RADIOGRAPHY *in the* DIGITAL AGE

SECOND EDITION

PHYSICS
EXPOSURE
RADIATION BIOLOGY

Quinn B. Carroll, M.Ed., R.T.

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Physics—Exposure—Radiation Biology

By

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REVIEWERS

C. William Mulkey, PhD, RT(R)

Dean, Dept. of Radiologic Sciences
Midlands Technical College
West Columbia, North Carolina

Philip Heintz, PhD

Director, Biomedical Physics, Dept. of Radiology
University of New Mexico Medical Center
Albuquerque, New Mexico

Donna Endicott, MEd, RT(R)

Director, Radiologic Technology
Xavier University
Cincinnati, Ohio

Dennis Bowman, AS, RT(R)

Clinical Instructor
Community Hospital of the Monterey Peninsula
Marina, California

Miranda Poage, PhD

Associate Professor, Biology
Midland College
Midland, Texas

PREFACE

New to This Edition

This edition was peer-reviewed by five colleagues who brought many valuable corrections and improvements to the text. Several sections have been deleted, moved, or reorganized to provide smoother transitions and development of the topics, with particular focus on the digital imaging chapters. Material on *rescaling* the digital image has been greatly strengthened, and new graphs have been added that make histogram analysis and errors much easier to grasp.

The large chapter (Chapter 29) on digital image processing was split into two chapters, "Digital Image Preprocessing" and "Digital Image Postprocessing" (Chapters 30 and 31), rewritten for the student to more easily assimilate these concepts even while assuring a thorough overview. Important new practical material has been added on the limitations of digital features such as smoothing and edge enhancement, with direct implications for clinical practice. A new chapter (Chapter 36) is dedicated to PACS (picture archiving and communication systems) from the perspective of what a practicing staff radiographer should know.

The large chapter (Chapter 13) on qualities of the radiographic image was divided into two chapters, "Visibility Qualities of the Image" and "Geometrical Qualities of the Image" (Chapters 13 and 14) and revised for easier reading. The math review chapter (Chapter 3) includes a section on basic graphs. Along with material on the x-ray beam spectrum, a new section titled "Understanding the Digital Histogram" has been added, which includes foundational support exercises directly related to the later chapters on digital image processing.

A glossary of technical radiographic and digital imaging terms has been added for quick reference. In addition, a deliberate effort has been made to include the content areas identified in the Curriculum Guide published by the American Society of Radiologic Technologists, and to address the Standard Definitions published by the American Registry of Radiologic Technologists.

Scope and Philosophical Approach

The advent of digital radiographic imaging has radically changed many paradigms in radiography education. In order to bring the material we present completely up to date, and in the final analysis to fully serve our students, much more is needed than simply adding two or three chapters on digital imaging to our textbooks.

First, the entire emphasis of the *foundational* physics our students learn must be adjusted in order to properly support the specific information on digital imaging that will follow. For example, a better basic understanding of waves, frequency, amplitude and interference is needed so that students can later grasp the concepts of spatial frequency processing to enhance image sharpness. A more thorough coverage of the basic construction and interpretation of graphs prepares the student for histograms and look-up tables. Lasers are also more thoroughly discussed here, since they have not only medical applications, but are such an integral part of computer technology and optical disc storage.

Second, there has been a paradigm shift in our use of image terminology. Perhaps the most disconcerting example is that we can no longer describe the direct effects of kVp upon image contrast. Rather, we can only describe the effects of kVp upon the subject contrast in the remnant beam signal reaching the image detector, a signal whose contrast will then be drastically manipulated by digital processing techniques. Considerable confusion continues to surround the subject of scatter radiation and its effects on the imaging chain. Great care is needed in choosing appropriate terminology, accurate descriptions and lucid illustrations for this material.

