Lec 2a: Neural Functioning

Cogs 17 * Dept of Cognitive Science * UCSD
The Cell

- DNA
- Endoplasmic reticulum
- Free ribosomes
- Mitochondria
- Ribosomes (dots)
- Nucleus
- Cell membrane
Double Lipid Membrane

Various Functions -
(More to come)

Neuron membrane
Neurons & Glia
Some of the many functions of **GLIA CELLS**

- Microglial cell
- Astrocyte
- Ependymal cell
- Oligodendrocyte

1/10 size of a neuron
10X as many
50% of brain by weight

< Myelinization

(a) Central nervous system
The Neuron
The Principal Structures or Regions of a Multipolar Neuron

- **Soma (cell body)**
- **Dendrites**
- **Axon**
- **Myelin sheath**
- **Terminal buttons**
- **Release NTs**
- **w/Receptor Sites**

Messages

Copyright © 1995 by Allyn and Bacon
The IONS

Charged particles w/extra electrons (-) or fewer electrons (+)

\[ \text{Na}^+ \quad \text{Sodium} \]

\[ \text{K}^+ \quad \text{Potassium} \]

\[ \text{Cl}^- \quad \text{Chloride} \]

\[ \text{Ca}^{++} \quad \text{Calcium} \]
The Nerve Impulse

To understand how Neurons “communicate” we first need to recognize that

\[ \text{Nature seeks a Balance} \ldots \]

Any GRADIENT (inequality) between chemicals inside vs. outside cell will, if allowed, tend toward an equilibrium...

Concentration Gradient

Electrical Gradient
Concentration Gradient
Neuron membrane
Inside Cell

Double Lipid Membrane

Outside Cell

Ion Gates
CONCENTRATION Gradient

Higher Concentration

Na+  Na+  Na+  Na+  Na+

Lower Concentration

via Diffusion
CONCENTRATION Gradient

Na+ via Diffusion

Equilibrium

via Diffusion
CONCENTRATION Gradient

Lower Concentration

Higher Concentration

via Diffusion
CONCENTRATION Gradient

via Diffusion
Electrical Gradient

Identical charges REPEL
ELECTRICAL Gradient

via Electrostatic Pressure

+7

+4-1=+3

Na+  K+  Na+  Na+  Na+

K+  Na+  K+  Na+

K+  Cl-  K+

Na+
ELECTRICAL Gradient

Equilibrium

via Electrostatic Pressure
Equilibrium = NO Potential
Equilibrium = NO Potential

No message possible!
Let's look at ion conditions in an actual neuron...
Instead of being at Equilibrium, a "Resting" Neuron is HIGHLY POLARIZED
It reaches this HIGHLY POLARIZED state by moving **3 Na+ Out for every 2 K+ In**

Accomplished by **Energy-REquiring Na+/K+ PUMP**
Then all gates are locked = "Resting Potential"

-70mV

"Highly Polarized"
Giant Squid Axons

Unlike most neurons, those of the Giant Squid are actually visible.
Compare difference between charge INSIDE vs. OUTSIDE the axon.

Resting Potential
-70 mV
Resting Potential MNEMONIC

The Resting Cell is Polarized, more positive OUT than it is INSIDE

Resting Potential -70 mV
The AXON

Axon Hillock

Ion Gates

Terminal Button

Vesicles of Neurotransmitter
The **Resting Potential**

Cell is ready to **FIRE!**

**-70mV**

*Fewer Positive ions Inside than Outside Cell*
A change in the polarity of the neuron (we'll explain how, later) initiates an **ACTION POTENTIAL**
The Action Potential

Na+ Gates at Hillock Open, Na+ Enters Cell
The Action Potential

Local Depolarization

More Positive Inside than Outside Cell

+50mV

Resting Polarization

-70mV

Na+ Gates at Hillock Open, Na+ Enters Cell
The Action Potential

This local polarity change causes the next Na+ Gates to open & **Na+ Enters Cell**
The **Action Potential**

Then the previous Na+ Gates Close

This local polarity change causes the next Na+ Gates to open & **Na+ Enters Cell** . . .
The Action Potential

