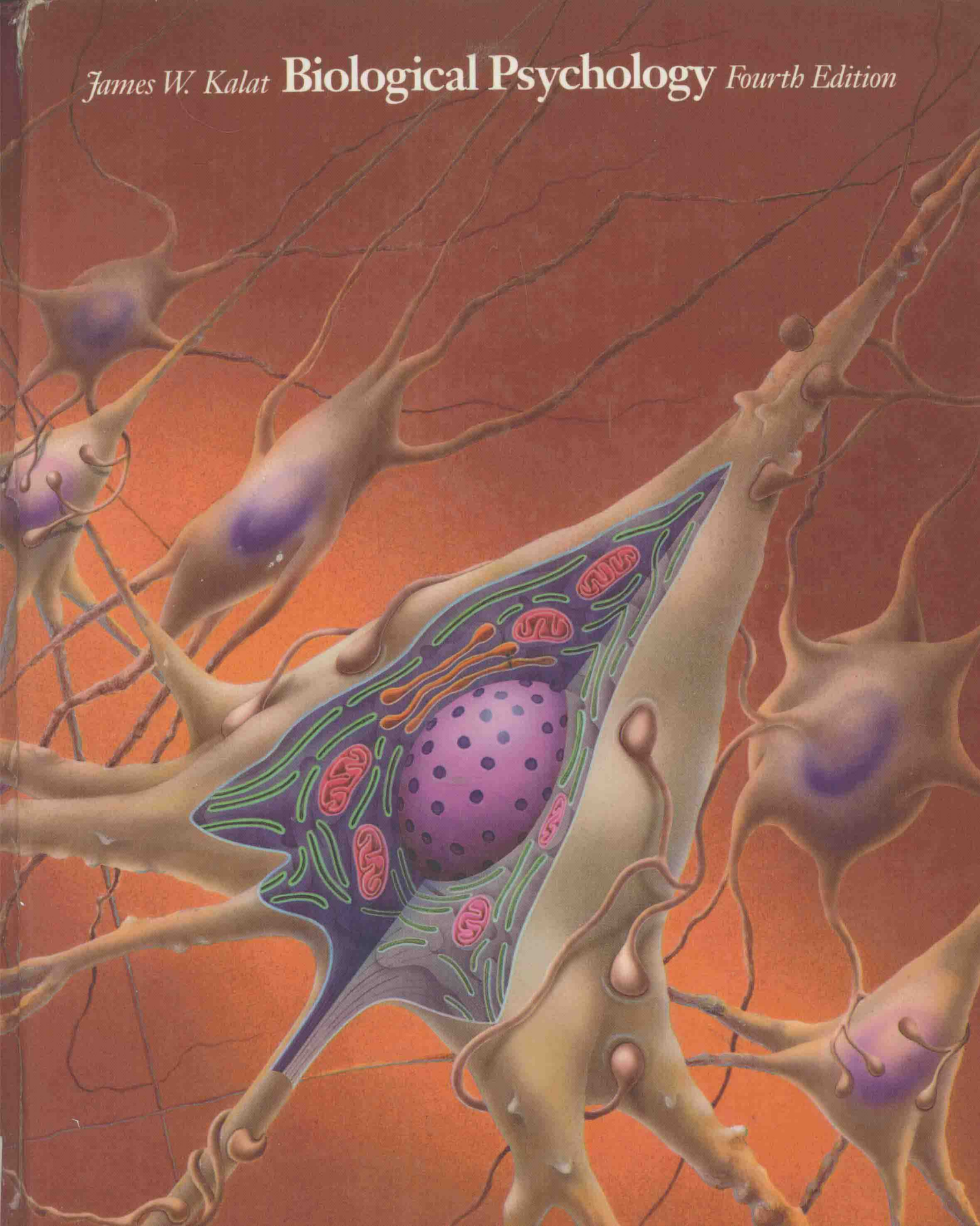


James W. Kalat **Biological Psychology** *Fourth Edition*



Biological Psychology

FOURTH EDITION

JAMES W. KALAT

North Carolina State University

Wadsworth Publishing Company
Belmont, California
A Division of Wadsworth, Inc.

