

Bear: Neuroscience: Exploring the Brain 3e

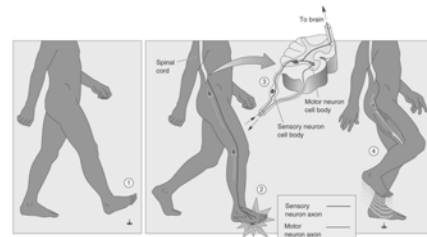
◆ Chapter 03: The Neuronal Membrane at Rest

Slide 1

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Introduction

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



Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 2

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

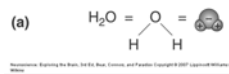
The Cast of Chemicals

◆ Cytosolic and Extracellular Fluid

◆ Water

- ◆ Key ingredient in intracellular and extracellular fluid

- ◆ Key feature - uneven charge



Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 3

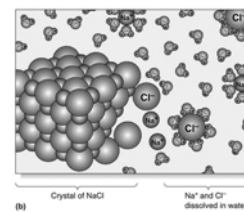
Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Cast of Chemicals

◆ Cytosolic and Extracellular Fluid (Cont'd)

- ◆ Ions: Atoms or molecules with a net electrical charge

- ◆ Spheres of hydration



(b) Crystal of NaCl Na⁺ and Cl⁻ dissolved in water

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 4

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Cast of Chemicals

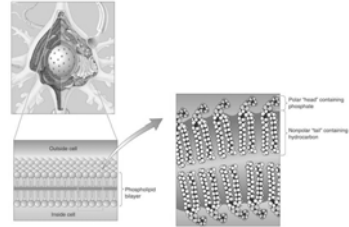
- ◆ The Phospholipid Membrane
 - ✦ Hydrophilic
 - * Dissolve in water due to uneven electrical charge (e.g., salt)
 - ✦ Hydrophobic
 - * Does not dissolve in water due to even electrical charge (e.g., oil)
 - ✦ Lipids are hydrophobic
 - * Contribute to resting and action potentials

Slide 5

Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Cast of Chemicals

- ◆ The Phospholipid Membrane
 - ✦ The Phospholipid Bilayer



Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 6

Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Cast of Chemicals

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

Slide 7

Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Cast of Chemicals

- ◆ Protein
 - ✦ Structure
 - * Amino acids
 - * Concept of alpha carbon and R groups



Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

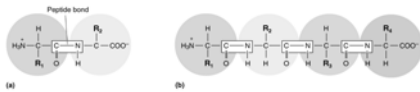
Slide 8

Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Cast of Chemicals

◆ Protein

- ◆ Structure (Cont'd)
 - ◆ Peptide bonds and polypeptides
 - ◆ Four levels of protein structure



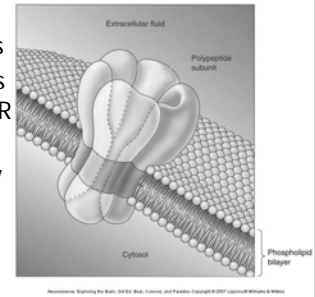
Slide 9

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Cast of Chemicals

◆ Protein

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



Slide 10

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Cast of Chemicals

◆ Protein

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

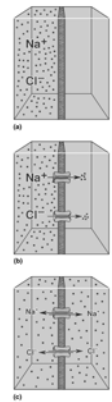
Slide 11

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Movement of Ions

◆ Diffusion

- ◆ Dissolved ions distribute evenly
- ◆ Ions flow down concentration gradient
- ◆ Channels permeable to specific ions
- ◆ Concentration gradient across the membrane



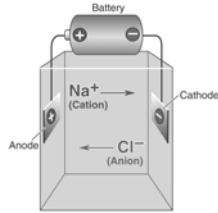
Slide 12

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Movements of Ions

Electricity

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



Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

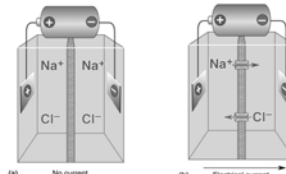
Slide 13

Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Cast of Chemicals

Electricity

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



Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

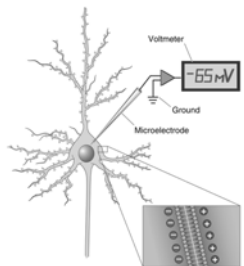
Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 14

Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Ionic Basis of The Resting Membrane Potential

