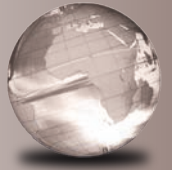


GLOBAL
EDITION



Introduction to Biopsychology

NINTH EDITION

John P. J. Pinel

Steven J. Barnes



Introduction to Biopsychology

Ninth Edition

Global Edition

John P.J. Pinel

University of British Columbia

Steven J. Barnes

University of British Columbia

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montréal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

To Maggie, the love of my life.

Acquisitions Editor: *Amber Chow*
Editorial Assistant: *Alexis Rodriguez*
Head of Learning Asset Acquisition: *Laura Dent*
Director of Marketing: *Brandy Dawson*
Marketing Assistant: *Frank Alarcon*
Senior Managing Editor: *Linda Bebhrens*
Procurement Manager: *Mary Fischer*
Senior Procurement Specialist: *Diane Peirano*
Program Manager: *Diane Szulecki*
Creative Director: *Blair Brown*
Senior Art Director: *Janet Slowik Cruz*
Media Production Manager: *Peggy Bliss*

Media Project Manager: *Pamela Weldin*
Digital Media Editor: *Lisa Dotson*
Acquisitions Editor, Global Edition: *Vrinda Malik*
Associate Project Editor, Global Edition:
Binita Roy
Senior Manufacturing Controller, Production, Global
Edition: *Trudy Kimber*
Cover Designer: *Karen Salzbach*
Cover Photo: © *Andrey_Kuzmin/Shutterstock*
Full-Service Project Management: *Integra-Chicago/*
Angelique Chavez
Cover Printer: *Courier Kendallville*

Credits and acknowledgments borrowed from other sources and reproduced, with permission, in this textbook appear on appropriate page within text or on page 557.

Pearson Education Limited
Edinburgh Gate
Harlow
Essex CM20 2JE
England

and Associated Companies throughout the world

Visit us on the World Wide Web at:
www.pearsonglobaleditions.com

© Pearson Education Limited 2014

The rights of John P.J. Pinel and Steven J. Barnes to be identified as the authors of this work have been asserted by them in accordance with the Copyright, Designs and Patents Act 1988.

Authorized adaptation from the United States edition, entitled Biopsychology, 9th edition, ISBN 978-0-205-91557-6, by John P.J. Pinel, published by Pearson Education © 2014.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without either the prior written permission of the publisher or a license permitting restricted copying in the United Kingdom issued by the Copyright Licensing Agency Ltd, Saffron House, 6–10 Kirby Street, London EC1N 8TS.

All trademarks used herein are the property of their respective owners. The use of any trademark in this text does not vest in the author or publisher any trademark ownership rights in such trademarks, nor does the use of such trademarks imply any affiliation with or endorsement of this book by such owners.

ISBN 10: 1-292-05891-9

ISBN 13: 978-1-292-05891-7 (Print)

ISBN 13: 978-1-292-06673-8 (PDF)

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library

10 9 8 7 6 5 4 3 2 1

14 13 12 11 10

Typeset in Minion Pro 10.5/12 by Integra-Chicago

Printed and bound by Courier Kendallville in The United States of America

Brief Contents

Part One

What Is Biopsychology?

- 1 Biopsychology as a Neuroscience** 25
What Is Biopsychology, Anyway?

Part Two

Foundations of Biopsychology

- 2 Evolution, Genetics, and Experience** 44
Thinking about the Biology of Behavior
- 3 Anatomy of the Nervous System** 75
Systems, Structures, and Cells That Make Up Your Nervous System
- 4 Neural Conduction and Synaptic Transmission** 100
How Neurons Send and Receive Signals
- 5 The Research Methods of Biopsychology** 124
Understanding What Biopsychologists Do

Part Three

Sensory and Motor Systems

- 6 The Visual System** 153
How We See
- 7 Mechanisms of Perception: Hearing, Touch, Smell, Taste, and Attention** 185
How You Know the World
- 8 The Sensorimotor System** 212
How You Move

Part Four

Brain Plasticity

- 9 Development of the Nervous System** 237
From Fertilized Egg to You

- 10 Brain Damage and Neuroplasticity** 257
Can the Brain Recover from Damage?

- 11 Learning, Memory, and Amnesia** 283
How Your Brain Stores Information

Part Five

Biopsychology of Motivation

- 12 Hunger, Eating, and Health** 311
Why Do Many People Eat Too Much?
- 13 Hormones and Sex** 338
What's Wrong with the Mamawawa?
- 14 Sleep, Dreaming, and Circadian Rhythms** 365
How Much Do You Need to Sleep?
- 15 Drug Addiction and the Brain's Reward Circuits** 392
Chemicals That Harm with Pleasure

Part Six

Disorders of Cognition and Emotion


- 16 Lateralization, Language, and the Split Brain** 417
The Left Brain and the Right Brain
- 17 Biopsychology of Emotion, Stress, and Health** 447
Fear, the Dark Side of Emotion
- 18 Biopsychology of Psychiatric Disorders** 470
The Brain Unhinged

Contents

Preface	16
To the Student	23
About the Author	23

Part One


What Is Biopsychology?

1		Biopsychology as a Neuroscience 25
		What Is Biopsychology, Anyway?
		<i>The Case of Jimmie G., the Man Frozen in Time</i> 27
		Four Major Themes of This Text 27
1.1		What Is Biopsychology? 28
1.2		What Is the Relation between Biopsychology and the Other Disciplines of Neuroscience? 28
1.3		What Types of Research Characterize the Biopsychological Approach? 28
		Human and Nonhuman Subjects 29
		Experiments and Nonexperiments 29
		Pure and Applied Research 31
1.4		What Are the Divisions of Biopsychology? 32
		Physiological Psychology 32
		Psychopharmacology 33
		Neuropsychology 33
		<i>The Case of Mr. R., the Brain-Damaged Student Who Switched to Architecture</i> 33
		Psychophysiology 33
		Cognitive Neuroscience 34
		Comparative Psychology 35
1.5		Converging Operations: How Do Biopsychologists Work Together? 36
1.6		Scientific Inference: How Do Biopsychologists Study the Unobservable Workings of the Brain? 37
1.7		Critical Thinking about Biopsychological Claims 38
		<i>Case 1: José and the Bull</i> 39

	<i>Case 2: Becky, Moniz, and Prefrontal Lobotomy</i>	39
	Themes Revisited	41
	Think about It	42
	Key Terms	42
	Quick Review	42

Part Two

Foundations of Biopsychology

2		Evolution, Genetics, and Experience 44
		Thinking about the Biology of Behavior
2.1		Thinking about the Biology of Behavior: From Dichotomies to Interactions 45
		Is It Physiological, or Is It Psychological? 45
		Is It Inherited, or Is It Learned? 46
		Problems with Thinking about the Biology of Behavior in Terms of Traditional Dichotomies 46
		<i>The Case of the Man Who Fell Out of Bed</i> 47
		<i>Case of the Chimps with Mirrors</i> 47
		<i>The Case of the Thinking Student</i> 48
2.2		Human Evolution 48
		Evolution and Behavior 50
		Course of Human Evolution 51
		Thinking about Human Evolution 54
		Evolution of the Human Brain 56
		Evolutionary Psychology: Understanding Mate Bonding 57
		Thinking about Evolutionary Psychology 58
2.3		Fundamental Genetics 59
		Mendelian Genetics 59
		Chromosomes: Reproduction and Recombination 60

Chromosomes: Structure and Replication	61		
Sex Chromosomes and Sex-Linked Traits	62		
Genetic Code and Gene Expression	62		
Mitochondrial DNA	64		
Human Genome Project	65		
Modern Genetics: Growth of Epigenetics	65		
2.4 Epigenetics of Behavioral Development: Interaction of Genetic Factors and Experience	67		
Selective Breeding of “Maze-Bright” and “Maze-Dull” Rats	67		
Phenylketonuria: A Single-Gene Metabolic Disorder	68		
Development of Birdsong	69		
2.5 Genetics of Human Psychological Differences	70		
Development of Individuals versus Development of Differences among Individuals	70		
Minnesota Study of Twins Reared Apart	71		
A Look into the Future: Two Kinds of Twin Studies	71		
Themes Revisited	73		
Think about It	73		
Key Terms	73		
Quick Review	74		
3			
		Anatomy of the Nervous System	75
		Systems, Structures, and Cells That Make Up Your Nervous System	
3.1 General Layout of the Nervous System	76		
Divisions of the Nervous System	76		
Meninges, Ventricles, and Cerebrospinal Fluid	77		
Blood–Brain Barrier	78		
3.2 Cells of the Nervous System	80		
Anatomy of Neurons	80		
Glia: The Forgotten Cells	80		
3.3 Neuroanatomical Techniques and Directions	85		
Neuroanatomical Techniques	85		
Directions in the Vertebrate Nervous System	86		
3.4 Spinal Cord	88		
3.5 Five Major Divisions of the Brain	88		
3.6 Major Structures of the Brain	89		
Myelencephalon	89		
Metencephalon	89		
Mesencephalon	90		
Diencephalon	90		
Telencephalon	92		
Limbic System and the Basal Ganglia	94		
Themes Revisited	98		
Think about It	98		
Key Terms	99		
Quick Review	99		
4			
		Neural Conduction and Synaptic Transmission	100
		How Neurons Send and Receive Signals	
		<i>The Lizard, a Case of Parkinson’s Disease</i>	101
4.1 Resting Membrane Potential	102		
Recording the Membrane Potential	102		
Ionic Basis of the Resting Potential	102		
4.2 Generation and Conduction of Postsynaptic Potentials	103		
4.3 Integration of Postsynaptic Potentials and Generation of Action Potentials	103		
4.4 Conduction of Action Potentials	106		
Ionic Basis of Action Potentials	106		
Refractory Periods	107		
Axonal Conduction of Action Potentials	107		
Conduction in Myelinated Axons	107		
The Velocity of Axonal Conduction	108		
Conduction in Neurons without Axons	108		
The Hodgkin-Huxley Model in Perspective	109		
4.5 Synaptic Transmission: Chemical Transmission of Signals among Neurons	109		
Structure of Synapses	109		
Synthesis, Packaging, and Transport of Neurotransmitter Molecules	110		
Release of Neurotransmitter Molecules	111		
Activation of Receptors by Neurotransmitter Molecules	111		
Reuptake, Enzymatic Degradation, and Recycling	113		
Glia, Gap Junctions, and Synaptic Transmission	114		

4.6 Neurotransmitters 116
 Amino Acid Neurotransmitters 116
 Monoamine Neurotransmitters 116
 Acetylcholine 117
 Unconventional Neurotransmitters 117
 Neuropeptides 118

