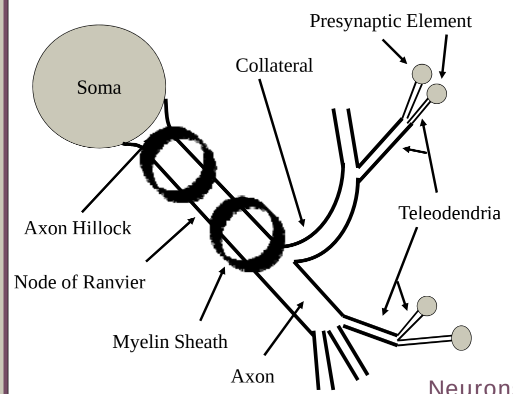
University of Idaho

Overview of Neurons

Psychology 472

Pharmacology of Psychoactive Drugs



Neurons

Structures

Soma or cell body

- Is where cell metabolism takes place
- Has places where messages from other neurons can be received called a Post Synaptic Element)
- Contains many other structures related to metabolism
  - Mitochondria
  - Endoplasmic Reticulum
  - Golgi apparatus
  - Other structures
    - These structures are not important for this class.

Axons and Related Structures

- Axons are structures that send information to other neurons or muscle cells.
- Have many structures

Axon Hillock

- Is at the base of the axon
- Is the place where neurons decide to send a signal (called an action potential) to another neuron

Body of the Axon

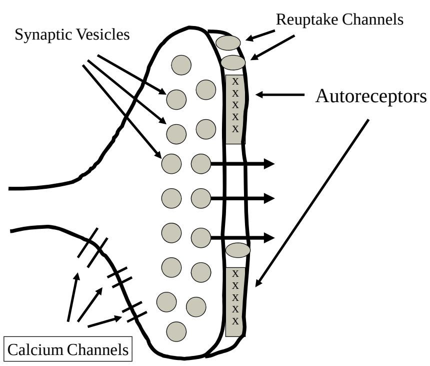
- This structure can branch (called a collateral)
- Branching continues into smaller and smaller branches called Teleodendria

Presynaptic Element

- Also called terminal buttons, terminal boutons, and other names)
- We will call it presynaptic element

Contains Several Structures

- Synaptic Vesicles (sacks)
  - Sacks contain chemicals called neurotransmitters
- Presynaptic Membrane
  - Autoreceptors
  - Reuptake channels
- Receptors from other neurons
- Calcium Channels



Presynaptic Element

Axons can be one of two types

- Myelinated
  - Myelin is a fatty covering over the axon
  - Helps to increase the speed of the action potential
  - The more myelin there is, the faster the speed of the action potential

Non-Myelinated axons

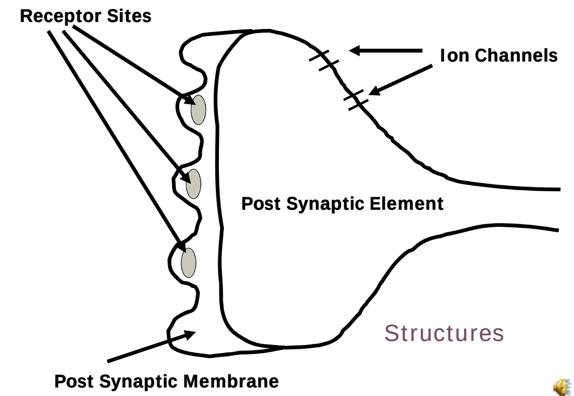
- Many axons do not have myelin
- Are slower than myelinated axons
- However, the fatter the axon is, the faster the action potential will go.

Dendrites

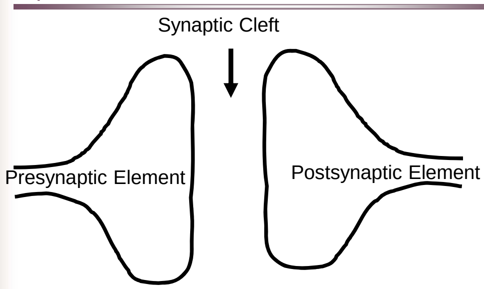
- Some neurons do not contain this structure.
  - only have soma's and axons
- Generally only receive information
- Contain a post synaptic element
  - Has a post synaptic membrane
  - Have receptor sites to receive neurotransmitters

Dendrites

- So, both Dendrites and Soma's can receive information. Both contain a post synaptic element.



