Nerve Cells & Nerve Impulses

Cells of the Nervous System

1

Overview

- Anatomy of Neurons and Glia
  - Central Nervous System
  - Role of Santiago Ramon y Cajal: Continuous or Not?
  - Structures of Animal Cells
  - Structure of a Neuron
  - Variation Among Neurons
  - Glia (Glial Cells)
- The Blood-Brain Barrier
- Nourishment in Vertebrate Neurons

2

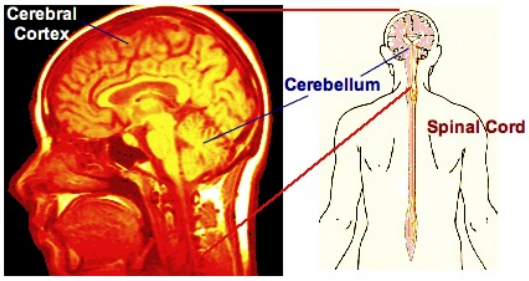
Some Questions to Think About

- If you get a brain tumor, doctors can do two things: surgically remove the tissue and/or use radiation to kill cancer cells. Why can't brain tumors be treated like other cancers by using chemotherapy?
- Does a brain tumor really involve brain tissue?
- What kind of cells form the largest number found in the brain?
- Why do pain killers like morphine gradually lose their effectiveness?

3

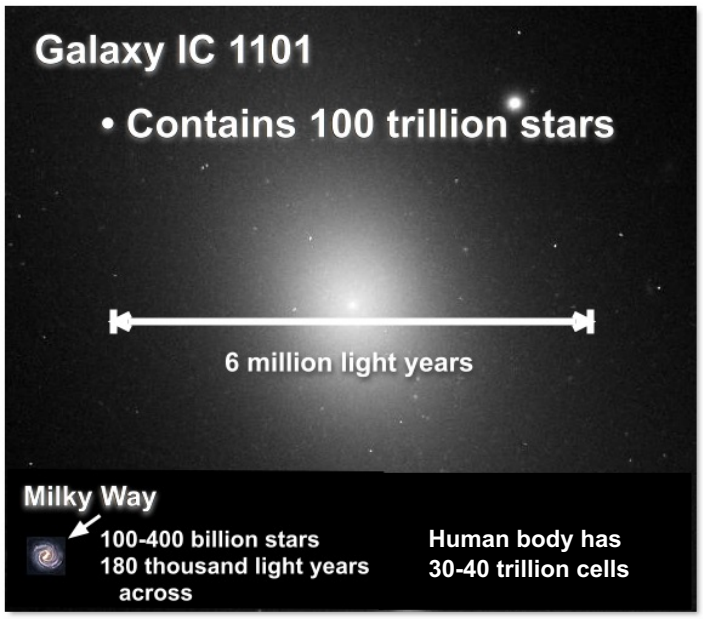
Central Nervous System (CNS)

- **Cerebral Cortex**
  16-17 billion neurons
  (new estimate)
- **Cerebellum**
  70 billion neurons
- **Spinal Cord**
  1 billion neurons



- Interconnections: 1 cell connects with up to 10,000 other cells
- Estimate: 100 trillion interconnections in CNS
  (100,000,000,000,000)

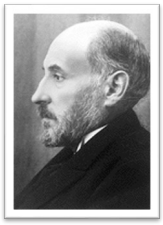
4



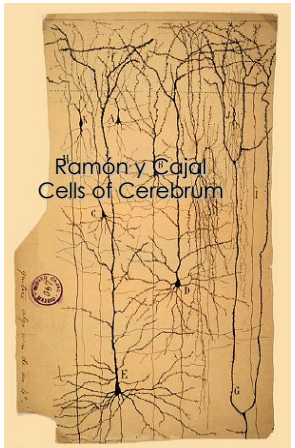
5

Are Nerve Cells Continuous or Separate?