4.7 Pharmacology of Synaptic Transmission and Behavior 118
 How Drugs Influence Synaptic Transmission 119
 Behavioral Pharmacology: Three Influential Lines of Research 120
Themes Revisited 122
Think about It 122
Key Terms 123
Quick Review 123

5.4 Pharmacological Research Methods 137
 Routes of Drug Administration 137
 Selective Chemical Lesions 137
 Measuring Chemical Activity of the Brain 137
 Locating Neurotransmitters and Receptors in the Brain 137

5.5 Genetic Engineering 139
 Gene Knockout Techniques 139
 Gene Replacement Techniques 139
 Fantastic Fluorescence and the Brainbow 139

PART TWO Behavioral Research Methods of Biopsychology

5.6 Neuropsychological Testing 141
 Modern Approach to Neuropsychological Testing 141
 Tests of the Common Neuropsychological Test Battery 142
 Tests of Specific Neuropsychological Function 143
 Frontal-Lobe Function 144

5.7 Behavioral Methods of Cognitive Neuroscience 145

5.8 Biopsychological Paradigms of Animal Behavior 146
 Paradigms for Assessment of Species-Common Behaviors 146
 Traditional Conditioning Paradigms 147
 Seminal Animal Learning Paradigms 148
Themes Revisited 150
Think about It 150
Key Terms 151
Quick Review 152

5  **The Research Methods of Biopsychology 124**
 Understanding What Biopsychologists Do

The Ironic Case of Professor P. 125

PART ONE Methods of Studying the Nervous System

5.1 Methods of Visualizing and Stimulating the Living Human Brain 126
 Contrast X-Rays 126
 X-Ray Computed Tomography 126
 Magnetic Resonance Imaging 127
 Positron Emission Tomography 127
 Functional MRI 128
 Diffusion Tensor Imaging 129
 Transcranial Magnetic Stimulation 130

5.2 Recording Human Psychophysiological Activity 130
 Scalp Electroencephalography 130
 Magnetoencephalography 132
 Muscle Tension 132
 Eye Movement 132
 Skin Conductance 133
 Cardiovascular Activity 133

5.3 Invasive Physiological Research Methods 133
 Stereotaxic Surgery 134
 Lesion Methods 134
 Electrical Stimulation 135
 Invasive Electrophysiological Recording Methods 135

Part Three

Sensory and Motor Systems


6  **The Visual System 153**
 How We See
The Case of Mrs. Richards: Fortification Illusions and the Astronomer 154

6.1 Light Enters the Eye and Reaches the Retina 155
 Pupil and the Lens 156
 Eye Position and Binocular Disparity 157

6.2	Retina and Translation of Light into Neural Signals	157
	Cone and Rod Vision	159
	Spectral Sensitivity	161
	Eye Movement	162
	Visual Transduction: The Conversion of Light to Neural Signals	163
6.3	From Retina to Primary Visual Cortex	164
	Retinotopic Organization	165
	The M and P Channels	165
6.4	Seeing Edges	166
	Lateral Inhibition and Contrast Enhancement	166
	Receptive Fields of Visual Neurons	167
	Receptive Fields: Neurons of the Retina-Geniculate-Striate System	168
	Receptive Fields: Simple Cortical Cells	169
	Receptive Fields: Complex Cortical Cells	170
	Organization of Primary Visual Cortex	170
	<i>The Case of Mrs. Richards, Revisited</i>	171
	Changing Concept of Visual Receptive Fields: Contextual Influences in Visual Processing	171
6.5	Seeing Color	171
	Component and Opponent Processing	172
	Color Constancy and the Retinex Theory	173
6.6	Cortical Mechanisms of Vision and Conscious Awareness	175
	Damage to Primary Visual Cortex: Scotomas and Completion	176
	<i>The Case of the Physiological Psychologist Who Made Faces Disappear</i>	176
	Damage to Primary Visual Cortex: Scotomas, Blindsight, and Conscious Awareness	176
	<i>The Case of D.B., the Man Confused by His Own Blindsight</i>	177
	Functional Areas of Secondary and Association Visual Cortex	177
	Dorsal and Ventral Streams	178
	<i>The Case of D.F., the Woman Who Could Grasp Objects She Did Not Consciously See</i>	180
	<i>The Case of A.T., the Woman Who Could Not Accurately Grasp Unfamiliar Objects That She Saw</i>	180
	Prosopagnosia	180
	<i>R.P., a Typical Prosopagnosic</i>	181
	Akinetopsia	181
	<i>Two Cases of Drug-Induced Akinetopsia</i>	181
	Conclusion	182

Themes Revisited	182
Think about It	183
Key Terms	183
Quick Review	184

7



Mechanisms of Perception: Hearing, Touch, Smell, Taste, and Attention 185

How You Know the World

The Case of the Man Who Could See Only One Thing at a Time 186

7.1	Principles of Sensory System Organization	186
	Hierarchical Organization	187
	<i>The Case of the Man Who Mistook His Wife for a Hat</i>	187
	Functional Segregation	187
	Parallel Processing	187
	Summary Model of Sensory System Organization	188

7.2	Auditory System	188
	The Ear	189
	From the Ear to the Primary Auditory Cortex	191
	Subcortical Mechanisms of Sound Localization	192
	Auditory Cortex	192
	Effects of Damage to the Auditory System	194

7.3	Somatosensory System: Touch and Pain	195
	Cutaneous Receptors	195
	Dermatomes	196
	Two Major Somatosensory Pathways	197
	Cortical Areas of Somatosensation	198
	Effects of Damage to the Primary Somatosensory Cortex	199
	Somatosensory System and Association Cortex	199
	<i>The Case of W.M., Who Reduced His Scotoma with His Hand</i>	199
	Somatosensory Agnosias	200
	<i>The Case of Aunt Betty, Who Lost Half of Her Body</i>	200
	Rubber-Hand Illusion	201
	Perception of Pain	201
	<i>The Case of Miss C., the Woman Who Felt No Pain</i>	201
	Neuropathic Pain	203

7.4 Chemical Senses: Smell and Taste 203
 Olfactory System 204
 Gustatory System 205
 Brain Damage and the Chemical Senses 206
 Broad Tuning vs. Narrow Tuning 206

7.5 Selective Attention 208
 Change Blindness 208
 Neural Mechanisms of Attention 209
 Simultanagnosia 210
Themes Revisited 210
Think about It 210
Key Terms 211
Quick Review 211

8



The Sensorimotor System 212
 How You Move
The Case of Rhonda, the Dexterous Cashier 213

8.1 Three Principles of Sensorimotor Function 214
 The Sensorimotor System Is Hierarchically Organized 214
 Motor Output Is Guided by Sensory Input 214
The Case of G.O., the Man with Too Little Feedback 214
 Learning Changes the Nature and Locus of Sensorimotor Control 215
 General Model of Sensorimotor System Function 215

8.2 Sensorimotor Association Cortex 215
 Posterior Parietal Association Cortex 215
The Case of Mrs. S., the Woman Who Turned in Circles 216
 Dorsolateral Prefrontal Association Cortex 217

8.3 Secondary Motor Cortex 218
 Identifying the Areas of Secondary Motor Cortex 218
 Mirror Neurons 219

8.4 Primary Motor Cortex 220
Belle: The Monkey That Controlled a Robot with Her Mind 221

8.5 Cerebellum and Basal Ganglia 222
 Cerebellum 222
 Basal Ganglia 222

8.6 Descending Motor Pathways 223
 Dorsolateral Corticospinal Tract and Dorsolateral Corticorubrospinal Tract 223

Ventromedial Corticospinal Tract and Ventromedial Cortico-Brainstem-Spinal Tract 223
 Comparison of the Two Dorsolateral Motor Pathways and the Two Ventromedial Motor Pathways 224

8.7 Sensorimotor Spinal Circuits 226
 Muscles 226
 Receptor Organs of Tendons and Muscles 227
 Stretch Reflex 228
 Withdrawal Reflex 229
 Reciprocal Innervation 229
 Recurrent Collateral Inhibition 229
 Walking: A Complex Sensorimotor Reflex 230

8.8 Central Sensorimotor Programs and Learning 231
 Central Sensorimotor Programs Are Capable of Motor Equivalence 232
 Sensory Information That Controls Central Sensorimotor Programs Is Not Necessarily Conscious 232
 Central Sensorimotor Programs Can Develop without Practice 233
 Practice Can Create Central Sensorimotor Programs 233
 Functional Brain Imaging of Sensorimotor Learning 233
The Case of Rhonda, Revisited 235
Themes Revisited 235
Think about It 235
Key Terms 235
Quick Review 236

Part Four

Brain Plasticity

9



Development of the Nervous System 237
 From Fertilized Egg to You
The Case of Genie 238


9.1 Phases of Neurodevelopment 238
 Induction of the Neural Plate 239
 Neural Proliferation 239
 Migration and Aggregation 240
 Axon Growth and Synapse Formation 241
 Neuron Death and Synapse Rearrangement 244

9.2 Postnatal Cerebral Development in Human Infants 245
 Postnatal Growth of the Human Brain 245
 Development of the Prefrontal Cortex 246

9.3 Effects of Experience on Postnatal Development of Neural Circuits 247
 Early Studies of Experience and Neurodevelopment: Deprivation and Enrichment 247
 Competitive Nature of Experience and Neurodevelopment: Ocular Dominance Columns 247
 Effects of Experience on Topographic Sensory Cortex Maps 248
 Experience Fine-Tunes Neurodevelopment 248

9.4 Neuroplasticity in Adults 249
 Neurogenesis in Adult Mammals 249
 Effects of Experience on the Reorganization of the Adult Cortex 250

9.5 Disorders of Neurodevelopment: Autism and Williams Syndrome 251
 Autism 251
The Case of Alex: Are You Ready to Rock? 251
Cases of Amazing Savant Abilities 252
 Williams Syndrome 253
The Case of Anne Louise McGarrah: Uneven Abilities 253
 Epilogue 254
Themes Revisited 255
Think about It 255
Key Terms 255
Quick Review 255

10  **Brain Damage and Neuroplasticity** 257
 Can the Brain Recover from Damage?
The Ironic Case of Professor P. 258


10.1 Causes of Brain Damage 259
 Brain Tumors 259
 Cerebrovascular Disorders: Strokes 259
 Closed-Head Injuries 261
The Case of Jerry Quarry, Ex-Boxer 262
 Infections of the Brain 262
 Neurotoxins 263
 Genetic Factors 263
 Programmed Cell Death 263

10.2 Neurological Diseases 264
 Epilepsy 264
The Subtlety of Complex Partial Seizures: Two Cases 265
 Parkinson's Disease 266
 Huntington's Disease 267
 Multiple Sclerosis 267
 Alzheimer's Disease 268

