Two good texts for clinical applications of nmr

NMR Imaging in Biomedicine

P. Mansfield, P. Morris

354 pages, Academic, New York, 1982. $49.50

Nuclear Magnetic Resonance and Its Applications to Living Systems.

E. Gadian

Oxford U.P., New York, 1982. $29.95

Reviewed by R. Mark Henkelman

It is always an exciting phase in the development of science when an academic and basic field of study blossoms into a greatly expanded area of application. This prolific development, now occurring with the use of nuclear magnetic resonance in medicine, stems from two new capabilities: to make images using nuclear magnetic resonance and to measure nmr spectra in living subjects.

Physicists first proposed nmr imaging in the early 1970s as a way of making pictures of biological structures. Several academic laboratories, of which one of the most committed was at the physics department of the University of Nottingham, investigated the original idea, developed a number of imaging methods and constructed prototype imaging spectrometers to assess the practicality of imaging humans. Initial results through the mid-1970s were of such poor quality that they were medically rather uninteresting although they served to demonstrate the feasibility of making pictures with nmr. Commercial involvement by the major medical imaging manufacturers in the late 1970s accelerated the technological development and produced images of human anatomy that were of obvious clinical value. Projections are now being made that nmr imaging will be a billion-dollar industry and will possibly replace one-third of the use of medical x rays.

NMR Imaging in Biomedicine by Peter Mansfield of Nottingham University and P. Morris of the National Institute for Medical Research in London serves as an excellent introduction to the physicist who wishes to move into this new area of research. This book contains by far the most complete description of the physical and mathematical bases of nmr imaging methods. Mansfield and Morris describe many of these from the practical perspective of Mansfield's own research on these methods. They present a number of practical hints and warnings along with a formal analysis of imaging methods. The discussion of the medical applications of nmr imaging, much less satisfying, shows a lack of appreciation of the goals and needs of medical imaging. However, it is probably premature to attempt to put nmr imaging into clinical perspective because the answers about medical efficacy are not yet known. In an excellent chapter on biomagnetic effects they give a thorough discussion of the possible sources of hazard to the patient.

Nuclear magnetic resonance spectra from within living subjects are opening new windows onto *in vivo* biochemistry and metabolism. While the medical application of this technique is not yet as dramatic as imaging, it is being applied clinically and may well be the major contribution of nmr to medicine.

David Gadian of Oxford University has written *Nuclear Magnetic Resonance and Its Applications to Living Systems* for biologists with no prior nmr experience to convince them that nmr provides unique and valuable information about living systems and to assure them with a gentle introduction that nmr technology is not beyond their mastery. The first half of the book discusses the kinds of information that can be obtained from H^1, C^{13} and P^{31} spectra of living systems. Probably the most fascinating spectra are those from phosphorus, where the identification of ATP, phosphocreatine and inorganic phosphate levels can permit an assessment of the energetic status of tissues. Some of the discussions of the relation of these measurements to other biochemical assays such as freeze clamping become rather technical and detailed for a physicist not involved in this specialty. The latter half of the book is an introduction to nmr with a particular sensitivity to the problems of *in vivo* measurements. The final chapter provides a good discussion of the particular problems of probe design for live samples. The introduction to nmr is too qualitative and descriptive to be of much use to other than the starting physicist, but it is excellent as an introduction for medical or biological researchers.

It is difficult for books that are written while a field is rapidly changing to have a balanced perspective and to make contributions that will not become rapidly obsolete. These two books, however, succeed and make major contributions as the best texts now available for physicists who want to learn about the blossoming of nmr into medicine.

A human head (transverse section) in an nmr image provided by Technicare Corporation.

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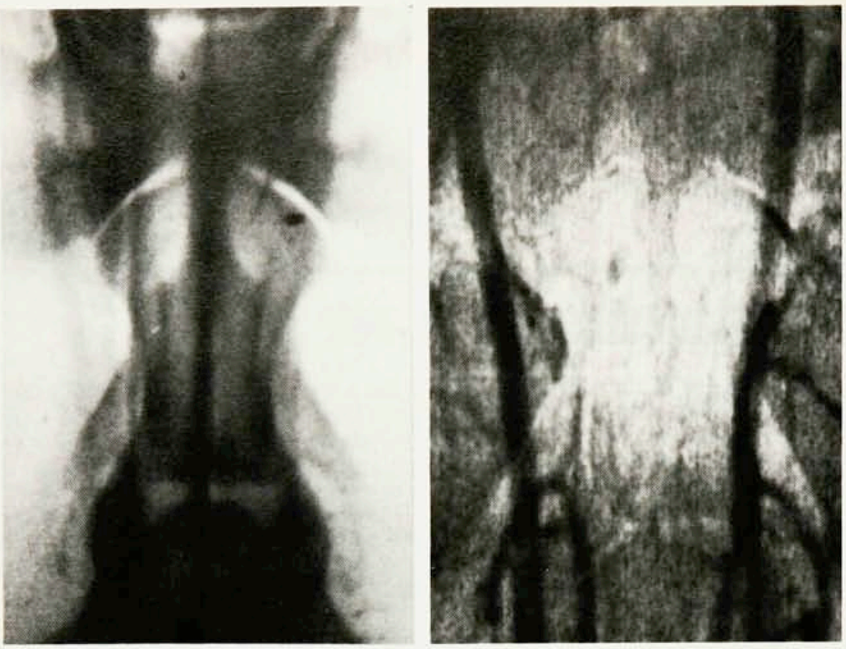
R. Mark Henkelman, whose research concerns medical imaging, is associate chairman of the department of medical biophysics, University of Toronto.

