Neurons and Nerve Cells and Neurophysiology

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General Nervous Systems

Central Nervous System (CNS):
- Brain
  - Brain Stem
- Spinal cord

Peripheral Nervous System (PNS):
- Cranial Nerves
- Spinal Nerves

Autonomic Nervous System (ANS):
- Sympathetic vs. Parasympathetic Systems
Neurons + Nerve Cells

- Key Units of CNS + PNS
- Comprise a neural network system
- Synthesize protein to produce energy
- Generate impulses + modulate activity
  - → Excite
  - → Inhibit
Within the CNS

- Nerve cells $\rightarrow$ neurons
- Neuroglial cells $\rightarrow$ association cells

- form the nervous system architecture
- functional integrity of nervous system
- highly specialized to receive + elicit stimuli
- conduct nerve impulses $\rightarrow$ action potentials
Classification of Neurons

Number, length, branching:
- Bipolar
- Unipolar
- Multipolar

Size of neuron:
- Golgi type I
- Golgi type II
Bipolar and Unipolar Neurons

- Cilia are sensitive to physical stimuli
- Dendrites are sensitive to physical stimuli

(a) Bipolar neuron

(b) Unipolar neuron

Axon

To brain

Terminal buttons

Soma of bipolar neuron

Soma of unipolar neuron
Golgi I
Golgi II
Nerve Cell Body: Main structures

• **Nucleus:** controls cell activity
  – stores genes + chromosomes (nucleolus $\rightarrow$ RNA)

Cytoplasmic organelles

– Nissl substance: protein synthesis $\rightarrow$ repair
– Golgi apparatus: cell membrane production (store Nissl)
– Mitochondria: chemical energy (3-carboxylic acid ++)  
– Neurofibrils: cell transport + cytoskeleton make-up
– Microtubules: cell transport $\rightarrow$ > or < motor movement
– Lysosomes: cell scavengers (1, 2, residual)
– Centrioles: cell division (form microtubules)
– Lipofuscin: metabolic by-product
– Melanin: formation of dopa (substantia nigra $\rightarrow$ midbrain)
Neurons of CNS

Supported by non-excitable cells:

– Neuroglial Cells: specialized tissue
  • Astrocytes - lining material: brain + vessels
  • Oligodendrocytes- myelin
  • Microglia – engulf debris (multipurpose)
    – phagocytosis
  • Ependyma – line ventricular system (CSF)
Neurons of PNS

Nerve fibers supported by:
  – Areola tissue
  – Glial cells:
    • Schwann cells - myelin
    • Satellite cells -
    • Fibroblasts
Myelination of PNS and CNS Axons

Myelination in the Peripheral Nervous System

Myelination in the Central Nervous System

- Axon
- Nucleus
- Schwann cell

- Axon
- Nucleus
- Oligodendroglia
Neuron Composition

- Cell Body (soma)
- Dendrites (receptors)
- Axons (effector)
Dendrites & Axons: cytoplasmic extensions

Each nerve cell has (neurites):

- Dendrites
- Axons
Dendrites

- Afferent (receptive)
- Transmit $\rightarrow$ toward cell body
- Short with branches
- “spikes” to increase synaptic transmission
Axons

- the “nerve fiber”
- Efferent (motoric)
- Transmit $\rightarrow$ away from cell body
- Extends long distances
- Extends from *Axon Hillock*
- Collaterals
- Telodendria $\rightarrow$ terminal extension
- Terminal boutons $\rightarrow$ release neurotransmitter
What is Myelin?

- Sheath for insulation
- Composed of lipid (fat)
- Increase nerve conduction
- Prevents escape of electrical energy
Within the CNS

Oligodendroglia cells produce myelin
- Axons are wrapped in myelin
- Nodes of Ranvier: spaces between internodes
- 1 oligodendroglia per node
- Facilitate saltatory conduction → yields speed
- Transmission:
  - Node of Ranvier → Node of Ranvier
Within the PNS

Schwann cells produce myelin
  – Axons wrapped in myelin
  – Jelly-role fashion, myelin on outside
  – Looks like a *cow-tail* candy
Myelination of PNS and CNS Axons

Myelination in the Peripheral Nervous System

- Axon
- Nucleus
- Schwann cell

Myelination in the Central Nervous System

- Nucleus
- Axon
- Oligodendroglia
The Synapse

• Presynaptic cell
  • Transmits neurotransmitter via ➔
  • Terminal bouton to synaptic cleft

• Post-synaptic cell
  – Receives neurotransmitter
  – Generates impulse

• Receptor site ➔ adjacent nerve cell
Neuromuscular Junction

Motor nerve fiber
Myelin
Axon terminal
Schwann cell

Synaptic vesicles (containing ACh)
Basement membrane (containing AChE)
Synaptic cleft
Junctional folds

Active zone
Sarcolemma
Region of sarcolemma with ACh receptors
Nucleus of muscle fiber
Mechanics of a Synapse

• Neurotransmitter deposited in synaptic cleft
• Particular chemical reaction results
• Sodium + potassium exchange: in → out
• Negative chloride
• Depolarization or hyperpolarization
• EPSP vs. IPSP results
The figure illustrates the movement of an action potential along an axon. At time $T_0$, the myelin sheath is intact, and the nodes of Ranvier are shown.

At $T_1$, the action potential has reached node B, causing depolarization and the generation of an action potential.

At $T_2$, the action potential has reached node C, completing the propagation of the impulse along the axon.

At $T_3$, the myelin sheath at node A is shown, indicating the resting state of the axon between impulses.
Please note:

- Axons release neurotransmitter into cleft area of other:
  - Axons
  - Dendrites
  - Same nerve cell body
Regeneration of Nerve Cells

• Within PNS $\rightarrow$ good, 3-4 days
• Within CNS $\rightarrow$ poor
• Why?
  – PNS’ ability for nerve cell to sprout protein
  – in the CNS, sprouting hindered 2º scars (astrocytes)
  – Sprouting is influenced by growth hormone factors
  – PNS: endoneurial membrane + neurilemma
    • Schwann cells
Brain Injury Effects

- Axonal retrograde reaction
- Wallerian degeneration
- Chromatolysis
- Neuroglial response
Axonal retrograde reaction

- Injury within cell body
- Affected axon injured
Wallerian Degeneration

- Anterograde degeneration of:
  - axonal region detached → away
- Leads to inflammation
  - 12-20 hours post-injury
  - connected muscle denervate → fasciculations
- 7 days, disintegrates
- 3-6 months atrophies
Chromatolysis

• Degeneration process:
  – axon hillock $\rightarrow$ nucleus $\rightarrow$ Nissl bodies
  – Nissl substance $\rightarrow$ peripheral concentration

• Occurs 10-18 days post insult

• Free ribosomes come to the rescue

• Increased RNA production + protein synthesis

• Rebuild cell $\rightarrow$ chromatolysis stops
Example: Multiple Sclerosis

- Results from decrease in myelin
- Results in decrease nerve conduction