The elimination of much obsolete and extraneous material is long overdue. Our students need to know the electrical physics which directly bear upon the production of x-rays in the x-ray tube—they do not need to solve parallel and series circuit problems in their daily practice of radiography, nor do they need to be spending time solving problems on velocity. MRI is briefly overviewed when *radio* waves are discussed under basic physics, sonography is also discussed under the general heading of *waves*, and CT is described along with attenuation coefficients under digital imaging.

It is time to bring our teaching of image display systems up to date by presenting the basics of LCD screens and the basics of quality control for electronic images. These have been addressed in this work, as part of eleven full chapters dealing specifically with digital and electronic imaging concepts. If you agree with this educational philosophy, you will find this textbook of great use.

Organization

The basic layout is as follows: In Part I, "The Physics of Radiography," ten chapters are devoted to laying a firm foundation of math and basic physics skills. The descriptions of atomic structure and bonding go into a little more depth than previous textbooks have done. A focus is maintained on *energy* physics rather than mechanical physics. The nature of electromagnetic waves is more carefully and thoroughly discussed than what most textbooks provide. Chapters on electricity are limited to only those concepts which bear directly upon the production of x-rays in the x-ray tube.

Part 2, "Production of the Radiographic Image," presents a full discussion of the x-ray beam and its interactions within the patient, the production and characteristics of subject contrast within the remnant beam, and the proper use of radiographic technique. This is conventional information, but the terminology and descriptions used have been adapted with great care to the digital environment.

Part 3, "Digital Radiography," includes nine chapters covering the physics of digital image capture, extensive information on digital processing techniques, and the practical application issues of both CR and DR.

Part 4, "Special Imaging Methods," includes chapters on mobile radiography, digital fluoroscopy and an extensive chapter on quality control which includes digital image QC. Finally, Part 5 consists of five chapters on "Radiation Biology and Protection," including an unflinching look at current issues and practical applications.

Feedback

For a textbook to retain enduring value and usefulness, professional feedback is always needed. Colleagues who have adopted the text are invited to provide continuing input so that improvements might be made in the accuracy of the information as well as the presentation of the material. Personal contact information is available in the *Instructor and Laboratory Manual* on disc.

This is intended to be a textbook written "by technologists for technologists," with proper focus and scope for the practice of radiography in this digital age. It is sincerely hoped that it will make a substantial contribution not only to the practice of radiography and to patient care, but to the satisfaction and fulfillment of radiographers in their careers as well.

Instructional Resources

Instructor Resources CD for Radiography in the Digital Age. This disc includes the answer key for all chapter review questions and a bank of over 1450 multiple choice questions with permission for instructors' use. It also includes 35 laboratory exercises with 15 demonstrating the applications of CR equipment. The manual is available only on disc from Charles C. Thomas, Publisher.

PowerPoint Slides on Disc. *PowerPoint*™ slides are available for classroom use, covering the entire textbook and as many as four courses in a typical radiography curriculum. The four titles are available from Charles C. Thomas, Publisher:

The Physics and Equipment of Radiography
Principles of Radiographic Imaging
Digital Image Acquisition and Display
Radiation Biology and Protection

Student Workbook for Radiography in the Digital Age. This 312-page supplement covers everything in the textbook and as many as four courses in a typical radiography curriculum It is deliberately organized in a concise "fill-in-the-blank" format that provokes students to participate in class without excessive note taking. Questions focus on key words that correlate perfectly with the above slide series. Available from Charles C. Thomas, Publisher.

DVD Mini-Lessons. To assist the instructor on particularly difficult digital topics, a series of 20-minute video mini-lessons are available from Digital Imaging Consultants that correlate with and supplement *Radiography in the Digital Age*. Video object-lessons are combined with lucid graphics and clear, progressive explanations to make difficult material "click" for the student. Visit the website at dicwebinars.com.

ACKNOWLEDGMENTS

Many thanks to the reviewers for the second edition, C. William Mulkey, Donna Endicott, Philip Heintz, Dennis Bowman, and Miranda Poage, who provided many improvements for content, organization and readability.

