nuclear medicine

Second Edition

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foreword

In recent years, much has been said and written about the Scientific Revolution. We have all been heartened by the successes which the physical sciences have enjoyed in the past few decades. At the same time we have recognized that physical scientists have enjoyed certain advantages over their colleagues in other fields. Measurements of our inanimate world can be made with great precision, and we are able to settle upon general laws with considerable assurance. As a physical scientist myself, I have sympathized with the biologic and medical scientists whose world in general has been so complex, so dynamic, and so filled with variables. It is a staggering challenge to discern order in the material of life.

The advances in biology and medicine, nevertheless, have been of the highest order, and discoveries with profound implications for man's future have been made. Biologic and medical scientists have used great ingenuity in adapting many of the tools and techniques of the physical sciences to their complex problems. Radioisotopes have given them eyes to see what was formerly invisible. An impressive and ever-increasing array of instruments and techniques based upon physical principles has extended the exploration of living materials to the molecular level. Research tools of this sort greatly facilitate the identification, measurement, isolation, and characterization of the components of living systems. The result has been increasing precision in the perception, measurement, and definition of biologic phenomena. Perhaps the outstanding example of the use of a variety of advanced techniques combined with great intellectual insight is to be found in the deciphering of the genetic code in the nucleic acids.

It is not unlikely that these new and more accurate penetrations of the biologic world will place the life sciences at the forefront of the scientific revolution. This revolution in biology and medicine is characterized by an increasing capacity to define order in the material of life. We have entered a period when biologic phenomena can be defined in chemical terms—in terms of chemical structure and dynamics. Significant definitions can already be made at the molecular level, and experimental methods are now so highly developed that we can foresee enormous progress in the near future. In the next decade or two, considering the accelerating expansion of scientific knowledge, we are almost sure to witness progress in understanding the material of life which will cause basic reorientation in our approaches not only in biology and medicine but also to the study of animal and human behavior and, I may add, which will call upon the physical sciences for their utmost support.

Perhaps no field in the life sciences so typifies this revolution as the field of nuclear medicine. In the past 25 years, it has emerged as an integrated medical discipline. The present revised text, edited by Dr. William H. Blahd, fills a timely need for a comprehensive, authoritative, and up-to-date work on nuclear medicine. This treatise of broad scope covering all aspects of a rapidly growing medical discipline, its diagnostic techniques, and therapeutic procedures, not only advances information to a current status but, at the same time, makes the reader aware of the need for continuing progress in nuclear medicine. I am certain that it will be of value and interest to both the medical practitioner and the medical educator.

Glenn T. Seaborg
Chairman
U. S. Atomic Energy Commission

preface

Since the publication of the first edition of *Nuclear Medicine* approximately 5 years ago, there have been vast changes in the nuclear medicine field. Changes have occurred primarily in the areas of instrumentation and radiopharmaceutical development. These new developments have had a major impact on the practice of clinical medicine. Nuclear medicine now plays a major role in patient management and has significantly expanded the physician's armamentarium. It provides a unique methodology that includes a varied group of radioisotopic techniques. Most of these techniques may be characterized as diagnostic screening procedures and as such are singularly atraumatic and innocuous, representing some of the most powerful diagnostic tools of modern medicine. Therapeutic applications, although more limited, have led to the control of thyroid cancer and the effective and definitive treatment of hyperthyroidism.

As in the previous edition of this book, the field of nuclear medicine has been presented as an integrated medical discipline. An attempt has been made to consider the various facets of the field, including fundamentals, clinical applications, and new developments, in a comprehensive manner. All chapters have been written by acknowledged authorities and often by pioneers in the field. Although the major approach has been clinical, major topics have been presented in sufficient depth to be of interest and value to both the medical Investigator and instructor. Each chapter contains an extensive bibliography, and thus the book may serve as a useful reference source. To obviate the confusion concerning radiopharmaceutical nomenclature that pervades the nuclear medicine field, *United States Adopted Names* (USAN) * designations for radiopharmaceuticals have been employed throughout this edition of *Nuclear Medicine.*

* Published by the United States Pharmacopeial Convention, Inc., Bethesda, Maryland.

I am indebted to the contributors to this book. They have shown great patience and forebearance with respect to unforeseen delays as well as the changes in manuscript style and content that were made in the interest of continuity and in an attempt to create an integrated text. I would like to acknowledge the unstinting efforts and invaluable assistance of Kazuko Endow, who assisted in all aspects of the preparation of the manuscript; the able editorial assistance of Malcolm Palmatier; and the invaluable advice of Dr. Benedict Cassen. I am also indebted to Marianne Lederer and Dr. Gerald Gambino for their kind assistance.

William H. Blahd

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part one
fundamentals

chapter 1
radioisotopes and their radiations

THE SUBMICROSCOPIC STRUCTURE OF MATTER

Investigations of the structure of atoms have shown that each atom possesses at its center a small, dense, positively charged core, or nucleus. Outside the nucleus, the atom consists only of a small swarm of electrons, which are negatively charged and whose number is just sufficient to provide enough negative charge in the atom to balance the positive charge on the nucleus, so that the complete atom is electrically neutral. It is possible to modify the structure of atomic nuclei and thus to produce new atoms having unusual properties. In many cases these man-made atoms are radioactive and can be applied usefully either as sources of radiation or as tracer substances in biology and medicine, engineering, physics, chemistry, and geology.

In modern scientific activities, only the physician and the engineer deal with objects with dimensions readily appreciated by the human mind. Thus, the height of a man, the length of a bridge, the weight of a dog, or the speed of an automobile are all magnitudes which we can appreciate readily through our fundamental senses. This domain lies midway between those with which the astronomer and the nuclear physicist must deal. At one end of the scale, the astronomer is concerned with distances and masses and times so vast that we cannot appreciate their size as compared with the experiences of everyday life. At the opposite end of the scale, in the domain of the atomic and nuclear physicist, the dimensions are so minute as to challenge comprehension.

Atoms are small, and numerous. If we were capable of marking every atom in a glass of water so that we could recognize each atom if we found it again at a later time and were then to pour that glass of water into the ocean and allow it to become thoroughly mixed with all the water in all the lakes, rivers, glaciers, seas, and oceans of the entire world, we would find that every glass of water, regardless of what part of the world samples were taken from, would contain over 5,000 of our original marked atoms.

The glass of water contains about 20 million million million million atoms. Let us imagine that we can enlarge the scale of this glass of water until we are able to see and examine the individual atoms and their internal structure. If we were able to enlarge the scale to make the glass so big that it could contain the entire earth, we would be able to see the individual