

Brief Contents

CHAPTER 1 Biological Psychology: Scope and Outlook 3

PART I Biological Foundations of Behavior 21

CHAPTER 2 Functional Neuroanatomy: The Nervous System and Behavior 23

CHAPTER 3 Neurophysiology: The Generation, Transmission, and Integration of Neural Signals 59

CHAPTER 4 The Chemical Bases of Behavior: Neurotransmitters and Neuropharmacology 89

CHAPTER 5 Hormones and the Brain 119

PART II Evolution and Development of the Nervous System 149

CHAPTER 6 Evolution of the Brain and Behavior 151

CHAPTER 7 Life-Span Development of the Brain and Behavior 181

PART III Perception and Action 215

CHAPTER 8 General Principles of Sensory Processing, Touch, and Pain 217

CHAPTER 9 Hearing, Vestibular Perception, Taste, and Smell 249

CHAPTER 10 Vision: From Eye to Brain 285

CHAPTER 11 Motor Control and Plasticity 321

PART IV Regulation and Behavior 353

CHAPTER 12 Sex: Evolutionary, Hormonal, and Neural Bases 355

CHAPTER 13 Homeostasis: Active Regulation of Internal States 387

CHAPTER 14 Biological Rhythms, Sleep, and Dreaming 419

PART V Emotions and Mental Disorders 449

CHAPTER 15 Emotions, Aggression, and Stress 451

CHAPTER 16 Psychopathology: Biological Basis of Behavioral Disorders 481

PART VI Cognitive Neuroscience 511

CHAPTER 17 Learning and Memory: Biological Perspectives 513

CHAPTER 18 Learning and Memory: Neural Mechanisms 543

CHAPTER 19 Language and Cognition 571

Contents

Preface xiii

1 **Biological Psychology: Scope and Outlook** 3

What Is Biological Psychology? 3

Five Viewpoints Explore the Biology of Behavior 4

Three Approaches Relate Brain and Behavior 6

Neural Plasticity: Behavior Can Change the Brain 9

**Biological Psychologists Use Several Levels of
Analysis** 11

PART I

BIOLOGICAL FOUNDATIONS OF B

2 **Functional Neuroanatomy: The Nervous System and Behavior** 23

The Nervous System Is Composed of Cells 23

**The Nervous System Consists of Central and Peripheral
Divisions** 34

The Brain Is Described by Both Structure and Function 44

**Specialized Support Systems Protect and Nourish the
Brain** 49

**Newer Imaging Techniques Allow Us to Look into the
Living Human Brain** 51

Summary 55

Recommended Reading 56

**BOX 2.1 Neuroanatomical Methods Provide Ways to Make Sense
of the Brain** 30

**BOX 2.2 Three Customary Orientations for Viewing the Brain
and Body** 42

BOX 2.3 Isolating Specific Brain Activity 53

A Preview of the Book: Fables and Facts about the Brain	12
Neuroscience Contributes to Our Understanding of Psychiatric Disorders	14
Animal Research Makes Vital Contributions	14
The History of Research on the Brain and Behavior Begins in Antiquity	15
Recommended Reading	20
BOX 1.1 We Are All Alike, and We Are All Different	7
BOX 1.2 Is Bigger Better? The Case of the Brain and Intelligence	18

BEHAVIOR 21

3 Neurophysiology: The Generation, Transmission, and Integration of Neural Signals 59

Electrical Signals Are the Vocabulary of the Nervous System	59
The Sequence of Transmission Processes at Chemical Synapses	75
Neurons and Synapses Combine to Make Circuits	80
Gross Electrical Activity of the Human Brain	82
Summary	85
Recommended Reading	87
BOX 3.1 Changing the Channel	67
BOX 3.2 Electrical Synapses Work with No Time Delay	71
BOX 3.3 Seizure Disorders	84

