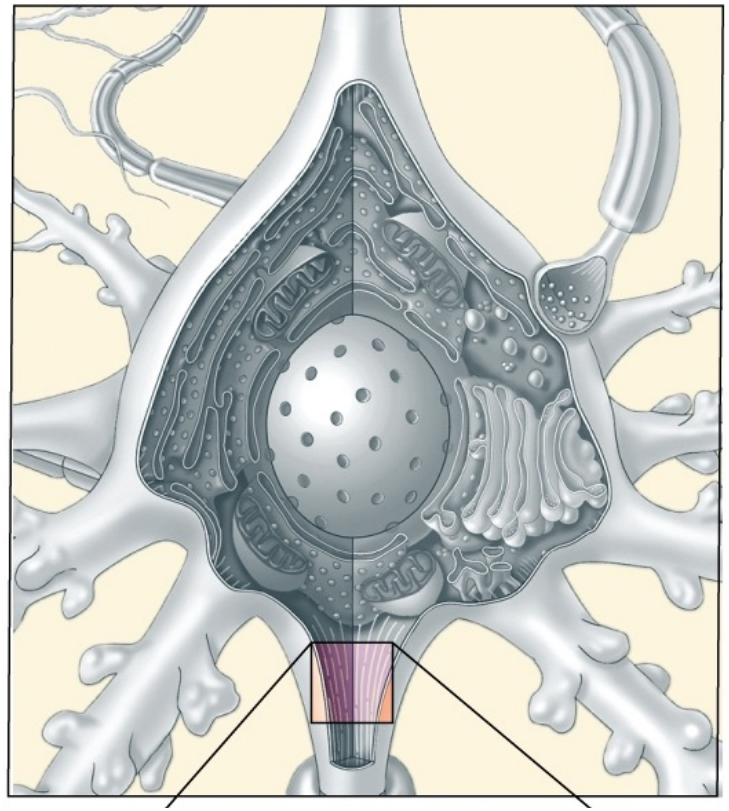


Kinesin: anterograde transport
Dynein: retrograde transport

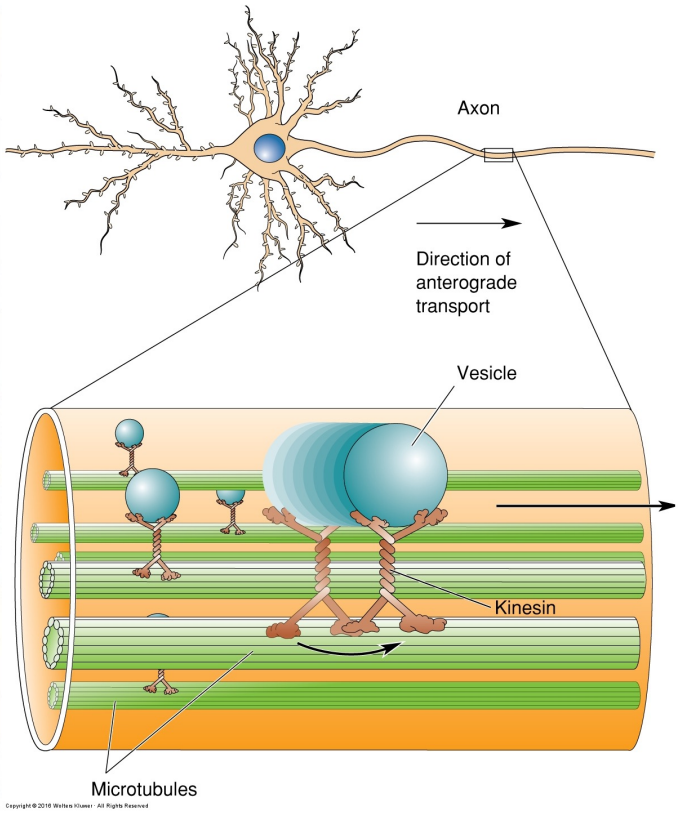
Alzheimer's disease



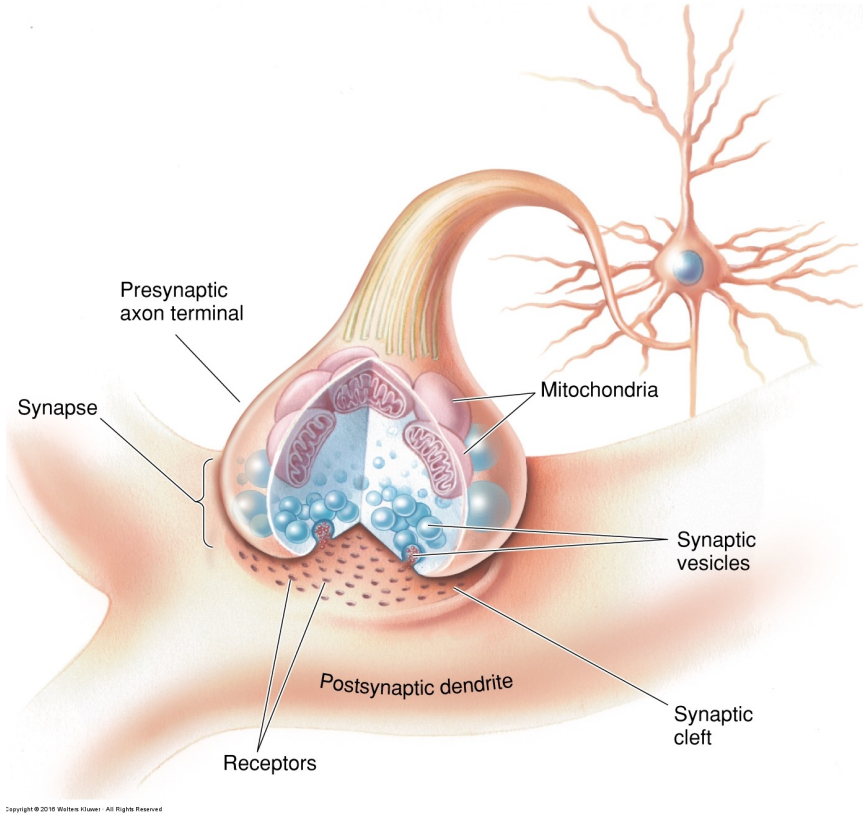
The axon



