Contents

Preface IX

New Concepts of the Motor Unit

KUGELBERG, E.: Properties of the Rat Hind-Limb Motor Units 2
BRANDSTATER, M. E. and LAMBERT, E. H.: Motor Unit Anatomy. Type and Spatial
Arrangement of Muscle Fibers 14
BUKKE, R. E.; TsAIRIS, P.; LEVINE, D. N.; ZAJAC III, F. E., and ENGEL, W. K.: Direct
Correlation of Physiological and Histochemical Characteristics in Motor
Units of Cat Triceps Surae Muscle 23
MAYER, R. F.: Observations on Motor Units in Cat Anterior Tibial Muscle . . 31
WARMOLRs, J. R. and ENGEL, W. K.: Correlation of Motor Unit Behavior with Histochemical
Myofiber Type in Humans by Open-Biopsy Electromyography . . 35
SANTA, T. and ENGEL, A. G.: Histometric Analysis of Neuromuscular Junction
Ultrastructure in Rat Red, White and Intermediate Muscle Fibers 41
ILCOMAS, A. J.; S'cn, R. E. P., and CAMPBELL, M. J.: Numbers and Sizes of Human
Motor Units in Health and Disease 55
S'CA, R. E. P. and MCCOMAS, A. J.: Single Motor Unit Twitches in Man 64
ROSSELLE, N. and STEVENS, A.: Unexpected Incidence of Neurogenic Atrophy of
the Extensor Digitorum Brevis Muscle in Young Normal Adults 69
BUCHTHAL, F. ánd RosENFALCK, P.: On the Structure of Motor Units 71
Ioku, M. and JiiliAj, D.: Fast and Slow Motor Unit Activates in EMG 86
EKSTEDT, J. and STÅLBERG, E.: Single Fibre Electromyography for the Study of the
Microphysiology of the Human Muscle 89
STÅLBERG, E. and EKSTEDT, J.: Single Fibre EIG and Microphysiology of the Motor
Unit in Normal and Diseased Human Muscle 113
BoRENsrEIN, S. and DEsMEnr, J. E.: Electromyographycal Signs of Collateral Reinnervation
ENGEL, W. K. and WARMOLrs, J. R.: The Motor Unit (with colour plate I and II) 141

Contents VI

Campa, J. F. and Engel, W. K.: Histochemistry of Motoneurons Innervating Slow and Fast Motor Units (with colour plate III)178


Neuromuscular Disorders, Myasthenia, Muscular Dystrophy, Myotonia

Engel, A. G. and Santa, T.: Motor Endplate Fine Structure. Quantitative Analysis in Disorders of Neuromuscular Transmission and Prostigmine - Induced Alterations (with colour plate IV) 196

Elmqvist, D.: Neuromuscular Transmission Defects 229

Desmedt, J. E.: The Neuromuscular Disorder in Myasthenia Gravis. I. Electrical and Mechanical Responses to Nerve Stimulation in Hand Muscles 241

Desmedt, J. E.: The Neuromuscular Disorder in Myasthenia Gravis. II. Presynaptic Cholinergic Metabolism, Mysathenic-Like Syndromes and a Hypothesis 305

Daube, J. R. and Lambert, E. H.: Post-Activation Exhaustion in Rat Muscle 343

Borenstein, S. and Desmedt, J. E.: New Diagnostic Procedures in Myasthenia Gravis 350

Cherington, M.: Botulism: Electrophysiologic and Therapeutic Observations 375


Ludin, H. P.: Action Potentials of Normal and Dystrophic Human Muscle Fibres 400

Becker, P. E.: Generalized Non-dystrophic Myotonia. The Dominant (Thomsen) Type and the Recently Identified Recessive Type 407

Kuhn, E.: Myotonia. The Clinical Evidence 413

Bryant, S. H.: The Electrophysiology of Myotonia, with a Review of Congenital Myotonia of Goats 420

Lipicky, R. J. and Bryant, S. H.: A Biophysical Study of the Human Myotonias 451


Rudel, R. and Senges, J.: Experimental Myotonia 483


Electromyography in Biomechanical Studies
Introduction
Jonsson, B.: Electromyographic Kinesiology. Aims and Fields of Use. 498

Methods of Electromyographic Kinesiology
Basmajian, J. V.: Electrodes and Electrode Connectors 502
McLeod, W. D.: EMG Instrumentation in Biomechanical Studies: Amplifiers, Recorders and Integrators 511
Kadefors, R.: Myo-Electric Signal Processing as an Estimation Problem 519
Bouisset, S. and Maton, B.: Comparison between Surface and Intramuscular EMG during Voluntary Movement 533

Contents VII

Quantitative Electromyography
Bouisset, S.: EMG and Muscle Force in Normal Motor Activities 547
Komi, P. V.: Relationship between Muscle Tension, EMG and Velocity of Contraction under Concentric and Eccentric Work 596
Vredenbregt, J. and Rau, G.: Surface Electromyography in Relation to Force, Muscle Length and Endurance 607
Kadefors, R.; Petersen, I., and Broman, H.: Spectral Analysis of Events in the Electromyogram 628
Employment of Electromyographic Kinesiology
Broman, H.; Magnusson, R.; Petersen, I., and Ortengren, R.: Vocational Electromyography Methodology of Muscle Fatigue Studies 656
Joseph, J.: Sequential Contraction of Muscles Producing the Same Movement at a Joint 665
Moritz, U.; Svantesson, G., and Haffajee, D.: A Biomechanical Study of Muscle Torque as Affected by Motor Unit Activity, Length-Tension Relationship and Muscle Force Lever 675
Preface