Psychology Editor: Kenneth King
Development Editor: Mary Arbogast
Assistant Editor: Julie Johnson
Editorial Assistant: Cynthia Campbell
Production Editor: Sandra Craig
Designer: Carolyn Deacy
Print Buyer: Karen Hunt
Art Editor: Kelly Murphy
Permissions Editor, Photo Researcher: Marion Hansen
Copy Editor: Pat Tompkins
Technical Illustrations: Darwen and Vally Hennings,
Joel Ito, Carlyn Iversen, Precision Graphics,
Nadine Sokol, John and Judy Waller
Cover Illustration: Tomo Narashima
Composition and prepress services: Interactive
Composition Corporation
Printer: Arcata Graphics/Hawkins

©1992 by Wadsworth, Inc. All rights reserved. No part of this book may be reproduced, stored in a retrieval system, or transcribed, in any form or by any means, without the prior written permission of the publisher, Wadsworth Publishing Company, Belmont, California 94002.

1 2 3 4 5 6 7 8 9 10—96 95 94 93 92

Library of Congress Cataloging-in-Publication Data

Kalat, James, W.

Biological psychology / James W. Kalat. — 4th ed.
p. cm.

Includes bibliographical references and indexes.

ISBN 0-534-16254-1 (alk. paper)

1. Neuropsychology. 2. Psychobiology. I. Title.

[DNLM:

1. Neurophysiology. 2. Psychophysiology. WL 103 K14b]

QP360.K33 1992

612.8—dc20

DNLM/DLC

for Library of Congress

91-24288

Preface

TO THE INSTRUCTOR (Students can read it too.)

Biological psychology is the most interesting topic in the world. I am sure every professor and every textbook author feels that way about his or her own topic. But the others are wrong; this really *is* the most interesting topic. It deals with the fundamental questions of what the human mind is, what its relationship with the brain is, how it works, and why we are the way we are.

My primary goal in writing this text has been to engage readers' interest. I have tried to focus on the biological mechanisms that are most relevant to key issues in psychology—topics such as the mind-body problem, the development of language and learning, sexual behavior, alcoholism, psychosomatic illnesses, anxiety, aggressive behavior, recovery from brain damage, depression, and schizophrenia. I hope that by the end of the book readers will clearly see what the study of the brain has to do with “real psychology” and that they will be interested in learning more.

Every chapter in this text has been revised. The most substantial revisions are in Chapters 1 (Global Issues), 7 (Vision), and 14 (The Biology of Learning and Memory). The organization of the fourth edition differs from that of the third in these ways:

- Chapter 6 (Sensory Systems) now covers the sensory systems other than vision, with all material on vision deferred to Chapter 7, except for material on development of the visual system, which is in Chapter 8.
- Chapter 8, Development of the Brain and Brain-Behavior Relationships, is new, although it incorporates some material previously discussed in the chapters on anatomy and the visual system.
- The chapters on depression and schizophrenia, previously separate, have been combined into Chapter 16, Biology of Mood Disorders, Schizophrenia, and Autism.
- The BioSketches have been deleted, but a number of noted investigators are pictured and quoted on the inside covers.
- All chapters except Chapter 1 are divided into modules, each beginning with its own introduction and finishing with its own summary and questions. This organization makes it easier for instructors to assign part of a chapter per day instead of assigning a whole chapter per week. Parts of chapters can also be covered in a different order.

- The most noticeable change in the fourth edition is the use of four-color illustrations throughout the text. I hope this adds to both the clarity and the enjoyment.

Instructors adopting this text for class use may obtain from the publisher a copy of the Instructor's Manual, written by Thomas Stonebraker of Greenville College. Contained in the manual are nearly two thousand multiple-choice test items, which are also available on diskette for IBM and Macintosh computers. Additionally, there is a set of overhead transparencies. A Study Guide, written by Elaine Hull of SUNY-Buffalo, is available for student purchase. I am grateful for the excellent work of Stonebraker and Hull.