Axon hillock
Axon initial segment

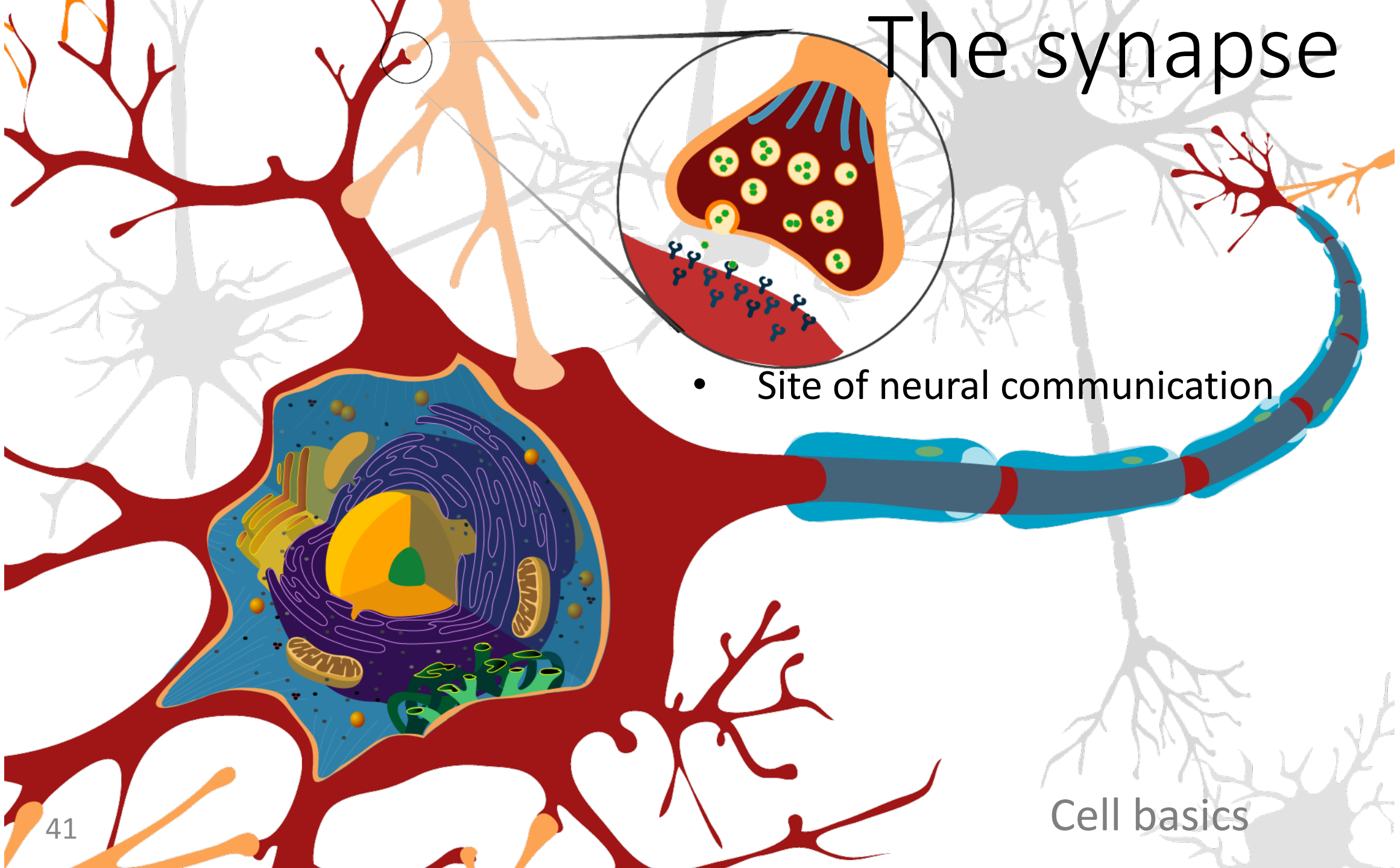


No ER
Mostly no mitochondria



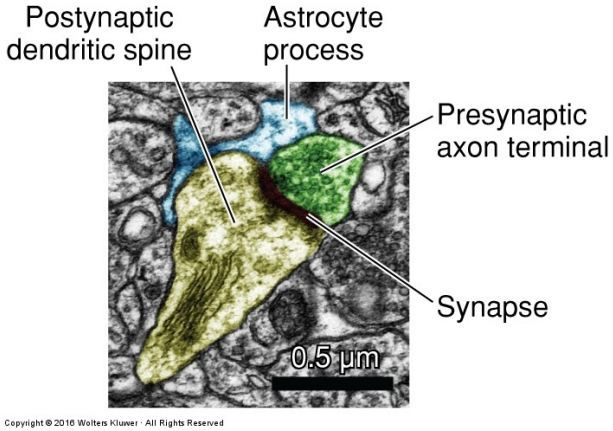
Terminal bouton

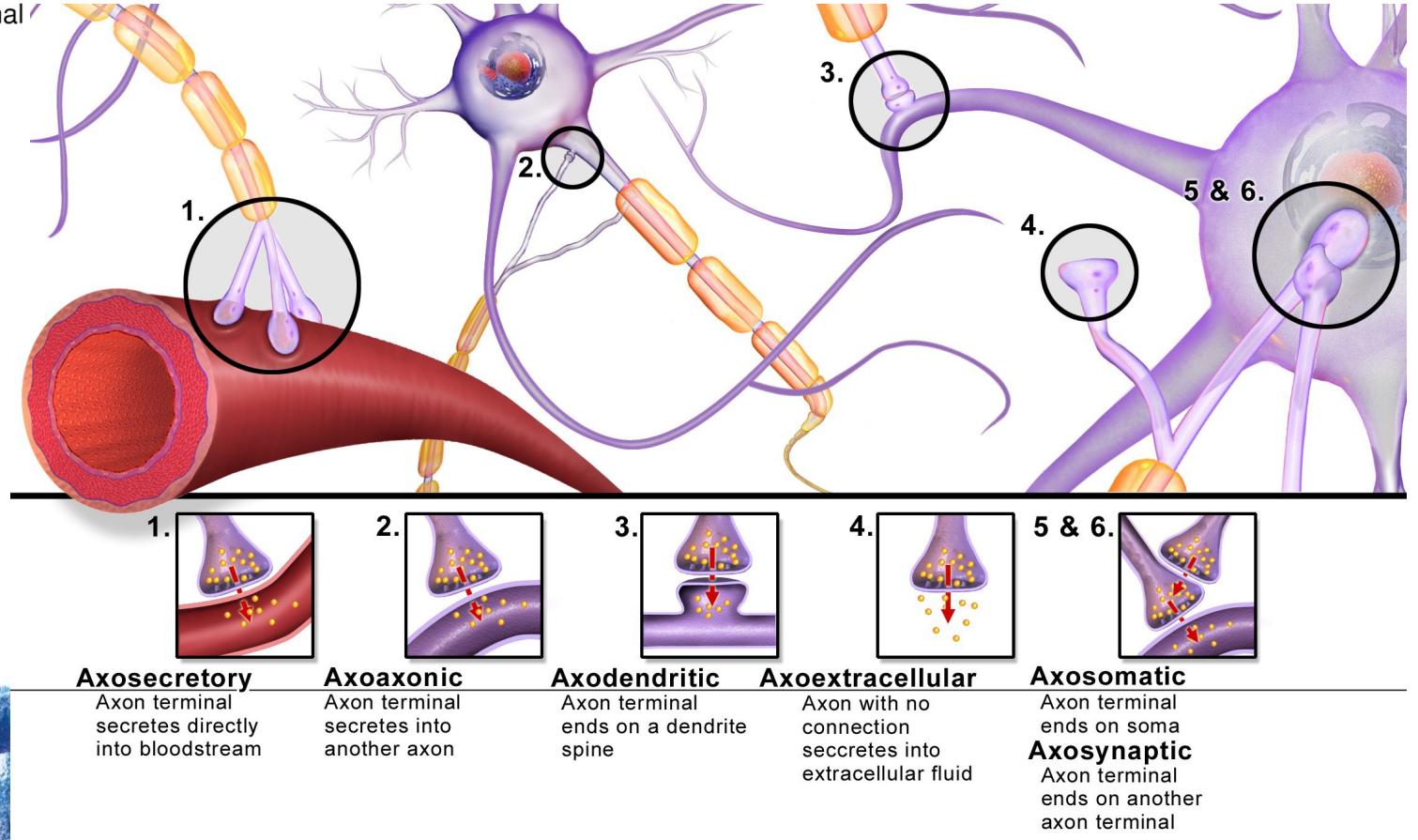
The synapse