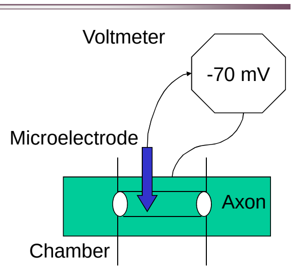
Space



How Neurons Work

Measuring the Neuron Resting Membrane Potential

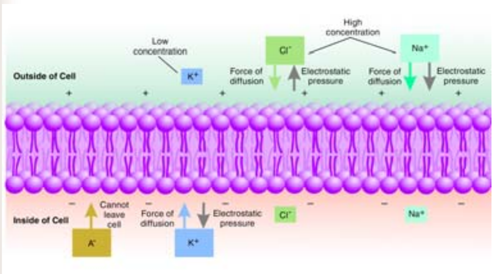
- Giant axon from a squid is placed in seawater in a recording chamber.
- Glass microelectrode is inserted into axon.
- Voltage measures -70 mV inside with respect to outside



How Neurons Work

- Based on concentration gradients of four ions
- Sodium (Na), Potassium (K), Chloride (Cl), and Structures inside the axon called Anions (A)
- Sodium and Potassium are positively charged and are balanced out by chloride and anions

Membrane Ion Concentrations



How Neurons Work Cont.

- Normally some sodium leaks into the axon.
- But cells don't like sodium, so they have pumps that remove sodium called sodium potassium pumps.
- The pumps remove sodium to the outside.

How Neurons Work Cont.

- The inside of axons have lots of potassium and anions and are negatively charged. Potassium also leaks to the outside of the neuron
- The outside of axons have lots of sodium and chloride and are positively charged.
- When an axon is at rest, the outside of the axon is positively charged and the inside is negatively charged.
  - Called the Resting Potential

Concept

- Influx Material (Ions) moving to the inside of a membrane.
- Efflux Material (Ions) moving from the inside to the outside of a membrane.
- Equilibrium Where material (ions, concentrations, etc.) are equal on both sides of a membrane.

Why do Ion's Move?

- Concentration Differences
  - Compounds move from high concentrations to lower concentrations.
- Electrostatic Pressure
  - Like charges repel each other
  - Opposite charges attract each other.

Why is There a Resting State?

- The neuron membrane is selectively permeable to certain ions.
- Sodium Na^{+}
- Potassium K^{+}
- Chloride Cl^{-}
- Calcium Ca^{++}

- When Na is at equilibrium (+55mV) there is a large efflux of K
- When K is at equilibrium (-70mV) there is a influx of Na
- Nature thus splits the difference. (approx.-65mV)
  - Get some efflux of K
  - Get some influx of Na

- Best solution uses the least amount of energy (ATP)

Result

- Balance between the ions moving through the membrane makes the resting state

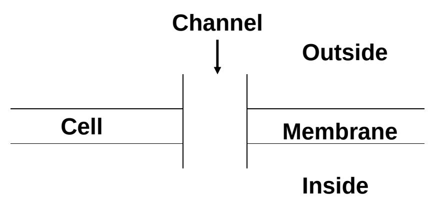
- Note: the resting state can range between -30mV to -65mV

Axon Pores

- Axons have two types of channels or pores for different ions.
  - Passive Channels
    - Are open all of the time and allow ions to pass through the membrane.
  - Active or Gated Channels
    - Are activated by changes in voltage
    - E.g., voltage-gated Na channels

Passive

Are open all the time



- Many K passive channels are open
- Some Na passive channels are also open
- Channels are selective
  - Na channels are only selective for Na, K doesn't get through.
  - Ions go through channels at different rates.
    - 12 K to 1 Na

Some ions are moving but not many. It lots of movement you get equilibrium.

Voltage-Gated Channels

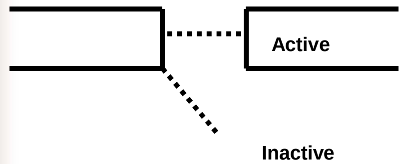
- Are needed for the action Potential.

- Membrane potential must depolarize 15mV before voltage-gated channels open.
- Thus, only certain receptors sites close to the hillock will open voltage-gated channels.

Voltage-Gated Channels

- Have two gates
  - Active - Waiting for thresholds
  - Inactive - Waiting for positive charges or zero point

Sodium Voltage Gated Channel



Active Gates are Usually Closed

With Depolarization, Active Gates Open

Steps

- Get Depolarization
- If depolarize 15mV – Active Gates Open
  - Get an action potential

  If does not depolarize 15mV – Nothing

So, All or nothing

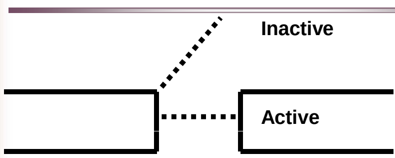
Is happening at the Axon Hillock.

Characteristics

- Several types – Na, K, Ca
- Channels are only one way.
- Channels are Ion specific
- Active gates open at depolarization, then inactive gate closes at zero or above

  After inactive gate closes, Active Gate closes, inactive gate then opens. Repeat.