- **Camilio Golgi** (1843-1926)
  - Thought cells continuous
  - Created way to stain nervous tissue so that only 1 in 100 neurons can be seen



- **Santiago Ramón y Cajal** (1852-1934)
  - neurons are independent cells -- contiguous but <u>not</u> continuous
  - founder of "The Neuron Doctrine" = neurons do the work of the brain



http://www.psu.edu/nasa/images/cajal13.jpg

6

Structures of Animal Cells

Membrane
- 2 layers of fat molecules (see next slide)
- Uncharged ions (H_2O, CO_2, O_2) pass through

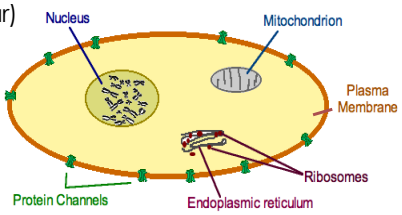
Protein Channels
- Allow charged ions (Na+, K+, Cl-) to pass through to inside of cell

Nucleus
- Contains chromosomes (strands of DNA)

Mitochondria (mitochondrion = singular)
- Metabolic activities
- Fuel & oxygen needed

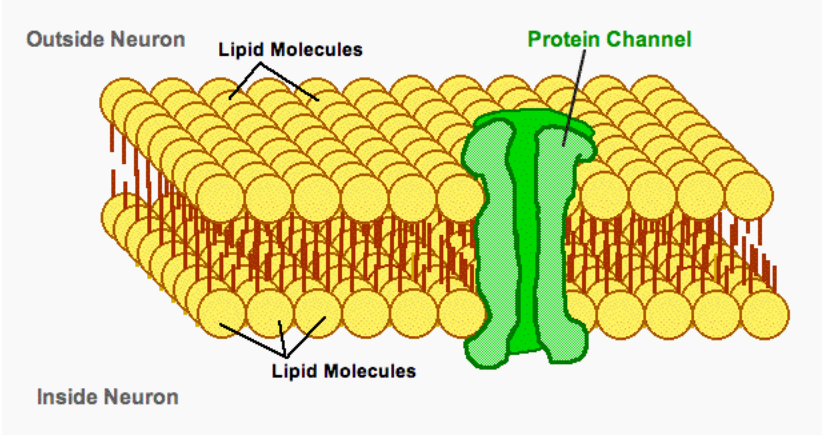
Ribosomes
- New proteins synthesized

Endoplasmic reticulum
- Protein transport to other locations in cell



7

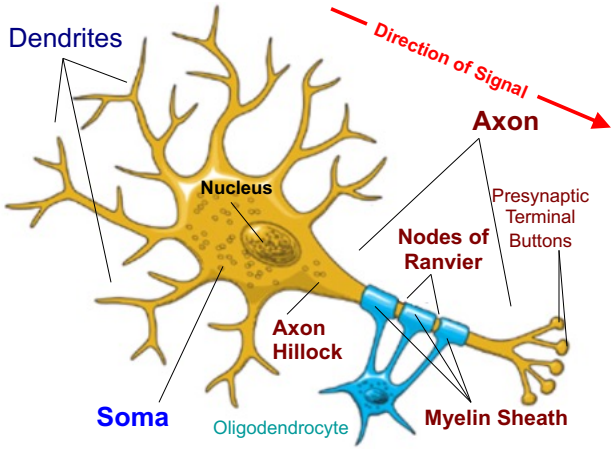
Neuron Membrane



8

Neuron Inside the Cortex

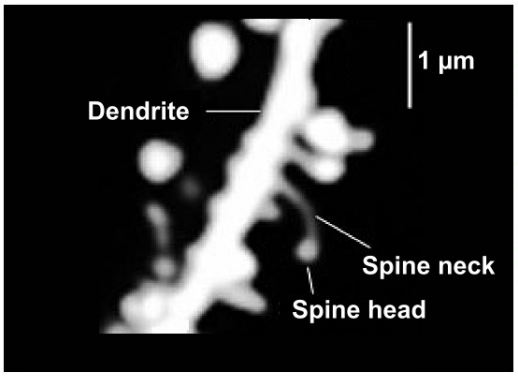
In many neurons the dendrites make up 80% of the volume of the cell



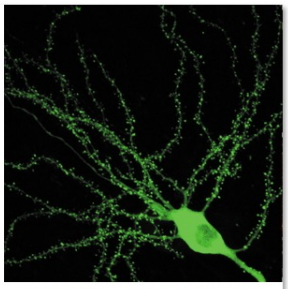
http://www.ninds.nih.gov/img/neuron_cover1.jpg

