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Introduction to Radiologic & Imaging Science & Patient Care

SEVENTH EDITION

ARLENE ADLER | RICHARD CARLTO

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Dedication

To Don, Meredith, and Katie Adler and to D. Raleigh and Hazel Carlton

and

In memory of Ronald J. Berg, a wonderful patient model

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Preface

It has now been over 25 years and 7 editions since we first published *Introduction to Radiologic and Imaging Sciences and Patient Care.* We continue to be pleased with the success of the book, because it was quickly adopted in radiologic and imaging science classrooms, and we continue to receive comments and suggestions from our colleagues as they make it part of their teaching. We have been delighted with the success of many of our contributing authors over the years, and we think you will find this new edition to be no exception in the quality and relevance of their coverage of the critical issues for beginning clinical practice in our field.

We are always pleased when we are contacted by a teacher and even more pleased when we are contacted by a student in regard to this book. We encourage you to email, phone, write, or simply come up and talk with us at professional meetings. We consider dialogue with you to be absolutely critical to improving our profession, and we do value each and every comment, suggestion, correction, or improvement that you can provide. As with all our new editions, there are numerous updates, clarifications, expanded coverage, and new topics that we added as a result of the commentary we received from students and faculty.

We remain committed to providing a reasonably priced but comprehensive introduction to our profession. We continue to strive to provide the breadth necessary to permit well-informed and properly oriented students their first real clinical practice. We attempt to sufficiently pry open the doors to technical areas so that students will respect not only what they know but how much they don't know as well. We have found that the most dangerous person in a school may well be the first-year student who has had an introduction to psychology but has not yet glimpsed the vast depth of knowledge in this field. He or she runs around trying to apply elementary concepts in interpersonal relationships just enough to thoroughly damage the friendships with anyone foolish enough to take their advice. The danger, of course, is not in what the student knows, but in the failure to appreciate what they do not know. We hope we have avoided setting anyone up for this error by treating our readers as serious new professionals, who are perfectly capable of deducing the potential dangers of the clinical environment while at the same time beginning to learn how to function competently in a manner that begins to make a contribution to our field.

The major changes you will find in the seventh edition include the following:

- Updates made consistent with the relevant Introduction and Patient Care sections of the ASRT curriculum
- Expansion and significant updates to Introduction to Clinical Education
- Additional ethical dilemma examples
- Updates on the current status of digital imaging instrumentation
- Ancillary support for teachers that includes an updated test bank and PowerPoint slides, as well as all artwork for cut and paste use by faculty members—this is available on the accompanying Evolve site online at https://evolve.elsevier.com.
- Patient care laboratories and review questions are included in the printed text and are also available to students on the accompanying Evolve website at http://evolve.elsevier.com to provide evidence that students have met the necessary clinical prerequisite information before beginning clinical experience.

We continue to assume full responsibility for any errors, including those that may be construed as having arisen from quoting others out of context. We have made every effort to ensure the accuracy of the information. We ask that you remember that it is the responsibility of every practitioner to evaluate the appropriateness of a particular procedure in the context of an actual clinical situation. Consequently, neither the authors nor the publisher take responsibility or accept any liability for the actions of persons applying the information contained herein in an unprofessional manner.

We highly value your point of view. We have learned that the most precious commodity to an author is criticism. As the reader, your perceptions are very important to us and we always appreciate that you communicate with us regarding any aspect of the book you like, dislike, or would like to see changed. As in all our books, we point out that a book such as this is never finished but merely abandoned until the next edition.

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PART I

The Profession of Radiologic Technology

OUTLINE

Introduction to Imaging and Radiologic Sciences

Arlene M. Adler, MEd, RT(R), FAEIRS, and Richard R. Carlton, MS, RT(R)(CV), FAEIRS

OUTLINE

OBJECTIVES

On completion of this chapter, the student will be able to:
- Explain the use of radiation in medicine.
- Provide an overview of the history of medicine.
- Describe the discovery of x-rays.
- Define terms related to radiologic technology.
- Explain the career opportunities within the profession of radiologic technology.
- Identify the various specialties within a radiology department.
- Describe the typical responsibilities of the members of the radiology team.
- Explain the career-ladder opportunities within a radiology department.
- Discuss the roles of other members of the health care team.