- Membrane potential: Voltage across the neuronal membrane



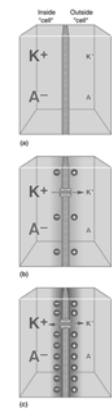
Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 15

Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

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



Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 16

Neuroscience: Exploring the Brain, 3rd Ed., Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Ionic Basis of The Resting Membrane Potential

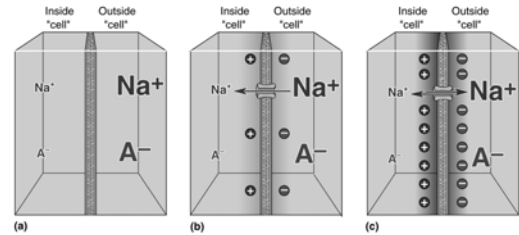
- ◆ Equilibrium Potentials (Cont'd)
 - ✦ Four important points
 - * Large changes in V_m
 - * Minuscule changes in ionic concentrations
 - * Net difference in electrical charge
 - * Inside and outside membrane surface
 - * Rate of movement of ions across membrane
 - * Proportional $V_m - E_{ion}$
 - * Concentration difference known: Equilibrium potential can be calculated

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 17

The Ionic Basis of The Resting Membrane Potential

- ◆ Equilibrium Potentials (Cont'd)



Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 18

The Ionic 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

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

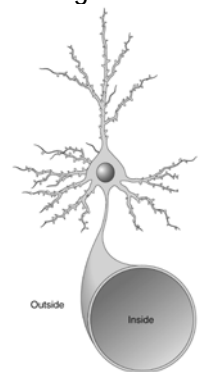
Slide 19

The Ionic Basis of The Resting Membrane Potential

- ◆ The Distribution of Ions Across The Membrane

Ion	Concentration outside (mM)	Concentration inside (mM)	Ratio Out:In	E_{ion} (at 37°C)
K ⁺	5	100	1 : 20	-80 mV
Na ⁺	150	15	10 : 1	62 mV
Ca ²⁺	2	0.0002	10,000 : 1	123 mV
Cl ⁻	150	13	11.5 : 1	-65 mV

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

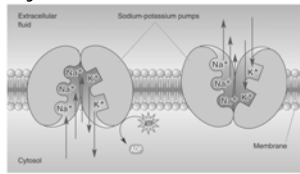


Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 20

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



Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 21

The Ionic Basis of The Resting Membrane Potential

- ◆ Relative Ion Permeabilities of the Membrane at Rest
 - ✦ Neurons permeable to more than one type of ion
 - ✦ Membrane permeability determines membrane potential (changes)
 - ✦ Goldman equation
 - ✦ Takes into account permeability of membrane to different ions

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 22

The Ionic Basis of The Resting Membrane Potential

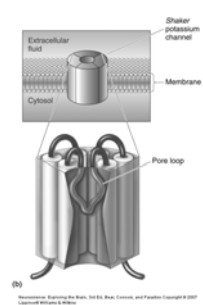
- ◆ Relative Ion Permeabilities of the Membrane at Rest
 - ✦ The Wide World of Potassium Channels
 - ✦ Shaker Potassium Channel
 - ✦ Lily & Yuh Nung Jan—amino acid sequences; Family of K^+ channels

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 23

The Ionic Basis of The Resting Membrane Potential

- ◆ Relative Ion Permeabilities of the Membrane at Rest
 - ✦ K^+ channels: 4 subunits
 - ✦ Channel selectively permeable to K^+ ions
 - ✦ MacKinnon—2003 Nobel Prize
 - ✦ Mutations of specific K^+ channels; Inherited neurological disorders

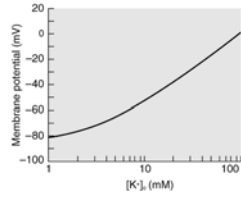


Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 24

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



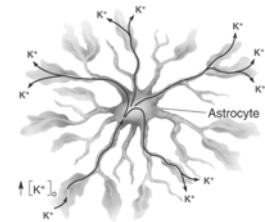
Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 25

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

The Ionic Basis of The Resting Membrane Potential

- ◆ Relative Ion Permeabilities of the Membrane at Rest
 - ◆ The importance of Regulating the External Potassium Concentration
 - ◆ Blood-Brain barrier
 - ◆ Potassium spatial buffering



Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 26

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

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

Neuroscience: Exploring the Brain, 3rd Ed. Bear, Connors, and Paradiso Copyright © 2007 Lippincott Williams & Wilkins

Slide 27