Potassium Voltage Gated Channel



Active Gates are Usually Closed

With Depolarization, Active Gates open

Points

- **Like the Na Channel, the gates are sluggish**
- **It takes awhile for them to close**

Summary

1. **Active Channels are usually closed. They open when you depolarize them.**
2. **Once Na has entered and begins to approach equilibrium, the inactive gate begins to close and ultimately stops Na from entering**
3. **The inactive gate is sluggish – thus, it takes awhile to close. Consequence, you get a positive overshoot in the process of the action potential.**

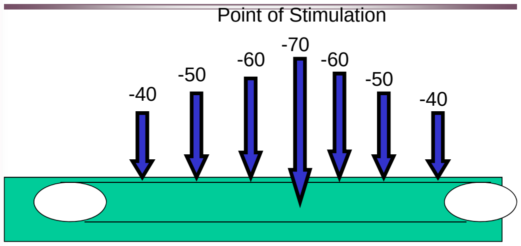
4. When Na enters, the pumps start up and begin to remove Na and bring in K (3Na/2K)
5. Finally inactive gate closes.
6. After enough Na is removed and K enters, the active gate closes and inactive gate opens
7. Process repeats again.

Types of Potentials

Electrotonic Potentials also called Passive Potentials

- Are decremental – they decay
  - Rate of decay depends on
    - Amount of Myelin
    - Length of the axon.
    - Diameter of the axon

Decremental Changes

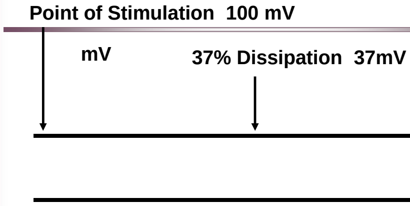


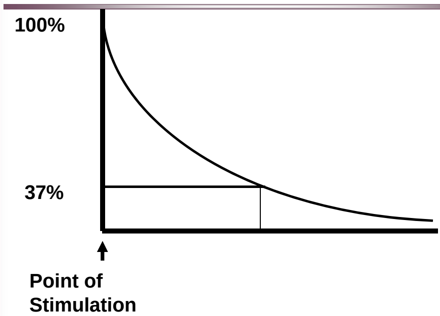
Charges Decrease in Both Directions

- Begin to stimulate, get depolarization (becomes more positive)
- K begins to move against the membrane and tries to leave by passive diffusion.
  - If the membrane is thick, the length of dissipation also increases.

Length Constant

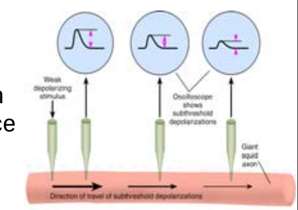
- Distance along the membrane from the point of stimulation where the change in the resting potential has dissipated to 37% of the original





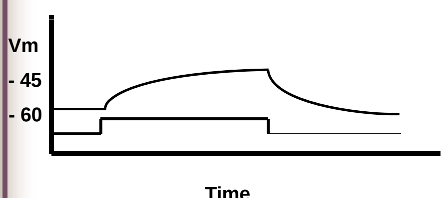
Summary

- Local potentials degrade with time and distance
- Local potentials can summate to produce an Action Potential



Temporal Summation

- Present a stimulus every ___ milliseconds.
- Observe depolarization



Resistance

- If membrane is resistant to K leaving, it becomes more difficult or K to leave
- Speed is the same
- All is done by passive channels.
- Decrease resistance by increasing the diameter of the axon.

Thus, length constant will also dictate temporal summation

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Action Potential

- Occurs because voltage-gated channels open
  - (Different from Passive Channels)
- Results in rapid and large Na influx
- The inside of the neuron becomes more positive (depolarization) and then becomes more negative (hyperpolarization)

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Influences

- Distance away - Length constant
- Temporal summation
- Inhibitory neurons
  - Cause hyperpolarization to the hillock (becomes more negative)
- Combination of depolarization and hyperpolarization determines if Voltage-Gated channels open.