KEY TERMS

Bone Densitometry (BD) Measurement of bone density using dual-energy x-ray absorptiometry (DEXA or DXA) to detect osteoporosis

Cardiovascular Interventional Technology (CVIT) Radiologic procedures for the diagnosis and treatment of diseases of the cardiovascular system

Computed Tomography (CT) Recording of a predetermined plane in the body using an x-ray beam that is measured, recorded, and then processed by a computer for display on a monitor

Diagnostic Medical Sonography Visualization of deep structures of the body by recording the reflections of pulses of ultrasonic waves directed into the tissue

Energy Capacity to operate or work

Ionization Any process by which a neutral atom gains or loses an electron, thus acquiring a net charge

Magnetic Resonance Imaging (MRI) Process of using a magnetic field and radiofrequencies to create sectional images of the body

Mammography Radiography of the breast

Nuclear Medicine Technology Branch of radiology that involves the introduction of radioactive substances into the body for both diagnostic and therapeutic purposes

Positron Emission Tomography (PET) The creation of sectional images of the body that demonstrate the physiologic function of various organs and systems

Radiation Energy transmitted by waves through space or through a medium

Radiation Therapy Branch of radiology involved in the treatment of disease by means of x-rays or radioactive substances

Radiography Making of records (radiographs) of internal structures of the body by passing x-rays or gamma rays through the body to act on specially sensitized film or an imaging plate or system

Radiologic Technologist (RT) General term applied to an individual who performs radiography, radiation therapy, or nuclear medicine technology

Radiologist Physician who specializes in the use of x-rays and other forms of both ionizing and nonionizing radiation in the diagnosis and treatment of disease

Radiologist Assistant (RA) An advanced-level radiographer who extends the capacity of the radiologist in the diagnostic imaging environment, thereby enhancing patient care

Radiology Branch of the health sciences dealing with radioactive substances and radiant energy and with the diagnosis and treatment of disease by means of both ionizing (e.g., roentgen rays) and nonionizing (e.g., ultrasound) radiation

Roentgen Ray Synonym for *x-ray*

X-ray Electromagnetic radiation of short wavelength that is produced when electrons moving at high velocity are suddenly stopped

> *During World War I, the demand for x-ray technicians in military hospitals was so great that a shortage of technical workers became acute at home. The value of the well-trained technician was emphasized, and the radiologist was no longer satisfied with someone who knew only how to throw the switch and develop films.*
>
> ***Margaret Hoing, The First Lady of Radiologic Technology***
> ***A History of the American Society of X-Ray Technicians, 1952***

Medical Radiation Sciences

When the term *radiation* is used, it generally evokes concern and a sense of danger. This circumstance is unfortunate because radiation not only is helpful but also is essential to life. **Radiation** is energy that is transmitted by waves through space or through a medium (matter); it has permeated the universe since the beginning of time and is a natural part of all of our lives. For example, the sun radiates light energy, and a stove radiates heat energy.

Energy is the capacity to operate or work. The many different forms of energy include mechanical, electrical, heat, nuclear, and electromagnetic energy. Many forms of energy are used in medicine to create images of anatomic structures or physiologic actions. These images are essential for the proper diagnosis of disease and treatment of the patient. All of these energy forms can be described as *radiation* because they can be, and in many instances must be, transmitted through matter.

Some higher energy forms, including x-rays, have the ability to ionize atoms in matter. **Ionization** is any process by which a neutral atom gains or loses an electron, thus acquiring a net charge. This process has the ability to disrupt the composition of the matter and, as a result, is capable of disrupting life processes. Special protection should be provided to prevent excessive exposure to ionizing radiation.

Sound is a form of mechanical energy. It is transmitted through matter, and images of the returning sound waves can be created. Diagnostic medical sonography is the field of study that creates anatomic images by recording reflected sound waves. Sound waves are a form of nonionizing radiation.

Electrocardiography and *electroencephalography* are methods of imaging the electrical activities of the heart and of the brain, respectively. The graphs they produce provide useful information about the physiologic activities of these organs.