I have received helpful comments and suggestions from many students and colleagues, including Stephen Black, Bartley Hoebel, Elaine Hull, William Moorcroft, Duane Rumbaugh, Thomas Stonebraker, and Thomas Wason. My special thanks to Dana Copeland for a large number of color photos of human brains. I appreciate the helpful comments provided by the following reviewers: Elizabeth Adkins-Regan, Cornell University; Peter Brunjes, University of Virginia, Charlottesville; Carl Erickson, Duke University; Dennis Feeney, University of New Mexico; Earl Hagstrom, University of New Hampshire; and Seth Sharpless, University of Colorado, Boulder. Jeffrey Willner, University of North Carolina, Chapel Hill, made a final check of a preliminary draft of this edition and provided detailed and extremely helpful recommendations. Early drafts of the illustrations were reviewed by Francisco Gonzalez-Lima, Robert Graham, and Robert Lansing. I thank them for their excellent suggestions.

Thanks also to the staffs of the libraries at North Carolina State University and at the Marine Biological Laboratory of Woods Hole, Massachusetts, for helping me locate various obscure materials.

In preparing this text I have been most fortunate to work with Mary Arbogast on the writing and organization, and with Sandra Craig on the production. Both have offered excellent judgment and many good ideas; both have voluntarily put in far more effort than I could possibly have asked. I have also been fortunate to work with Kelly Murphy and Marion Hansen on the art program and with Julie Johnson on supplements. Carolyn Deacy designed the text and cover. Pat Tompkins did a thorough job of copy editing the manuscript. The artwork was prepared by Darwen and Vally Hennings, Joel Ito, Carlyn Iverson, Precision Graphics, Nadine Sokol, and John and Judy Waller. I appreciate the splendid help these people provided.

I also thank Ken King, the best psychology editor in the business and a great friend. Thanks to my wife, Ann, and my children, David, Sam, and Robin, who listened every time I wanted to talk about the latest thing I had read. And thanks to my department head, Paul Thayer, for being consistently supportive and encouraging.

I welcome correspondence from both students and faculty. Write: James W. Kalat, Department of Psychology, Box 7801, North Carolina State University, Raleigh, NC 27695-7801, U.S.A.

TO THE STUDENT (Instructors can read it too.)

A college education serves many purposes: to prepare you for a job or for post-graduate education; to provide a background useful to such nonoccupational roles as citizen and parent; to develop your ability to analyze an issue, assemble the relevant information, reach a conclusion, and apply the conclusion; and to satisfy intellectual curiosity and generate new intellectual curiosity.

Yet another goal that we don't always talk about may be even more important: to help you develop a philosophy of life—a coherent set of beliefs about the nature of the universe, the nature of life, and the purposes of your own life; a philosophy to help you organize future thinking and determine priorities and values.

A college education promotes the formation of a philosophy of life by bringing together a wide variety of people from diverse backgrounds, with different views and values. Course work in philosophy, literature, religion, history, and the like introduce you to the views of some great thinkers. Science courses contribute by addressing the questions of what the universe is all about. Consider: The scientific theories we generally regard as the greatest include Copernicus's theory that the earth goes around the sun and Darwin's theory of evolution by natural selection. We identify these theories as great because they affect our basic beliefs about the place of human beings in the universe, not because they contribute directly to our standard of living.

Some philosophies of life can be stated briefly:

- Do unto others as you would have others do unto you.
- From each according to ability, to each according to need.
- Eat, drink, and be merry, for tomorrow we die.
- My country, right or wrong. I only regret that I have but one life to lose for my country.

My own philosophy of life—well, one of my philosophies of life—is that life is a game in which the players do not know the rules. The game starts without warning or preparation (birth); we do not know when it will end (death). We do not know the object of the game, how the scorekeeper (if any) keeps score, or what rewards or penalties might be based on one's score. Initially we play by the rules given by our parents, until at maturity we realize that our parents have no claim to ultimate authority. We must then decide for ourselves the rules by which we shall live.

To make an intelligent decision, we need to understand as much as we can about the universe and especially about ourselves. What are we? How did we come to be the way we are? Why are we conscious?

Biological psychology provides at least a few tentative answers and certainly helps to clarify the questions. This book will, I hope, provoke you to think about what we mean when we say that the brain controls behavior. We all (I presume) know that is true, and yet most of us find this fact difficult to reconcile with our experience of making conscious decisions. What is the relationship between mind and brain? If they are in some sense the same thing, what does it mean to say they are the same thing?

In this textbook you will learn a great deal of detailed information, as is necessary in any field. The point is not to learn those details for their own sake but to apply them to the overall issues of mind and brain and the fundamental questions of what we are and what our relationship to the universe is.

