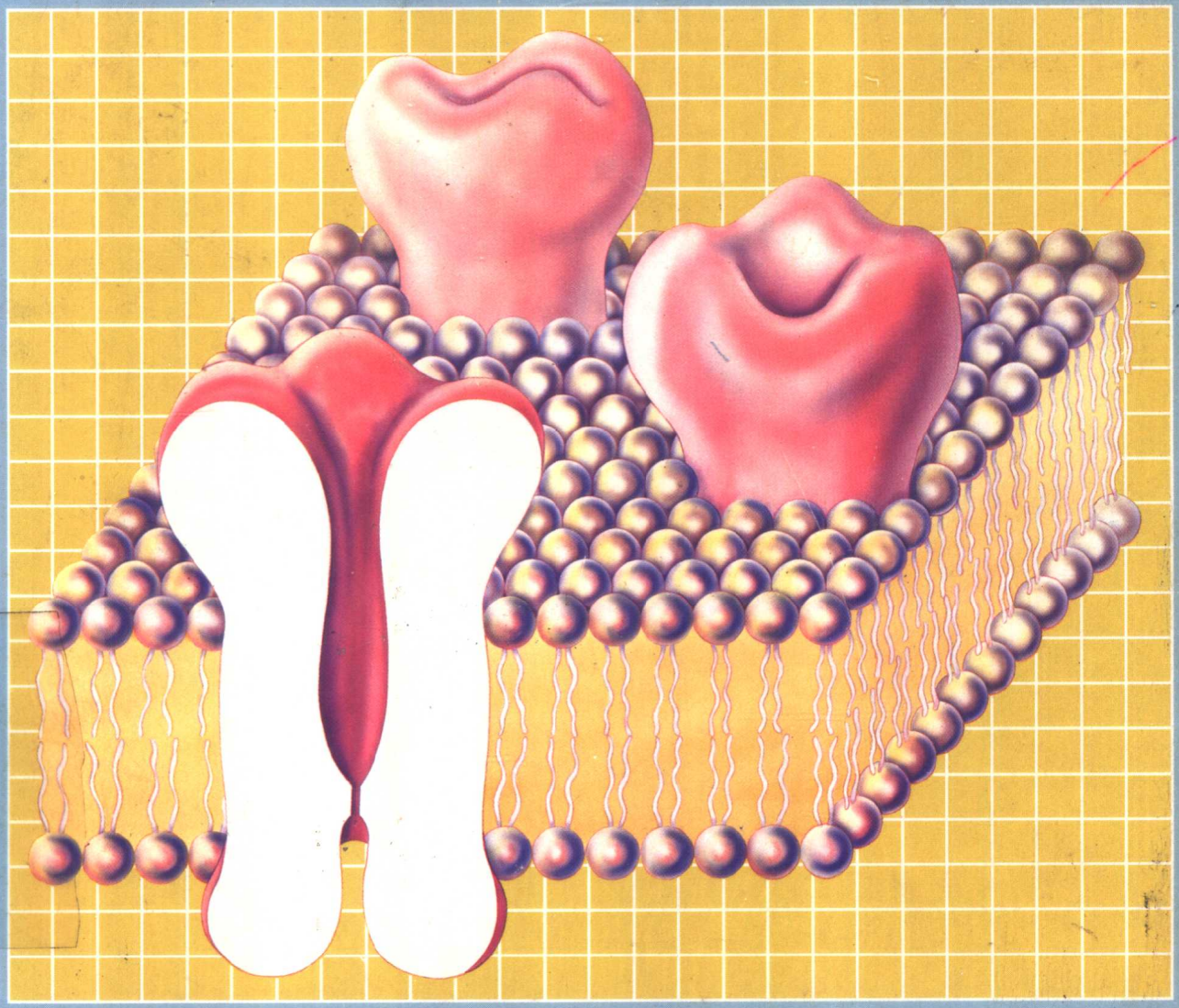
James W. Kalat

BIOLOGICAL PSYCHOLOGY

THIRD EDITION



BIOLOGICAL PSYCHOLOGY

THIRD EDITION

James W. Kalat
North Carolina State University

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

About the cover: Every cell of the nervous system is bounded by a membrane. Embedded in the membrane are receptors that respond to synaptic transmitters, which are chemical messengers released by other neurons. The receptor that responds to the transmitter substance GABA is shown here. Tranquilizers and several other chemicals influence behavior by attaching to sites on this complex and thereby modifying the responsiveness of the GABA receptor.

