Lecture 5 - Electrical Activity in Neurons

The organization of the membrane

Neurons transmit information through changes in ion flow

- Ions come in and out
- Cell body sums up all of the ions
- If results larger than threshold –> Action Potential
- Ion
    - Charged atom
    - Either gained or lost an electron
- Neurons have ions inside them and are also surrounded by fluid that has ions
- Cell membranes are made of lipids and not permeable to ions
- What kind of molecules can go through lipid bilayers?

Normal ion distribution in the body

Banana in the ocean

- Intracellular
    - A-

    - K+
- Extracellular
    - Cl-
    - Na+

Channels

For ions to go through, they must go through specialized molecules called channels or be moved by protein pumps

Channels are specific

- We have hundred different types of channels
- The most common type of ions that flow through membrane channels are Na+, Cl-, K+, Ca2+
- Each channel is permeable to only one or a few ions
    - So if a channel is permeable to Calcium, it won't be permeable to Cl-

Movement of ions through channels is passive

- Ions move following their concentration and electrical gradients
- Thus, no external energy needs to be applied for ions to move

Channels can be always open or gated

- Channels can be
    - Always open
        - Called Resting or Leak Channels
    - Gated by

        - Voltage
        - Mechanical stimulus
        - Binding of a ligand (Such as a neurotransmitter)
        - Phosphorylation/dephosphorylation

The Na+/K+ Pump

- The most important pump in cells
- Maintains normal concentrations of K+ and Na+ inside and outside cell
- Conducts Na+ and K+ **against** their concentration gradients
    - Exchanges 3 Na+ for 2 K+, using 1 ATP
- **Electrogenic**
    - Exchanges 3+ charges for 2, making the cell more negative

Energy Consumption in the Brain

- Na+/K+ pumps are working all the time
- Since the brain has so many neurons and pumps, the brain is the largest consumer of energy at rest
- At rest, the body required ~700 kilo calories (kcal) per day
    - If you sit without moving a single muscle, your brain will be using most of your energy
    - The brain uses 50% of that (420 kcal)
        - 60% of that (~250 kcal) goes to run the Na+/K+ pumps in the brain
        - Which is equivalent of 36% of the body's total energy requirement at rest

- Amount of power used (energy/time)
    - ~700 kcal = 34 watts
    - ~420 kcal = 20 watts

Understanding electrical signals

Neurons use electricity to represent information

- A neuron has different charges inside and outside the cell
- Thus, there is a difference in electrical potential – > **resting membrane potential**

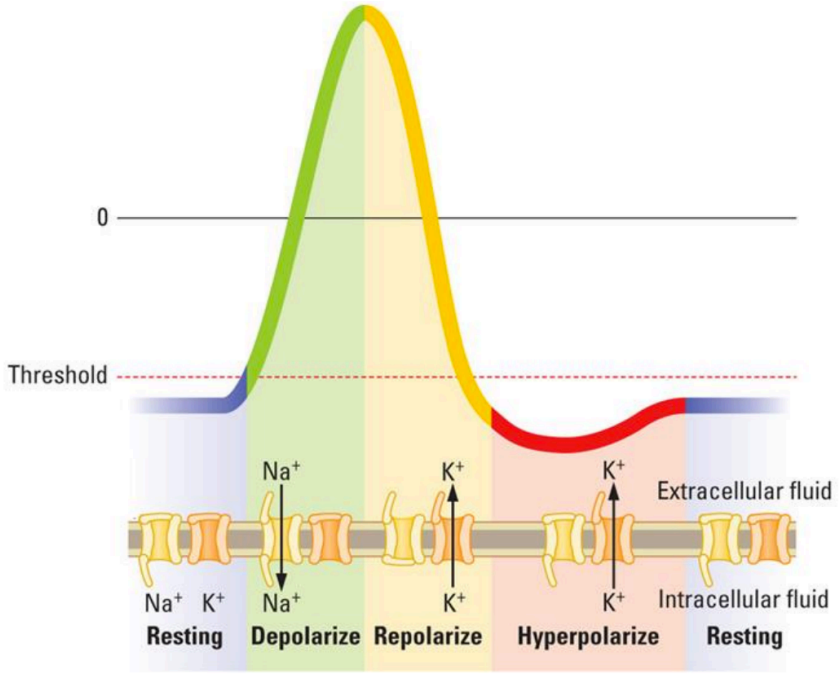
Graded Potentials

- Depolarization
    - Decrease in electrical charge across a membrane (more positive)
    - Usually due to the inward flow of sodium
- Hyperpolarization
    - Increase in electrical charge across a membrane (more negative)
    - Usually due to the
        - Inward flow of chloride ions **or**
        - Outward flow of potassium ions

The Action Potential

- Action Potential

    - Large, brief reversal in polarity of an axon
    - Lasts approximately 1 millisecond (ms)
- Threshold Potential
    - Voltage on a neural membrane at which an action potential is triggered
    - Opening of Na+ and K+ voltage-sensitive channels
    - Approximately –40mV



Refractory Period

- Action potentials can not be triggered one right after the other
- Period of time where it is not possible to fire another action potential (due to voltage gated Na+ channels being refractory themselves)
- Function
    - Prevents Action Potentials from traveling backwards!

    - In the heart, prevents heart rates from being too fast

Myelin is Important for Action Potential Conduction

- Vertebrate Axons are covered in myelin
- Myelin works as an insulator, preventing the loss of signal to the environment
- Every once in a while, there is a break in the myelin known as “nodes of Ranvier”
- These nodes are full of voltage gated channels and Na/K pumps
- Action potentials are regenerated at the nodes of Ranvier

Multiple Sclerosis (MS)

- A devastating demyelinating disorder
- Starts ~30–40 years of age, most common in women
- Autoimmune disorder
- Results in problems in conduction of action potentials to the target, and eventual atrophy of target cells and death of neurons