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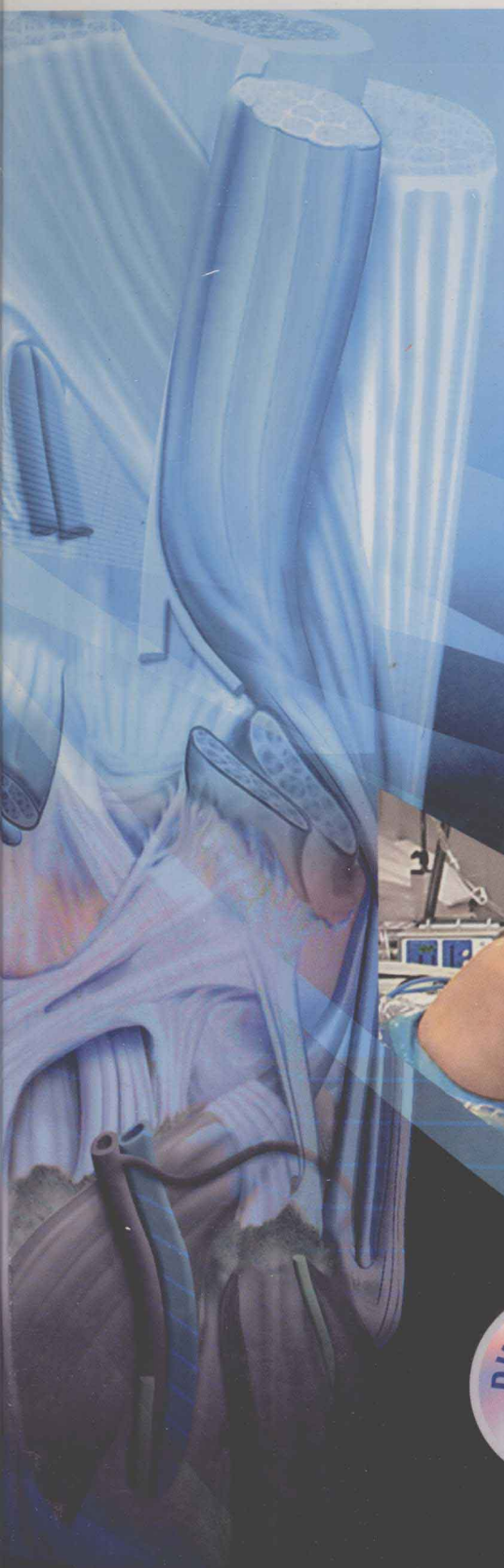
Knee Disorders

Surgery, Rehabilitation, Clinical Outcomes

Frank R. Noyes



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Noyes' Knee Disorders

Surgery, Rehabilitation, Clinical Outcomes

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NOYES' KNEE DISORDERS: SURGERY, REHABILITATION, CLINICAL OUTCOMES

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DEDICATION

To JoAnne, my loving and precious wife,
and to all our families.

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Preface

I am grateful to all of the contributors to this book on Knee Disorders, which is appropriately subtitled "Surgery, Rehabilitation, Clinical Outcomes." The chapters reflect the writings and teachings of the scientific and clinical disciplines required for the modern treatment of clinical afflictions of the knee joint. The goal of the writers of each chapter is to present rational evidence-based treatment programs based on published basic science and clinical outcomes to achieve the most optimal outcomes for our patients.

The "KEY" to understanding the different disorders of the knee joint encountered in clinical practice truly rests on a multiple disciplinarian approach and includes a comprehensive understanding of knee anatomy, biomechanics, kinematics, and biology of soft tissue healing. Restoration of knee function then requires a precise diagnosis of the functional abnormality of the involved knee structures, a surgical technique that is precise and successful, and a rehabilitation program directed by skilled professionals to restore function and avoid complications. Each chapter follows a concise outline of indications, contraindications, physical examination and diagnosis, step-by-step open and arthroscopic surgical procedures, clinical outcomes, and analysis of relevant published studies.