Psychology Editor: Kenneth King
Production: Del Mar Associates
Designer: Louis Neiheisel
Copy Editor: Jackie Estrada
Photo Researcher: Linda Rill
Illustrator: Linda McVay
Compositor: Thompson Type
Cover: John Odam

Printed in the United States of America
3 4 5 6 7 8 9 10—92 91 90 89

ISBN 0-534-08466-4

Library of Congress Cataloging-in-Publication Data
Kalat, James W.
Biological psychology.

Bibliography: p.
Includes index.
1. Neuropsychology. 2. Psychobiology. I. Title.
[DNLM: 1. Neurophysiology. 2. Psychophysiology.
WL 103 K14b]
QP360.K33 1987 612'.8 87-23137
ISBN 0-534-08466-4

BIOLOGICAL PSYCHOLOGY

THIRD EDITION

To my parents, Edward and Rachael Kalat
and my in-laws, David and Sara Pickard

About the Author

James W. Kalat (rhymes with ballot), born in 1946, received an A.B. degree summa cum laude from Duke University in 1968 and a Ph.D. in psychology in 1971 from the University of Pennsylvania, where he worked with Paul Rozin. He was a faculty member at Duke University from 1971 to 1977 and has been at North Carolina State University since 1977. He is also the author of *Introduction to Psychology*, published by Wadsworth in 1986.

Preface

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

My primary goal in writing this text has been to engage the reader's interest. I have tried not to focus on biological mechanisms for their own sake but to concentrate on their relationship to some of the central phenomena of psychology—topics such as the mind-body problem, the evolution of behavior, the relationship of sleep to mood and work efficiency, eating disorders, alcoholism, language development, sexual behavior, psychosomatic illnesses, anxiety, aggressive behavior, amnesia, recovery from brain damage, depression, and schizophrenia. I hope that no reader who finishes the book will still be wondering what the study of the brain has to do with "real psychology."

In a field that progresses as rapidly as biological psychology has, no text can tell the reader everything that is important to know now, much less everything that will be important to know ten years from now. One important function of a text is to give the reader enough background to go to the library to read the latest professional books and journal articles. With that in mind, I have introduced a much expanded glossary, which includes a number of terms that a student might encounter in outside readings, even if the terms are not used in this text. I hope this will prove a useful reference source both during the course and afterward for many students.

The organization of the third edition is the same as the second, with these exceptions: (1) Chapter 1 has been extensively revised, with new sections on issues in the evolution of behavior and the ethics of animal experimentation. (2) The chapter on language and lateralization has been moved from Chapter 13 to Chapter 5. (3) The autonomic nervous system is now discussed in Chapter 4, and ulcers are discussed in the chapter on emotion. In the second edition, both were in Chapter 1.

The main change has been in bringing this text up-to-date. More than one-third of the references in this edition were published in the years 1983–1987. At least small revisions were made in almost every section, other than the Introduction. Two of the BioSketches are new. Many of the illustrations are new or revised, and color has been added throughout. New to this edition are two sections of full-color photos and illustrations.

Some of the new topics in this edition: ways a drug can affect synaptic transmission (Chapter 3), the relationship between brain size and body size (4), the history of prefrontal lobotomy (4), Geschwind's hypothesis on the

determination of handedness (5), the controversy on "blindsight" (7), biological rhythms and three kinds of insomnia (9), biological predispositions toward alcohol abuse (10), puberty (11), biological predisposition to panic disorder (12), reference memory and working memory (13), infant amnesia and old-age loss of memory (13), test batteries to evaluate human brain damage (14), sensory neglect and sensory extinction (14), viral hypotheses of depression and schizophrenia (15 and 16), altered sleep patterns as an antidepressant (15), seasonal affective disorder and light therapy (15), and prediction or early diagnosis of schizophrenia (16). Among topics that have been expanded in light of current research are Parkinson's disease and Huntington's disease (8), and tranquilizers and GABA synapses (12).

Each chapter starts with a list of main ideas. Key words appear in boldface the first time they are used and defined. Most chapters include one or more BioSketches of key investigators and one or more Digressions that introduce peripheral but interesting information. Each chapter concludes with a summary, review questions, thought questions that challenge the student to go beyond the text, terms to remember, and suggestions for further reading. The text concludes with the glossary and a thorough subject index and name index. A study guide is available at an additional charge. A manual is also available for instructors who adopt the text.

I have received a great deal of mail from readers of the second edition, both students and faculty. A number of the changes I made were in response to their questions and suggestions. I would like to thank two of those students for their especially helpful comments, William Barto from Seton Hall University and Richard DeWald from the University of Texas. Mr. DeWald provided particularly insightful suggestions for the vision chapter, which led to new ways of presenting lateral inhibition and visual fields.