4 The Chemical Bases of Behavior: Neurotransmitters and Neuropharmacology 89

Many Chemical Neurotransmitters Have Been Identified 89

Neurotransmitter Systems Form a Complex Array in the Brain 91

Research on Drugs Ranges from Molecular Processes to Effects on Behavior 95

Drugs Affect Each Stage of Neural Conduction and Synaptic Transmission 101

Drugs That Affect the Brain Can Be Divided into Functional Classes 103

Drug Abuse Is Pervasive 111

Summary 116

Recommended Reading 117

PART II

EVOLUTION AND DEVELOPMENT

6 Evolution of the Brain and Behavior 151

Why Should We Study Other Species? 151

How Closely Related Are Two Species? 152

Comparative Methods Help Us Study the Biological Mechanisms of Behavior 158

Nervous Systems Differ Widely in Structure 159

The Evolution of Vertebrate Brains Can Be Related to Changes in Behavior 165

Evolution Continues Today 176

Summary 178

Recommended Reading 178

BOX 6.1 To Each Its Own Sensory World 159

BOX 6.2 Why Should We Study Particular Species? 163

BOX 6.3 Evolutionary Psychology 174

BOX 4.1 Mind the Curves 98

BOX 4.2 The Terminology of Substance-Related Disorders 112

5 Hormones and the Brain 119

Hormones Act in a Great Variety of Ways throughout the Body 119

Hormones Act on a Wide Variety of Cellular Mechanisms 128

Each Endocrine Gland Secretes Specific Hormones 132

Hormones Affect Behavior in Many Different Ways 144

Hormonal and Neural Systems Interact to Produce Integrated Responses 146

Summary 147

Recommended Reading 148

BOX 5.1 Techniques of Modern Behavioral Endocrinology 124

BOX 5.2 Stress and Growth: Psychosocial Dwarfism 138

OF THE NERVOUS SYSTEM 149

7 Life-Span Development of the Brain and Behavior 181

Growth and Development of the Brain Are Orderly Processes 181

Development of the Nervous System Can Be Divided into Six Distinct Stages 182

Glial Cells Provide Myelin, Which Is Vital for Brain Function 197

Genes Interact with Experience to Guide Brain Development 198

Experience Is an Important Influence on Brain Development 202

Developmental Disorders of the Brain Impair Behavior 206

The Brain Continues to Change As We Grow Older 210

Two Timescales Are Needed to Describe Brain Development 213

Summary 214

Recommended Reading 214

BOX 7.1 Degeneration and Regeneration of Nervous Tissue 189

BOX 7.2 The Frog Retinotectal System Demonstrates Intrinsic and Extrinsic Factors in Neural Development 196

PART III

PERCEPTION AND ACTION 215

8 General Principles of Sensory Processing, Touch, and Pain 217

SENSORY PROCESSING 217

Sensory Receptor Organs Detect Energy or Substances 217

What Type of Stimulus Was That? 219

Sensory Processing Begins in Receptor Cells 221

Sensory Information Processing Is Selective and Analytical 222

TOUCH: MANY SENSATIONS BLENDED TOGETHER 228

Skin Is a Complex Organ That Contains a Variety of Sensory Receptors 228

The Dorsal Column System Carries Somatosensory Information from the Skin to the Brain 230