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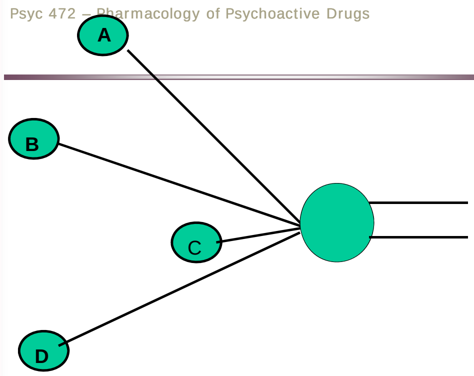

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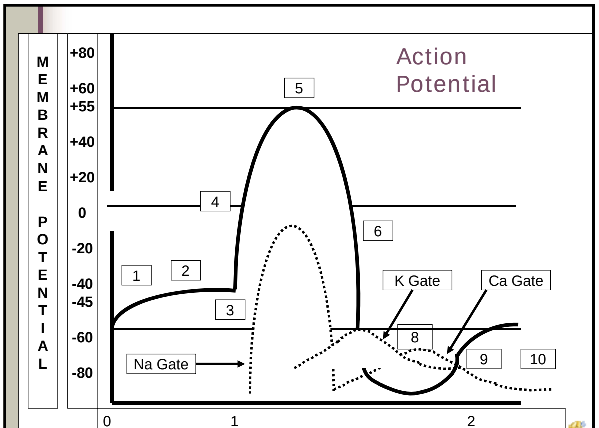
- C alone — Voltage channels open – get AP
- A alone — Get Nothing
- B alone — Get Nothing
- D alone — Get Nothing

A + B + D — Voltage channels open – get AP



Process of an Action Potential

1. Stimulation Begins
2. K begins to leave by passive channels. Na enters by passive channels.
   - Get a change in concentration gradients
   - Amount that leaves depends on the strength of the stimulus, how often it occurs, etc.
   - Begins to become more positive (depolarization).
3. If depolarization is reaches 15mV, voltage-gated Na channels open.
   - Sodium enters the neuron (influx)
4. Sodium-Potassium Pumps (Na K ATPases) start
   - Removes Na and brings in K
   - K also leaves through passive channels.
   - K voltage gated channel begins to open about ½ millisecond after Na voltage gated channels open

Process of an Action Potential (cont.)

5. Na voltage-gated channel finally closes,
   - Action potential begins to fall
6. K gate finally closes
   - K is still leaving by passive channels
   - Na is leaving by Na K pump
   - Action potential continues to fall
   - Get a negative undershoot from resting state.
7. Ca voltage-gated channel begins to open
8. Still do not have enough K so Calcium continues to enter the neuron (influx)
9. Finally enough K has entered so the Calcium channel begins to close
10. Ca channel finally closes
11. Process Repeats

Review

- When a stimulus enters a receptor on a dendrite, it causes change in polarity.
- Causes a change in the chemical concentration gradients.
- Allows sodium to enter in small amounts and depolarizes (makes it more positive) the neuron.
- The depolarization travels to the axon hillock. If the charge depolarizes the hillock 15mv, get an action potential.
- If the charge is not strong enough, the signal stops.

Review cont.

- Causes sodium gates in the axon to open.
- Get Na Influx
- Result, the axon goes from negative on the inside to positive on the inside.
- This change goes down the axon like a wave.
- After the sodium enters, the sodium potassium pumps turn on and begin removing sodium.
- Also goes down like a wave

Review

- So we have two waves going down the axon,
  - The sodium entering the axon
  - The sodium being pumped out
- Ultimately the result is a negative undershoot

When the axon potential reaches the presynaptic element

1. It causes calcium (Ca) to enter the presynaptic element.
   - Calcium causes the synaptic vesicles to bind with the presynaptic membrane
   - The neurotransmitter is then released into the synaptic cleft.
   - The neurotransmitter crosses the cleft and binds on receptors in the post synaptic element on either the dendrite or soma.
2. Causes a small electrical charge and the process repeats itself.

How neurotransmitters (NT) are removed from receptors

- NT is removed two ways:
  1. It is degraded by enzymes made by glial cells or within the post synaptic membrane
  2. It is reabsorbed into the presynaptic element.

Impact of Drugs

- Impacts the neuron several ways
  - Entire neuron (Alcohol)
  - Presynaptic Element (Cocaine, Meth.)
  - Postsynaptic Element (Opiates)
  - Specific receptor sites (Barbiturates)
  - All of the above (Alcohol).

Entire Neuron

- Alters the lipid bilayer of the neuron
- Slows ion flow
- Ultimately reduces the height of the action potential
- Ultimately reduces Calcium influx
- Fewer NT is released
- Less stimulation on post synaptic element
- Less depolarization in the next neuron
  - Does not become as positive
- Result - Fewer action potentials in the next neuron

Presynaptic elements

- Drugs block the reabsorption of the NT
- Result, NT remains on post synaptic receptors longer
- Get more action potentials

Post Synaptic Elements

- Blocks the NT from binding on the receptor
- Less depolarization
- Fewer action potentials
- Depending on the brain area impacted (medulla) can cause death or temporary memory loss (hippocampus).

Conclusions

- Very important area
- Has had tremendous impacts in our understanding of drug effects (positive and negative)