Scientific Basis of Medical Imaging

P. N. T. Wells, ed.

Livingstone, New York, 1982. $55.00.

In the past decade, medical imaging has gone beyond the x-ray-film age to the computer age. Researchers have developed new modalities for imaging internal structure and function of the living human body almost yearly; many professionals, even in the field of



Digital radiographs of arteries near the spinal column. The image at left was obtained after a radio-opaque medium was injected into the arteries. The image at right was obtained from that at left by subtracting from it an image obtained before the injection. (Courtesy R. W. Redington.)

medicine, are left behind the times. Several new books have come out recently to bridge the gap between the current level of understanding of professionals and the new technologies. In one, P. N. T. Wells has compiled seven articles on various topics on medical imaging for a varied group of professionals. As one might expect, difficulties abound in attempting to write one source book for "doctors, radiographers, technicians, engineers and physicists." Each specialty has a different background, different vocabulary, different approach and different needs. Any one book aimed at this diverse audience must be limited in its goals. Wells has sought to describe fundamental principles at a level similar to *Scientific American* articles. The resulting work, while containing much useful and interesting information, includes items of varying quality and has a somewhat limited usefulness. The only readers with the background to comprehend most of the chapters will be physicists and engineers. In general it appears that limited space has forced authors to choose among clinical, technical, and basic material; this choice is not consistent among the authors.

G. A. Hay's chapter on "traditional imaging" is spotty. It includes some excellent sections (for example, on film design, blurriness of images, and contrast vs. detail in images) and some insufficient ones (image improvement with scanning slits, image enhancement, mammographic radiological equipment). The brief bibliography of this chapter is useful and necessary in filling gaps.

Malcolm Davison's chapter on computerized tomography, a quite adequate literature review, has a good discussion of artifacts, using examples, and a good bibliography. The weakest portion of the chapter is its discussion of resolution. The author's outline of a quality assurance program is welcome.

D. A. Weber and R. E. Omara's section on radionuclide imaging is concise and up-to-date. It gives brief discussions of pharmaceuticals, equipment performance (but not principles) and comparitive resolutions and many tables. The best part of this chapter is on clinical applications; its biggest weakness is its lack of radiation dosimetry considerations (a necessary topic for physicists in medicine).

Wells's section on ultrasound is an excellent introduction, with minimal mathematical and technical detail in the text but many specifics and computations in numerous sketchlike figures. Discussions of transducers, artifacts, the Doppler effect, transmission scanning, microscopy, biological hazards, are thought-provoking and fairly complete.

C. H. Jones's short section on thermographic imaging discusses liquid-crystal thermography and the use of bolometers and pyroelectric detectors, including their inherent limitations in temperature differentiation. Figures on clinical applications illustrate the technique's use in various diseases.

E. R. Andrew's section on the rapidly growing area of nuclear magnetic resonance imaging is admittedly incomplete but provides basic reviews of the physics of nmr interactions and their technological needs. Andrews presents both the physics in their design and the initial clinical results obtained from several of the currently used techiques of imaging. He presents the limited data on biohazards and views the wide open future of the field.

The final chapter, by M. Susan Chesters, is perhaps the hardest to evaluate. Perception and evaluation of images is undoubtedly the least understood of the topics covered in the book. Chesters describes various models of the visual system both neurologically and mathematically. Clinical data to evaluate models are scanty, as they are in most psychophysical systems. Therefore, the chapter, serving mostly as a compendium of phenomena, touches on such topics as the usefulness of image enhancement and restoration, the interaction of images with noise, and the usefulness (but not the theory or detailed techniques of construction) of ROC curves, matched filters, and so on.

This book can be useful especially to professional medical scientists who wish to get an introduction to another area of medical science: imaging. While it is a textbook neither in medical imaging nor in medical physics, it is a starting point for study in a field where there are few.

ROBERT STANTON
Cooper Medical Center

Stochastic Processes in Physics and Chemistry

N. G. van Kampen
419 pp. North-Holland, New York, 1981. $76.50

Macroscopic evolution equations may be used successfully to model a wide variety of nonequilibrium physical and chemical processes. These describe the relationships between macroscopic quantities such as concentrations and phenomenologically determined quantities such as rate constants or diffusion coefficients, whose relations, in turn, to microscopic dynamics appear in the appropriate averages of microscopic rates or in the fluctuation–dissipation theorem. A familiar example of the latter is Langevin's treatment of Brownian motion, which introduces a frictional force term in the classical equation of motion of the Brownian particle, with the friction coefficient related to the statistical properties of the fluctuations that are the microscopic origin of the friction itself. The resulting Langevin equation is one special case, the Fokker–Planck equation another, of a large and important class of evolution equations called master equations. Such equations arise in theories of rate processes, first-passage