The body's naturally emitted heat energy can also produce images for diagnostic purposes. These images are called *thermograms,* and they can be useful in demonstrating conditions such as changes in the body's circulation.

Nuclear energy is emitted by the nucleus of an atom. Nuclear medicine technology uses this type of energy to create images of both anatomic structures and physiologic actions. It involves the introduction of a radioactive substance into the body for diagnostic and therapeutic purposes. These substances emit gamma radiation from their nuclei. *Gamma radiation* is a form of electromagnetic energy that has the ability to ionize atoms. As a result, proper radiation protection is important in the nuclear medicine department.

Electromagnetic energy has many forms (Fig. 1.1). Many of these forms are used in medicine to deliver high-quality patient care. For example, light is an essential energy form in many of the scopes used by physicians to view inside the body. In addition, **x-rays** are a human-made form of electromagnetic energy. They are created when electrons moving at high speed are suddenly stopped. X-rays, also called **roentgen rays**, named after their discoverer, Wilhelm Conrad Röntgen, allow physicians to visualize many of the anatomic structures that were once visible only at surgery.

Radiography is the making of records, known as *radiographs*, of internal structures of the body by passage of x-rays or gamma rays through the body to act on, historically, specially sensitized film or, most commonly, on a digital imaging plate or detector. In the diagnostic radiography department, images are created using x-rays that pass through the body (Fig. 1.2). In addition, very-high-energy x-rays are used in the radiation therapy department for the treatment of many forms of cancer. In both of these departments, proper radiation protection is essential.

Radio waves are another form of electromagnetic radiation. They are a nonionizing form of radiation and are important in **magnetic resonance imaging (MRI)** (Fig. 1.3).

Medical radiation science involves the study of the use of radiation throughout medicine. The fact that many forms of radiation are used in all branches of medicine should be apparent. Because many laypeople assume that the terms *radiation* and *ionizing radiation* are used interchangeably, the term *imaging sciences* has been preferred to the term *radiation* or *radiologic sciences* in areas that use a nonionizing form of radiation such as diagnostic medical sonography and MRI. Furthermore, because radiation therapy is primarily involved in treatment and not imaging, the term *imaging sciences* alone is not encompassing enough. As a result, many feel that our profession is best described by both terms, *imaging* and *radiation* or *radiologic sciences.* With regard to the profession, the term *radiologic technology* is used by the American Registry of Radiologic Technologists (ARRT) to encompass all of our individual disciplines.