10.3 Animal Models of Human Neurological Diseases 270
 Kindling Model of Epilepsy 270
 Transgenic Mouse Model of Alzheimer's Disease 270
 MPTP Model of Parkinson's Disease 271
The Cases of the Frozen Addicts 271

10.4 Responses to Nervous System Damage: Degeneration, Regeneration, Reorganization, and Recovery 271
 Neural Degeneration 271
 Neural Regeneration 272
 Neural Reorganization 274
 Recovery of Function after CNS Damage 275

10.5 Neuroplasticity and the Treatment of CNS Damage 276
 Neurotransplantation as a Treatment for CNS Damage: Early Research 277
The Case of Roberto Garcia d'Orta: The Lizard Gets an Autotransplant 277
 Modern Research on Neurotransplantation 278
 Promoting Recovery from CNS Damage by Rehabilitative Training 278
The Cases of Tom and Philip: Phantom Limbs and Ramachandran 280
The Ironic Case of Professor P.: Recovery 280
Themes Revisited 281
Think about It 281
Key Terms 282
Quick Review 282

11  **Learning, Memory, and Amnesia** 283
 How Your Brain Stores Information

11.1 Amnesic Effects of Bilateral Medial Temporal Lobectomy 284
The Case of H.M., the Man Who Changed the Study of Memory 284
 Formal Assessment of H.M.'s Anterograde Amnesia: Discovery of Unconscious Memories 285

Three Major Scientific Contributions of H.M.'s Case 286

Medial Temporal Lobe Amnesia 287

Semantic and Episodic Memories 288

The Case of K.C., the Man Who Can't Time Travel 288

The Case of the Clever Neuropsychologist: Spotting Episodic Memory Deficits 289

Effects of Global Cerebral Ischemia on the Hippocampus and Memory 289

The Case of R.B., Product of a Bungled Operation 289

11.2 Amnesia of Korsakoff's Syndrome 290

The Up-Your-Nose Case of N.A. 291

11.3 Amnesia of Alzheimer's Disease 291

11.4 Amnesia after Concussion: Evidence for Consolidation 291

Posttraumatic Amnesia 291

Gradients of Retrograde Amnesia and Memory Consolidation 292

Hippocampus and Consolidation 293

Reconsolidation 293

11.5 Evolving Perspective of the Role of the Hippocampus in Memory 294

Monkey Model of Object-Recognition Amnesia: The Delayed Nonmatching-to Sample Test 294

Delayed Nonmatching-to-Sample Test for Rats 295

Neuroanatomical Basis of the Object-Recognition Deficits Resulting from Medial Temporal Lobectomy 296

11.6 Neurons of the Medial Temporal Lobes and Memory 297

Two Tests of Rodent Spatial Memory 298

Hippocampal and Entorhinal Grid Cells 299

Comparative Studies of the Hippocampus and Spatial Memory 300

Jennifer Aniston Neurons: Concept Cells 301

11.7 Where Are Memories Stored? 301

Inferotemporal Cortex 302

Amygdala 302

Prefrontal Cortex 303

The Case of the Cook Who Couldn't 303

Cerebellum and Striatum 303

11.8 Synaptic Mechanisms of Learning and Memory 304

Long-Term Potentiation 304

Induction of LTP: Learning 305

Maintenance and Expression of LTP: Storage and Recall 306

Variability of LTP 307

11.9 Conclusion: Biopsychology of Memory and You 308

Infantile Amnesia 308

Smart Drugs: Do They Work? 308

Posttraumatic Amnesia and Episodic Memory 309

The Case of R.M., the Biopsychologist Who Remembered H.M. 309

Themes Revisited 309

Think about It 309

Key Terms 310

Quick Review 310

Part Five

Biopsychology of Motivation

12 Hunger, Eating, and Health 311



Why Do Many People Eat Too Much? 311

The Case of the Man Who Forgot Not to Eat 313

12.1 Digestion, Energy Storage, and Energy Utilization 313

Digestion 313

Energy Storage in the Body 313

Three Phases of Energy Metabolism 313

12.2 Theories of Hunger and Eating: Set Points versus Positive Incentives 315

Set-Point Assumption 315

Glucostatic and Lipostatic Set-Point Theories of Hunger and Eating 315

Problems with Set-Point Theories of Hunger and Eating 317

Positive-Incentive Perspective 317

12.3 Factors That Determine What, When, and How Much We Eat 318

Factors That Determine What We Eat 318

Factors That Influence When We Eat 318

Factors That Influence How Much We Eat 319

12.4 Physiological Research on Hunger and Satiety 321

Role of Blood Glucose Levels in Hunger and Satiety 321

Myth of Hypothalamic Hunger and Satiety Centers	321	Classes of Hormones	340
Role of the Gastrointestinal Tract in Satiety	323	Sex Steroids	341
Hunger and Satiety Peptides	323	Hormones of the Pituitary	341
Serotonin and Satiety	325	Female Gonadal Hormone Levels Are Cyclic; Male Gonadal Hormone Levels Are Steady	342
Prader-Willi Syndrome: Patients with Insatiable Hunger	325	Neural Control of the Pituitary	342
<i>Prader-Willi Syndrome: The Case of Miss A.</i>	325	Control of the Anterior and Posterior Pituitary by the Hypothalamus	342
12.5 Body Weight Regulation: Set Points versus Settling Points	325	Discovery of Hypothalamic Releasing Hormones	343
Set-Point Assumptions about Body Weight and Eating	326	Regulation of Hormone Levels	344
Set Points and Settling Points in Weight Control	327	Pulsatile Hormone Release	344
12.6 Human Obesity: Causes, Mechanisms, and Treatments	329	Summary Model of Gonadal Endocrine Regulation	344
Who Needs to Be Concerned about Obesity?	330	13.2 Hormones and Sexual Development of the Body	344
Why Is There an Epidemic of Obesity?	330	Puberty: Hormones and Development of Secondary Sex Characteristics	347
Why Do Some People Become Obese While Others Do Not?	330	13.3 Hormones and Sexual Development of Brain and Behavior	348
Why Are Weight-Loss Programs Often Ineffective?	331	Sex Differences in the Brain	348
Leptin and the Regulation of Body Fat	331	Development of Sex Differences in Behavior	350
<i>The Case of the Child with No Leptin</i>	333	13.4 Three Cases of Exceptional Human Sexual Development	352
Treatment of Obesity	333	<i>The Case of Anne S., the Woman Who Wasn't</i>	352
12.7 Anorexia and Bulimia Nervosa	333	<i>The Case of the Little Girl Who Grew into a Boy</i>	352
Relation between Anorexia and Bulimia	334	<i>The Case of the Twin Who Lost His Penis</i>	353
Anorexia and Positive Incentives	335	Do the Exceptional Cases Prove the Rule?	354
Anorexia Nervosa: A Hypothesis	336	13.5 Effects of Gonadal Hormones on Adults	354
<i>The Case of the Anorexic Student</i>	336	Male Reproduction-Related Behavior and Testosterone	354
Themes Revisited	336	<i>The Case of the Man Who Lost and Regained His Manhood</i>	355
Think about It	336	Female Reproduction-Related Behavior and Gonadal Hormones	355
Key Terms	337	Anabolic Steroid Abuse	357
Quick Review	337	13.6 Brain Mechanisms of Sexual Behavior	358
13		Cortex and Sexual Activity	358
		Hypothalamus and Sexual Activity	358
Hormones and Sex	338	Amygdala and Sexual Activity	359
What's Wrong with the Mamawawa?		Ventral Striatum and Sexual Activity	360
Men-Are-Men-and-Women-Are-Women Assumption	339	13.7 Sexual Orientation and Sexual Identity	360
Developmental and Activational Effects of Sex Hormones	339	Sexual Orientation and Genes	360
13.1 The Neuroendocrine System	339	Sexual Orientation and Early Hormones	360
Glands	340		
Gonads	340		

What Triggers the Development of Sexual Attraction? 361

Is There a Difference in the Brains of Homosexuals and Heterosexuals? 361

Sexual Identity 361

Independence of Sexual Orientation and Sexual Identity 362

Themes Revisited 363

Think about It 363

Key Terms 363

Quick Review 364

14



Sleep, Dreaming, and Circadian Rhythms 365

How Much Do You Need to Sleep?