I thank the reviewers who made extensive and most helpful suggestions based on the second edition or earlier drafts of the third edition: Herbert Alpern, University of Colorado, Boulder; Kent Berridge, University of Michigan; Harry Carlisle, University of California, Santa Barbara; Gaylord Ellison, University of California, Los Angeles; Michael Gardner, Los Angeles Valley College; Joel E. Grace, Mansfield University; Elaine M. Hull, State University of New York, Buffalo; Lynn Nadel, University of Arizona; Peter H. Platenius, Queen's University; Paul R. Sanberg, University of Cincinnati; Roc Walley, University of Alberta. Thanks in particular to Elaine Hull, who not only provided comments on this text but also wrote the study guide to accompany it. A great many colleagues kindly provided me with suggestions, manuscripts, illustration materials, and other help. Among them were Lewis R. Baxter Jr., Bernhardt Bogerts, Bruce Bridgeman, Douglas Chute, Richard Coss, Timothy Crow, Allan Geliebter, Patricia Goldman-Rakic, Laura Grimes, John Haig, Stephen Hobbs, John Hostetler, A. J. Hudspeth, J. G. MacFarlane, T. Nilsson, Sergio Pellis, Howard Poizner, Robert Provine, Joseph Rogers, Paul Sanberg, Evelyn Satinoff, Sue Savage-Rumbaugh, Susan Schiffman, Thomas Stonebraker, Barbara Szekely, Phillip Teitelbaum, Luigi Valzelli, Diana Woodruff-Pak, J. A. Yaryura-Tobias.

Thanks also to the staffs of the libraries at North Carolina State Univer-

sity and at the Marine Biological Laboratory of Woods Hole, Massachusetts, where I spent one summer.

In the production of this text I have had the extraordinary good fortune to work for a second time with Del Mar Associates. Nancy Sjoberg supervised all phases of the production in a manner that was prompt, efficient, and creative. Linda McVay, who rendered the airbrush artwork, converted my crudest sketches into attractive works of art. Jackie Estrada did an excellent and thorough job with the copyediting. Advice from these three led to other drawings that I hadn't even known I wanted until I saw them. Linda Rill selected the color photos. John Odam designed the cover and the color insert sections. I appreciate the good work from all of these people.

Ken King, my editor at Wadsworth, not only continues to be the best editor in the business, but keeps getting better. I thank him for his encouragement, advice, and friendship. I thank my wife, Ann, and my children, David, Sam, and Robin, for their patience, for their support, and for showing interest every time I wanted to talk about the latest bit of esoterica I had read.

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

Acknowledgments

Figure 1-1: Photo courtesy of the Cincinnati Zoo.

Figure 1-3: Redrawn from "Vom Wirkungsgefüge der Triebe" by E. von Holst and U. von St. Paul, in *Naturwissenschaften*, 1960, 47:409–422. Used by permission of Springer-Verlag.

Figures 1-4 and 1-5: From *Physical control of the mind* by José M. R. Delgado, 1969. Reprinted by permission of José Delgado. Photos provided by José Delgado.

Figures 1-7 and 1-8: Wide World Photos.

Biosketch 2-1: Photo from S. Ramon y Cajal (1960). *Studies on vertebrate neurogenesis*. Courtesy of Charles C Thomas, Publisher, Springfield, Illinois.

Figure 2-5(f): From R. G. Coss, *Brain Research*, 1982. Used by permission of R. G. Coss.

Figure 2-7: From "Spine stems on tectal interneurons in Jewel fish are shortened by social stimulation" by R. G. Coss and A. Globus, in *Science*, 1978, 200:787–790. Copyright 1978 by the American Association for the Advancement of Science. Reprinted by permission of R. G. Coss and AAAS.

Biosketch 3-1: Photo used by permission of Yale University Press.

Figure 3-6: Based on *An approach to neuroanatomical and neurochemical psychophysiology* by L. Valzelli, 1980, Tables 47–50. Used by permission of L. Valzelli.

Figure 3-9: Redrawn from "Autoimmune response to acetylcholine receptors in myasthenia gravis and its animal model" by J. Lindstrom, in H. G. Kunkel and F. J. Dixon (eds.), *Advances in Immunology*, 1979, 27:1–50. Used by permission of J. Lindstrom and Academic Press, Inc.

Biosketch 4-1: Photo and quote used by permission of Paul MacLean.