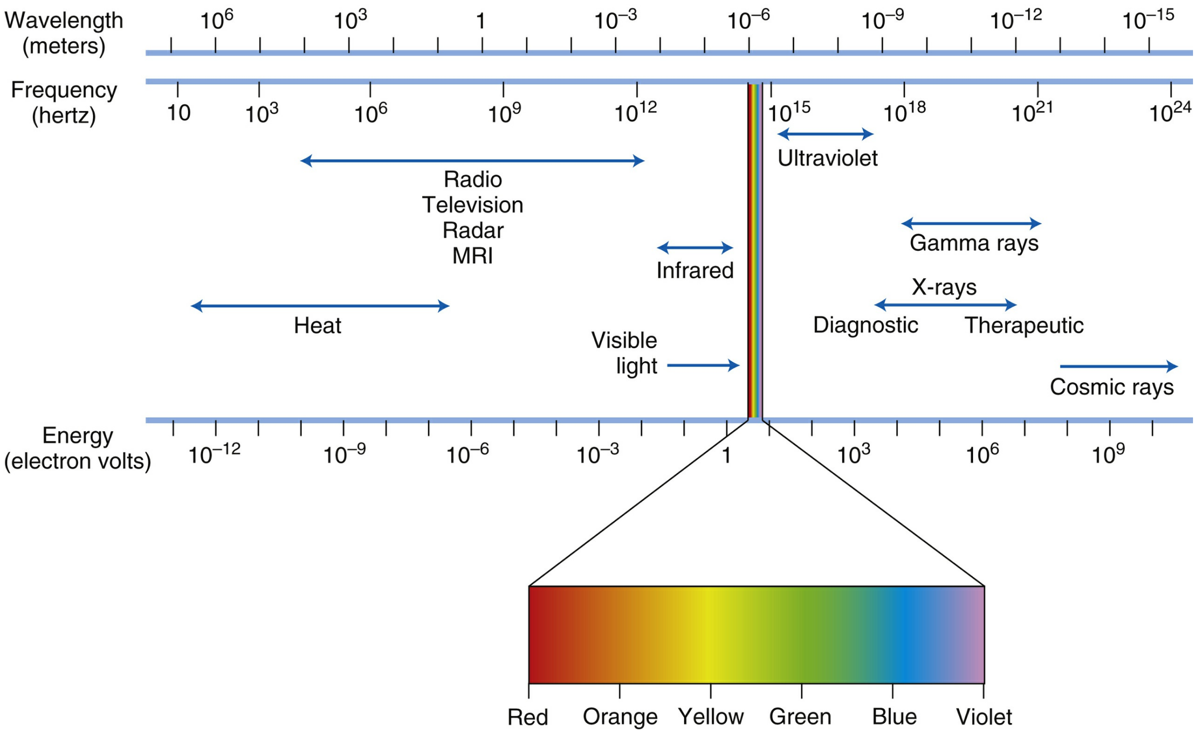

FIG. 1.1 The electromagnetic spectrum. *MRI*, Magnetic resonance imaging.