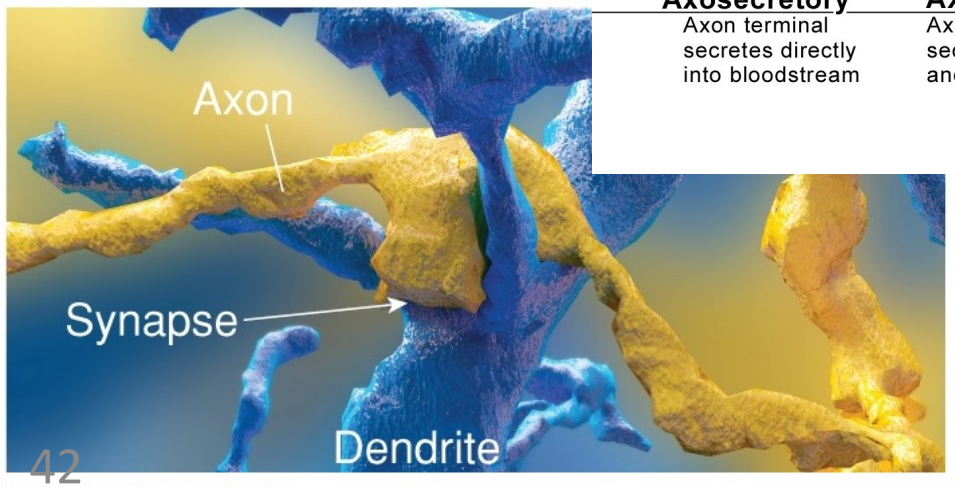


- Site of neural communication

The synapse

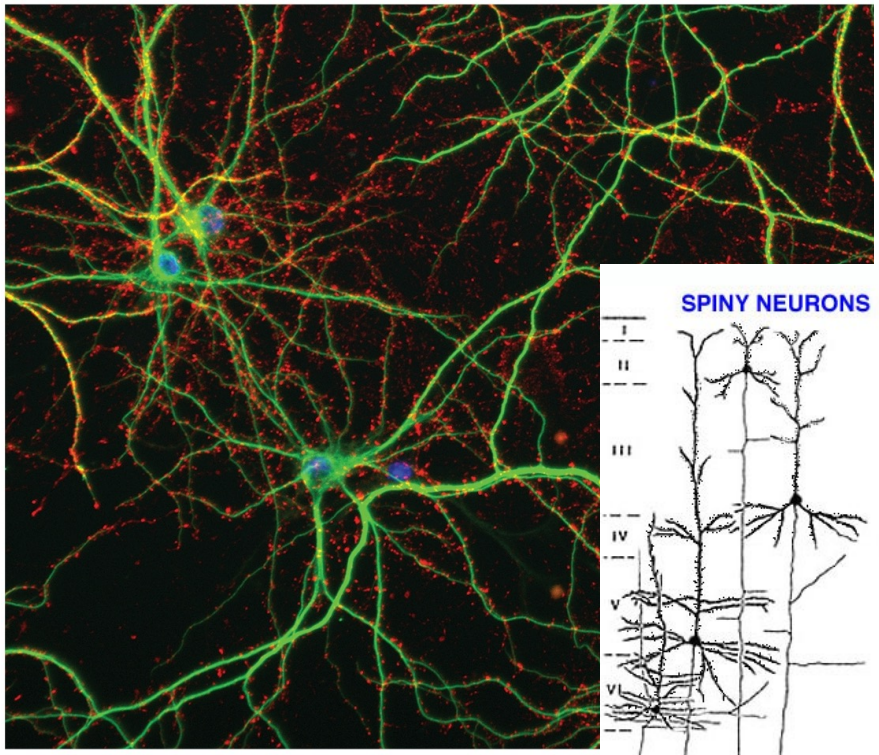






- The reality is often harder to understand than the diagrams

The dendrites