The Case of the Woman Who Wouldn't Sleep 366

14.1 Stages of Sleep 367

Three Standard Psychophysiological Measures of Sleep 367

Four Stages of Sleep EEG 367

REM Sleep and Dreaming 368

Testing Common Beliefs about Dreaming 369

The Interpretation of Dreams 369

14.2 Why Do We Sleep, and Why Do We Sleep When We Do? 370

Comparative Analysis of Sleep 370

14.3 Effects of Sleep Deprivation 371

Interpretation of the Effects of Sleep Deprivation: The Stress Problem 371

Predictions of Recuperation Theries about Sleep Deprivation 372

Two Classic Sleep-Deprivation Case Studies 372

The Case of the Sleep-Deprived Students 372

The Case of Randy Gardner 372

Experimental Studies of Sleep Deprivation in Humans 372

Sleep-Deprivation Studies with Laboratory Animals 373

REM-Sleep Deprivation 374

Sleep Deprivation Increases the Efficiency of Sleep 375

14.4 Circadian Sleep Cycles 376

Free-Running Circadian Sleep–Wake Cycles 376

Jet Lag and Shift Work 377

A Circadian Clock in the Suprachiasmatic Nuclei 378

Neural Mechanisms of Entrainment 378

Genetics of Circadian Rhythms 378

The Case of Constantin von Economo, the Insightful Neurologist 379

14.5 Four Areas of the Brain Involved in Sleep 379

Two Areas of the Hypothalamus Involved in Sleep 379

Reticular Formation and Sleep 380

Reticular REM-Sleep Nuclei 381

14.6 Drugs That Affect Sleep 382

Hypnotic Drugs 382

Antihypnotic Drugs 383

Melatonin 383

14.7 Sleep Disorders 384

Insomnia 384

Mr. B., the Case of Iatrogenic Insomnia 384

Hypersomnia 385

REM-Sleep–Related Disorders 386

The Case of the Sleeper Who Ran Over Tackle 386

14.8 Effects of Long-Term Sleep Reduction 386

Differences Between Short and Long Sleepers 386

Long-Term Reduction of Nightly Sleep 387

Long-Term Sleep Reduction by Napping 387

Effects of Shorter Sleep Times on Health 388

Long-Term Sleep Reduction: A Personal Case Study 388

The Case of the Author Who Reduced His Sleep 389

Conclusion 389

Themes Revisited 390

Think about It 390

Key Terms 390

Quick Review 391

15



Drug Addiction and the Brain's Reward Circuits 392

Chemicals That Harm with Pleasure

The Case of the Drugged High School Teachers 393

15.1 Basic Principles of Drug Action 393

Drug Administration and Absorption 393

Drug Penetration of the Central Nervous System 394

Mechanisms of Drug Action 394

Drug Metabolism and Elimination	394	16.1 Cerebral Lateralization of Function: Introduction	419
Drug Tolerance	394	Discovery of the Specific Contributions of Left-Hemisphere Damage to Aphasia and Apraxia	419
Drug Withdrawal Effects and Physical Dependence	395	Tests of Cerebral Lateralization	419
Drug Addiction: What Is It?	395	Discovery of the Relation between Speech Laterality and Handedness	420
15.2 Role of Learning in Drug Tolerance	396	Sex Differences in Brain Lateralization	420
Contingent Drug Tolerance	396	16.2 The Split Brain	421
Conditioned Drug Tolerance	396	Groundbreaking Experiment of Myers and Sperry	421
Thinking about Drug Conditioning	398	Commissurotomy in Human Epileptics	423
15.3 Five Commonly Abused Drugs	398	Evidence That the Hemispheres of Split-Brain Patients Can Function Independently	424
Tobacco	398	Cross-Cuing	424
Alcohol	399	Doing Two Things at Once	425
Marijuana	401	The Z Lens	425
Cocaine and Other Stimulants	403	Dual Mental Functioning and Conflict in Split-Brain Patients	426
The Opiates: Heroin and Morphine	404	<i>The Case of Peter, the Split-Brain Patient Tormented by Conflict</i>	426
“Interpreting Studies of the Health Hazards of Drugs”	406	Independence of Split Hemispheres: Current Perspective	427
Comparison of the Hazards of Tobacco, Alcohol, Marijuana, Cocaine, and Heroin	406	16.3 Differences between the Left and Right Hemispheres	427
15.4 Early Biopsychological Research on Addictions	408	Examples of Cerebral Lateralization of Function	428
Physical-Dependence and Positive-Incentive Perspectives of Addiction	408	What Is Lateralized—Broad Clusters of Abilities or Individual Cognitive Processes?	429
Intracranial Self-Stimulation and the Mesotelencephalic Dopamine System	408	Anatomical Asymmetries of the Brain	430
Early Evidence of the Involvement of Dopamine in Drug Addiction	409	16.4 Evolutionary Perspective of Cerebral Lateralization and Language	431
Nucleus Accumbens and Drug Addiction	410	Theories of the Evolution of Cerebral Lateralization	431
15.5 Current Approaches to the Mechanisms of Addiction	411	<i>The Case of W.L., the Man Who Experienced Aphasia for Sign Language</i>	432
Initial Drug Taking	411	When Did Cerebral Lateralization Evolve?	432
Habitual Drug Taking	412	What Are the Survival Advantages of Cerebral Lateralization?	432
Drug Craving and Addiction Relapse	413	Evolution of Human Language	433
Current Concerns about the Drug Self-Administration Paradigm	414	16.5 Cortical Localization of Language: Wernicke-Geschwind Model	434
15.6 A Noteworthy Case of Addiction	414	Historical Antecedents of the Wernicke-Geschwind Model	434
<i>The Case of Sigmund Freud</i>	414	The Wernicke-Geschwind Model	435
Themes Revisited	415	16.6 Wernicke-Geschwind Model: The Evidence	436
Think about It	415	Effects of Cortical Damage on Language Abilities	437
Key Terms	416		
Quick Review	416		

Part Six

Disorders of Cognition and Emotion

16



Lateralization, Language, and the Split Brain 417
 The Left Brain and the Right Brain

Effects of Electrical Stimulation to the Cortex on Language Abilities 438
 Current Status of the Wernicke-Geschwind Model 440

16.7 Cognitive Neuroscience of Language 440

Functional Brain Imaging and the Localization of Language 441

16.8 Cognitive Neuroscience of Dyslexia 442

Developmental Dyslexia: Causes and Neural Mechanisms 442
 Developmental Dyslexia and Culture 443
 Cognitive Neuroscience of Deep and Surface Dyslexia 443
The Case of N.I., the Woman Who Read with Her Right Hemisphere 444

Themes Revisited 444
Think about It 445
Key Terms 445
Quick Review 445

17



Biopsychology of Emotion, Stress, and Health 447
 Fear, the Dark Side of Emotion

17.1 Biopsychology of Emotion: Introduction 448

Early Landmarks in the Biopsychological Investigation of Emotion 448
The Mind-Blowing Case of Phineas Gage 448
A Human Case of Klüver-Bucy Syndrome 451
 Emotions and the Autonomic Nervous System 452
 Emotions and Facial Expression 452

17.2 Fear, Defense, and Aggression 455

Types of Aggressive and Defensive Behaviors 455
 Aggression and Testosterone 456

17.3 Neural Mechanisms of Fear Conditioning 457

Amygdala and Fear Conditioning 457
 Contextual Fear Conditioning and the Hippocampus 458
 Amygdala Complex and Fear Conditioning 458

17.4 Brain Mechanisms of Human Emotion 459

Cognitive Neuroscience of Emotion 459
 Amygdala and Human Emotion 460
The Case of S.P., the Woman Who Couldn't Perceive Fear 460
 Medial Prefrontal Lobes and Human Emotion 460

Lateralization of Emotion 461
 Neural Mechanisms of Human Emotion: Current Perspectives 462

17.5 Stress and Health 462

The Stress Response 462
 Animal Models of Stress 463
 Psychosomatic Disorders: The Case of Gastric Ulcers 463
 Psychoneuroimmunology: Stress, the Immune System, and the Brain 464
 Early Experience of Stress 466
 Stress and the Hippocampus 467
 Conclusion 467
The Case of Charles Whitman, the Texas Tower Sniper 467

Themes Revisited 468
Think about It 468
Key Terms 469
Quick Review 469

18



Biopsychology of Psychiatric Disorders 470
 The Brain Unhinged

18.1 Schizophrenia 471

The Case of Lena, the Catatonic Schizophrenic 471
 What Is Schizophrenia? 472
 Causal Factors in Schizophrenia 472
 Discovery of the First Antischizophrenic Drugs 473
 Dopamine Theory of Schizophrenia 473
 Schizophrenia: Current Research and Treatment 475
 Conclusion 477

18.2 Affective Disorders: Depression and Mania 477

The Case of P.S., the Weeping Widow 478
 Major Categories of Affective Disorders 478
 Causal Factors in Affective Disorders 479
 Discovery of Antidepressant Drugs 479
 Brain Pathology and Affective Disorders 481
 Theories of Depression 482
 Treatment of Depression with Brain Stimulation 482
 Conclusion 483

18.3 Anxiety Disorders 483

The Case of M.R., the Woman Who Was Afraid to Go Out 484

Five Classes of Anxiety Disorders	484	Effectiveness of Clinical Trials	491
Etiology of Anxiety Disorders	484	Conclusion	492
Pharmacological Treatment of Anxiety Disorders	485	<i>The Case of S.B., the Biopsychology Student Who Took Control</i>	492
Animal Models of Anxiety	485	Themes Revisited	493
Neural Bases of Anxiety Disorders	486	Think about It	493
18.4 Tourette Syndrome	486	Key Terms	494
<i>The Case of R.G.—Barking Mad</i>	486	Quick Review	494
What Is Tourette Syndrome?	487		
Neuropathology of Tourette Syndrome	487	Epilogue	495
Treatment of Tourette Syndrome	488	Appendixes	496
<i>The Case of P.H., the Neuroscientist with Tourette Syndrome</i>	488	Glossary	502
18.5 Clinical Trials: Development of New Psychotherapeutic Drugs	489	References	522
Clinical Trials: The Three Phases	489	Credits	557
Controversial Aspects of Clinical Trials	490	Name Index	559
		Subject Index	566

Preface

Welcome to the Ninth Edition of *Biopsychology*! This edition builds on the strengths of its predecessors, but it also takes important new steps: In addition to covering many new cutting-edge research topics, it sharpens its focus on the human element of biopsychology and on promoting student thinking. Most importantly, this is the first edition of *Biopsychology* to focus on epigenetics. It introduces this new field, summarizes current knowledge, and most importantly stresses the relevance of epigenetic concepts to issues of human brain and behavior.

The Ninth Edition of *Biopsychology* is a clear, engaging introduction to current biopsychological theory and research. It is intended for use as a primary text in one- or two-semester courses in biopsychology—variously titled Biopsychology, Physiological Psychology, Brain and Behavior, Psychobiology, Behavioral Neuroscience, or Behavioral Neurobiology.

The defining feature of *Biopsychology* is its unique combination of biopsychological science and personal, reader-oriented discourse. It is a textbook that is “un-textbooklike.” Instead of presenting the concepts of biopsychology in the usual textbook fashion, it addresses students directly and interweaves the fundamentals of the field with clinical case studies, social issues, personal implications, useful metaphors, and memorable anecdotes.

Key Features Maintained in the Ninth Edition

The following are features that have characterized recent editions of *Biopsychology* and have been maintained or expanded in this edition.

Emphasis on Broad Themes The emphasis of *Biopsychology* is “the big picture.” Four broad themes are highlighted throughout the text by distinctive tabs: (1) thinking creatively, (2) clinical implications, (3) evolutionary perspective, and (4) neuroplasticity. A Themes Revisited section at the end of each chapter briefly summarizes how each theme was developed in that chapter. The four major themes provide excellent topics for essay assignments and exam questions.

Clinical
Implications

Evolutionary
Perspective

Neuroplasticity

Thinking
Creatively

Effective Use of Case Studies *Biopsychology* features many carefully selected case studies, which are highlighted in the text. These provocative cases stimulate interest, promote retention, and allow students to learn how biopsychological principles apply to the diagnosis and treatment of brain disorders.

Remarkable Illustrations The illustrations in *Biopsychology* are special. Each one was conceptualized and meticulously designed to clarify and reinforce the text by a uniquely qualified scientist–artist team: Pinel and his artist/designer wife, Maggie Edwards.

Focus on Behavior In some biopsychological textbooks, the coverage of neurophysiology, neurochemistry, and neuroanatomy subverts the coverage of behavioral research. *Biopsychology* gives top billing to behavior: It stresses that neuroscience is a team effort and that the unique contribution made by biopsychologists to this effort is their behavioral expertise.

Emphasis on the Scientific Method *Biopsychology* emphasizes the scientific method. It portrays the scientific method as a means of answering questions that is as applicable in daily life as in the laboratory. And *Biopsychology* emphasizes that being a scientist is fun.