PAIN: AN UNPLEASANT BUT ADAPTIVE EXPERIENCE 236

Human Pain Can Be Measured 236

Summary 246

Recommended Reading 247

BOX 8.1 Synesthesia 229

9 Hearing, Vestibular Perception, Taste, and Smell 249

HEARING 249

Each Part of the Ear Performs a Specific Function in Hearing 250

Auditory System Pathways Run from the Brainstem to the Cortex 256

Two Main Theories Describe How We Discriminate Pitch 258

By Comparing the Ears, We Can Localize Sounds 260

The Auditory Cortex Performs Complex Tasks in the Perception of Sound 262

Deafness Is a Major Disorder of the Nervous System 265

BOX 7.3 Transgenic and Knockout Mice 201

VESTIBULAR PERCEPTION 267

**The Receptor Mechanisms for the Vestibular System
Are in the Inner Ear 268**

**Evolution Has Shaped the Auditory and Vestibular End
Organs 269**

**Nerve Fibers from the Vestibular Portion of the Vestibu-
locochlear Nerve (VIII) Synapse in the Brainstem 269**

**Some Forms of Vestibular Excitation Produce Motion
Sickness 270**

THE CHEMICAL SENSES: TASTE AND SMELL 270

Chemicals in Tastants Elicit Taste Sensations 271

Chemicals in the Air Elicit Odor Sensations 274

Summary 281

Recommended Reading 283

BOX 9.1 The Basics of Sound 252

10 Vision: From Eye to Brain 285

**Vision Provides Information about the Form, Color,
Location, Movement, and Identity of Objects 285**

**The Visual System Extends from the Eye
to the Brain 289**

**The Eye Is Both an Optical Device and a Neural
Organ 289**

**Neural Signals Travel from the Retina to Several Brain
Regions 299**

**Neurons at Different Levels of the Visual System Have
Very Different Receptive Fields 300**

Area V1 Is Organized in Columns and Slabs 308

**Color Vision Depends on Special Channels from the
Retinal Cones through Cortical Area V4 310**

**Perception of Visual Motion Is Analyzed by a Special
System That Includes Cortical Area V5 314**

**The Many Cortical Visual Areas Are Organized into Two
Major Systems 314**

Visual Neuroscience Can Be Applied to Alleviate Some Visual Deficiencies 316

Summary 318

Recommended Reading 319

BOX 10.1 The Basics of Light 288

BOX 10.2 Eyes with Lenses Have Evolved in Several Phyla 298

11 Motor Control and Plasticity 321

The Behavioral View 321

The Control Systems View 323

PART IV

REGULATION AND BEHAVIOR 35

12 Sex: Evolutionary, Hormonal, and Neural Bases 355

SEXUAL BEHAVIOR 355

Reproductive Behavior Can Be Divided into Four Stages 355

The Neural Circuitry of the Brain Regulates Reproductive Behavior 360

Pheromones Guide Reproductive Behavior in Many Species 362

The Hallmark of Human Sexual Behavior Is Diversity 363

Many Vertebrates Depend on Their Parents for Survival 366

SEXUAL DIFFERENTIATION 368

The Sex of an Individual Is Determined Early in Life 368

How Should We Define Gender—by Genes, Gonads, Genitals, or the Brain? 372

Gonadal Hormones Direct Sexual Differentiation of the Brain and Behavior 373

Social Influences Affect Sexual Differentiation of the Nervous System 378

Do Early Gonadal Hormones Masculinize Human Behaviors in Adulthood? 380

Summary 383

Recommended Reading 384

The Neuroscience View 324

Movements Are Controlled at Several Nervous System Levels 332

Extrapyramidal Systems Also Modulate Motor Commands 339

Disorders of Muscle, Spinal Cord, or Brain Can Disrupt Movement 342

We Can Trace a Choice Response from Input to Output 350

Summary 351

Recommended Reading 352

BOX 11.1 Cortical Neurons Control Movements of a Robotic Arm 337

BOX 11.2 The Frozen Addicts 347

3

BOX 12.1 The Paradoxical Sexual Differentiation of the Spotted Hyena 376

13 Homeostasis: Active Regulation of Internal States 387

Homeostasis Maintains Internal States within a Critical Range 387

TEMPERATURE REGULATION 388

Body Temperature Is a Critical Condition for All Biological Processes 388

Some Animals Generate Heat; Others Must Obtain Heat from the Environment 389

Which Behaviors Can Adjust Body Temperature? 391

The Brain Monitors and Regulates Body Temperature 393

FLUID REGULATION 394

Our Cells Evolved to Function in Seawater 394

Two Internal Cues Trigger Thirst 397

Homeostatic Regulation of Salt Is Required for Effective Regulation of Water 400

FOOD AND ENERGY REGULATION 401

Nutrient Regulation Requires the Anticipation of Future Needs 401

Insulin Is Crucial for the Regulation of Body Metabolism 403

The Hypothalamus Coordinates Multiple Systems That Control Hunger 405

Obesity Is Difficult to Treat 411

Eating Disorders Are Life-Threatening 413

Summary 415

Recommended Reading 416

BOX 13.1 Body Fat Stores Are Tightly Regulated, Even after Surgical Removal of Fat 412

14 Biological Rhythms, Sleep, and Dreaming 419

Many Animals Show Daily Rhythms in Activity 419

The Hypothalamus Houses an Endogenous Circadian Clock 421

PART V

EMOTIONS AND MENTAL DISORDERS

15 Emotions, Aggression, and Stress 451

What Are Emotions? 451

Broad Theories of Emotion Emphasize Bodily Responses 452

How Many Emotions Do We Experience? 454

Emotions from the Comparative/Evolutionary Viewpoint 457

Individuals Differ in Their Emotional Responsiveness 460

Do Distinct Brain Circuits Mediate Emotions? 460

Neural Circuitry, Hormones, and Synaptic Transmitters Mediate Violence and Aggression 469