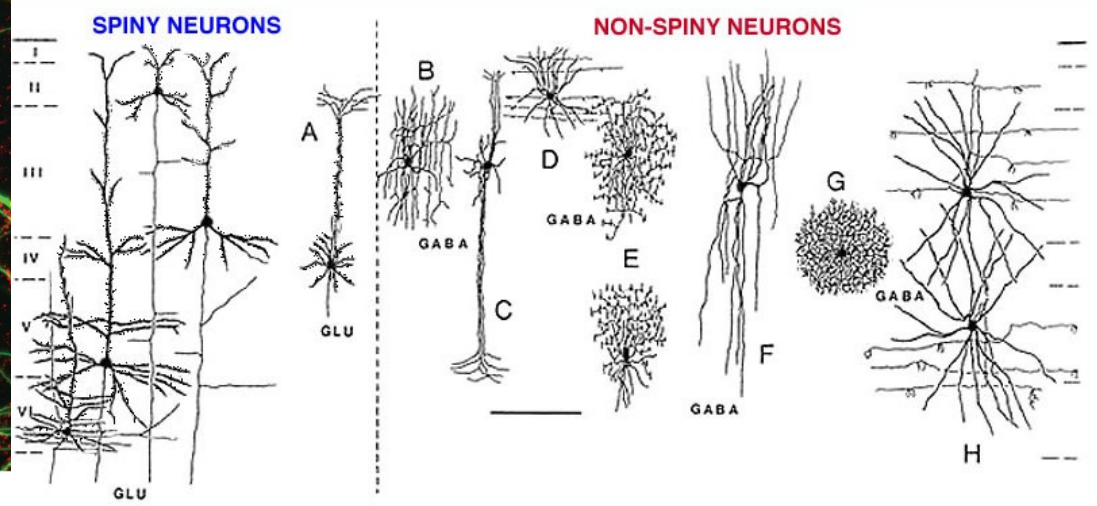


Figure 12. Basic cell types in the monkey cerebral cortex. Left: spiny neurons that include pyramidal cells and stellate cells (A). Spiny neurons utilize the neurotransmitter glutamate (Glu). Right: smooth cells that use the neurotransmitter GABA. B, cell with local axon arcades; C, double bouquet cell; D, H, basket cells; E, chandelier cells; F, bitufted, usually peptide-containing cell; G, neurogliaform cell.