Discussion of Personal and Social Implications Several chapters of *Biopsychology*—particularly those on eating, sleeping, sex, and drug addiction—carry strong personal and social messages. In these chapters, students are encouraged to consider the relevance of biopsychological research to their lives outside the classroom.

Engaging, Inspiring Voice Arguably the strongest pedagogical feature of *Biopsychology* is its personal tone. Pinel addresses students directly and talks to them with warmth, enthusiasm, and good humor about recent advances in biopsychological science. Many students report being engaged and inspired by this approach.

Additions to the Ninth Edition

Four new or expanded features appear in the Ninth Edition of *Biopsychology*.

NEW! Chapter-Opening Study Objectives Each chapter begins with a list of study objectives designed to direct students’ reading and studying.

NEW! Blog-On! *Biopsychology* now comes with an accompanying author-run blog and website (www.biopsyc.com). The blog contains discussions of exciting new biopsychological research and theoretical issues not covered in the text. In addition to the blog, the website also contains a wide variety of links and materials to help students in their studying.

NEW! Even More MyPsychLab (www.mypsychlab.com) MyPsychLab is an online study resource that offers a wealth of animations and practice tests as well as additional study and research tools. This edition adds even more exciting content to MyPsychLab for students.

NEW! More Illustrations and Brain Images Building on *Biopsychology's* strong art package, a number of new illustrations and brain images have been added. These have been carefully selected, designed, and positioned to support interest, clarity, and memorability.

New Coverage in the Ninth Edition

Biopsychology remains one of the most rapidly progressing scientific fields. Like previous editions, the Ninth Edition of *Biopsychology* has meticulously incorporated recent developments in the field—it contains more than 750 citations of articles or books that did not appear in the preceding edition. These recent developments have dictated changes to many parts of the text. The following list presents some of the content changes to this edition, organized by chapter.

Chapter 1: Biopsychology as a Neuroscience

- 3 new citations

Chapter 2: Evolution, Genetics, and Experience

- New section on epigenetics
- A figure illustrating and emphasizing epigenetic mechanisms
- Summary of important recent discoveries of hominin fossils
- New summary of the human genome project, emphasizing the small number of human genes
- Clear statement of the failure to find major links between genes and neurological disorders
- Updated coverage of heritability estimates
- 50 new citations

Chapter 3: Anatomy of the Nervous System

- Updated coverage of glial function
- 15 new citations

Chapter 4: Neural Conduction and Synaptic Transmission

- Simplified explanation of the resting potential
- Recent discovery that action potentials originate in the axon initial segment
- Role of glia in synaptic transmission
- Additional coverage of gap junctions
- 22 new citations

Chapter 5: The Research Methods of Biopsychology

- Use of PET to determine the distribution in the brain of particular molecules
- Introduction of diffusion tensor imaging with a new illustration
- Simplified coverage of reversible brain lesions
- Updated coverage of gene replacement
- 19 new citations

Chapter 6: The Visual System

- Simplified coverage of the organization of neurons in the primary visual cortex
- Explanation of the role of context on the responses of visual neurons
- Improved discussion of dorsal and ventral streams
- Comparison of MT and fusiform face area
- 24 new citations

Chapter 7: Mechanisms of Perception: Hearing, Touch, Smell, Taste, and Attention

- Updated coverage of primary auditory cortex
- Statement of the role of cutaneous receptors in particular sensations
- More comparisons of auditory and visual cortex
- Discussion of rubber-hand illusion and bimodal neurons
- Improved coverage of the olfactory system
- Updated and clearer coverage of the gustatory system
- Updated coverage of attention
- 62 new citations

Chapter 8: The Sensorimotor System

- Shorter but clearer coverage of contralateral neglect
- Recent research on mirror neurons
- Discussion of evidence for mirror neurons in humans
- Updated discussion of functions of the cerebellum
- Simplified discussion of functional brain imaging studies of sensorimotor learning
- 37 new citations

Chapter 9: Development of the Nervous System

- Updated description of increased cell fate specification and related stem cell terminology

- New description of interaction of glial and neural development
- Discovery that radial glial cells develop into neurons
- Overall editing designed to shorten and simplify
- 59 new citations

Chapter 10: Brain Damage and Neuroplasticity

- Definition of gliomas
- Improved coverage of strokes
- Updated discussion of genetic factors and neurological disorders
- Introduction of the term *absence seizures*
- More concise coverage of the etiology of multiple sclerosis
- Concise summary of genes linked to Alzheimer's disease
- Role of microbleeds in Alzheimer's disease
- Importance of early diagnosis in the treatment of Alzheimer's disease
- Improved coverage of MPTP model
- Revised coverage of recovery of function
- Neurotransplantation is revised, updated, and out in a historical perspective
- 95 new citations

Chapter 11: Learning, Memory, and Amnesia

- Tightened up coverage of HM
- New discussion of transient global amnesia
- Tightened up and updated discussion of consolidation
- New section on evolving perspectives of the role of the hippocampus in memory
- New section on neurons of the medial temporal lobes and memory
- Updated coverage of place cells and grid cells
- Introduction and focus on Jennifer Aniston neurons
- Tightened up coverage of LTP
- 35 new citations

Chapter 12: Hunger, Eating, and Health

- Shortened and simplified by aggressive editing
- 10 new citations

Chapter 13: Hormones and Sex

- New section on the modern perspective of sex differences in the brain
- New section on development of sex differences in human behavior
- Discussion of sex differences in susceptibility to disease
- Updated coverage of anabolic steroid use
- New coverage of human sexual arousal and the brain
- 56 new citations

Chapter 14: Sleep, Dreaming, and Circadian Rhythms

- Updated coverage of the relationship between REM sleep and dreaming

- Circadian activity cycles of SCN neurons
- 33 new citations

Chapter 15: Drug Addiction and the Brain's Reward Circuits

- International statistics of drug use
- Increased coverage of the therapeutic effects of THC
- Increased coverage of the effects of MDMA
- Updated description of the treatment of heroin addiction
- Section on critical thinking about illegal drugs
- Major revision of discussion of early theories of addiction
- Major update of current approaches to the study of addiction
- 102 new citations

Chapter 16: Lateralization, Language, and the Split Brain

- Discussion of the interactions between the hemispheres of split brains
- Current status of the theory that right hemispheres are specialized for emotion
- Update of research on neuroanatomical asymmetries in the brain
- Improved coverage of the motor theory of speech perception
- 24 new citations

Chapter 17: Biopsychology of Emotion, Stress, and Health

- Chapter reorganized by moving *Stress and Health* to the end
- Reference to bullying
- Updated and simplified coverage of the neural mechanisms of emotion
- New section on current perspectives of neural mechanism of human emotion
- New description of the immune system
- 45 new citations

Chapter 18: Biopsychology of Psychiatric Disorders

- Introduction of the anticipated DSM-V and the need for continual refinement of diagnoses
- New section on the current research and treatment of schizophrenia
- Updated coverage of treatments for depression
- Updated discussion of the monoamine theory of depression
- New description of the neuroplasticity theory of depression
- Discussion of current treatments for anxiety
- Discussion of problems with current system of diagnosis

- Introduction to the idea that pharmaceutical companies suppress negative findings
- 60 new research citations

Pedagogical Learning Aids

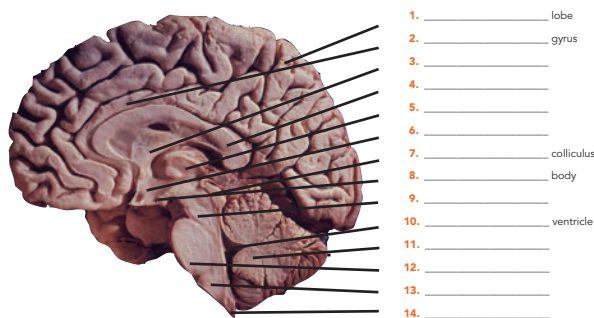
Biopsychology has several features expressly designed to help students learn and remember the material:

- **Scan Your Brain** study exercises appear within chapters at key transition points, where students can benefit most from pausing to consolidate material before continuing.

SCAN YOUR BRAIN

If you have not previously studied the gross anatomy of the brain, your own brain is probably straining under the burden of new terms. To determine whether you are ready to proceed, scan your brain by labeling the following midsagittal view of a real human brain. You may find it challenging to switch from color-coded diagrams to a photograph of a real brain.

The correct answers are provided at the end of the exercise. Before proceeding, review material related to your errors and omissions. Notice that Figure 3.29 includes all the brain anatomy terms that have appeared in bold type in this section and thus is an excellent review tool.



Scan Your Brain answers: (1) parietal, (2) occipital, (3) fornix, (4) corpus callosum, (5) thalamus, (6) hypothalamus, (7) superior, (8) mammillary, (9) tegmentum, (10) fourth, (11) cerebellum, (12) pons, (13) medulla, or myelencephalon, (14) spinal cord.

- **Think about It** discussion questions at the end of each chapter challenge students to think critically and creatively about the content.
- **Check It Out** demonstrations apply biopsychological phenomena and concepts for students to experience themselves.

CHECK IT OUT The Position of Eyes

Here you see three animals whose eyes are on the front of their heads (a human, an owl, and a lion) and three whose eyes are on the sides of their heads (an antelope, a canary, and a squirrel). Why do a few vertebrate species have their eyes side by side on the front of the head while most species have one eye on each side?

In general, predators tend to have the front-facing eyes because this enables them to accurately perceive how far away prey animals are; prey animals tend to have side-facing eyes because this gives them a larger field of vision and the ability to see predators approaching from most directions.



- **Themes Revisited** section at the end of each chapter summarizes the ways in which the book's four major themes relate to that chapter's subject matter.
- **Key Terms** appear in **boldface**, and other important terms of lesser significance appear in *italics*.
- **Appendixes** serve as convenient sources of additional information for students who want to expand their knowledge of selected biopsychology topics.

Ancillary Materials Available with *Biopsychology*

For Instructors

Pearson Education is pleased to offer the following supplements to qualified adopters.

Test Bank The test bank for the Ninth Edition of *Biopsychology* comprises more than 2,000 multiple-choice questions, including questions about accompanying brain images. The difficulty of each item is rated—easy (1), moderate (2), or difficult (3)—to assist instructors with test construction. Each item is also labeled with a topic and a page reference so that instructors can easily select appropriate questions for their tests. Textbook authors rarely prepare their own test banks; the fact that Pinel insists on preparing the *Biopsychology* test bank attests to its consistency with the text—and his commitment to helping students learn.