Figure 4-2: Adapted from H.J. Jerison (1985). Animal intelligence as encephalization. *Phylosophical Transactions of the Royal Society of London*, B, *308*, 21–35. Used by permission of The Royal Society and H.J. Jerison.

Figures 4-5, 4-16, 4-18, 4-20, 12-8, 13-6, 14-1, and 16-1: Photos courtesy of Dr. Dana Copeland.

Figures 4-14 and 6-7: After *Anatomie des Menschen, 3. Band: Periphere Liestungsbahnen II. Centrales Nervensystem, Sinnesorgane, 2. Auflage* by H. Braus, 1960. Used by permission of Springer-Verlag.

Figure 4-21: From *The anatomy of the nervous system* by S. W. Ranson and S. L. Clark, 1959. Reprinted by permission of W. B. Saunders Co.

Figure 4-23: After *The cerebral cortex of man* by W. Penfield and R. Rasmussen, 1950. Used by permission of Macmillan Publishing Co.

Figures 4-25, 4-28, and 6-21: Photos provided by James W. Kalat.

Figure 4-27: From *A stereotaxic atlas of the rat brain* by L. J. Pellegrino and A. J. Cushman, 1967. Reprinted by permission of Plenum Publishing Corp. and Louis Pellegrino.

Figure 4-29: From "Dendritic-tree anatomy codes form vision physiology in tadpole retina" by B. Pomeranz and S. H. Chung, in *Science*, 1970, 170:983–984. Copyright 1970 by the American Association for the Advancement of Science. Reprinted by permission of AAAS and B. Pomeranz. Photos provided courtesy of B. Pomeranz.

Biosketch 5-1: Photo used by permission of Roger Sperry. Sperry quote from a letter by Jerre Levy.

Biosketch 5-2: Photo and quote used by permission of Jerre Levy.

Biosketch 5-3: Photo used by permission of Norman Geschwind. Quote from "Disconnexion syndromes in animals and man" by N. Geschwind, in *Brain*, 1965, 88:237–294, 585–644. Reprinted by permission of Oxford University Press and N. Geschwind.

Figure 5-4: From "Human brain: Left-right asymmetries in temporal speech region" by N. Geschwind and W. Levitsky, in *Science*, 1968, 161:186–187. Copyright 1968 by the American Association for the Advancement of Science. Reprinted by permission of AAAS and N. Geschwind.

Figure 5-5: Redrawn from "Variations in writing posture and cerebral organization" by J. Levy and M. Reid, in *Science*, 1976, 194:337–339. Copyright 1976 by the American Association for the Advancement of Science. Used by permission of J. Levy.

Figure 5-6: Photo courtesy of Ann Premack.

Figure 5-7: Photo courtesy of Sue Savage-Rumbaugh.

Pages 136–138: Quote from tape recording by Nancy Kaplan, provided courtesy of the Duke University Department of Speech Pathology and Audiology.

Biosketch 6-1: Photo and quote used by permission of Susan Schiffman.

Biosketch 6-2: Photo used by permission of Candace Pert.

Figure 6-3(b): Courtesy of Dr. M. Gary Wickham.

Figure 6-9: By permission of A. J. Hudspeth. Photos courtesy of A. J. Hudspeth, R. Jacobs, P. Leake, and M. Miller.

Figure 6-13: After *Human information processing* by P. H. Lindsay and D. A. Norman, 1972. Used by permission of Academic Press and P. H. Lindsay.

Figure 6-18: After "A psychophysical model for gustatory quality" by S. S. Schiffman and R. P. Erickson, in *Physiology and Behavior*, 1971, 7:617–633. Used by permission of Pergamon Press, Inc., and S. S. Schiffman.

Figure 6-19: After "Sensory affect and motivation" by C. Pfaffmann, R. Norgren, and H. Grill, in *Annals of the New York Academy of Sciences*, 1977, 290:18–34. Used by permission of New York Academy of Sciences and Carl Pfaffmann.

Figure 6-20: From "Sensory neural patterns and gustation" by R. P. Erickson, in Y. Zotterman (ed.), *Olfaction and taste*, 1963. Used by permission of Pergamon Press Ltd. and Robert P. Erickson.

Biosketch 7-1: Photos used by permission of Colin Blakemore. Quote used by permission of David Hubel.

Figures 7-3 and 7-7: After "Organization of the primate retina" by J. E. Dowling and B. B. Boycott, in *Proceedings of the Royal Society of London*, B, 1966, 166:80–111. Used by permission of the Royal Society of London and John Dowling.