Special thanks to Georg Kornweibel and Doctor Ralph Koenker at Philips Healthcare, and to Gregg Cretellen at FujiMed for their sustained assistance. Thanks also to Lori Barski at Carestream Health (previously Kodak). All were extremely helpful in obtaining images and a good deal of information related to digital imaging and processing. Doctor J. Anthony Seibert at the University of California Davis Medical Center was generous with his time and expertise, as well as providing energy-subtraction images. His help was greatly appreciated.

Some material was adopted and adapted from contributing authors to my textbook, *Practical Radiographic Imaging* (previously *Fuchs's Radiographic Exposure, Processing and Quality Control*). They include Robert DeAngelis, BSRT in Rutland, Vermont, Robert Parelli, MA, RT(R) in Cypress, California, and Euclid Seeram, RTR, MSc, in Burnaby, British Columbia, Canada. Their contributions are still greatly valued.

Many photographs and radiographs were made available through the gracious assistance of several local radiographers including Kathy Ives, RT, Steven Hirt, RT, Jason Swopes, RT, Phil Jensen, RT, Sungunuko Funjiro, RT, Trevor Morris, RT, and Brady Widner, RT, all graduates whom I proudly claim. Thanks, in particular, to William S. Heathman, BSRT, my colleague in radiography education for many years.

Photographs were also helpfully provided by Fyte Fire and Safety in Midland, Texas and Apogee Imaging Systems in Roseville, California, and made available in the public domain by the U.S. Army and U.S. Navy.

Trevor Ollech at Charles C Thomas, Publisher rendered many dozens of pieces of artwork for this project. His many hours of patient labor are greatly appreciated, and the quality of his illustrations is self-evident throughout the book.

I appreciate the long-suffering editorial assistance of Lynn Bergesen and the support of Michael Payne Thomas at Charles C Thomas, Publisher.

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On a more personal note, I wish to express appreciation for the professional support and loyal friendship of Doctor Eileen Piwetz, which never waivered over 25 years, along with my love and admiration for all my colleagues in health sciences education, who, often against all odds, make miracles happen on the "front line" every day.