Biological Psychology

1. The Role of the Amygdala in Emotional Processing

The amygdala, a small almond-shaped structure located deep within the brain, plays a central role in processing emotional information. It acts as a hub for integrating sensory input with emotional responses, influencing both the conscious experience of emotion and the autonomic nervous system. Damage to the amygdala, as seen in the case of patient S.M., results in a profound inability to experience or express emotions, highlighting its critical function in emotional regulation.

1. The amygdala is involved in the initial processing of emotionally charged stimuli, such as faces and scenes, and is responsible for triggering appropriate emotional responses.
2. It also plays a role in the modulation of memory, particularly in the consolidation of emotionally significant events.
3. The amygdala's activity is closely linked to the hypothalamus, which initiates the physiological responses associated with different emotional states.

Understanding the amygdala's function is crucial for comprehending the neural basis of emotional disorders and developing targeted interventions.

2. The Impact of Stress on the Endocrine System

1. Stress, a complex physiological and psychological response to perceived threats, triggers the activation of the hypothalamic-pituitary-adrenal (HPA) axis.
2. The hypothalamus releases corticotropin-releasing hormone (CRH), which stimulates the pituitary gland to secrete adrenocorticotropic hormone (ACTH).
3. ACTH then prompts the adrenal cortex to produce and release cortisol, the primary stress hormone.
4. Cortisol exerts widespread effects on the body, including increasing blood sugar, suppressing the immune system, and altering metabolism.

Chronic exposure to elevated cortisol levels can lead to significant health consequences, such as hypertension, diabetes, and depression.

CHAPTER ONE

The Global Issues of Biological Psychology

MAIN IDEAS

1. Biological psychologists seek to explain behavior in terms of its physiology, its development, its evolution, and its function.
2. Mind and brain are closely related, but we do not know the exact nature of their relationship or what mind really is. Both philosophers and scientists would like to know whether minds could exist independently of brains, whether brains could function equally well if they did not give rise to minds, and what aspects of brain activity are responsible for conscious experience.
3. Direct electrical stimulation of the brain can induce behavioral changes and subjective experiences. Studies of electrical stimulation of the brain provide strong evidence that the brain is responsible for mental activity.
4. Many experiments in biological psychology use animal subjects. Some of those experiments inflict pain or distress. The ethics of such experiments has become controversial.

Brief Contents

| | | |
|----|--|-----|
| 1 | The Global Issues of Biological Psychology | 1 |
| 2 | Nerve Cells and Nerve Impulses | 22 |
| 3 | Synapses and Drugs | 56 |
| 4 | Anatomy of the Nervous System and Methods of Investigation | 94 |
| 5 | Lateralization, Language, and Brain Disconnection Syndromes | 150 |
| 6 | Sensory Systems | 186 |
| 7 | Vision | 228 |
| 8 | Development of the Brain and Brain-Behavior Relationships | 270 |
| 9 | Movement | 308 |
| 10 | Wakefulness and Sleep | 346 |
| 11 | The Regulation of Internal Body States | 382 |
| 12 | Hormones and Sexual Behavior | 414 |
| 13 | Emotional Behaviors and Stress | 450 |
| 14 | The Biology of Learning and Memory | 484 |
| 15 | Recovery from Brain Damage | 526 |
| 16 | Biology of Mood Disorders, Schizophrenia, and Autism | 552 |
| | Appendix A Genetics and Evolution | 593 |
| | Appendix B Brief, Basic Chemistry | 606 |
| | Appendix C Society for Neuroscience Guidelines for Animal Research | 615 |

Contents

Preface xix

CHAPTER 1 THE GLOBAL ISSUES OF BIOLOGICAL PSYCHOLOGY 1

- Biological Explanations of Behavior 4
- An Example: Bird Song 5
- Biological Explanations of Human Behavior 8
- The Mind-Brain Relationship 9
- Why Investigators Study Animals, and the Ethics of Animal Research 13

CHAPTER 2 NERVE CELLS AND NERVE IMPULSES 22

The Cells of the Nervous System 24

- Neurons and Glia 24
- The Blood-Brain Barrier 33
- The Nourishment of Vertebrate Neurons 33
- Changes in the Structure of Neurons and Glia 35

