

Fundamentals of Neurophysiology

SPRINGER
STUDY
EDITION

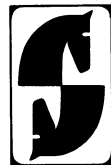
Fundamentals of Neurophysiology

edited by
Robert F. Schmidt

with contributions by
Josef Dudel
Wilfrid Jänig
Robert F. Schmidt
Manfred Zimmermann

translated by
M. A. Biederman-Thorson

Second Edition
revised and enlarged



Springer Science+Business Media, LLC

Robert F. Schmidt
Physiologisches Institut der Universität Kiel
Olshausenstrasse 40/60
2300 Kiel
Federal Republic of Germany

Josef Dudel
Physiologisches Institut der Technischen
Universität München
Biedersteiner Str. 29
8000 München 40
Federal Republic of Germany

Wilfrid Jänig
Physiologisches Institut der Universität Kiel
Olshausenstrasse 40/60
2300 Kiel
Federal Republic of Germany

Manfred Zimmermann
II. Physiologisches Institut der Universität Heidelberg
Im Neuenheimer Feld 326
6900 Heidelberg
Federal Republic of Germany

Library of Congress Cataloging in Publication Data

Schmidt, Robert F.

Fundamentals of neurophysiology.

Translation of Grundriss der Neurophysiologie.

Bibliography: p.

Includes index.

1. Neurophysiology. I. Dudel, Josef. II. Title.

[DNLM: 1. Neurophysiology. WL102.4 G889]

QP361.S3213 1978 612'.8 78-1437

All rights reserved.

No part of this book may be translated or reproduced in any form without written permission from Springer-Verlag Berlin Heidelberg GmbH.

© 1978 by Springer Science+Business Media New York

Originally published by Springer-Verlag New York Heidelberg Berlin in 1978

9 8 7 6 5 4 3

ISBN 978-3-540-08188-3 ISBN 978-3-662-01154-6 (eBook)

DOI 10.1007/978-3-662-01154-6

PREFACE

Although just two years have passed since the first English edition of this book, advances in neurophysiology have dictated considerable revision of most of the chapters. The chapters on synaptic transmission, motor systems, and the autonomic nervous system, for example, have been revised, extended, and in some parts entirely rewritten.

In response to a frequently expressed wish, a chapter on the integrative functions of the nervous system has been added. Here the use of the term “integrative functions” expresses our lack of a better general term covering such diverse activities and states of the nervous system as waking, sleeping, dreaming, consciousness, speech, learning, and memory. This chapter also includes an introduction to the physiology of the cerebral cortex and the characteristics of the electroencephalogram.

Another new section is a chapter on the control-systems aspects of central nervous activity, a reflection of the fact that many processes, particularly those involving motor activity and the autonomic nervous system, can best be described and analyzed in terms of control theory. The previous Chapter 7, *Sensory Systems*, has been largely included in another volume, “*Fundamentals of Sensory Physiology*.”

Finally—again at the suggestion of readers—a bibliography has been added to guide the student further into the topics of the individual chapters. Most of the references are recent; they offer access to the current original literature.

As previously, the book is designed to show both the established background and the most important new results in the field of brain research. The level chosen is one that can be absorbed in a reasonable time by students of physiology, whatever their major field—medicine, psychology, zoology, biology, pharmacology, or other natural sciences involved peripherally in physiology. No prior knowledge of anatomy or physiology is assumed; as each term is introduced it is defined and

explained. Anyone studying at the university level ought to have no difficulty in comprehending the contents of the book. In conjunction with "Fundamentals of Sensory Physiology," which appears as a volume of the same series, the text provides an extensive introduction to the physiology of the nervous system. In particular, we hope the approach is not limited to well-established facts, but touches as well on the questions and challenges of brain research that remain open.

The text questions at the end of each section have been retained and revised as necessary. The illustrations, as in the previous edition, consist almost entirely of schematic diagrams. We are particularly grateful to Mr. L. H. Schnellbacher, who was responsible for designing the finished drawings from the authors' sketches.