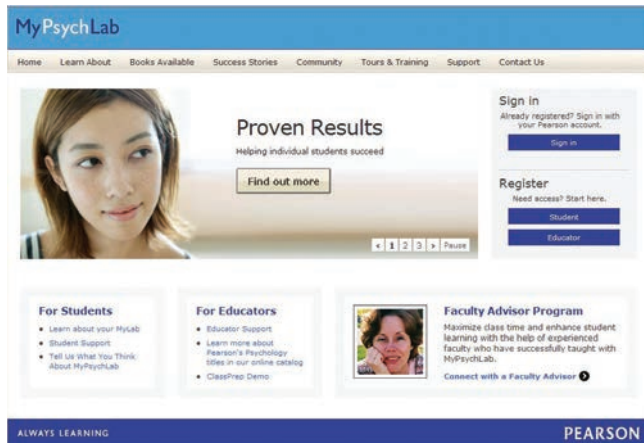
MyTest Test Bank This test bank is available in computerized format, which allows instructors to create and print quizzes and exams. Questions and tests can be authored online, allowing instructors maximum flexibility and the ability to efficiently manage assessments anytime, anywhere. Instructors can easily access existing questions and edit, create, and store questions using simple drag-and-drop controls. For more information, go to www.PearsonMyTest.com.

Instructor's Manual The instructor's manual contains helpful teaching tools, including at-a-glance grids, activities and demonstrations for the classroom, handouts, lecture notes, chapter outlines, and other valuable course organization material for new and experienced instructors. Additional resources have been added for the Ninth Edition, including information on MyPsychLab video assets and the Visual Brain.

Standard Lecture PowerPoint Slides These slides have a more traditional format, with excerpts of the text material and artwork, and are available online at <http://www.pearsonglobaleditions.com/Pinel>.

NEW! MyPsychLab (www.mypsychlab.com)

MyPsychLab is an online homework, tutorial, and assessment program that truly engages students in learning. It helps students better prepare for class, quizzes, and exams—resulting in better performance in the course. It provides educators a dynamic set of tools for gauging individual and class performance.



- **Customizable**—MyPsychLab is customizable. Instructors choose what students' courses look like. Homework, applications, and more can easily be turned on and off.
- **Blackboard Single Sign-on**—MyPsychLab can be used by itself or linked to any course management system. Blackboard single sign-on provides deep linking to all New MyPsychLab resources.
- **Pearson eText and Chapter Audio**—Like the printed text, students can highlight relevant passages and add notes. The Pearson eText can be accessed through laptops, iPads, and tablets. Download the free Pearson eText app to use on tablets. Students can also listen to their text with the Audio eText.
- **Assignment Calendar and Gradebook**—A drag and drop assignment calendar makes assigning and completing work easy. The automatically graded assessment provides instant feedback and flows into the gradebook, which can be used in MyPsychLab or exported.
- **Personalized Study Plan**—Students' personalized plans promote better critical thinking skills. The study plan organizes students' study needs into sections such as Remembering, Understanding, Applying, and Analyzing.

- **MyPsychLab Margin Icons**—Margin icons guide students from their reading material to relevant videos and simulations.

NEW! The Visual Brain

Explore the **Visual System** module in MyPsychLab.

Available within MyPsychLab, the new **Visual Brain** is an interactive virtual brain designed to help students better understand neuroanatomy, physiology, and human behavior. Fifteen new modules bring to life many of the

most difficult topics typically covered in the biopsychology course. Every module includes sections that explore relevant anatomy, physiological animations, and engaging case studies that bring behavioral neuroscience to life. At the end of each module, students can take an assessment that will help measure their understanding. This hands-on experience engages students and helps make course content and terminology relevant. References throughout the text direct students to content in MyPsychLab, and a new feature at the end of each chapter directs students to **MyPsychLab Brain** modules.

For Students

MyPsychLab With this exciting new tool, students are able to self-assess using embedded diagnostic tests and instantly view results along with a customized study plan.

The customized study plan will focus on the student's strengths and weaknesses, based on the results of the diagnostic testing, and present a list of activities and resources for review and remediation, organized by chapter section. Some study resources intended for use with portable electronic devices, such as key terms flashcards and video clips, are made available exclusively through MyPsychLab. Students will be able to quickly and easily analyze their own comprehension level of the course material and study more efficiently, leading to exceptional exam results! An access code is required and can be purchased at <http://www.pearsonglobaleditions.com/Pinel> or at www.mypsychlab.com.

A Colorful Introduction to the Anatomy of the Human Brain, Second Edition This book, written by John P. J. Pinel and Maggie Edwards, provides an easy and enjoyable means of learning or reviewing the fundamentals of human neuroanatomy through the acclaimed directed-coloring method.

Acknowledgments

Two people deserve special credit for helping me create this edition of *Biopsychology*: Maggie Edwards and Steven Barnes. Maggie is an artist/designer/writer/personal trainer, who is my partner in life. She is responsible for the design of most of the illustrations in this book. Steven is a colleague/artist/computer wizard, whose contributions to this edition were immense. He kept my writing on schedule, prepared the manuscripts, compiled the reference list, did some editing and writing, designed all the new illustrations, created the author-run blog and website, and compiled all of the electronic links. It exhausts me just thinking about it.

Pearson Education did a remarkable job of producing this book. They shared my dream of a textbook that meets the highest standards of pedagogy but is also personal, attractive, and enjoyable. Thank you to Bill Barke, Stephen Frail, Susan Hartman, and other executives for having faith in *Biopsychology* and providing the financial and personal support necessary for it to stay at the forefront of its field. Special thanks also go to Joan Foley, Amber Chow, Diane Szulecki, and Judy Casillo at Pearson and Angel Chavez at Integra for coordinating the production—an excruciatingly difficult and often thankless job.

I thank the following instructors for providing me with reviews of various editions of *Biopsychology*. Their comments have contributed substantially to the evolution of this edition:

L. Joseph Acher, Baylor University
 Nelson Adams, Winston-Salem State University
 Marwa Azab, Golden West College
 Michael Babcock, Montana State University–Bozeman
 Ronald Baenninger, College of St. Benedict
 Mark Basham, Regis University
 Carol Batt, Sacred Heart University
 Noel Jay Bean, Vassar College
 Patricia Bellas, Irvine Valley College
 Danny Benbasset, George Washington University
 Thomas Bennett, Colorado State University
 Linda Brannon, McNeese State University
 Peter Brunjes, University of Virginia
 John Bryant, Bowie State University
 Michelle Butler, United States Air Force Academy
 Donald Peter Cain, University of Western Ontario
 Deborah A. Carroll, Southern Connecticut State University
 John Conklin, Camosun College
 Sherry Dingman, Marist College
 Michael A. Dowdle, Mt. San Antonio College
 Doug Engwall, Central Connecticut State University
 Gregory Ervin, Brigham Young University

Robert B. Fischer, Ball State University
 Allison Fox, University of Wollongong
 Michael Foy, Loyola Marymount University
 Ed Fox, Purdue University
 Thomas Goettsche, SAS Institute, Inc.
 Arnold M. Golub, California State University–Sacramento
 Nakia Gordon, Marquette University
 Mary Gotch, Solano College
 Jeffrey Grimm, Western Washington University
 Kenneth Guttman, Citrus College
 Melody Smith Harrington, St. Gregory’s University
 Theresa D. Hernandez, University of Colorado
 Cindy Ellen Herzog, Frostburg State University
 Peter Hickmott, University of California–Riverside
 Michael Jarvinen, Emmanuel College
 Tony Jelsma, Atlantic Baptist University
 Roger Johnson, Ramapo College
 John Jonides, University of Michigan
 Jon Kahane, Springfield College
 Craig Kinsley, University of Richmond
 Ora Kofman, Ben-Gurion University of the Negev
 Louis Koppel, Utah State University
 Maria J. Lavooy, University of Central Florida
 Victoria Littlefield, Augsburg College
 Eric Littman, University of Cincinnati
 Linda Lockwood, Metropolitan State College of Denver
 Charles Malsbury, Memorial University
 Michael R. Markham, Florida International University
 Vincent Markowski, State University of New York–Geneseo
 Michael P. Matthews, Drury College
 Lin Meyers, California State University–Stanislaus
 Maura Mitrushina, California State University, Northridge
 Russ Morgan, Western Illinois University
 Henry Morlock, SUNY–Plattsburgh
 Caroline Olko, Nassau Community College
 Laretta Park, Clemson University
 Ted Parsons, University of Wisconsin–Platteville
 Jim H. Patton, Baylor University
 Edison Perdorno, Minnesota State University
 Michael Peters, University of Guelph
 Michelle Pilati, Rio Hondo College
 Joseph H. Porter, Virginia Commonwealth University
 David Robbins, Ohio Wesleyan University
 Dennis Rodriguez, Indiana University–South Bend
 Margaret G. Ruddy, College of New Jersey
 Jeanne P. Ryan, SUNY–Plattsburgh
 Jerome Siegel, David Geffen School of Medicine, UCLA
 Angela Sikorski, Texas A&M University–Texarkana

Patti Simone, Santa Clara University
Ken Sobel, University of Central Arkansas
David Soderquist, University of North Carolina at
Greensboro
Michael Stoloff, James Madison University
Stuart Tousman, Rockford College
Dallas Treit, University of Alberta
Margaret Upchurch, Transylvania University

Dennis Vincenzi, University of Central Florida
Ashkat Vyas, Hunter College
Charles Weaver, Baylor University
Linda Walsh, University of Northern Iowa
David Widman, Juniata College
Jon Williams, Kenyon College
David Yager, University of Maryland
H.P. Ziegler, Hunter College

Pearson wishes to thank and acknowledge the following people for their work on the Global Edition:

Neelam Rathee, Post Graduate Government College for Girls, Sector 11, Chandigarh
B.S. Shankaranarayana Rao, National Institute of Mental Health and Neuro Sciences
Dinesh Chhabra, University of Delhi
Alpana Vaidya, Symbiosis College

To the Student

In the 1960s, I was, in the parlance of the times, “turned on” by an undergraduate course in biopsychology. I could not imagine anything more interesting than a field of science dedicated to studying the relation between psychological processes and the brain. My initial fascination led to a long career as a student, researcher, teacher, and writer of biopsychological science. *Biopsychology* is my attempt to share my fascination with you.

I have tried to make *Biopsychology* a different kind of textbook, a textbook that includes clear, concise, and well-organized explanations of the key points but is still interesting to read—a book from which you might suggest suitable sections to an interested friend or relative. To accomplish this goal, I thought about what kind of textbook I would have liked when I was a student, and I decided to avoid the stern formality and ponderous style of conventional textbook writing and to focus on ideas of relevance to your personal life.