The Nerve Impulse 38

- The Resting Potential of the Neuron 38
- The Action Potential 44
- Propagation of the Action Potential 49
- The Myelin Sheath and Saltatory Conduction 50
- Signaling Without Action Potentials 52

CHAPTER 3 SYNAPSES AND DRUGS 56

The Concept of the Synapse 58

- The Properties of Synapses 58
- Relationship Among EPSP, IPSP, and Action Potential 63
- The Neuronal Decision Process 64

Chemical Events at the Synapse 66

- The Discovery That Most Synaptic Transmission Is Chemical 66
- The Sequence of Chemical Events at a Synapse 67
- Neurotransmitters and Behavior 80

Synapses, Drugs, and Behavior 83

- How Drugs Can Affect Synapses 83
- Hallucinogenic Drugs 87
- Alcohol Abuse 89

CHAPTER 4 ANATOMY OF THE NERVOUS SYSTEM AND METHODS OF INVESTIGATION 94

Basic Subdivisions of the Vertebrate Nervous System 96

- Some Terminology 98
- The Spinal Cord and Its Communication with the Periphery 101
- The Autonomic Nervous System 104
- The Hindbrain 107
- The Midbrain 108
- The Forebrain 110
- The Ventricles 115

The Cerebral Cortex 119

- Organization of the Cerebral Cortex 119
- Occipital Lobe 123
- Parietal Lobe 124
- Temporal Lobe 126
- Frontal Lobe 126
- Evolution of the Brain and the Cerebral Cortex 129

**Methods of Investigating How
the Brain Controls Behavior 133**

- The Stereotaxic Instrument 134
- Lesions and Ablations 136
- Stimulation of and Recording from the Brain 138
- Labeling Brain Activity 139
- Studies That Use the Natural Development of the Brain 140
- Studies of the Structure of Living Human Brains 141
- Measurement of Human Brain Activity 142

**CHAPTER 5 LATERALIZATION, LANGUAGE, AND
BRAIN DISCONNECTION SYNDROMES 150**

**Lateralization of Function
and the Corpus Callosum 152**

- Connections of the Eyes to the Brain's Left and Right Hemispheres 153
- Effects of Cutting the Corpus Callosum 156
- Development of Lateralization and Its Relationship to Handedness 163

The Biological Basis of Language 170

- Nonhumans' Abilities to Acquire Language 170
- Effects of Brain Damage on Human Language 174

CHAPTER 6 SENSORY SYSTEMS 186

Reception, Transduction, and Coding 188

- Reception and Transduction 188
- Coding 189
- Labeled-Line Coding Versus Coding as a Pattern Across Fibers 191

Audition 193

- Sound 193
- Structures of the Ear 194
- Pitch Perception 197
- Deafness 199
- Localization of Sounds 200