9

Dendritic Spines



https://upload.wikimedia.org/wikipedia/commons/b/b1/Dendritic_spines.jpg

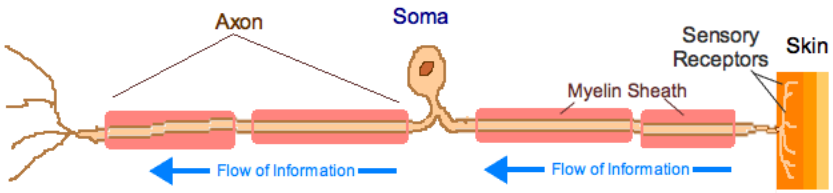


http://www.brain.riken.jp/bsi-news/bsinews17/no17/image/sp1-3b.gif

These spines along the dendrite are short outgrowths which receive information from other neurons

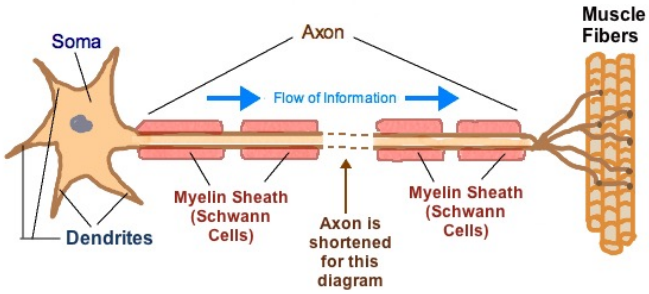
10

Sensory Neuron



11

Motor Neuron



12

Neuroanatomy

Two types of cells comprise the nervous system:

- **Neurons: receive, carry, and transmit information**
  - Old estimate: ~ 100 billion neurons
  - New estimate: ~ 86 (72-94) billion neurons*
- **Glia (glial cells): provide structure, nutrition, cleaning, and various other functions**
  - Increasing evidence that glial cells regulate neuronal signals by changing the blood supply & altering the availability of neurotransmitters
  - Most brain tumors arise from glia, not neurons
  - Old estimate: ~ 1 trillion glial cells
  - New estimate: ~ 85 (74-95) billion glial cells*

* See slide further below (Lent et al. 2012)

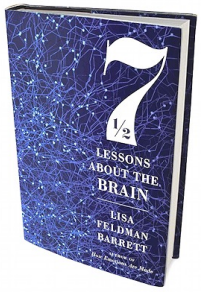
13

Neuroanatomy

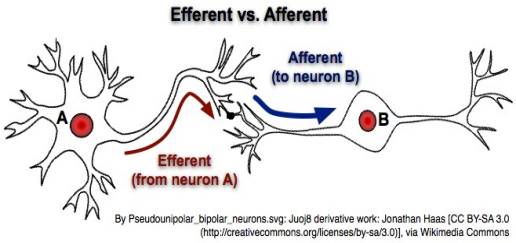
A comment on how many cells in our brain:

- Neurons: receive, carry, and transmit information
  - Old estimate: ~ 100 billion neurons
  - New estimate: ~ 86 (72-94) billion neurons

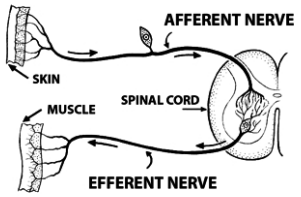
Lisa Feldman Barrett, a renowned neuroscientist who has made major contributions to understanding the biological basis of emotion, disagrees with the new estimate above. In her 2020 book, ***Seven and A Half Lessons About the Brain***, uses an estimate of 128 billion neurons. She claims that this figure comes from an alternative approach to counting cells. Perhaps her claim will be upheld in the future. For us, we'll use the **~86 billion** figure



14



By Pseudounipolar_bipolar_neurons.svg: Juoj8 derivative work: Jonathan Haas [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons



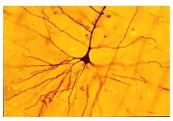
By Pearson Scott Foresman Afferent (PSF).jpg, Public Domain commons.wikimedia.org/w/index.php?curid=2499895

- ***Afferent*** fibers bring information into (ad-) another structure or, for axons, **into the CNS**
- ***Efferent*** fibers carry information away from (ex-) a structure or, for axons, **away from the CNS**
- **Interneuron** or **intrinsic neuron** = neural cell is entirely within a structure

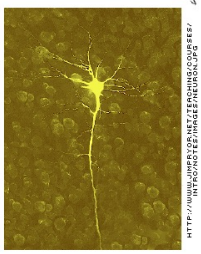
15

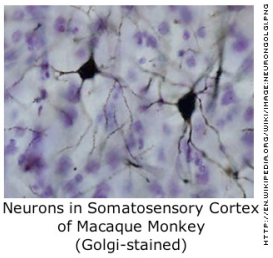
Variation among Neurons

Purkinje Cell



Pyramidal Cell
(Golgi-stained)