The first two chapters comprise an anatomic description of the structures of the knee joint. The photographs and illustrations represent the result of many cadaveric dissections to document knee anatomic structures. It was a pleasure to have four of our fellows (class of 2008-2009) involved in these dissections which resulted in two superb instructional anatomic videos that already have received awards and are included in the DVD. Numerous anatomic textbooks and publications were consulted during the course of these dissections to provide to the best of our ability accurate anatomic descriptions, realizing there is still ambiguity in the nomenclature used for certain knee structures. Special thanks to Joe Chovan who is a wonderful and highly talented professional medical illustrator. Joe attended anatomic dissections and worked hand-in-hand with us to produce the final anatomic illustrations. Joe and I held weekly to bi-monthly long working sessions for over two years that resulted in the anatomic and medical illustrations throughout this book that are unique, highly detailed, and believed to be anatomically accurate.

All surgeons appreciate that surgical procedures come and go, replaced by newer techniques that are more successful as techniques are discarded that may have proven inadequate by long-term clinical outcome studies. I am reminded that the basic knowledge of anatomy, biomechanics, kinematics, biology, statistics, and validated clinical outcome instruments always remain as our light-posts for patient treatment decisions. For this reason, there is ample space devoted in chapters to these scientific disciplines. Equally, the description of surgical techniques is presented in a step-by-step approach, with precise details by experienced surgeons on the critical points for each surgical technique to achieve a successful patient outcome. It is hoped that surgeons in training will appreciate the necessity for the basic science and anatomic approach that, combinaed with surgical and rehabilitation principles, is required to become a true "master of knee surgery and rehabilitation".

There is a special emphasis placed in each of the major book sections on rehabilitation principles and techniques including pre-operative assessment, postoperative protocols, and functional progression programs to restore lower limb function. We have published comprehensive rehabilitation protocols in this book that have been used and continually modified over many years which direct the postoperative treatment of our patients. My co-author on these sections, Tim Heckmann, is a superb physical therapist. We have worked together treating patients in a wonderful harmonious relationship for nearly 30 years. In addition, there are special programs for the female athlete to reduce the risk of an ACL injury. Sportsmetrics, a non-profit neuromuscular training and conditioning program developed at our Foundation, is one of the largest women's knee injury prevention programs in the United States and has been in existence for over 15 years. A number of scientists, therapists, athletic trainers, and physicians at our Foundation have been involved in the research efforts and publications of this program. All centers treating knee injuries in athletes are reminded of the importance of preventive neuromuscular and conditioning programs whose need has been well established by many published studies.

The entire staff at Cincinnati Sportsmedicine and Orthopaedic Center and the Foundation functions in a team effort, working together in various clinical, research, and rehabilitation programs. The concept of a team approach is given a lot of attention; and those who have visited our Center have seen the actual programs in place. This team effort is appreciated by all including patients, staff, surgeons, physical therapists, athletic trainers, administrative staff, and clinical research staff. Our administrative staff, directed by a superb clinical operations manager Linda Raterman, manages five major MD-PT-ATC orthopedic centers. As the President and CEO, I have been freed of many of the operational administrative duties because of this excellent staff, allowing time required for clinical and research

responsibilities. I have been blessed to be associated with a highly dedicated group of orthopedic partners who, besides providing excellent patient care and lively discussions at our academic meetings, have donated a defined income "tithing" every year for funding research and clinical education programs at our Foundation.

Nearly all of the patients treated at the Knee Institute are entered into prospective clinical studies by a dedicated clinical research group directed by Sue Barber-Westin and Cassie Fleckenstein. The staff meticulously tracks patients over many years to obtain in published studies a 90 to 100% follow-up. I invite you to read the forward of Sue Barber-Westin who has performed such an admirable and dedicated job in bringing our clinical outcome studies to publication. It is only through her efforts that we have been successful in large prospective clinical outcome studies. In each chapter, the results of these outcome studies are rigorously compared with other authors' publications. The research and educational staff work with fellows and students from many different disciplines including physicians, therapists, trainers and biomedical students. There have been 125 Orthopedic and Sportsmedicine Fellows who have received training at our Center. The scientific contribution of fellowship research projects are acknowledged numerous times in the chapters. Our staff enjoys the mentoring process and from a personal note, this has been one of my greatest professional joys.