I wanted *Biopsychology* to have a relaxed and personal style. In order to accomplish this, I imagined that you and I were chatting as I wrote, and that I was telling you—usually over a glass of something—about the interesting things that go on in the field of biopsychology. Imagining these chats kept my writing from drifting back

into conventional “textbookese,” and it never let me forget that I was writing this book for you.

Creative thinking is one of the major themes of this edition. Often science and creativity are considered to be opposites, but in my experience many of the major advances in biopsychological science have resulted from creative thinking. These major advances have been made by biopsychologists who have recognized that there are alternatives to the conventional ways of thinking about biopsychological issues that have been engrained in them by their culture and training and who have adopted creative new approaches. Two things in particular have fascinated me about the interplay between creative thinking and biopsychological science: how difficult it is to identify and shed conventional approaches even when they clearly haven’t been working, and how often solutions to long-standing problems become apparent when approached from a new perspective. The focus of this edition on creative thinking is intended to make the study of biopsychology more interesting for you and to encourage you become a more creative thinker.

I hope that *Biopsychology* teaches you much of relevance to your personal life and that reading it generates in you the same positive feelings that writing it did in me.

About the Author

John Pinel, the author of *Biopsychology*, obtained his Ph.D. from McGill University in Montreal and worked briefly at the Massachusetts Institute of Technology before taking a faculty position at the University of British Columbia in Vancouver, where he is currently Professor Emeritus. Professor Pinel is an award-winning teacher and the author of more than 200 scientific papers. However, he feels that *Biopsychology* is his major career-related accomplishment: “It ties together everything I love about my job: students, teaching, writing, and research.”

Pinel attributes much of his success to his wife, Maggie, who has at various times been a professional artist, designer, and personal trainer. Over the years, they have collaborated on many projects, and the high quality of *Biopsychology*’s illustrations is largely attributable to her skill and effort.

Pinel is an enthusiastic West African drummer who performs at local clubs, festivals, and drum circles with Nigerian drum master Kwasi Iruoje. For relaxation, he loves to cuddle his three cats: Rastaman, Sambala, and Squeak.

This page is intentionally left blank.

CHAPTER

1

Biopsychology as a Neuroscience

What Is Biopsychology, Anyway?



Explore the Visual
Brain in MyPsychLab.

- 1.1 What Is Biopsychology?
- 1.2 What Is the Relation between Biopsychology and the Other Disciplines of Neuroscience?
- 1.3 What Types of Research Characterize the Biopsychological Approach?
- 1.4 What Are the Divisions of Biopsychology?
- 1.5 Converging Operations: How Do Biopsychologists Work Together?
- 1.6 Scientific Inference: How Do Biopsychologists Study the Unobservable Workings of the Brain?
- 1.7 Critical Thinking about Biopsychological Claims

LEARNING OBJECTIVES

- LO1 Define and discuss the field of biopsychology.
- LO2 Biopsychology is an integrative discipline. Explain.
- LO3 Describe six areas of neuroscience that are particularly relevant to biopsychological inquiry.
- LO4 Compare the advantages and disadvantages of humans and nonhumans as subjects in biopsychological research.
- LO5 Compare experiments, quasiexperimental studies, and case studies, emphasizing the study of causal effects.
- LO6 Describe and compare the six divisions of biopsychology.
- LO7 Explain how converging operations has contributed to the study of Korsakoff's syndrome.
- LO8 Explain scientific inference with reference to research on eye movement and the visual perception of motion.
- LO9 Explain critical thinking and its relation to creative thinking in science.
- LO10 Discuss Delgado's bull-ring demonstration, emphasizing its flawed interpretation.
- LO11 Describe the rise and fall of prefrontal lobotomy.

The appearance of the human brain is far from impressive (see Figure 1.1). The human brain is a squishy, wrinkled, walnut-shaped hunk of tissue weighing about 1.3 kilograms. It looks more like something you might find washed up on a beach than like one of the wonders of the world—which it surely is. Despite its disagreeable external appearance, the human brain is an amazingly intricate network of **neurons** (cells that receive and transmit electrochemical signals). Contemplate for a moment the complexity of your own brain's neural circuits. Consider the 100 billion neurons in complex array (see Azevedo et al., 2009), the estimated 100 trillion connections among them, and the almost infinite number of paths that neural signals can follow through this morass (see Zimmer, 2011). The complexity of the human brain is hardly surprising, considering what it can do. An organ capable of creating a *Mona Lisa*, an artificial limb, and a supersonic aircraft; of traveling to the moon and to the depths of the sea; and of experiencing the wonders of an alpine sunset, a newborn infant, and a reverse slam dunk *must* be complex. Paradoxically, **neuroscience** (the scientific study of the nervous system) may prove to be the brain's ultimate challenge: Does the brain have the capacity to understand something as complex as itself (see Gazzaniga, 2010)?

Neuroscience comprises several related disciplines. The primary purpose of this chapter is to introduce you to one of them: biopsychology. Each of this chapter's seven sections characterizes the neuroscience of biopsychology in a different way.



FIGURE 1.1 The human brain.

Before you proceed to the body of this chapter, I would like to tell you about two things: (1) the case of Jimmie G. (Sacks, 1986), which will give you a taste of the interesting things that lie ahead, and (2) the major themes of this text.

*The Case of Jimmie G., the Man Frozen in Time

Jimmie G. was a good-looking, friendly 49-year-old. He liked to talk about his school days and his experiences in the navy, which he was able to describe in detail. Jimmie was an intelligent man with superior abilities in math and science. In fact, it was not readily apparent why he was a resident of a neurological ward.

When Jimmie talked about his past, there was a hint of his problem. When he talked about his school days, he used the past tense; when he recounted his early experiences in the navy, however, he switched to the present tense. More worrisome was that he never talked about anything that happened to him after his time in the navy.

Jimmie G. was tested by eminent neurologist Oliver Sacks, and a few simple questions revealed a curious fact: The 49-year-old patient believed that he was 19. When he was asked to describe what he saw in a mirror, Jimmie became so frantic and confused that Dr. Sacks immediately took the mirror out of the room.

Returning a few minutes later, Dr. Sacks was greeted by a once-again cheerful Jimmie, who acted as if he had never seen Sacks before. Indeed, even when Sacks suggested that they had met recently, Jimmie was certain that they had not.

Then Dr. Sacks asked where Jimmie thought he was. Jimmie replied that all the beds and patients made him think that the place was a hospital. But he couldn't understand why he would be in a hospital. He was afraid that he might have been admitted because he was sick, but didn't know it.

Further testing confirmed what Dr. Sacks feared. Although Jimmie had good sensory, motor, and cognitive abilities, he had one terrible problem: He forgot everything that was said or shown to him within a few seconds. Basically, Jimmie could not remember anything that had happened to him since his early 20s, and he was not going to remember anything that happened to him for the rest of his life. Sacks was stunned by the implications of Jimmie's condition.

Jimmie G.'s situation was heart-wrenching. Unable to form new lasting memories, he was, in effect, a man frozen in time, a man without a recent past and no prospects for a future, stuck in a continuous present, lacking any context or meaning.

Remember Jimmie G.; you will encounter him again, later in this chapter.

FOUR MAJOR THEMES OF THIS TEXT

You will learn many new facts in this text—new findings, concepts, terms, and the like. But more importantly, many years from now, long after you have forgotten most of those facts, you will still be carrying with you

productive new ways of thinking. I have selected four of these for special emphasis: They are the major themes of this text.



Watch
Themes at
MyPsychLab

To help give these themes the special attention they deserve and to help you follow their development as you progress through the text, I have marked relevant passages with tabs. The following are the four major themes and their related tabs.

Thinking Creatively about Biopsychology We are all fed a steady diet of biopsychological information, misinformation, and opinion—by television, newspapers, the Internet, friends, relatives, teachers, etc. As a result, you likely already hold strong views about many of the topics you will encounter in this text. Because these preconceptions are shared by many biopsychological researchers, they have often impeded scientific progress, and some of the most important advances in biopsychological science have been made by researchers who have managed to overcome the restrictive effects of conventional thinking and have taken creative new approaches. Indeed, **thinking creatively** (thinking in productive, unconventional ways) is the cornerstone of any science. The thinking creatively tab marks points in the text where I describe research that involves thinking “outside the box,” where I have tried to be creative in the analysis of the research that I am presenting, or where I encourage you to base your thinking on the evidence rather than on widely accepted views.

Thinking Creatively

Clinical Implications **Clinical** (pertaining to illness or treatment) considerations are woven through the fabric of biopsychology. There are two aspects to clinical implications: Much of what biopsychologists learn about the functioning of the normal brain comes from studying the diseased or damaged brain; and, conversely, much of what biopsychologists discover has relevance for the treatment of brain disorders.

Clinical Implications

This text focuses on the interplay between brain dysfunction and biopsychological research, and each major example is highlighted by a clinical implications tab.

The Evolutionary Perspective Although the events that led to the evolution of the human species can never be determined with certainty, thinking of the environmental pressures that likely led to the evolution of our brains and behavior often leads to important biopsychological insights. This approach is called the evolutionary perspective. An important component of the **evolutionary perspective** is the comparative approach (trying to understand biological phenomena by comparing them in different species). You will learn throughout the text that we humans have learned much

Evolutionary Perspective

*Based on “The Case of Jimmie G., the Man Frozen in Time,” Simon & Schuster, Inc. and Pan Macmillan, London from *The Man Who Mistook His Wife for a Hat and Other Clinical Tales* by Oliver Sacks. Copyright © 1970, 1981, 1983, 1984, 1986 by Oliver Sacks.

about ourselves by studying species that are related to us through evolution. The evolutionary approach has proven to be one of the cornerstones of modern biopsychological inquiry. Each discussion that relates to the evolutionary perspective is marked by an evolutionary perspective tab.

Neuroplasticity Until the early 1990s, most neuroscientists thought of the brain as a three-dimensional array of

Neuroplasticity

neural elements “wired” together in a massive network of circuits. The complexity of this “wiring diagram” of the brain was staggering, but it failed to capture one of the brain’s most important features. In the last two decades, research has clearly demonstrated that the adult brain is not a static network of neurons: It is a plastic (changeable) organ that continuously

BLOG-ON

I have a website with blog posts, a link collection, and other items: www.biopsyc.com. Keep an eye out for “blog-on” boxes—they indicate that material on my site is relevant to what you have just been reading.

grows and changes in response to the individual’s genes and experiences. The discovery of neuroplasticity, arguably the single most influential discovery in modern neuroscience, is currently influencing many areas of biopsychological research. A neuroplasticity tab marks each discussion or study of neuroplasticity.

