**SPRINGER HANDBOOK OF
AUDITORY RESEARCH**

Series Editors: Richard R. Fay and Arthur N. Popper

SPRINGER HANDBOOK OF AUDITORY RESEARCH

Volume 1: The Mammalian Auditory Pathway: Neuroanatomy

Edited by Douglas B. Webster, Arthur N. Popper, and Richard R. Fay

Volume 2: The Mammalian Auditory Pathway: Neurophysiology

Edited by Arthur N. Popper and Richard R. Fay

Volume 3: Human Psychophysics

Edited by William Yost, Arthur N. Popper, and Richard R. Fay

Volume 4: Comparative Hearing: Mammals

Edited by Richard R. Fay and Arthur N. Popper

Volume 5: Hearing by Bats

Edited by Arthur N. Popper and Richard R. Fay

Volume 6: Auditory Computation

Edited by Harold L. Hawkins, Teresa A. McMullen, Arthur N. Popper, and Richard R. Fay

Volume 7: Clinical Aspects of Hearing

Edited by Thomas R. Van De Water, Arthur N. Popper, and Richard R. Fay

Volume 8: The Cochlea

Edited by Peter Dallos, Arthur N. Popper, and Richard R. Fay

Volume 9: Development of the Auditory System

Edited by Edwin W. Rubel, Arthur N. Popper, and Richard R. Fay

Volume 10: Comparative Hearing: Insects

Edited by Ronald Hoy, Arthur N. Popper, and Richard R. Fay

Volume 11: Comparative Hearing: Fish and Amphibians

Edited by Richard R. Fay and Arthur N. Popper

Volume 12: Hearing by Whales and Dolphins

Edited by Whitlow W.L. Au, Arthur N. Popper, and Richard R. Fay

Volume 13: Comparative Hearing: Birds and Reptiles

Edited by Robert Dooling, Arthur N. Popper, and Richard R. Fay

Volume 14: Genetics and Auditory Disorders

Edited by Bronya J.B. Keats, Arthur N. Popper, and Richard R. Fay

Volume 15: Integrative Functions in the Mammalian Auditory Pathway

Edited by Donata Oertel, Richard R. Fay, and Arthur N. Popper

Volume 16: Acoustic Communication

Edited by Andrea Simmons, Arthur N. Popper, and Richard R. Fay

Volume 17: Compression: From Cochlea to Cochlear Implants

Edited by Sid P. Bacon, Richard R. Fay, and Arthur N. Popper

Volume 18: Speech Processing in the Auditory System

Edited by Steven Greenberg, William Ainsworth, Arthur N. Popper, and Richard R. Fay

Volume 19: The Vestibular System

Edited by Stephen M. Highstein, Richard R. Fay, and Arthur N. Popper

Volume 20: Cochlear Implants: Auditory Prostheses and Electric Hearing

Edited by Fan-Gang Zeng, Arthur N. Popper, and Richard R. Fay

Volume 21: Plasticity of the Auditory System

Edited by Thomas N. Parks, Edwin W. Rubel, and Richard N. Popper

Thomas N. Parks
Edwin W Rubel
Arthur N. Popper
Richard R. Fay
Editors

Plasticity of the Auditory System

With 48 Illustrations

Springer

Thomas N. Parks
Department of Neurobiology &
Anatomy
University of Utah School of Medicine
Salt Lake City, UT 84132-3401
USA
Tom.Parks@neuro.utah.edu

Edwin W Rubel
Virginia Merrill Bloedel Hearing Research Center
and
Department of Otolaryngology–Head and Neck
Surgery
University of Washington
Seattle, WA 98195
rubel@u.washington.edu

Arthur N. Popper
Department of Biology and
Neuroscience and Cognitive Science
Program
University of Maryland
College Park, MD 20742-4415, USA
apopper@umd.edu

Richard R. Fay
Department of Psychology and Parnly Hearing
Institute
Loyola University of Chicago
Chicago, IL 60626, USA
rfay@wpo.it.luc.edu

Series Editors: Richard R. Fay and Arthur N. Popper

Cover illustration: Modified from Figure 2.2, page 27 from Garden GA, Canady KS, Lurie DI, Bothwell M, Rubel EW (1994) A biphasic change in ribosomal conformation during transneuronal degeneration is altered by inhibition of mitochondrial, but not cytoplasmic protein synthesis. *J Neurosci* 14:1994–2008.