Figures 7-10 and 7-11: Based on "Receptive fields of single neurons in the cat's striate cortex" by D. H. Hubel and T. N. Wiesel, in *Journal of Physiology*, 1959, 148:574–591. Used by permission of the Journal of Physiology and David Hubel.

Figure 8-4: Reprinted with permission from *Physiology and Behavior*, 34, S. M. Pellis, Y. C. Chen, and P. Teitelbaum, Fractionation of the cataleptic bracing response in rats. Copyright 1985, Pergamon Journals, Ltd. Photo courtesy of P. Teitelbaum.

Figure 8-9: From *A physiological approach to clinical neurology* by J. W. Lance and J. G. McLeod, 1975. Photo courtesy of J. W. Lance.

Biosketch 9-1: Photo used by permission of Michel Jouvet.

Biosketch 9-2: Photo used by permission of William C. Dement.

Figure 9-1: From "Phase control of activity in a rodent" by P. J. DeCoursey, in *Cold Spring Harbor Symposia on Quantitative Biology*, 1960, 25:49–55. Used by permission of Cold Spring Harbor Laboratory and P. J. DeCoursey.

Figure 9-2: From *Sleep and wakefulness* by N. Kleitman, by permission of The University of Chicago Press and N. Kleitman. © 1963 by The University of Chicago. All rights reserved.

Figure 9-3: Photo by Jackie Estrada.

Figure 9-4: From "Deep hypothermia and its effect on the 24-hour clock of rats and hamsters" by C. P. Richter, in *Johns Hopkins Medical Journal*, 1975, 136:1–10. Copyright 1975 by The Johns Hopkins University Press. Used by permission. Photos provided courtesy of C. P. Richter.

Figure 9-7: Records provided by T. E. LeVere.

Figure 9-8: From "Cyclic variations in EEG during sleep and their relation to eye movements, body motility, and dreaming" by W. Dement and N. Kleitman, in *Electroencephalography and Clinical Neuropsychology*, 1957, 9:673–690. Reproduced by permission of Elsevier/North Holland Biomedical Press and W. C. Dement.

Figure 9-9: From "Ontogenesis of the states of sleep in rat, cat, and guinea pig during the first postnatal month" by D. Jouvet-Mounier, L. Astic, and D. Lacote, in *Developmental Psychobiology*, 1969, 2:216–239. Copyright © 1969 by John Wiley & Sons, Inc. Used by permission of John Wiley & Sons.

Biosketch 10-1: Photo from *The way of an investigator* by W. B. Cannon, 1945. Used by permission of Bradford Cannon.

Biosketch 10-2: Photo and quote used by permission of Edward Stricker.

Figure 10-6: From "The role of activation in the regulation of food intake" by D. L. Wolgin, J. Cytawa, and P. Teitelbaum, in D. Novin, W. Wyrwicka, and G. Bray (eds.), *Hunger: Basic mechanisms and clinical implications*, 1976. Copyright 1976 by Raven Press. Reprinted by permission of Raven Press. Photo provided courtesy of P. Teitelbaum.

Figure 10-8: Redrawn from H. Begleiter, Event-related brain potentials in boys at risk for alcoholism, *Science*, 225, September 28, 1984, pp. 1493–1496. Copyright 1984 by AAAS. Used by permission of AAAS and H. Begleiter.

Biosketch 11-1: Photo and quote used by permission of Frank Beach.

Figure 11-6: Redrawn from "Effects of gonadal hormones on urinary behavior in dogs" by F. A. Beach, in *Physiology and Behavior*, 1974, 12:1005–1013. Used by permission of Brain Research Publications, Inc., and F. A. Beach.

Figure 11-7: Redrawn from Figure 12, W. A. Marshall & J. M. Tanner (1986). In F. Falkner & J. M. Tanner (eds.), *Human growth*, 2nd ed., Vol 2, *Postnatal Growth, Neurobiology*, pp. 171–224. New York: Plenum Publishing Corporation. Reprinted by permission of the publisher.

Figure 11-8: From "Rise in female-initiated sexual activity at ovulation and its suppression by oral contraceptives" by D. B. Adams, A. R. Gold, and A. D. Burt, in *New England Journal of Medicine*, 1978, 299:1145–1150. Reprinted by permission, from *The New England Journal of Medicine*.

Figure 11-11: From "Sex-hormone-dependent brain differentiation and sexual functions" by G. Dörner, in G. Dörner (ed.), *Endocrinology of sex*. Copyright 1975 by Johann Ambrosius Barth. Reprinted by permission of Johann Ambrosius Barth.