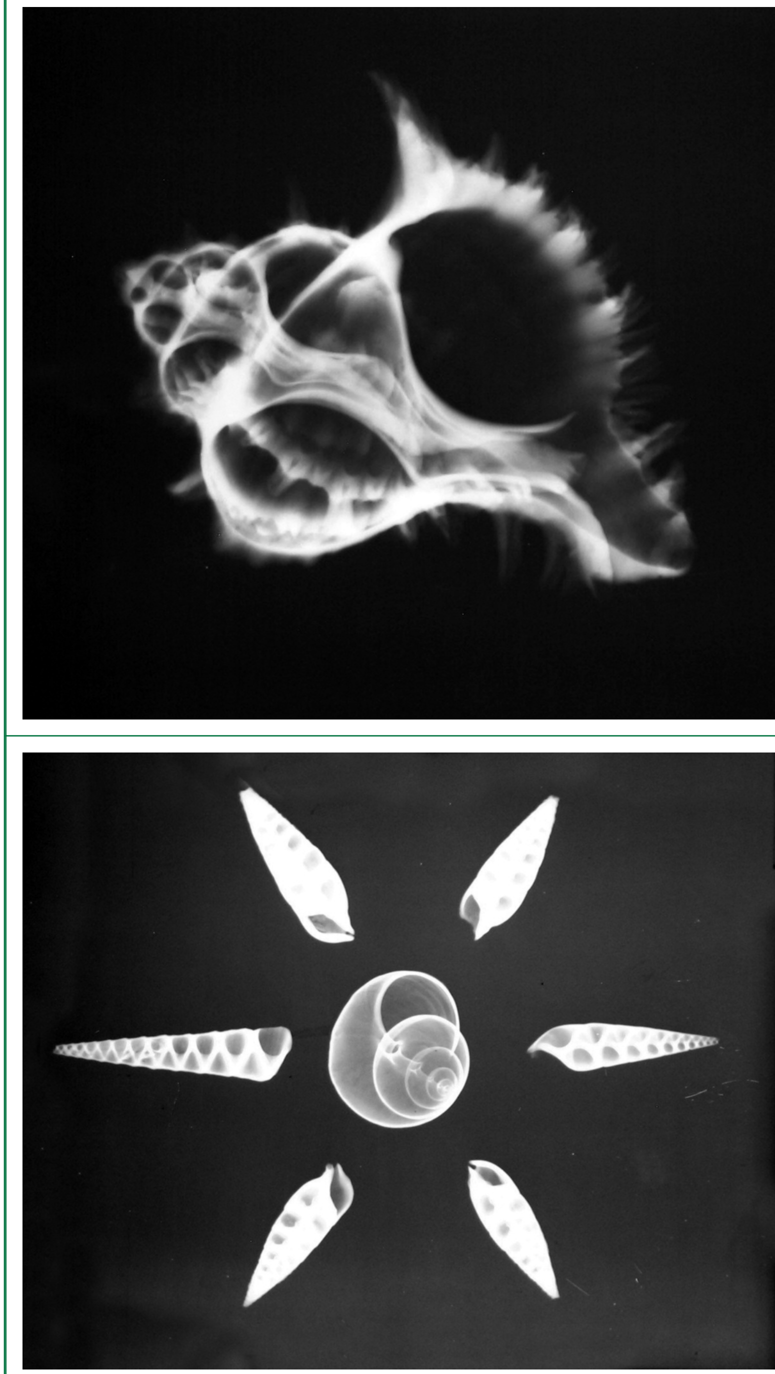
CONTENTS

PART II: PRODUCTION OF THE RADIOGRAPHIC IMAGE

RADIOGRAPHY IN THE DIGITAL AGE

Part I

THE PHYSICS OF RADIOGRAPHY



Radiographs of various seashells.

Chapter 1

INTRODUCTION TO RADIOGRAPHIC SCIENCE

Objectives:

Upon completion of this chapter, you should be able to:

1. List the foundational principles of the scientific method and how they relate to the standard of practice for radiographers.
2. Describe landmark events in the development of medical radiography, with particular focus on those that brought about reductions in patient exposure.
3. Overview landmark events in the development of modern digital radiographic imaging.
4. Present a scientifically balanced perspective on the hazards of radiation in our environment and workplace.
5. Understand and appreciate the ALARA philosophy in modern radiographic imaging.

THE SCIENTIFIC APPROACH

Radiography is a branch of the modern *science* of medicine. Science is objective, observable, demonstrable knowledge. Try to imagine your doctor engaging in practices that were not grounded in scientific knowledge! What is it that sets science apart from art, philosophy, religion and other human endeavors? There are actually several foundational principles to scientific method. It is worthwhile to give a brief overview of them. They include:

Parsimony: The attempt to simplify concepts and formulas, to economize explanations; the philosophy that simple explanations are more likely to be true than elaborate, complex ones.

Reproducibility: The requirement that proofs (experiments) can be duplicated by different people at different times and in different locations with precisely the same results.

Falsifiability: The requirement that any theory or hypothesis can logically and logistically be proven *false*. Anything that cannot be proven false is not science, but belongs in another realm of human experience.

Observation: The requirement that experiments and their results can be directly observed with the human senses.

Measurability: The requirement that results can be quantified mathematically and measured.

As a fun practice exercise, consider the following three statements. Which one is scientific?

1. *The moon is made of green cheese.*
2. *Intelligent life likely exists elsewhere in the universe.*
3. *Albert Einstein was the greatest physicist in the twentieth century.*

The most scientific statement is No. 1. Even though it may not be a true statement, it is nonetheless a statement that can be (and has been) proven false with modern travel technology, it is simple, and experiments proving that moon rocks do not consist of green cheese can be reproduced by anyone, anywhere on earth with the same, observable, measurable results. Statement No. 2 may be true or