Library of Congress Cataloging-in-Publication Data
Parks, Thomas N.

Plasticity of the auditory system / Thomas N. Parks, Edwin W. Rubel, Arthur N. Popper.
p. cm.—(Springer handbook of auditory research ; v. 23)
Includes bibliographical references and index.

1. Audiometry. 2. Auditory pathways. 3. Plasticity. 4. Hearing. I. Rubel, Edwin W. II.
Popper, Arthur N. III. Title. IV. Series.
RF291.P37 2004
617.8'075—dc22

2004041730

ISBN 978-1-4419-1932-8
DOI 10.1007/978-1-4757-4219-0

ISBN 978-1-4757-4219-0 (eBook)

Printed on acid-free paper.

© 2004 Springer Science+Business Media New York
Originally published by Springer Science + Business Media Inc. in 2004

All rights reserved. This work may not be translated or copied in whole or in part without the written permission of the publisher (Springer Science+Business Media, LLC), except for brief excerpts in connection with reviews or scholarly analysis. Use in connection with any form of information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed is forbidden.
The use in this publication of trade names, trademarks, service marks, and similar terms, even if they are not identified as such, is not to be taken as an expression of opinion as to whether or not they are subject to proprietary rights.

9 8 7 6 5 4 3 2 1

SPIN 10940556

www.springer-ny.com

springeronline.com

Series Preface

The *Springer Handbook of Auditory Research* presents a series of comprehensive and synthetic reviews of the fundamental topics in modern auditory research. The volumes are aimed at all individuals with interests in hearing research including advanced graduate students, postdoctoral researchers, and clinical investigators. The volumes are intended to introduce new investigators to important aspects of hearing science and to help established investigators to better understand the fundamental theories and data in fields of hearing that they may not normally follow closely.

Each volume presents a particular topic comprehensively, and each serves as a synthetic overview and guide to the literature. As such, the chapters present neither exhaustive data reviews nor original research that has not yet appeared in peer-reviewed journals. The volumes focus on topics that have developed a solid data and conceptual foundation rather than on those for which a literature is only beginning to develop. New research areas will be covered on a timely basis in the series as they begin to mature.

Each volume in the series consists of a few substantial chapters on a particular topic. In some cases, the topics will be ones of traditional interest for which there is a substantial body of data and theory, such as auditory neuroanatomy (Vol. 1) and neurophysiology (Vol. 2). Other volumes in the series deal with topics that have begun to mature more recently, such as development, plasticity, and computational models of neural processing. In many cases, the series editors are joined by a co-editor having special expertise in the topic of the volume.

RICHARD R. FAY, Chicago, Illinois
ARTHUR N. POPPER, College Park, Maryland

Volume Preface

Basic science studies of the auditory system have provided neuroscience with some of its most instructive examples of highly specialized functions arising from unique structures. Working out the developmental mechanisms by which these structures and functions arise continues to provide information of great value to general developmental biology as well as increases our understanding of how the many complex elements coalesce during normal development to form a functional auditory system. Such an understanding of the developing auditory system could potentially impact the optimization of treatment of developmental hearing losses in humans during the first years of life when the auditory system is most plastic, and thus serve in the mitigation of hearing problems in the large numbers of people who experience significant hearing loss.

The chapters in this volume provide a unique understanding of the development and plasticity of the auditory system. In Chapter 1, Parks and Rubel provide an overview of the rest of the volume, as well as discuss the meaning and use of the concept of plasticity. Rubel, Parks, and Zirpel (Chapter 2) focus on development of the cochlear nucleus (CN), among the best understood of the central nervous system (CNS) auditory centers. In reviewing the extensive research literature on normal development of the mammalian superior olivary complex (SOC), Friauf (Chapter 3) notes how many key events occur prior to the onset of hearing: neurogenesis, cell migration, axon and dendrite outgrowth, target selection, and synaptogenesis. Moore and King (Chapter 4) note that adjustments in binaural hearing are probably involved in the natural response to growth-related changes in head size and other natural changes in interaural cues, as well as disease- and injury-induced hearing asymmetries. Although studying plasticity in the auditory cortex is important, it is particularly difficult, for reasons Weinberger considers in Chapter 5. Analysis of auditory neuron function in awake behaving organisms has yielded some of its most impressive results in the study of birdsong. As Brenowitz and Woolley (Chapter 6) discuss, the study of neural plasticity in birdsong has also led neuroscience to recognize the existence of ongoing generation and replacement of projection neurons in the endotherm brain and hormonally induced seasonal changes in the morphology, pharmacology, and physiology of CNS neurons. Finally, Lakes-Harlan

(Chapter 7) approaches plasticity in the insect auditory system by considering four contexts in which it occurs.