In regard to mentoring, one might ask where the specialty of orthopedics (or any medical specialty) would be today without the professional mentoring "system" that trains new surgeons and advances our specialty, providing for a continuum of patient treatment approaches and advances. The informal dedication of the teacher to the student, often providing wisdom and guidance over many years, is actually contrary to capitalistic principles as the hours of dedication are rarely if ever compensated. It is the gift from one generation to another and I mention this specifically as I hope that I have been able to repay in part the mentors who provided this instruction and added time and interest for my career. I graduated from the University of Utah with a philosophy degree which provided an understanding of the writings and wisdom of the great scientists and "thinkers" of our times, taught by superb educators in premedical courses and philosophy. I received an M.D. degree from George Washington University and am thankful to the dedicated teachers who laid a solid medical foundation for their students and taught the serious dedication and obligation that physicians have in treating patients. I was fortunate to be accepted for internship and residency at the University of Michigan and remember the opportunity to be associated with truly outstanding clinicians and surgeons. Under the mentorship of the chairman William S. Smith, M.D., I and my fellow residents knew one of the finest orthopedic surgeons and dedicated teachers one could be associated with who was a truly humble man that inspired decades of orthopedic residents. Many graduates of this program have continued as orthopedic educators and researchers, which is a great tribute to Bill Smith and his mentorship. My fellow residents remember one of his many favorite sayings provided to remind residents of the need for humility. After a particularly enthusiastic lecture or presentation by a prominent surgeon and glowing statements of admiration, Bill Smith would say with a wink and smile, "He puts his pants on one leg at a time just like you do".

After orthopedic residency, I accepted a four-year combined clinical and research biomechanics position at the Aerospace Medical Research Laboratories with the United States Air Force in Dayton, Ohio. The facilities and veterinary support for biomechanical knee studies were unheralded and it was here that some of the first high strain-rate experiments on mechanical properties of knee ligaments were performed using the unique laboratory testing equipment available. I am indebted to Victor Frankel and Albert Burstein, the true fathers of biomechanics in the United States, as they guided me in these formative years of my career. I was particularly fortunate to have a close association with Al Burstein who mentored me in the discipline of orthopedic biomechanics. This research effort also included professors and students at the Air Force Institute of Technology. I am grateful to all of them for instructing me in the early years of my research training. As biomechanics was just in its infancy, it was obvious that substantive research was only possible with a combined MD-PhD team approach.

One of the most fortunate blessings in my professional life is the relationship I have had with Edward S. Grood, Ph.D. I established a close working relationship with Ed nd we currently have the longest MD-PhD (or PhD-MD) team that I know of which is still active today as we conduct the next round of knee ligament function studies using sophisticated three-dimensional robotic methodologies. We worked together in establishing one of the first Biomechanical and Bioengineering programs in the country at the University of Cincinnati College of Engineering, and I greatly appreciated that it was named the Noyes Biomechanics and Tissue Engineering Laboratory. This initial effort expanded with leadership and dedicated faculty and resulted in a separate Bioengineering Department within the College of Engineering with a complete program for undergraduate and graduate students. Dr. Grood pioneered this effort with other faculty and developed the educational curriculum for the five-year undergraduate program. Many students of this program have completed important research advances that are referenced in this book. David Butler, Ph.D. joined this effort in its early years and contributed important and unique research works that are also credited throughout the chapters. This collaborative effort of many scientists and physicians resulted in three Kappa Delta awards, the Orthopedic Research and Education Clinical Research award, AOSSM Research Awards, and the support of numerous grants from NIH, NSF, and other organizations. Thomas Andriacchi, Ph.D. collaborated on important clinical studies that provided an understanding of joint kinematics and gait abnormalities. It has been an honor to have Tom associated with our efforts throughout the years.