The Mechanical Senses 204

Vestibular Sensation 205

Somatosensation 206

Pain 208

The Chemical Senses 215

Taste 215

Olfaction 221

CHAPTER 7 VISION 228

Visual Coding and the Retinal Receptors 230

The Eye and Its Connections to the Brain 230

Visual Receptors: Rods and Cones 234

Color Vision 237

Neural Basis of Visual Perception 245

Mechanisms of Processing in the Visual System 245

Parallel Pathways in the Visual System 250

Mechanisms of Shape Perception 256

Role of the Superior Colliculus 265

CHAPTER 8 DEVELOPMENT OF THE BRAIN AND BRAIN-BEHAVIOR RELATIONSHIPS 270

Development of the Brain 272

Growth and Differentiation of the Vertebrate Brain 272

Pathfinding by Axons 274

Pioneer Neurons 283

Development of the Visual System 286

Infant Vision 286

Development of Binocular Interaction 287

Development of Pattern Perception 294

Development of Other Aspects of Vision 296

Competition Among Axons as a General Principle of Neural Functioning 297

Abnormalities of Development 299

Mental Retardation 299

CHAPTER 9 MOVEMENT 308

The Control of Movement 310

Muscles and Their Movements 310

Units of Movement 316

Brain Mechanisms of Movement 322

The Role of the Spinal Cord 322

The Role of the Cerebellum 323

The Role of the Basal Ganglia 327

The Role of the Cerebral Cortex 328

Disorders of Movement 333

Myasthenia Gravis 333

Parkinson's Disease 334

Huntington's Disease 339

Apraxia 341

CHAPTER 10 WAKEFULNESS AND SLEEP 346

**The Alternation of Sleeping
and Waking 348**

Endogenous Rhythms in Behavior 348

Resetting the Biological Clock 352

Location and Nature of the Biological Clock 353

The Functions of Sleep 356

Sleeping and Dreaming 361

The Stages of Sleep 361

Paradoxical, or REM, Sleep 363

A Biological Perspective on Dreaming 369

Brain Mechanisms in Sleep and Its Disorders 371

Wakefulness and the Reticular Activating System 371

Sleep-Inducing Areas of the Brain 373

Abnormalities of Sleep 376

CHAPTER 11 THE REGULATION OF INTERNAL BODY STATES 382

Temperature Regulation 384

Homeostasis 384

Mechanisms of Controlling Body Temperature 385

Homeostasis Revisited 389

Thirst 390

Mechanisms of Maintaining Water Balance 390

The Multiple Causes of Drinking 391

Osmotic Thirst 391

Hypovolemic Thirst 393

Hunger 396

The Digestive System and Food Selection 396

Physiological Mechanisms of Hunger and Satiety 399

Brain Mechanisms in Hunger and Satiety 407

Integration of Multiple Mechanisms 411

CHAPTER 12 HORMONES AND SEXUAL BEHAVIOR 414

Hormones and Behavior 416

Mechanisms of Hormone Actions 416

Organizing Effects of Sex Hormones 425

Activating Effects of Sex Hormones 431

Puberty 435

Parental Behavior 436

**Variations in Sexual Development
and Sexual Orientation 439**

- Determinants of Gender Identity 439
- Possible Biological Bases of Homosexuality 443
- Genetic Abnormalities of Sexual Development 446

CHAPTER 13 EMOTIONAL BEHAVIORS AND STRESS 450

**Emotion, Autonomic Nervous System
Arousal, and Health Problems 452**

- Role of the Autonomic Nervous System in Emotional Behaviors 452
- Emotions, Autonomic Responses, and Health 455
- Chronic Stress, the Immune System, and Health 459

**Reinforcement, Escape and Attack
Behaviors, and the Brain 463**

- The Limbic System and Emotions 463
- Brain Activity and Reinforcement 465
- Fear and Anxiety 468
- Aggressive Behaviors 473

CHAPTER 14 THE BIOLOGY OF LEARNING AND MEMORY 484

**Learning, Memory, Amnesia,
and Brain Functioning 486**

- Localized or Diffuse Representations of Memory 486
- Brain Damage and Human Amnesia 489
- Memory Consolidation 497
- Role of the Hippocampus, Amygdala, and Frontal Cortex 499

**Mechanisms of Storing Information
in the Nervous System 507**

- Learning and the Hebbian Synapse 507
- Single-Cell Mechanisms of Invertebrate Behavior Change 510
- Long-Term Potentiation in the Mammalian Brain 514
- Learning Elsewhere in the Nervous System 517
- The Biochemistry of Learning and Memory 518
- Brain and Memory in Young and Old 521

CHAPTER 15 RECOVERY FROM BRAIN DAMAGE 526

Brain Damage and Mechanisms of Recovery 528

Causes of Human Brain Damage 528

Diagnosis of Brain Damage 531

The Precarious Nature of Recovery from Brain Damage 532

Possible Mechanisms of Recovery from Brain Damage 533

Factors Influencing Recovery from Brain Damage 543

Effects of Age at the Time of the Damage 543

Differences Between Slow-Onset and Rapid-Onset Lesions 546

Therapies for Brain Damage 547

CHAPTER 16 BIOLOGY OF MOOD DISORDERS, SCHIZOPHRENIA, AND AUTISM 552

Depression 554

Types of Depression 554

Possible Biological Causes of Depression 556

Animal Models of Depression and Bipolar Disorder 560

Monoamines and Depression 562

Other Biological Therapies for Depression and Bipolar Disorder 563

Schizophrenia and Autism 570

The Characteristics of Schizophrenia 570

Brain Atrophy or Dysfunction 572

Possible Causes of Schizophrenia 574

The Biochemistry of Schizophrenia 581

Prospects for Prediction or Early Diagnosis of Schizophrenia 585

Infantile Autism 586