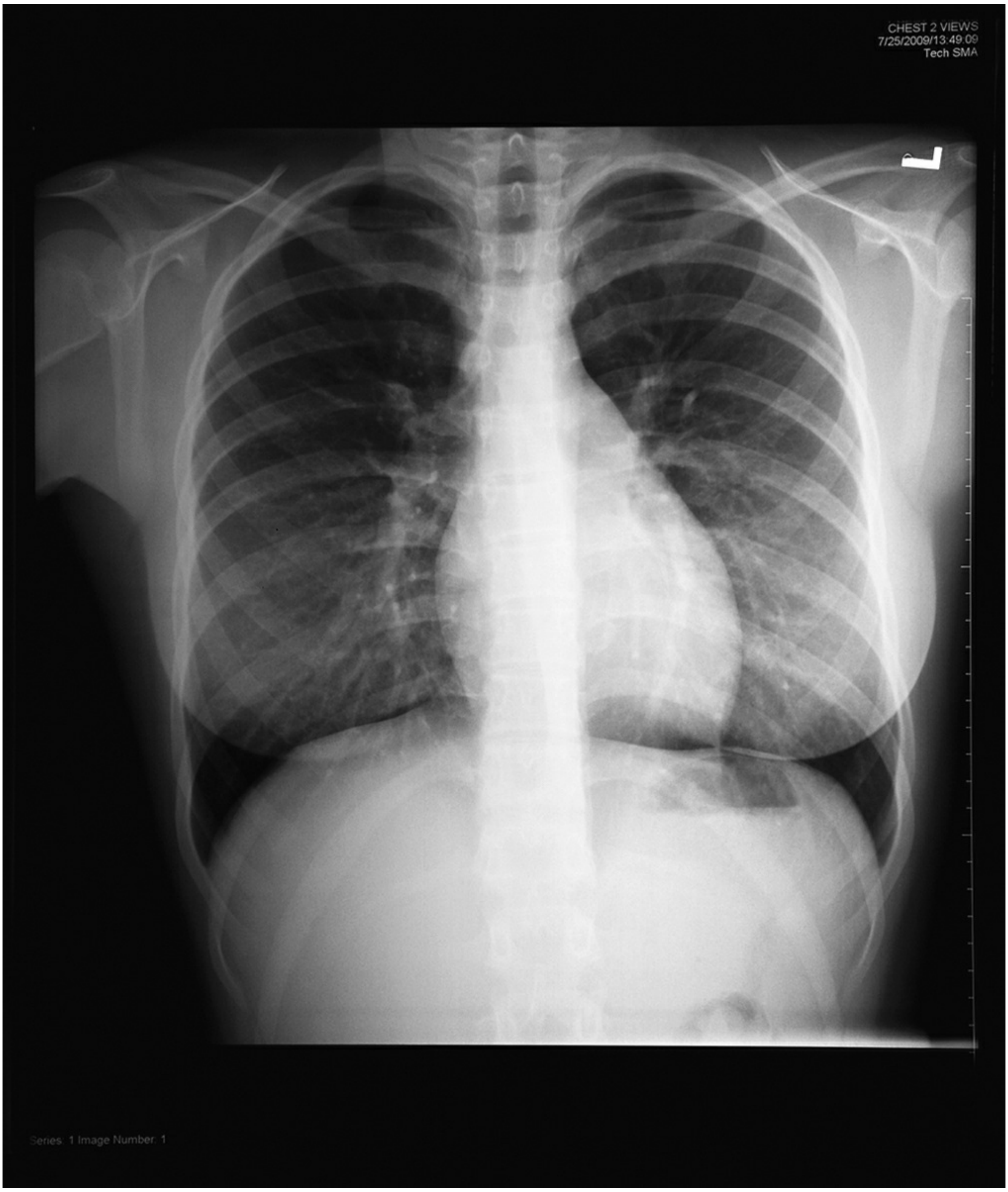

FIG. 1.2 Radiograph of the chest.
Courtesy Julie Aguayo, AS, RT[R], Methodist Hospital Southlake Campus, Merrillville, IN.

FIG. 1.3 Sagittal image of the brain created using magnetic resonance imaging.
Courtesy Julie Aguayo, AS, RT[R], Methodist Hospital Southlake Campus, Merrillville, IN.

Overview of the History of Medicine

Humankind's attempt to treat and cure diseases can be dated back almost 5000 years to Egypt and Mesopotamia, where evidence exists that medicine was being practiced in combination with religious beliefs. Prehistoric skulls found in Europe and South America also demonstrate that early humans deliberately removed bone from the skull successfully. Whether this action was performed as a surgical treatment or as a religious attempt to release evil spirits is unknown. In addition, evidence exists that many potent drugs still in use today, such as castor oil and opium, were used in ancient Egypt for medicinal purposes. However, the Egyptians demonstrated little knowledge of anatomy, despite their sophisticated embalming skills.

The understanding of human anatomy and physiology by the early Greek philosophers was of such high quality that it was not equaled for hundreds of years. Hippocrates (c. 460–370 BC) was a Greek physician who is considered the father of Western medicine. Little is really known about him, but the fact that he was a contemporary of Socrates and was one of the most famous physicians and teachers of medicine of his time is generally accepted. More than 60 medical treatises, called the *Hippocratic Corpus*, traditionally have been attributed to him; however, Hippocrates did not write most of them himself. The writings are similar in that they emphasize rational and natural explanations for the treatment of disease and reject sorcery and magic. Hippocrates emphasized the importance of carefully observing the patient. He believed in the powers of nature to heal over time and taught the prevention of disease through a regimen of diet and exercise. He is also attributed with developing a high standard of ethical conduct, as incorporated in the Hippocratic Oath, which provided guidelines for physician-patient relationships, for the rights of patients to privacy, and for the use of treatment for curative purposes only. The Hippocratic Oath still governs the ethical conduct of physicians today.

The Romans recognized the importance of proper sanitation for good public health, evidenced by their construction of aqueducts, baths, sewers, and hospitals. Unfortunately, during the Middle Ages the destruction or neglect of the Roman sanitary facilities resulted in many local epidemics that eventually led to the great plague, known as the *Black Death*, during the 14th century. Medicine was strongly controlled by religious groups during this period, and it was not until the early 1500s that a physician in England had to be licensed to practice.

By the 17th century, medicine began to develop an increasingly scientific experimental approach. William Harvey (1578–1657), an English physician, is considered by many scholars to have laid the foundation of modern medicine. Harvey was first to demonstrate the function of the heart and the circulation of the blood. This feat is especially remarkable because it was accomplished without the aid of a microscope. By the end of the 17th century, bacteria had been described by Anton Van Leeuwenhoek (1632–1723), a Dutch zoologist, who isolated the microorganism with a microscope he made. With the development of improved microscopes, the discovery of the capillary system of the blood helped complete Harvey's explanation of blood circulation.