My finest mentors were my parents, a dedicated and loving father, Marion B. Noyes, M.D. who was a true renaissance surgeon entirely comfortable doing thoracic, general surgery, and orthopedics and who, as Chief Surgeon, trained decades of surgical residents. Early in my life, I read through classic Sobotta anatomic textbooks and orthopedic textbooks which remain in my library with his writings and notations along side. Later in my training, I was fortunate to scrub with him on surgical cases. My loving mother, a nurse by training, was truly God's gift to our family for many generations as she provided unqualified love and sage and expert advice to our entire family with knowledge, wisdom, and the admiration of all of us living into her nineties. She expected excellence, performance, and adherence to a rigorous value system. These are also the attributes of the most wonderful gift of all, the opportunity to go through life with a loving and true soul mate, my wife JoAnne Noyes that I remain eternally grateful and devoted. Our family includes a fabulous

daughter and son-in-law, two wonderful grandchildren, my devoted son who graduated in Physics and mentors me in nuclear and atomic matters outside my reach, and a third wonderful and dedicated son and daughter-in-law with three additional grand-children. Together, with JoAnne and all our brothers and sisters, we enjoy wonderful family events together. As I look back on my career, it is the closeness of family and friends that has provided the greatest enrichment.

In closing I wish to specially thank Kim Murphy, the Publishing Director of Elsevier and their staff who are true professionals and were a joy to work with in completing this textbook. Given all the decisions that must be made in bringing a textbook to publication, at the end of the process the Elsevier team made everything work in a harmonious manner always striving for the highest quality possible.

FRANK R. NOYES, MD

Preface

My interest in conducting clinical research stemmed from my experience of undergoing open knee surgery as a collegiate athlete 30 years ago. Although the operation was done in an expert manner, it was followed by inadequate rehabilitation and a poor outcome. Three years later, the experience was repeated except that the patient education process was markedly improved, as was the postoperative therapy program, which produced a successful result. The tremendous contrast between these experiences prompted a lifelong interest in helping patients who face the difficulty of dealing with knee problems. Having undergone arthroscopic surgery recently, I can personally attest to the incredible advances sports medicine has achieved in the past three decades. However, it is important to acknowledge that there is still much to learn and understand regarding the complex knee joint.

My initial experience with research involved collecting and analyzing data from a prospective randomized study on the effect of immediate knee motion after ACL allograft reconstruction with Dr. Noyes and our rehabilitation staff. The experience was remarkable for the time Dr. Noyes spent mentoring me on all aspects of clinical studies, including critical analysis of the literature, correct study design, basis statistics, and manuscript writing. The scientific methodology adopted by Drs. Noyes and Grood, along with our center's philosophy of the physician-rehabilitation team approach, provided an extraordinary opportunity to learn and work with those on the forefront of orthopaedics and sports medicine. My second major project, used as the thesis for my undergraduate work, involved the analysis of functional hop testing. Dr. Noyes and our statistical consultant, Jack McCloskey, were invaluable in their assistance and efforts to see the investigations through to completion. I remain grateful for these initial stimulating experiences, which provided the basis and motivation for my research career.

The clinical outcomes sections of the chapters of this textbook represent a compilation of knowledge from studies involving thousands of patients from both our center and other published cohorts. We have attempted to justify the recommendations for treatment based in part on the results of our clinical studies which used a rigorous rating system to determine outcome. The development and validation of the Cincinnati Knee Rating System was a major research focus for Dr. Noyes and I for several years. As a result, we have long advocated that "outcome" must be measured using many factors including the patient perception of the knee condition along with valid functional, subjective, and objective measures. Although this topic has come under recent debate, we continue to strongly believe in this philosophy for many reasons. For instance, the purpose of an ACL reconstruction is to restore stability to the knee joint as measured by anterior tibial translation, the pivot-shift test, and knee function during strenuous activities. Some knee rating systems allow results of this operation to be rated as "excellent" or "good" even if the graft itself has failed (return of a positive pivot shift test). Patients in the short-term may appear to have a functional knee; however, over time a failed graft will cause problems and may require revision. A comprehensive evaluation that includes physical examination, knee arthrometer testing, function testing, and a subjective questionnaire is required to truly determine if an ACL reconstruction has been successful.