Biosketch 12-1: Photo from *The Psychobiology of Curt Richter*, Elliott Blass (ed.), 1976. Used by permission of York Press, Inc., and Elliott Blass.

Biosketch 12-2: Photo and quote used by permission of Luigi Valzelli.

Digression 12-1: Photo courtesy of Jules Asher. From G. Kolata, "New Drug Counters Alcohol Intoxication," *Science*, Vol. 234, No. 4781, December 5, 1986, p. 1199. Copyright 1986 by AAAS. Used by permission of AAAS.

Figure 12-1: Courtesy of Raleigh, North Carolina, Police Department.

Figure 12-2: From "Avoidance behavior and the development of gastroduodenal ulcers" by J. V. Brady, R. W. Porter, D. G. Conrad, and J. W. Mason, in *Journal of the Experimental Analysis of Behavior*, 1958, 1:69–72. Copyright 1958 by the Society for the Experimental Analysis of Behavior, Inc. Reprinted by permission of the Society for the Experimental Analysis of Behavior and J. V. Brady.

Figure 12-3: Redrawn from "On the phenomenon of sudden death in animals and man" by C. P. Richter, in *Psychosomatic Medicine*, 1957, 19:191–198. Used by permission of the American Psychosomatic Society.

Figure 12-4: From "Neuronal constellations in aggressive behavior" by José Delgado, in L. Valzelli and L. Morgese (eds.), *Aggression and violence: A psycho/biological and clinical approach*, Edizioni Saint Vincent, 1981. Used by permission of José Delgado.

Figure 12-5: Based on *Brain mechanisms and behaviour* by J. R. Smythies, 1970. Used by permission of Blackwell Scientific Publications Ltd., Oxford, UK.

Figure 12-6: Based on "Psychosomatic disease and the 'visceral brain': Recent developments bearing on the Papez theory of emotion" by P. D. MacLean, in *Psychosomatic Medicine*, 1949, 11:338–353. Used by permission of the American Psychosomatic Society.

Figure 12-7: Redrawn from "Studies on limbic systems ('visceral brain') and their bearing on psychosomatic problems" by P. D. MacLean, in E. D. Wittkower and R. A. Cleghorn (eds.), *Recent developments in psychosomatic medicine*, 1954. Copyright Sir Isaac Pitman & Sons, Ltd. Used by permission of J. B. Lippincott Co. and Sir Isaac Pitman & Sons, Ltd.

Figure 12-9: From "Behavioral changes following rhinencephalic injury in cat" by L. Schreiner and A. Kling, in *Journal of Neurophysiology*, 1953, 16:643–659. Reprinted by permission of the American Physiological Society.

Figure 12-11: Based on Fig. 1, p. 140, of A. Guidotti, P. Ferrero, M. Fujimoto, R. M. Santi, & E. Costa (1986). Studies on endogenous ligands (endacoids) for the benzodiazepine/beta-carboline binding sites. *Advances in Biochemical Psychopharmacology, 41*, 137–148. With permission from Raven Press, New York.

Biosketch 13-1: Photo from *The neuropsychology of Lashley* by F. A. Beach, D. O. Hebb, C. T. Morgan, and H. W. Nissen (eds.), 1960. Reproduced by permission of McGraw-Hill Book Company, Inc.

Biosketch 13-2: Photo used by permission of John Garcia.

Biosketch 13-3: Photo and quote used by permission of Eric R. Kandel.

Digression 13-2: Based on "Learning of leg position by the ventral nerve cord in headless insects" by G. A. Horridge, in *Proceedings of the Royal Society of London*, B, 1962, 157:33–52. Used by permission of the Royal Society of London and G. A. Horridge.

Figure 13-3: Redrawn from "Neuronal mechanisms of habituation and dishabituation of the gill-withdrawal reflex in *Aplysia*" by V. Castellucci, H. Pinsker, I. Kupfermann, and E. R. Kandel, in *Science*, 1970, 167:1745–1748. Copyright 1970 by the American Association for the Advancement of Science. Used by permission of AAAS and V. Castellucci.

Figure 13-5: Adapted from Figure 1(b) in D. Alkon, Calcium-mediated reduction of ionic currents: A biophysical memory trace, *Science, 226*, November 30, 1984, pp. 1037–1045. Copyright 1984 by AAAS. Used by permission of AAAS and D. Alkon.

Figure 13-8: Copyright 1985 by the Society for Neuroscience. Photo courtesy of Dr. Joseph Rogers. Reprinted by permission of Dr. Joseph Rogers.

Biosketch 14-1: Photo courtesy of Patricia S. Goldman-Rakic.