This treatise presents a comprehensive and critical evaluation of the `state of the art' in the fast-growing discipline of electromyography, considered in the widest sense. Electromyography uses electrophysiological methods to investigate muscles, nerves, reflexes and motor systems in intact man, either normal or diseased. Rapid progress in the last three years has led to several reconsiderations of previously accepted views and to the appearance of new concepts, criteria, methods and/or procedures. The aim of the volumes is to present in a consistent manner these new developments and to clarify pending issues by putting together the various facets of the problems which are scattered in the literature of both the basic neurosciences and clinical medicine.

The world's foremost experts actively working in the field have been invited to write 170 chapters which review and evaluate in details the pertinent data, many of which are published here for the first time. Without trying to present exhaustive résumés of the earlier literature, the treatise emphasizes the hot areas of the discipline in an effort to rapidly disseminate the new data thereby promoting better efficiency and wider scope of electromyographic diagnostic procedures while serving as a catalyst for future interdisciplinary research.

The wealth of up-dated information thus assembled should provide suggestions and answers for virtually any question about the current topics of electromyography. The books will no doubt provide a useful reference source for those who wish to make full use of clinical neurophysiology in order to solve problems in neurology, physical medicine, revalidation, clinical pharmacology, physical education, psychiatry, orthopedic surgery, human factors studies, internal medicine and anesthesiology.

On the other hand, basic neuroscientists interested in the neurophysiology of normal man and primates will also find useful information about recent methods and results. Rapidity of publication of a treatise with so many chapters is a necessary condition for its full impact on the further development of the discipline but this can only be achieved through considerable efforts on the part of quite a few persons. Many authors of the chapters participated actively in September 1971 in the Fourth International Congress of
Electromyography in Brussels. The present publication represents considerably more than the congress proceedings but it would certainly not have been completed so rapidly with such a wide scope without the enthusiasm and dedication catalyzed by that successful congress. I am very grateful to all my colleagues who contributed so much to this venture, and I thank particularly Prof. EDWARD H. LAMBERT (Rochester, Minn.), Prof. BENGT JONSSON (Göteborg), Prof. ROGER W. GILLIATT (London), Dr. PETER J. Dnck (Rochester, Minn.), Dr. Rorni WILLisoN (London), Prof. Sir Joni ECCLES (Buffalo), Prof. KARL-ERIK HAGBARTH (Uppsala), Prof. ROBERT R. YOUNG (Boston), Prof. MAURICE HuGON (Marseille) and Dr. PAUL DELWAIDE (Liège) for their friendly advice in the planning of the books. I am also grateful to Miss GILLIAN DUNKLEY (London) who supervised the English and acted as editorial assistant.

JoHi E. DESMEDT, MD.

Editor's Note

To provide a comprehensive coverage of fast-growing areas in electromyography and to have it published rapidly represent two aims which are rather difficult to achieve simultaneously. On the one hand, the usual proceedings of international meetings can disseminate recent results but generally lack depth and perspective: their popularity seems to be declining in the context of the current publication explosion. On the other hand, the seasoned surveys of the handbook format can be helpful to take stock of well-established data but they may become inadequate and out-of-phase by the time they are published when the discipline is moving forward rapidly. It is not easy to preserve the strong points of either formula while eliminating their respective drawbacks, but this was nevertheless attempted here. The difficulties of such an enterprise increase with the number of different contributions to be assembled and with the speed imposed for the collection of manuscripts, the editing and the publishing tasks.

As far as possible, each topic has been dealt with in several chapters by different authors which provides access to recent unpublished results of several active research groups and also makes sure that the various facets of each problem are thoroughly discussed in relation to the various approaches. With careful editing this procedure can produce an updated presentation of recent data and concepts with, in fact, little undue duplication (see, for example, the sections on computer EMG analysis and on sphincter EMG in volume 2, or the section on blink reflexes and
on unloading reflexes in volume 3).
The symposia of the Brussels International Congress of Electromyography
(see appendix, vol. 3, p. 847) suggested for the books a

Editor's Note XII

general framework and the latter was elaborated subsequently. A number
of experts who could not attend the congress were invited to write
chapters. Authors were encouraged to extend the scope of their papers
and quite a few agreed to write several chapters in order to discuss critically
different problems they were actively studying. Quotations from the
literature emphasize publications of the last 3 years up to Fall 1972. A
number of chapters have been added to specifically discuss various
methods and procedures. For example, volume 3 opens up with a
discussion of the clinical criteria which can be recommended for the
selection of the patients with motor disorders who are submitted to
investigations of reflexes. The volume concludes with a report which is
based on recommendations of a number of experts and which describes
methods and pitfalls in the study of proprioceptive reflexes of the lower
limb in man.

In volume 3, all the references have been pooled in a single list at the
end in order to provide a convenient general bibliography. The procedure
appeared justified since this book fulfills a unique purpose and represents
the first comprehensive publication on the neurophysiology of reflexes in
normal man and in patients with motor disorders.