Even more compelling is the necessity to conduct long-term clinical studies with at least a 10-year follow-up evaluation. These studies must include all of the factors described (especially radiographs and in some cases, MRI) to determine the long-term sequela of various injuries and disorders. Simply collecting data from questionnaires does not, in our opinion, provide a scientific basis for treatment recommendations. At our Center, we will continue to conduct clinical research in this manner in our efforts to advance the state of knowledge of the knee joint and provide the best patient care possible.

Another area of particular research interest of mine over the years has been in the field of rehabilitation. In fact, the first clinical study I participated in was initiated while I worked on the physical therapy staff for two years. Having been a patient myself, I had a strong interest in studying the effects of different rehabilitation treatment programs on clinical outcomes. At our Center, we have always held the belief that postoperative rehabilitation is just as important as the operative procedure for a successful resolution of a problem. I have enjoyed working with Tim Heckmann in these studies for many years, as well as many other therapists, assistants, and athletic trainers who are all vital to the success of our rehabilitation research and clinical programs.

Many individuals have contributed to the success of our clinical research program over our nearly 30-year tenure and it is not possible to name them all. However, I want to especially recognize Jennifer Riccobene who, for 15 years, has doggedly tracked down and assisted hundreds of patients from all over the U.S. and beyond with their clinical research visits. Cassie Fleckenstein manages the studies in Cincinnati, keeping track of a multitude of tasks including fellowship involvement in research which has been a cornerstone of this program since the early 1980s. Our administrative department, especially Linda Raterman, has been particularly supportive of our

research efforts and deserve recognition. Various institutions in Cincinnati have contributed financial support to our clinical studies over the years, including Jewish Hospital, the Deaconess Hospital Foundation, and Bethesda Hospital. We are grateful for the statistical expertise provided by Marty Levy of the University of Cincinnati and Jack McCloskey of the University of Dayton.

Finally, I'd like to thank my family - my husband Rick and my children, Teri and Alex for their support during this endeavor. I hope this textbook will be of value to many different types of health professionals for many years to come.

SUE BARBER-WESTIN

Foreword

It has been my observations over the years that Frank Noyes has three fundamental beliefs, or organizing principles, around which he has dedicated his professional life, and which explain the contents of this book. These are:

1. *Diagnosis and treatment of patient disorders should be strongly informed by knowledge gained from basic science studies.*
2. *The outcome of surgical treatment is critically dependent on rehabilitation therapy.*
3. *Advancement of medical care, both surgical and non-surgical, requires carefully conducted outcome studies that account for differences in outcome caused by the type and intensity of a patient's activities and avoid bias due to the loss of patients to follow-up.*

These core beliefs help explain the many research studies he and his colleagues conducted. The results of these studies and their clinical correlations, along with the broader base of knowledge developed by numerous investigators, form the foundation of Dr. Noyes' approach to the diagnosis and treatment of knee disorders.

This book details the approaches Dr. Noyes has developed to the diagnosis and treatment of knee disorders, along with the scientific foundations on which his approaches are based. The result is a valuable reference book for both physicians and physical therapists who care for patients with knee disorders. The inclusion of supporting basic science data also makes this book an excellent reference for any investigator or student who is interested in improving the care provided patients with knee disorders by further advancing knowledge of the normal and pathologic knee.

Although the title is "Noyes' Knee Disorders", and the content in large part reflects his clinical approaches and research, it also includes the clinical approaches and research results of other leading surgeons and physical therapists. There is, however, a common thread in that the clinical approaches presented include the scientific foundations on which they are based. Further, the reader will find that the chapters that present the research of Dr. Noyes and his colleagues also include results of other leading scientific investigators. The studies included were selected to fill in gaps and provide a broader perspective in areas where a consensus has not yet been developed.

The quality of the content of this book is complimented by the quality of its production. Each chapter has "Critical Points" sections that focus the reader's attention on the main walk-away messages. There has been extensive use of color to enhance readability, particularly in the presentation of data. Great care has been taken to make the anatomical drawings and medical illustrations accurate and to carefully label all illustrations and photographs. The care put into the production by the publisher reflects the high standard and care Dr. Noyes brings to those projects he undertakes, including the care delivered to his patients and his dedication to advancing care through carefully conducted basic science and clinical research studies. While one result of the publisher's and Dr. Noyes' efforts is the book's visual appeal, it was not the goal. Rather, the visual appeal is a by-product of their efforts to provide the reader a useful text in which the content is easily understood and accessible to the reader.