Stress Activates Many Bodily Responses 472

Stress and Emotions Are Related to Some Human Diseases 474

Summary 479

Recommended Reading 479

BOX 15.1 Lie Detector? 454

- Animals Use Circannual Rhythms to Anticipate Seasonal Changes 426**
- Human Sleep Exhibits Different Stages 427**
- The Sleep of Different Species Provides Clues about the Evolution of Sleep 431**
- Our Sleep Patterns Change across the Life Span 432**
- Manipulating Sleep Reveals an Underlying Structure 434**
- What Are the Biological Functions of Sleep? 436**
- At Least Four Interacting Neural Systems Underlie Sleep 439**
- Sleep Disorders Can Be Serious, Even Life-Threatening 444**
- Recommended Reading 448**
- BOX 14.1 Sleep Deprivation Can Be Fatal 436**

DISORDERS 449

16 **Psychopathology: Biological Basis of Behavioral Disorders 481**

- The Toll of Psychiatric Disorders Is Huge 481**
- Schizophrenia Is the Major Neurobiological Challenge in Psychiatry 482**
- Mood Disorders Are a Major Psychiatric Category 494**
- There Are Several Types of Anxiety Disorders 502**
- Neurosurgery Has Been Used to Treat Psychiatric Disorders 508**
- Abnormal Prion Proteins Destroy the Brain 509**
- Summary 510**
- Recommended Reading 510**
- BOX 16.1 Long-Term Effects of Antipsychotic Drugs 492**
- BOX 16.2 The Season to Be Depressed 500**
- BOX 16.3 Tics, Twitches, and Snorts: The Unusual Character of Tourette's Syndrome 506**

PART VI**COGNITIVE NEUROSCIENCE 511**

17 Learning and Memory:
Biological Perspectives 513

Many Kinds of Brain Damage Can Impair Memory 513

There Are Several Kinds of Memory and Learning 517

**Memory Has Temporal Stages: Short, Intermediate,
and Long 520**

**Different Regions of the Brain Process Different Aspects
of Memory 524**

**Brain Imaging Provides Insights about Regions Involved
in Different Kinds of Memories 531**

**Comparative Approaches Yield Insights about the
Evolution of Learning and Memory 535**

Learning and Memory Change throughout Life 538

Summary 540

Recommended Reading 541

**BOX 17.1 Learning and Memory: Some Basic Concepts and
Definitions 518**

18 Learning and Memory:
Neural Mechanisms 543

**Changes in Synapses May Be Mechanisms of Memory
Storage 544**

**The Nervous System May Form and Store Memories in
Various Ways 545**

Cerebral Changes Result from Training 546

Invertebrate Nervous Systems Show Plasticity 550

**Could Long-Term Potentiation Be a Model for Studying
Mechanisms of Learning and Memory? 551**

**The Mammalian Cerebellum Houses the Brain Circuit for
a Simple Conditioned Reflex 559**

**Memories of Different Durations Form by Different
Neurochemical Mechanisms 561**

Memory Formation Can Be Modulated 564

**Some Brain Measures Correlate with Age-Related
Impairments of Memory 565**

Summary 568

Recommended Reading 569

19 Language and Cognition 571

The Development and Evolution of Speech and Language Are Remarkable and Mysterious 571

Language Disorders Result from Region-Specific Brain Injuries 577

Electrical Stimulation Provides Information about the Organization of Language in the Brain 585

Functional Neuroimaging Portrays the Organization of the Brain for Speech and Language 586

The Left Brain Is Different from the Right Brain 587

Williams Syndrome Offers Clues about Language 592

The Frontal Lobes of Humans Are Related to Higher-Order Aspects of Cognitive and Emotional Functions 593

Deficits in Spatial Perception Follow Some Types of Brain Injury 596

Following Some Injuries, the Brain Can Recover Function 598

Summary 602

Recommended Reading 603

BOX 19.1 The Wada Test 577

BOX 19.2 A Sport That Destroys the Mind 599

BOX 19.3 The Comparatively Minor Effects of Childhood Loss of One Hemisphere 601

AFTERWORD 605

APPENDIX A-1

GLOSSARY G-1

REFERENCES R-1

AUTHOR INDEX AI-1

SUBJECT INDEX SI-1

ILLUSTRATION CREDITS IC-1