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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/mmˆ3

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

Microglia in red invading dentate gyrus.

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
  - Mitochonrdria
  - 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 ~ 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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