This book presents much of the research conducted by Dr. Noyes and his collaborators, including much of my own research. I would like to take this opportunity to express my appreciation and gratitude to Frank Noyes for the opportunity of collaboration, for the time and energy he has devoted to our collaboration, and to the significant financial support he and his partners have provided our research. I first met Frank in 1973 when he was stationed with the 6570th Aerospace Medical Research Laboratory, located at Wright Patterson Air Force base just outside Dayton, OH. I had recently received my PhD and was working at the University of Dayton Research Institute. It was there we met thanks to the efforts of a mutual friend and colleague George "Bud" Graves. It was also in Dayton we did our first collaborations that led to our paper on the age-related strength of the anterior cruciate ligament. In 1975 we moved to the University of Cincinnati, thanks to the encouragement of Edward Miller, M.D., then Head of the Division of Orthopaedics at the University of Cincinnati. This move was made possible by the generosity of Nicholas Giannestras, M.D. and many other orthopaedic surgeons in the community who provided support to initiate a Biomechanics Laboratory. It was in Cincinnati where we initiated our first study on whole knee biomechanics and designed and initiated our studies on primary and secondary ligamentous restraints. We were fortunate to have David Butler join our group in late 1976 and complete the study in progress on the ACL and PCL restraints, a study for which he later received the Kappa Delta Award.

In addition to working with excellent colleagues, I have been fortunate to work with many engineering students, orthopaedic residents, post-doctoral students, sports medicine fellows, and visiting professors. Without their combined intellectual contribution and hard work, I would not have been able to have completed many of the studies which are included in this text. They all have my sincerest appreciation for their support and contributions.

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Foreword

It is a true privilege to write this Foreword for *Noyes' Knee Disorders: Surgery, Rehabilitation, Clinical Outcomes* by Dr. Frank Noyes. The objective of this book was to produce an all-inclusive text on the knee joint that would include a multi-discipline approach to the evaluation and treatment of knee disorders. The textbook was designed to provide both basic and clinical sciences to enhance the readers' knowledge of the knee joint.

The knee joint continues to be one of the most researched, written about, and talked about subject in orthopaedics and/or sports medicine. Even with the extensive literature available, Dr. Noyes and Ms. Barber-Westin have done a masterful job pulling a tremendous amount of information together into over 1200 pages, with over 3,000 references and more than 1,000 figures in one comprehensive textbook. There are numerous chapters on the anatomy and biomechanics of various knee structures. There are specific and detailed sections on the evaluation and treatment of specific knee lesions, including the ACL, PCL, articular cartilage, patellofemoral joint, the menisci, and other structures. There are numerous chapters on the rehabilitation for each of the various knee disorders, and even a section on the gender disparity in ACL injuries. Furthermore, there is a thorough section on clinical outcomes – which is a much needed area for clinicians to understand and utilize.

I have had the true pleasure of knowing Dr. Noyes for over 20 years and he has always practiced medicine employing several principles. These include a scientific basis (evidence) to support his treatment approach, a team approach to treatment, meticulous surgery, and the attitude to always do what is best for the patient. He has applied these key principles into this outstanding textbook. Dr. Noyes has always been a proponent of a team approach to the evaluation and treatment of patients with knee disorders. This book illustrates this point beautifully with thorough chapters written by biomechanists, orthopaedic surgeons, and physical therapists. Furthermore, Dr. Noyes has always searched for the "best treatments" for the patient, seeking clinical evidence to support the treatment.

As they have done over a hundred times before in published manuscripts and chapters, Dr. Noyes and Ms. Barber-Westin have teamed up to provide us with an outstanding reference book. This outstanding text will surely remain on every knee clinician's desk for a very long time. It should be read and studied by physicians, physical therapists, athletic trainers, and anyone involved in treating patients with knee disorders. This book will surely be a favorite for all practitioners.

This is a great contribution to the literature.

Thank you Dr. Noyes for the guidance you have and continue to give us,

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