Then K+ Gates at Hillock Open, K+ Exits Cell
The Action Potential

Then K+ Gates at Hillock Open, $K^+$ exits cell
The Action Potential

When K+ exits, creates a local re-polarization to −50mV (once again, less positive inside)
The **Action Potential**

Next Na+ Gates Open, Na+ Enters Cell. . .
The Action Potential

Next Na+ Gates Open, Na+ Enters Cell. . .
then previous Na+ Gates Close
The Action Potential

Then the next K+ Gates Open, K+ Exits Cell...
The Action Potential

Then the next K+ Gates Open, K+ Exits Cell. . .
then previous K+ Gates Close
The Action Potential

Next Na+ Gates Open, Na+ Enters Cell . . .
The Action Potential

Next Na+ Gates Open, Na+ Enters Cell . . .
then previous Na+ Gates Close
Next Na+ Gates Open, Na+ Enters Cell . . .
then previous Na+ Gates Close
The Action Potential

Next K+ Gates Open, K+ Exits Cell . . .
The Action Potential

Next K+ Gates Open, K+ Exits Cell . . .
The Action Potential

Next K+ Gates Open, K+ Exits Cell . . .
then previous K+ Gates Close
The Action Potential

When "Spike" of Depolarization reaches Terminal...
The Action Potential

When "Spike" of Depolarization reaches Terminal, CA++ enters cell & Neurotransmitter released –
The Action Potential

When "Spike" of Depolarization reaches Terminal, CA++ enters cell & Neurotransmitter released – The Cell Fires!
“Spike” of an Action Potential +50 mV
Restoring the **Resting Potential**

Final K+ gates open, and K+ exits cell
Polarity is back to negative, as it was initially, BUT --

K+ and Na+ are wrong side of membrane!
Restoring the **Resting** Potential

Energy requiring **Sodium–Potassium Pump**
Restoring the **Resting Potential**

Energy requiring **Sodium–Potassium Pump**
Takes in $2K^+$ for every $3+ Na^+$ it puts out
Restoring the **Resting Potential**

**Sodium–Potassium Pump**

Takes in 2K+ for every 3+ Na+ it puts out
Restoring the **Resting Potential**

**Sodium–Potassium Pump**
Takes in 2K+ for every 3+ Na+ it puts out

**Calcium Pump**
Ejects Ca++ from Terminal
While Resting Potential is being restored, cell can NOT fire

**Refractory Period**
Restoring the Resting Potential

Once Resting Potential is fully restored cell is ready to FIRE!
MNEMONICS for Resting Potential

When Ions of Sodium want to come in,
what does the Resting Cell say?

\[ \text{Na}^+, \text{ Na}^+, \text{ Na}^+ \]

This is because what minority is locked inside?

\[ \text{K}^+ \text{ K}^+ \text{ K}^+ \]

(Actually \( \text{K}^+\text{K}^+ \) for each \( \text{Na}^+\text{Na}^+\text{Na}^+ \))
Action Potential = "All or Nothing"

Action Potential results is same release of NT regardless of intensity of input
(as long as "Threshold for Firing" is crossed)

Every spike is the same
But message can vary Temporally!
Myelinization

Glia Cells, wrapped around the axon, w/gaps between called "Nodes of Ranvier"

Electrical Conduction

Ionic Conduction (Ions flow across membrane)

Slow, but stays strong

VERY fast, but decays over distance
Myelinization

Electrical Conduction
(Electricity flows thru axon under "insulation")

Ionic Conduction
(Ions flow across membrane)

Glia Cells, wrapped around the axon, w/gaps between called "Nodes of Ranvier"

So, overall, myelinated axons show "Saltatory" – or "jumping" - Conduction
Multiple Sclerosis
Multiple Sclerosis

How Multiple Sclerosis Works

Nucleus
Dendrites
Myelin Sheath
Cell Body
Synapses
Neuron

Axon
Nucleus
Myelin
Normal Nerve
Multiple Sclerosis

No ion gates under the myelin so signal does not propagate.
Graded Potentials

Not all Neurons show "Action Potentials"

Cells that fire "Graded Potentials" may release MORE or LESS neurotransmitter

e.g. "Hair cells"
Auditory receptors

Soft sound, cilia move a little

A little neurotransmitter is released

Loud sound, cilia move a lot

A lot of neurotransmitter is released