Figure 14-5: Redrawn by permission from *The Annual Review of Neuroscience*, Volume 6, © 1983 by Annual Reviews, Inc..Used by permission of Annual Reviews, Inc. and Jon H. Kaas.

Figure 15-1: Redrawn from E. Janosik and J. Davies, *Psychiatric mental health nursing*, 1986, p. 173. Used by permission of Jones and Bartlett Publishers, Inc.

Figure 15-2: From "Hormones and rhythms in man and animals" by C. P. Richter, in G. Pincus (ed.), *Recent progress in hormone research* (vol. 13), 1957. Used by permission of Academic Press and C. P. Richter.

Figure 15-4: Reprinted by permission of L. R. Baxter Jr. Photo courtesy of L. R. Baxter Jr.

Figure 15-9: From "Differential effects of amphetamines on clinically relevant dog models of hyperkinesis and stereotypy: Relevance to Huntington's chorea" by S. A. Corson, E. O'L. Corson, V. Kirilcuk, J. Kirilcuk, W. Knopp, and L. E. Arnold, in A. Barbeau, T. N. Chase, and G. W. Paulson (eds.), *Advances in neurology, Vol. 1, Huntington's chorea, 1872–1972*, 1973. Copyright 1973 by Raven Press. Reprinted by permission of Raven Press and S. Corson. Photo provided courtesy of S. Corson.

Digression 16-1: Quote from "An interactional description of schizophrenia" by J. Haley, in *Psychiatry*, 1959, 22:321–332. Reprinted by permission of William Alanson White Psychiatric Foundation, Inc.

Figure 16-2: Photos courtesy of B. Bogerts.

Figure 16-3: Photos courtesy of Arnold Scheibel.

Figure 16-4: From "Possible etiology of schizophrenia: Progressive damage to the noradrenergic reward system by 6-hydroxydopamine" by L. Stein and C. D. Wise, in *Science*, 1971, 171:1032–1036. Copyright 1971 by the American Association for the Advancement of Science. Used by permission of AAAS and L. Stein. Photos provided courtesy of L. Stein.

Figure 16-6: From P. Seeman, T. Lee, M. Chau-Wong, and K. Wong, Antipsychotic drug doses and neuroleptic/dopamine receptors," *Nature*, 261, (1976), 717-719. Copyright © 1976 Macmillan Magazines Limited. Reprinted by permission of *Nature* and Philip Seeman.

Color Plates

1, 7, 8, and 9: Dan McCoy/Rainbow

3 and 6: Robert B. Livingston, University of California, San Diego

4: Adapted with the permission of the publisher W. H. Freeman and Company from *Brain, Mind and Behavior* by Floyd E. Bloom et al. Copyright © 1985 Educational Broadcasting Company.

10, 11, and 14: Manfred Kage/Peter Arnold, Inc.

12: D. D. Kunkel, University of Washington/Biological Photo Service

13: Fritz Goro

15: McCoy/Scheilbel/Rainbow

16: J. F. McGinty/Peter Arnold, Inc.

17: SIU/Peter Arnold, Inc.

18, 19, and 22: Ed Reschke/Peter Arnold, Inc.

23: Courtesy of L. R. Baxter Jr.

24: Courtesy of Michael E. Phelps and John C. Mazziotta, University of California, Los Angeles, School of Medicine

25: Burt Glinn/Magnum Photos

26: Karen Berman and Daniel Weinberger, National Institute of Mental Health

27: © Tom McHugh/Photo Researchers

28: P. J. Bryant, University of California, Irvine/Biological Photo Service

Contents

The Global Issues of Biological Psychology

CHAPTER 1

MAIN IDEAS

1. Biological psychologists seek to explain behavior in terms of both its physiology and its evolution.

2. Mind and brain are closely related, but we do not know the exact nature of their relationship or what mind really is. Both philosophers and scientists would like to know whether minds could exist independently of brains, whether brains could function equally well if they did not give rise to minds, and what it is about the activity of the brain that is responsible for the mind.

3. Direct electrical stimulation of the brain can induce behavioral changes and subjective experiences. Studies of electrical stimulation of the brain provide strong evidence that the brain is responsible for mental activity.

4. Anything that is characteristic of a species, including a characteristic behavior, is presumed to be an outcome of evolution. In some cases, such as altruistic behavior, it is difficult to imagine how evolution might have favored the behavior.

5. Many experiments in biological psychology use animal subjects. Some of those experiments inflict pain or distress. The ethics of such experiments has become controversial.