During the 18th century a significant number of developments in medicine occurred. Surgery was becoming an experimental science, a large number of reforms were taking place in the area of mental health, and the heart drug digitalis was introduced. In 1796, Edward Jenner (1749–1823), an English physician, introduced a vaccine to prevent smallpox when he inoculated an 8-year-old boy, which proved that cowpox provided immunity against smallpox. This discovery served as the foundation for the field of immunology.

In the 19th century the theory that germs cause disease was established. Louis Pasteur (1822–1895), a French chemist, worked with bacteria to prove the germ theory of infection. Through his work, the process of pasteurization was developed. Robert Koch (1843–1910), a German bacteriologist, established the bacterial cause for many infections, such as anthrax, tuberculosis, and cholera. In 1905 Koch received a Nobel Prize for his work in developing tuberculin as a test for tuberculosis. During the mid-1800s Florence Nightingale (1820–1910), an English nurse, developed the foundations for modern nursing. In 1895, Wilhelm Röntgen discovered x-rays, and the radiologic imaging sciences had their start.

The 20th century saw development of the use of the scientific method throughout medicine. The early part of the century welcomed discovery of the first antibiotics. Sir Alexander Fleming (1881–1955), a Scottish bacteriologist, discovered penicillin in 1928. Further medical advances included the increased use of chemotherapy and a better understanding of the immune system, which resulted in the increased prophylactic use of vaccines such as the Salk vaccine, discovered by Jonas Salk (1914–1995), which helped to control and prevent poliomyelitis. Increased knowledge of the endocrine system has helped to treat diseases resulting from hormone imbalance, including the use of insulin to treat diabetes.

In 1953, at Cambridge University in England, Francis Crick (1916–2004), an English scientist, and James Watson (b. 1928), an American biologist, announced that they had discovered the *secret of life.* Through their work, they identified the molecular structure of deoxyribonucleic acid (DNA), a key to heredity and genetics. Currently, much research is being devoted to the field of genetics. Completed in 2003, the Human Genome Project (HGP) was a 13-year international scientific research project coordinated by the US Department of Energy and the National Institutes of Health. During the early years of the HGP, the Wellcome Trust (United Kingdom) became a major partner; additional partners came from Japan, France, Germany, China, and others. The project goals were to:

- *Identify* all of the approximately 20,000 to 25,000 genes in human DNA
- *Determine* the sequences of the 3 billion chemical base pairs that make up human DNA
- *Store* this information in databases
- *Improve* tools for data analysis
- *Transfer* related technologies to the private sector
- *Address* the ethical, legal, and social issues that may arise from the project

Although the HGP is finished, analyses of the data will continue for many years. The replacement of faulty genes through gene therapy offers promises of cures for a variety of hereditary diseases, and, through genetic engineering, important pharmaceuticals have been developed.

History of Radiologic Technology

The field of radiologic technology began on November 8, 1895, when Wilhelm Röntgen, a German physicist, was working in his laboratory at the University of Wurzburg. Röntgen had been experimenting with cathode rays and was exploring their properties outside glass tubes. He had covered the glass tube to prevent any visible light from escaping. During this work, Röntgen observed that a screen that had been painted with barium platinocyanide was emitting light *(fluorescing).* This effect had to be caused by invisible rays being emitted from the tube. During the next several weeks, Röntgen investigated these invisible rays. During his investigation, he saw the very first radiographic image—his own skeleton. Röntgen became the first radiographer when he produced a series of photographs of radiographic images, most notably the image of his wife's hand (Fig. 1.4). He termed these invisible rays *x-rays* because *x* is the symbol for an unknown variable.

Wilhelm Röntgen was born in Lennep, Germany, on March 27, 1845. In 1872, he married Anna Bertha Ludwig (1839–1919), and they had one adopted daughter. In 1888, Röntgen began working at the University of Wurzburg in the physics department. During the 1870s and 1880s, many physics departments were experimenting with cathode rays, electrons emanating from the negative (cathode) terminal of a tube. During his discovery, Röntgen worked with a Crookes tube. Sir William Crookes (1832–1919) used a large, partially evacuated glass tube that encompassed a cathode and an anode attached to an electrical supply. His tube was the early version of the modern fluorescent light. Crookes actually produced x-rays during his experimentation in the 1870s but failed to grasp the significance of his finding. He often found that photographic plates stored near his worktable were fogged. He even returned fogged photographic plates to the manufacturer, claiming they were defective. Many physicists created x-rays during the course of their work with cathode rays, but Röntgen was the first to appreciate the significance of the penetrating rays.

