Bear: Neuroscience: Exploring the Brain 3e

- Chapter 03: The Neuronal Membrane at Rest

Introduction

- Action potential in the nervous system
- Action potential vs. resting potential

The Cast of Chemicals

- Cytosolic and Extracellular Fluid
  - Water
    - Key ingredient in intracellular and extracellular fluid
    - Key feature - uneven charge
  - Ions: Atoms or molecules with a net electrical charge
    - Spheres of hydration
The Cast of Chemicals

- The Phospholipid Membrane
  - Hydrophilic
    - Dissolve in water due to uneven electrical charge (e.g., salt)
  - Hydrophobic
    - Does not dissolve in water due to even electrical charge (e.g., oil)
  - Lipids are hydrophobic
    - Contribute to resting and action potentials

- The Cast of Chemicals

- Protein
  - Molecules
    - Enzymes
    - Cytoskeleton
  - Receptors
    - Special transmembrane proteins
      - Control resting and action potentials

- The Cast of Chemicals

- Protein
  - Structure
    - Amino acids
  - Concept of alpha carbon and R groups
The Cast of Chemicals

- Protein
  - Structure (Cont’d)
    - Peptide bonds and polypeptides
  - Four levels of protein structure

The Cast of Chemicals

- Protein
  - Channel Proteins
    - Polar R groups and nonpolar R groups
    - Ion selectivity and gating

The Cast of Chemicals

- Protein
  - Ion Pumps
    - Formed by membrane spanning proteins
    - Uses energy from ATP breakdown
    - Neuronal signaling

The Movement of Ions

- Diffusion
  - Dissolved ions distribute evenly
  - Ions flow down concentration gradient
  - Channels permeable to specific ions
  - Concentration gradient across the membrane
The Movements of Ions

- Electricity
  - Electrical current and ion movement
  - Electrical conductance and electrical resistance
  - Electrical potential

The Cast of Chemicals

- Electricity
  - Electrical current flow across a membrane
  - Ohm's law relationship

The Ionic Basis of The Resting Membrane Potential

- Membrane potential: Voltage across the neuronal membrane

The Ionic Basis of The Resting Membrane Potential

- Equilibrium Potentials
  - No net movement of ions when separated by a phospholipid membrane
  - Equilibrium reached when K⁺ channels inserted into the phospholipid bilayer
The Ionic Basis of The Resting Membrane Potential

Equilibrium Potentials (Cont’d)

Four important points

- Large changes in $V_m$
  - Minuscule changes in ionic concentrations
- Net difference in electrical charge
  - Inside and outside membrane surface
- Rate of movement of ions across membrane
  - Proportional $V_m - E_{ion}$
- Concentration difference known: Equilibrium potential can be calculated

The Ion Basis of The Resting Membrane Potential

Equilibrium Potentials (Cont’d)

The Nernst Equation

Calculates the exact value of an equilibrium potential in mV

Takes into consideration:

- Charge of the ion
- Temperature
- Ratio of the external and internal ion concentrations

The Ionic Basis of The Resting Membrane Potential

Equilibrium Potentials (Cont’d)

The Distribution of Ions Across The Membrane
The Ionic Basis of The Resting Membrane Potential

- The sodium-potassium pump
  - Enzyme - breaks down ATP when Na present
  - Calcium pump: Actively transports Ca^{2+} out of cytosol

- The Wide World of Potassium Channels
  - Shaker Potassium Channel
  - Lily & Yuh Nung Jan—amino acid sequences; Family of K⁺ channels

- Relative Ion Permeabilities of the Membrane at Rest

- Goldman equation
  - Takes into account permeability of membrane to different ions

- Neurons permeable to more than one type of ion
- Membrane permeability determines membrane potential (changes)

- Mutations of specific K⁺ channels; Inherited neurological disorders
The Ionic Basis of The Resting Membrane Potential

- Relative Ion Permeabilities of the Membrane at Rest
  - The importance of Regulating the External Potassium Concentration
  - Depolarization

Concluding Remarks

- Activity of the sodium-potassium pump
- Movement of K+ ions across membrane
- Electrical potential difference across the membrane
  - Similar to a battery
- Potassium channels
  - Contribute to resting potential
- Roles of ion pumps

The importance of Regulating the External Potassium Concentration

- Blood-Brain barrier
- Potassium spatial buffering