It is often said that Man is unique among animals. It is worth looking at this term "unique" before we discuss our subject proper. The word may in this context have two slightly different meanings. It may mean: Man is strikingly different—he is not identical with any animal. This is of course true. It is true also of all other animals: Each species, even each individual is unique in this sense. But the term is also often used in a more absolute sense: Man is so different, so "essentially" different (whatever that means) that the gap between him and animals cannot possibly be bridged—he is something altogether new. Used in this absolute sense the term is scientifically meaningless. Its use also reveals and may reinforce conceit, and it leads to complacency and defeatism because it assumes that it will be futile even to search for animal roots. It is prejudging the issue.

——Niko Tinbergen (1973)

Human beings are part of nature. Although much sets us apart from other animal species, we have much in common with other species, too. To understand who we are, we need to understand our relationship to the rest of the animal kingdom.

To understand the nature of our experiences, our "minds" if you wish, we need to understand the physical structure that is responsible for them. Our experience, our behavior, our sense of personal identity—all are products of the brain. Biological psychology is an attempt to understand how the brain generates those products.

Biological psychology—also known as physiological psychology, behavioral neuroscience, psychobiology, and biopsychology—deals with a number of important practical questions: Can biological measurements determine which people are most likely to develop alcoholism, depression, schizophrenia, or impulsive violent behavior? How may such disorders as insomnia, hyperactivity, and anxiety attacks be prevented? How do tranquilizers, antidepressant drugs, and other medical treatments for psychological disorders work? Is it possible to promote behavioral recovery after brain damage?

In addition to the practical questions, biological psychologists deal with broad philosophical issues: What is the relationship between the mind and the brain? Could a mind exist independently of a brain? If not, then what is it about the physical structure and functioning of the brain that gives rise to the mind?

How does heredity influence behavior? Our capacity for behavior is a product of our evolutionary history. But did that evolutionary history leave us with genes that *force* us to think and act in certain ways? Or did it leave us with genes that merely make it easier for us to develop certain behaviors over others? Or did it leave us with genes that are completely adaptable to the influences of the environment, such that our thinking and behavior are entirely a product of the way we were brought up?

And what about our sense of personal identity? Each of us has a feeling

that "I am a single individual." Yet we know that the brain is composed of billions of cells that communicate with one another by paths that are sometimes long and indirect. Under certain circumstances, one part of the brain may fail to communicate with another part of the brain. How, then, does our sense of personal identity arise? And is it an illusion?

Biological psychologists do not have firm answers to any of these questions, but most of them are motivated by curiosity about such questions. Although our scientific investigations may not directly answer the great philosophical questions, they may improve the quality of our speculations.

In this chapter, we shall deal with the global issues of biological psychology. First we shall consider examples of biological explanations of behavior and the philosophical issues related to such explanations. Then we turn to issues concerning evolutionary explanations of behavior. Finally we deal with the ethical issues related to experimentation on animals. In later chapters we shall turn away from these global issues and develop a number of biological explanations in more detail.

BIOLOGICAL EXPLANATIONS OF BEHAVIOR

Throughout this book we shall be trying to explain behavior and experience in biological terms. Biological explanations fall into two major categories: physiological, and genetic-evolutionary. A **physiological explanation** deals with the underlying machinery: What physical processes cause this to happen? A genetic or **evolutionary explanation** deals with the genetic blueprints that led to the physiology: What genes caused the individual to develop this way, and how did that pattern of genes come about? In some cases we deal with only one of those categories of explanation; in other cases we are able to deal with both.

An Example: The Escape Flight of Certain Moths

Let us first consider the example of a moth flying away from a bat. We can ask what machinery causes the moth to do what it does (a physiological question) and why the machinery works the way it does (an evolutionary question). Most of this book will concentrate on vertebrates—humans when possible—but this example of the moth has the advantage that the mechanisms of behavior are understood in considerable detail.

An important problem faced by night-flying moths in many parts of the world is to avoid being eaten by bats. Bats hunt insects at night quite efficiently, sometimes catching ten to twenty per minute (Griffin, Webster, & Michael, 1960). For catching small flying insects at night, the sense of smell is practically useless. Vision would also be useless, even if bats' eyes were much better developed than they actually are. For catching insects, bats have evolved a specialized ability to locate them from echoes, using a well-developed sense of hearing.

A bat produces short bursts of high-pitched sounds, 20,000 to 100,000 Hz (hertz, or cycles per second), and then localizes nearby insects from the echoes. These sounds are mostly above the range of human hearing. Most adults cannot hear pitches as high as 20,000 Hz, although some children can hear pitches as high as 40,000 Hz.