Neurons in Somatosensory Cortex
of Macaque Monkey
(Golgi-stained)

16

Glia (= "glue")

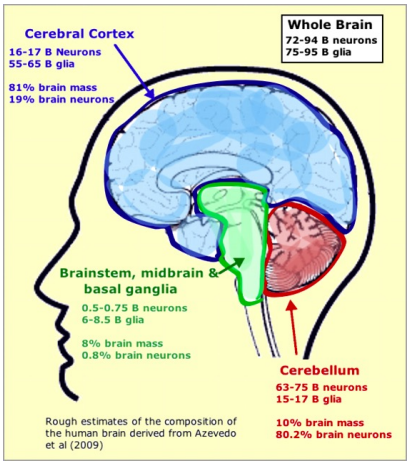
- **Astrocytes** ("star-shaped" cells)
  - Maintains balanced activity of neural circuits
  - Exchange chemicals between blood & neuron
  - Guide formation & elimination of synapses
  - Synchronize wave-like actions of related axons by absorbing & re-releasing chemicals from/to axon
  - Dilate capillaries for increased blood flow
  - May counteract effects of pain medicine
- **Oligodendrocytes** (CNS) & **Schwann C**ells (PNS)
  - Structure & insulation (myelin)
- **Microglia**
  - Defense system of brain, thus, waste removal (viruses, fungi, etc.) & response to immune system issues of the CNS, e.g., stress
  - Maintain integrity of the myelin sheath
- **Radial glia**
  - Guide neuron development in embryo

17

New Estimates of Glial Cell Numbers

- Old belief: 10 glial cells for each neuron (glial cells only 10% of size of neuron)
- New data: ~ 1:1 ratio of glial cells to neurons, BUT
- Uneven ratios (G:N) across brain
  - Cortex: 3.7:1
  - Cerebellum: 0.23:1
  - Brain stem *et al*: 11.4:1

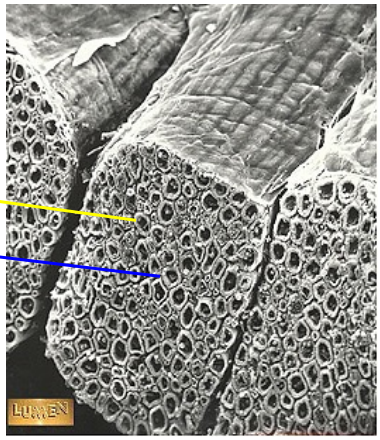
(Lent et al. 2012)



18

Nerves

- Cross-section of a Peripheral Nerve
- Axons surrounded by myelin sheathes
- Nerve is a bundle of the axons or sensory fibers of many neurons

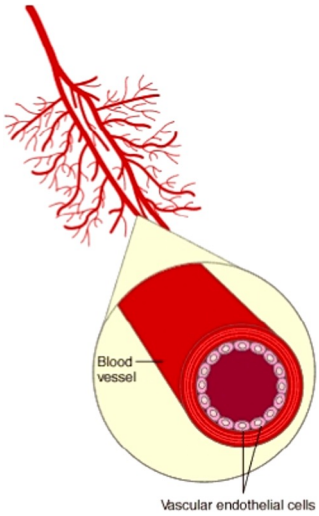


http://www.meddean.luc.edu/lumen/MedEd/Histo/frames/h_frame6.html

19

Blood-Brain Barrier

- Capillaries in brain are lined with endothelial cells which form the barrier
- Chemicals and microorganisms are blocked from the brain by this barrier
- Why? CNS neurons can't be replaced easily
- What does cross?
  - Uncharged molecules O^2 + CO^2
  - Lipid-soluble molecules
  - Molecules using active transport
    - Glucose: Brain's energy
    - Amino acids
    - Vitamins & hormones



http://rex.nci.nih.gov/behindthenews/uangio/06uangio/06uangio.gif

20

Nourishment in Neurons

- **Glucose** (primary) = a simple sugar
  - Crosses the blood-brain barrier
  - Produced from carbohydrates, amino acids, & glycerol (fat by-product) in liver
- **Oxygen**
  - Brain uses 20% of body's oxygen even though it is only 2-3% of body's weight
- **Thiamine (Vitamin B1)**
  - Necessary for use of glucose
  - Alcoholics may have chronic deficiency leading to Korsakoff's Syndrome

21