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Visualizing the microanatomy of the brain (4:29)

Today's Topics

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

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/mm³

Glia (neuroglia)

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

Astrocytes

- “Star-shaped”
- Physical and metabolic support
 - Blood/brain barrier
 - Ion (Ca⁺⁺/K⁺) buffering
 - Neurotransmitter (e.g., glutamate) buffering

Astrocytes

- Shape brain development, synaptic plasticity
- Regulate local blood flow
- Regulate/influence communication between neurons, (Bazargani and Attwell 2016)
- Disruption linked to cognitive impairment, disease (Chung et al. 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

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, and 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

Dendritic Spines

Soma (cell body)

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

Soma

Axons

- Another branch-like “extrusion” from soma
- Extend farther than dendrites
- Usually transmit info
- Parts
 - Initial segment (closest to soma, unmyelinated)
 - Nodes of Ranvier (unmyelinated segments along axon)
 - Terminals, axon terminals, terminal buttons, synaptic terminals, synaptic boutons

Axons

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

Classifying neurons

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

Neurons by type

Neural communication

- Electrical
 - Fast(er)
 - Within neurons
- Chemical
 - Slow(er)
 - Between neurons

How are messages generated?

- Electrical potential (== voltage)
 - Think of potential energy
 - Voltage \sim pressure
 - Energy that will be released if something changes

Potential energy

Types of neural electrical potentials

- Resting potential
- Action potential

Resting potential

- Measurement
 - Electrode on inside
 - Electrode on outside
 - Inside - Outside = potential

Resting potential

Resting potential

- Neuron (and other cells) have *potential energy*
 - Inside neuron is -60-70 mV, with respect to outside
 - About 1/20th typical AAA battery
- Like charges repel, opposites attract, so
 - Positively charged particles pulled in
 - Negatively charged particles pushed out

Where does the resting potential come from?

- Ions
- Ion channels
- Separation between charges
- A balance of forces

We are the champIONS, my friend

- Potassium, K⁺
- Sodium, Na⁺
- Chloride, Cl⁻
- Organic anions, A⁻

Party On

- Annie (A⁻) was having a party.
 - Used to date Nate (Na⁺), but now sees Karl (K⁺)
- Hired bouncers called
 - “The Channels”
 - Let Karl and friends in or out, keep Nate out
- Annie’s friends (A⁻) and Karl’s (K⁺) mostly inside
- Nate and friends (Na⁺) mostly outside
- Claudia (Cl⁻) tagging along

Party On

Next time

- Neural communication

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