

NEURAL CONDUCTION

1. Introduction to Basic Chemical Terms & Concepts

Atoms, subatomic particles: protons(+), neutrons, electrons(-)

Molecules (2+ different atoms)

Ions (ionization), charged atoms (lost/gained electrons)

Kinetic energy = random motion

Concentration gradient

Cell membranes & differential permeability

Permeable, semipermeable, impermeable

Ion channels = ion pores = channel proteins

Osmosis = movement of ions through a semiperm.memb.

Electrostatic gradient

“likes” repel, “opposites” attract rule

Active transport across a membrane (takes energy)

Dynamic equilibrium

Ions of relevance in neurons:

Sodium **Na⁺** Potassium **K⁺** Chloride **Cl⁻**

Amino Acid ions **AA⁻** Calcium **Ca⁺⁺**

2. The “Resting” Membrane Potential

Comparison of overall charge inside vs. outside the cell

-70 mV (1/1000th of a volt = 1 mV)

more negative inside than out (= more positive outside than in)

cell is “**polarized**”

True for all living cells (range: -30 to -90mV)

Takes 70% of each cell’s energy supply (calories) to maintain this -70 mV membrane potential

At “rest”, Na⁺ is mostly outside (1:10), K⁺ is mostly in (10:1), Cl⁻ is mostly outside (1:10), AA⁻ is all in

energy used in dumping out extra Na’s that have gotten in, and in hauling back in extra K’s that have left

the **sodium-potassium pump**

Definition of cell “death” is inability to maintain RMP

Cell’s potential becomes zero, no longer polarized

3. Graded (Post-Synaptic) Potentials

Occur at **synapses** (junction between an axon terminal and the next neuron in line (usually with the dendrite or soma))

Types of synapses:

Axodendritic	axon --- dendrite
Axosomatic	axon --- soma
Axoaxonal	axon --- axon
(Dendrodendritic)	dendrite --- dendrite (esp.local circuit/interneurons)

Can be in **positive (depolarizing)** direction or in **negative (hyperpolarizing)** direction

+ change (Na⁺ comes in)

- change (K⁺ goes out or Cl⁻ comes in)

Amount of neurotransmitter released by **presynaptic** cell determines the **amount of voltage change** seen in **postsyn.** cell (e.g. the more NT --- the more voltage change)

NTs attach to **chemically-gated** ion protein channels, which then open up, letting ions outside and inside the neuron move through the cell membrane more freely than before

Voltage changes across surface of postsynaptic cell are **graded over time and space** (i.e. decay over time and distance); are strongest at the location of the synapse itself

Voltage changes **spread out** from the synapse across the surface of the postsynaptic cell “instantly”

“passive conduction”

Two + voltage changes **can be additive** if occur close together spatially (different synapses) or close together in time (could be the same synapse), **“summation”**

A neuron's cell surface (esp. dendrites & soma) have 100's to 1000's of synapses on it, acts like a giant **“integrator”** of these incoming signals, the overall surface graded potential changing from msec to msec as the incoming graded potentials change

4. Action Potentials

axon hillock to axon terminal, **axon only**

threshold for “firing” the neuron (+5 to +10 mV)

depolarizing direction

a positive graded potential = “**EPSP**” (**excitatory** postsyn potential)

(a negative graded potential = “**IPSP**” (**inhibitory** postsyn potential))

summation of EPSP graded potentials

location of synapses in relation to axon hillock

Voltage-gated membrane protein channels

found only on the axon (especially at the axon hillock and the **Nodes of Ranvier** on myelinated axons; all along the length of an unmyelinated axon)

AP “jumps” from node to node, each triggered by a passively conducted graded potential on a myelinated axon

compared to an unmyelinated axon, where AP occurs at each consecutive location triggered by graded potential

All-or-none response (not a graded response)

from -70mV to +40/50 mV always (**non-decremental**)

amount of NT released by axon terminal depends on the of voltage change from the resting state to the peak amplitude of the AP, which is usually 110-120 mV change

a **self-propagated** wave of responses

takes time to travel down axon (100-120m/sec. to 1m/sec.)

What afferent axon conducts the fastest?

What efferent axon conducts the fastest?

larger diameter axons, more myelin --- faster conduction

orthodromic conduction vs. **antidromic** conduction

absolute refractory period vs. **relative refractory period**

RRP prevents antidromic conduction of AP

ARP sets limit on maximum firing rate (500-1000/sec.)

4. **Action Potentials** (cont.)

note: local circuit/interneurons without axons send signals back and forth (via dendrodendritic *electrical* synapses) via graded potentials & passive conduction

note: some dendrites are capable of generating APs and can conduct an AP away from the starting site toward or away from the soma

note: some dendrite signals (APs or GPs) occur just on specific portions of that dendrite

things just got more complicated...lots we do not yet know...

5. Electrical Signals

electroencephalogram = EEG

usually surface electrodes (on scalp)

recording from many neurons/glia at a time, a summed signal of many graded potentials and action potentials

used clinically & in research (e.g. seizures, sleep vs. wake)

single-cell recordings

using a microelectrode (lowered into or next to individual cells)

recording APs from individual neuron(s)

used as a research tool

evoked potentials (event-related potentials)

usually surface electrodes (on scalp)

recording signals from many cells in a sensory pathway

electrical signal is in response to a specific stimulus (hence the term “evoked”)

used both clinically & in research (e.g. identifying MS, in autistics, visual recognition)