1.1 What Is Biopsychology?

Biopsychology is the scientific study of the biology of behavior—see Dewsbury (1991). Some refer to this field as *psychobiology*, *behavioral biology*, or *behavioral neuroscience*; but I prefer the term biopsychology because it denotes a biological approach to the study of psychology rather than a psychological approach to the study of biology: Psychology commands center stage in this text. *Psychology* is the scientific study of behavior—the scientific study of all overt activities of the organism as well as all the internal processes that are presumed to underlie them (e.g., learning, memory, motivation, perception, and emotion).

The study of the biology of behavior has a long history, but biopsychology did not develop into a major neuroscientific discipline until the 20th century. Although it is not possible to specify the exact date of biopsychology’s birth, the publication of *The Organization of Behavior* in 1949 by D. O. Hebb played a key role in its emergence (see Brown & Milner, 2003; Cooper, 2005; Milner, 1993). In his book, Hebb developed the first comprehensive theory of how complex psychological phenomena, such as perceptions, emotions, thoughts, and memories, might be produced by brain activity. Hebb’s theory did much to discredit the view that psychological functioning is too complex to have its roots in the physiology and chemistry of the brain. Hebb based his theory on experiments involving both humans and laboratory animals, on clinical case studies, and on logical arguments developed from his own

insightful observations of daily life. This eclectic approach has become a hallmark of biopsychological inquiry.

In comparison to physics, chemistry, and biology, biopsychology is an infant—a healthy, rapidly growing infant, but an infant nonetheless. In this text, you will reap the benefits of biopsychology’s youth. Because biopsychology does not have a long and complex history, you will be able to move quickly to the excitement of current research.

1.2 What Is the Relation between Biopsychology and the Other Disciplines of Neuroscience?

Neuroscience is a team effort, and biopsychologists are important members of the team (see Albright, Kandel, & Posner, 2000; Kandel & Squire, 2000). Biopsychology can be further defined by its relation to other neuroscientific disciplines.

Biopsychologists are neuroscientists who bring to their research a knowledge of behavior and of the methods of behavioral research. It is their behavioral orientation and expertise that make their contribution to neuroscience unique (see Cacioppo & Decety, 2009). You will be able to better appreciate the importance of this contribution if you consider that the ultimate purpose of the nervous system is to produce and control behavior (see Grillner & Dickinson, 2002).

Biopsychology is an integrative discipline. Biopsychologists draw together knowledge from the other neuroscientific disciplines and apply it to the study of behavior. The following are a few of the disciplines of neuroscience that are particularly relevant to biopsychology:

- Neuroanatomy.** The study of the structure of the nervous system (see Chapter 3).
- Neurochemistry.** The study of the chemical bases of neural activity (see Chapter 4).
- Neuroendocrinology.** The study of interactions between the nervous system and the endocrine system (see Chapters 13 and 17).
- Neuropathology.** The study of nervous system disorders (see Chapter 10).
- Neuropharmacology.** The study of the effects of drugs on neural activity (see Chapters 4, 15, and 18).
- Neurophysiology.** The study of the functions and activities of the nervous system (see Chapter 4).

1.3 What Types of Research Characterize the Biopsychological Approach?

Although biopsychology is only one of many disciplines that contribute to neuroscience, it is broad and diverse. Biopsychologists study many different phenomena, and they

approach their research in many different ways. In order to characterize biopsychological research, this section discusses three major dimensions along which approaches to biopsychological research vary. Biopsychological research can involve either human or nonhuman subjects; it can take the form of either formal experiments or nonexperimental studies; and it can be either pure or applied.

HUMAN AND NONHUMAN SUBJECTS

Both human and nonhuman animals are the subject of biopsychological research. Of the nonhumans, mice and rats are the most common subjects; however, cats, dogs, and nonhuman primates are also commonly studied.

Humans have several advantages over other animals as experimental subjects of biopsychological research: They can follow instructions, they can report their subjective experiences, and their cages are easier to clean. Of course, I am joking about the cages, but the joke does serve to draw attention to one advantage humans have over other species of experimental subjects: Humans are often cheaper. Because only the highest standards of animal care are acceptable, the cost of maintaining an animal laboratory can be prohibitive for all but the most well-funded researchers.

Of course, the greatest advantage humans have as subjects in a field aimed at understanding the intricacies of human brain function is that they have human brains. In fact, you might wonder why biopsychologists would bother studying nonhuman subjects at all. The answer lies in the evolutionary continuity of the brain. The brains of humans differ from the brains of other mammals primarily in their overall size and the extent of their cortical development. In other words, the differences between the brains of humans and those of related species are more quantitative than qualitative, and thus many of the principles of human brain function can be clarified by the study of nonhumans (see Nakahara et al., 2002; Passingham, 2009; Platt & Spelke, 2009).

Evolutionary Perspective

Conversely, nonhuman animals have three advantages over humans as subjects in biopsychological research. The first is that the brains and behavior of nonhuman subjects are simpler than those of human subjects. Hence, the study of nonhuman species is more likely to reveal fundamental brain–behavior interactions. The second advantage is that insights frequently arise from the **comparative approach**, the study of biological processes by comparing different species. For example, comparing the behavior of species that do not have a cerebral cortex with the behavior of species that do can provide valuable clues about cortical function. The third advantage is that it is possible to conduct research on laboratory animals that, for ethical reasons, is not possible with human subjects. This is not to say that the study of nonhuman animals is not governed by a strict code of ethics (see

Demers et al., 2006; Goldberg & Hartung, 2006)—it is. However, there are fewer ethical constraints on the study of laboratory species than on the study of humans.

In my experience, most biopsychologists display considerable concern for their subjects, whether they are of their own species or not; however, ethical issues are not left to the discretion of the individual researcher. All biopsychological research, whether it involves human or nonhuman subjects, is regulated by independent committees according to strict ethical guidelines: “Researchers cannot escape the logic that if the animals we observe are reasonable models of our own most intricate actions, then they must be respected as we would respect our own sensibilities” (Ulrich, 1991, p. 197).

BLOG-ON

Concerned about the ethics of biopsychological research on nonhuman species? Go to www.biopsyc.com/animalresearch

EXPERIMENTS AND NONEXPERIMENTS

Biopsychological research involves both experiments and nonexperimental studies. Two common types of nonexperimental studies are quasiexperimental studies and case studies.

Experiments The experiment is the method used by scientists to study causation, that is, to find out what causes what. As such, it has been almost single-handedly responsible for the knowledge that is the basis for our modern way of life. It is paradoxical that a method capable of such complex feats is so simple. To conduct an experiment involving living subjects, the experimenter first designs two or more conditions under which the subjects will be tested. Usually, a different group of subjects is tested under each condition (**between-subjects design**), but sometimes it is possible to test the same group of subjects under each condition (**within-subjects design**). The experimenter assigns the subjects to conditions, administers the treatments, and measures the outcome in such a way that there is only one relevant difference between the conditions being compared. This difference between the conditions is called the **independent variable**. The variable measured by the experimenter to assess the effect of the independent variable is called the **dependent variable**. If the experiment is done correctly, any differences in the dependent variable between the conditions must have been caused by the independent variable.

Why is it critical that there be no differences between conditions other than the independent variable? The reason is that when there is more than one difference that could affect the dependent variable, it is difficult to determine whether it was the independent variable or the unintended difference—called a



Simulate Elements of an Experiment at MyPsychLab

confounded variable—that led to the observed effects on the dependent variable. Although the experimental method is conceptually simple, eliminating all confounded variables can be quite difficult. Readers of research papers must be constantly on the alert for confounded variables that have gone unnoticed by the experimenters.

An experiment by Lester and Gorzalka (1988) illustrates the prevention of confounded variables with good experimental design. The experiment was a demonstration of the **Coolidge effect**. The Coolidge effect is the fact that a copulating male who becomes incapable of continuing to copulate with one sex partner can often recommence copulating with a new sex partner (see Figure 1.2).



FIGURE 1.2 President Calvin Coolidge and Mrs. Grace Coolidge. Many students think the Coolidge effect is named after a biopsychologist named Coolidge. In fact, it is named after President Calvin Coolidge, of whom the following story is told. (If the story isn't true, it should be.) During a tour of a poultry farm, Mrs. Coolidge inquired of the farmer how his farm managed to produce so many eggs with such a small number of roosters. The farmer proudly explained that his roosters performed their duty dozens of times each day.

"Perhaps you could point that out to Mr. Coolidge," replied the First Lady in a pointedly loud voice.

The President, overhearing the remark, asked the farmer, "Does each rooster service the same hen each time?"

"No," replied the farmer, "there are many hens for each rooster."

"Perhaps you could point that out to Mrs. Coolidge," replied the President.

Before your imagination starts running wild, I should mention that the subjects in Lester and Gorzalka's experiment were hamsters, not students from the undergraduate subject pool.

Lester and Gorzalka argued that the Coolidge effect had not been demonstrated in females because it is more difficult to conduct well-controlled Coolidge-effect experiments with females—not because females do not display a Coolidge effect. The confusion, according to Lester and Gorzalka, stemmed from the fact that the males of most mammalian species become sexually fatigued more readily than the females. As a result, attempts to demonstrate the Coolidge effect in females are often confounded by the fatigue of the males. When, in the midst of copulation, a female is provided with a new sex partner, the increase in her sexual receptivity could be either a legitimate Coolidge effect or a reaction to the greater vigor of the new male. Because female mammals usually display little sexual fatigue, this confounded variable is not a serious problem in demonstrations of the Coolidge effect in males.

Lester and Gorzalka devised a clever procedure to control for this confounded variable. At the same time a female subject was copulating with one male (the familiar male), the other male to be used in the test (the unfamiliar male) was copulating with another female. Then, both males were given a rest while the female was copulating with a third male. Finally, the female subject was tested with either the familiar male or the unfamiliar male. The dependent variable was the amount of time that the female displayed **lordosis** (the arched-back, rump-up, tail-diverted posture of female rodent sexual receptivity) during each sex test. As Figure 1.3 illustrates, the females responded more vigorously to the unfamiliar males than they did to the familiar males during the third test, despite the fact that both the unfamiliar and familiar males were equally fatigued and both mounted the females with equal vigor. The purpose of this example—in case you have forgotten—is to illustrate the critical role played by good experimental design in preventing confounded variables.

Thinking
Creatively

Quasiexperimental Studies It is not possible for biopsychologists to bring the experimental method to bear on all problems of interest to them. Physical or ethical impediments frequently make it impossible to assign subjects to particular conditions or to administer the conditions once the subjects have been assigned to them. For example, experiments on the causes of brain damage in human alcoholics are not feasible because it would not be ethical to assign a subject to a condition that involves years of alcohol consumption. (Some of you may be more concerned about the ethics of assigning subjects to a control condition that involves years of sobriety.) In