On behalf of all the authors, I again have the pleasure of extending thanks to all those who helped bring this edition into being. Special thanks are due to Dr. Marguerite Biederman-Thorson of Oxford, England, for her excellent translation, and to the publishers, both in Heidelberg and New York, for their unfailing courtesy and for their extraordinary efficiency.

Galveston, Texas

Robert F. Schmidt

CONTENTS

1	The Structure of the Nervous System	1
	<i>(R. F. Schmidt)</i>	
1.1	The Nerve Cells	1
1.2	Supporting and Nutritive Tissue	5
1.3	The Nerves	8
1.4	The Structure of the Spinal Cord	12
2	Excitation of Nerve and Muscle	19
	<i>(J. Dudel)</i>	
2.1	Resting Potential	19
2.2	Resting Potential and Na ⁺ Influx	28
2.3	The Sodium Pump	32
2.4	The Action Potential	38
2.5	Kinetics of Excitation	44
2.6	Electrotonus and Stimulus	54
2.7	Propagation of the Action Potential	62
3	Synaptic Transmission	72
	<i>(R. F. Schmidt)</i>	
3.1	The Neuromuscular Junction: Example of a Chemical Synapse	73
3.2	The Quantal Nature of Chemical Transmission	84
3.3	Central Excitatory Synapses	88
3.4	Central Inhibitory Synapses	94
3.5	The Transmitter Substances at Chemical Synapses	103
4	The Physiology of Small Groups of Neurons; Reflexes	106
	<i>(R. F. Schmidt)</i>	
4.1	Typical Neuronal Circuits	106
4.2	The Monosynaptic Reflex Arc	116
4.3	Polysynaptic Motor Reflexes	124

5	Muscles (<i>J. Dudel</i>)	129
5.1	Contraction of the Muscle	129
5.2	Dependence of Muscle Contraction on Fiber Length, and Velocity of Contraction	138
5.3	Electromechanical Coupling	146
5.4	Regulation of Muscle Contraction	153
6	Motor Systems (<i>R. F. Schmidt</i>)	158
6.1	Spinal Motor Systems I: Roles of Muscle Spindles and Tendon Organs	159
6.2	Spinal Motor Systems II: Polysynaptic Motor Reflexes; the Flexor Reflex	168
6.3	Functional Anatomy of Supraspinal Motor Centers	175
6.4	Reflex Control of the Posture of the Body in Space	186
6.5	Functions of the Basal Ganglia, Cerebellum and Motor Cortex	195
7	Regulatory Functions of the Nervous System, as Exemplified by the Spinal Motor System (<i>M. Zimmermann</i>)	205
7.1	The Stretch Reflex as a Length-Control System	206
7.2	Static and Dynamic Properties of Control Systems	211
8	The Autonomic Nervous System (<i>W. Jänig</i>)	220
8.1	Functional Anatomy of the Peripheral Autonomic Nervous System and of its Spinal Reflex Centers	220
8.2	Smooth Muscle: Myogenic Activity and Responses to Stretching, Acetylcholine, and Adrenalin	227
8.3	The Antagonistic Effects of Sympathetic and Parasympathetic Activity on the Autonomic Effectors	234
8.4	Central Nervous Regulation of the Autonomic Effectors, by Spinal Cord and Brainstem	240
8.5	The Hypothalamus. The Regulation of Body Temperature, Osmolarity of the Extracellular Space, and the Endocrine Glands	250
8.6	Integrative Functions of the Hypothalamus. Limbic System	260

9 Integrative Functions of the Central Nervous System (<i>R. F. Schmidt</i>)	268
9.1 Structure and General Physiology of the Cerebral Cortex; the Electroencephalogram	269
9.2 Waking, Sleeping, Dreaming	280
9.3 Consciousness and Speech: Structural and Functional Prerequisites	290
9.4 Learning and Memory	300
9.5 The Frontal Lobes	305
10 Suggested Readings	309
11 Answer Key	314
Index	317