The actual day that the significance of Röntgen's finding became clear to him is the subject of much debate. However, Friday, November 8, 1895, is believed by historians to be the day that Röntgen created the famous image of his wife's hand (see Fig. 1.4). On Saturday, December 28, 1895, Röntgen submitted his first report, titled *On a New Kind of Rays,* to the Wurzburg Physico-Medical Society. Through his investigative methods, Röntgen identified the properties of x-rays. His methods were so thorough that no significant additions have been made to his work.

For his efforts, Röntgen was honored in 1901 with the first Nobel Prize in physics. He refused to patent any part of his discovery and rejected many commercial company offers. As a result, he saw little financial reward for his work. He died on February 10, 1923, of colon cancer.

Throughout the 20th century, the use of x-rays advanced significantly to include the imaging of almost all aspects of the human body and the treatment of diseases with radiation therapy. In addition, radioactive substances came into use for both imaging (nuclear medicine) and treatment. By the 1970s, imaging had further advanced to include diagnostic medical sonography, computed tomography (CT), and MRI. Today, through the use of hybrid scanners that combine nuclear medicine imaging with either CT or MRI, both anatomic and physiologic function can be assessed in a single examination.

FIG. 1.4 The first radiograph was an image of Wilhelm Röntgen's wife's hand.

Opportunities in Radiologic Technology

Radiologic technology is the technical science that deals with the use of x-rays or radioactive substances for diagnostic or therapeutic purposes in medicine. **Radiologic technologist (RT)** is a general term applied to persons qualified to use x-rays *(radiography)* or radioactive substances *(nuclear medicine)* to produce images of the internal parts of the body for interpretation by a physician known as a **radiologist.** Radiologic technology also involves the use of x-rays or radioactive substances in the treatment of disease *(radiation therapy).*

In addition to using x-rays and radioactive substances, RTs are also involved in using high-frequency sound waves (diagnostic medical sonography) and magnetic fields and radio waves (MRI) to create images of the internal anatomy of the body.

FIG. 1.5 A radiographer positions a patient for a radiographic examination.
Courtesy Philips Medical Systems.

The ARRT is the credentialing organization for medical imaging, interventional procedures, and radiation therapy. The organization identifies the following disciplines that are included in the profession of radiologic technology: radiography (R), nuclear medicine technology (N), radiation therapy (T), magnetic resonance imaging (MR), sonography (S), cardiovascular-interventional radiography (CV), mammography (M), computed tomography (CT), quality management (QM), bone densitometry (BD), vascular sonography (VS), cardiac-interventional radiography (CI), vascular-interventional radiography (VI), breast sonography (BS), and radiologist assistants (RRA). From this list, one can see how all-encompassing the profession of radiologic technology truly is.

Radiography

An RT specializing in the use of x-rays to create images of the body is known as a *radiographer* (Fig. 1.5). Radiographers perform a wide variety of diagnostic x-ray procedures, including examinations of the skeletal system, the chest, and the abdomen. They administer contrast media to permit visualization of the gastrointestinal (GI) tract and the genitourinary system. They also assist the radiologist during more specialized contrast media procedures, such as those used to visualize the spinal cord *(myelography)* and the joint spaces *(arthrography).*

To become a registered radiographer, one must complete an ARRT-recognized radiography program. Programs are most commonly sponsored by hospitals, community colleges, and universities. There are approximately 730 ARRT-recognized radiography programs, primarily in the United States. On successful completion of a recognized program, individuals are awarded a certificate, an associate degree, or a baccalaureate degree and are eligible to take the national examination in radiography offered by the ARRT. Effective January 1, 2015, all candidates must have earned an academic degree to qualify for this certification. A registered radiographer uses the initials *RT(R)(ARRT)* after his or her name. This abbreviation means *registered technologist (radiography).*