As is often the case with chapters in the volumes in the Springer Handbook of Auditory Research, related chapters are often found in other volumes. The structure and function of the CNS discussed in most of the chapters in this volume are considered in great depth for mammals in Vol. 15 (*Integrative Functions in the Mammalian Auditory Pathway*). Related chapters in hearing in birds can be found in Vol. 13 (*Comparative Hearing: Birds and Reptiles*) and on insects in Vol. 10 (*Comparative Hearing: Insects*). Most extensively, issues on development of the auditory system are also found in Vol. 9, which can almost be considered as a companion to this one, *Development of the Auditory System*, and especially in chapters by Sanes and Walsh on development of central auditory processing and Cant on structural development of the central auditory pathways in mammals.

THOMAS N. PARKS, Salt Lake City, Utah
EDWIN W RUBEL, Seattle, Washington
RICHARD R. FAY, Chicago, Illinois
ARTHUR N. POPPER, College Park, Maryland

Contents

Series Preface	v
Volume Preface	vii
Contributors	xi
 Chapter 1 Overview: Development and Plasticity of the Central Auditory System	 1
THOMAS N. PARKS AND EDWIN W RUBEL	
 Chapter 2 Assembling, Connecting, and Maintaining the Cochlear Nucleus	 8
EDWIN W RUBEL, THOMAS N. PARKS, AND LANCE ZIRPEL	
 Chapter 3 Developmental Changes and Cellular Plasticity in the Superior Olivary Complex	 49
ECKHARD FRIAUF	
 Chapter 4 Plasticity of Binaural Systems	 96
DAVID R. MOORE AND ANDREW J. KING	
 Chapter 5 Experience-Dependent Response Plasticity in the Auditory Cortex: Issues, Characteristics, Mechanisms, and Functions	 173
NORMAN M. WEINBERGER	
 Chapter 6 The Avian Song Control System: A Model for Understanding Changes in Neural Structure and Function	 228
ELIOT A. BRENOWITZ AND SARAH M.N. WOOLLEY	

x Contents

Chapter 7 Plasticity in the Auditory System of Insects	285
REINHARD LAKES-HARLAN	

Index	313
-----------------	-----

Contributors

ELIOT A. BRENOWITZ

Departments of Psychology and Biology and Virginia Merrill Bloedel Hearing Research Center, University of Washington, Seattle, WA 98195-1525, USA

ECKHARD FRIAUF

Abteilung Tierphysiologie, Fachbereich Biologie, Universität Kaiserslautern, D-67653 Kaiserslautern, Germany

ANDREW J. KING

University Laboratory of Physiology, Parks Road, Oxford OX1 3PT, UK

REINHARD LAKES-HARLAN

Georg-August Universität Göttingen, Institut für Zoologie und Anthropologie, 37073 Göttingen, Germany

DAVID R. MOORE¹

MRC Institute of Hearing Research, University Park, Nottingham NG7 2RD, UK

THOMAS N. PARKS

Department of Neurobiology & Anatomy, University of Utah School of Medicine, Salt Lake City, UT 84132-3401, USA

EDWIN W. RUBEL

Virginia Merrill Bloedel Hearing Research Center and Department of Otolaryngology–Head and Neck Surgery, University of Washington, Seattle, WA 98195, USA

NORMAN M. WEINBERGER

Center for the Neurobiology of Learning and Memory and Department of Neurobiology & Behavior, University of California, Irvine, CA 92697, USA

¹Former address: University Laboratory of Physiology, Parks Road, Oxford OX1 3PT, UK

SARAH M.N. WOOLLEY

Department of Psychology, University of California, Berkeley, CA 94720, USA

LANCE ZIRPEL

Department of Neuroscience, University of Minnesota Medical School, Minneapolis, MN 55455, USA