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History of Anatomy

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Clinical Case Study

A 55-year-old women visits the village apothecary for her increasing shortness of breath. The physician, learning of the woman's symptoms and finding swelling in her legs, makes the diagnosis of dropsy and prescribes a course of therapy meant to rid the body of evil humors. He applies a dozen of his healthiest leeches to the woman's legs and drains a pint of her blood by opening a vein in her arm. Within hours, the patient is feeling much better and breathing easily. The experience reinforces to the doctor the concept of evil humors and the effectiveness of bloodletting as a therapy.

Dropsy (L. *hydrops;* from Gk. *hydor,* water) is an antiquated term commonly referring to any condition of edema (accumulation of tissue fluid), and was typically a result of congestive heart failure. Current therapy for this condition is oral fluid restriction and medications that induce diuresis (increased urination) with the ultimate goal of decreasing fluid volume. It is no wonder that losing a pint of blood made this woman feel better in the short term. Unfortunately, repeated courses of this crude therapy left patients profoundly anemic (low red blood cell count) and actually worsened their heart failure.

Throughout medical history, how has an accurate understanding of human anatomy and physiology led to better disease therapy?

FIGURE: Blood letting was a technique of medical practice widely used for over two thousand years.

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DEFINITION OF THE SCIENCE

The science of human anatomy is concerned with the structural organization of the human body. The descriptive anatomical terminology is principally of Greek and Latin derivation.

Objective 1 Define *anatomy.*

Objective 2 Distinguish between anatomy, physiology, and biology.

Objective 3 Explain why most anatomical terms are derived from Greek and Latin words.

Human anatomy is the science concerned with the structure of the human body. The term **anatomy** is derived from a Greek word meaning "to cut up"; indeed, in ancient times, the word *anatomize* was more commonly used than the word *dissect*. The science of **physiology** is concerned with the function of the body. It is inseparable from anatomy in that structure tends to reflect function. The term *physiology* is derived from another Greek word—this one meaning "the study of nature." The "nature" of an organism is its function. Anatomy and physiology are both subdivisions of the science of **biology,** the study of living organisms. The anatomy of every structure of the body is adapted for performing a function, or perhaps several functions.

The dissection of human **cadavers** (*kă-dav'erz*) has served as the basis for understanding the structure and function of the human body for many centuries. Every beginning anatomy student can discover and learn firsthand as the structures of the body are systematically dissected and examined. The anatomical terms that a student learns while becoming acquainted with a structure represent the work of hundreds of dedicated anatomists of the past, who have dissected, diagrammed, described, and named the multitude of body parts.

Most of the terms that form the language of anatomy are of Greek or Latin derivation. Latin was the language of the Roman Empire, during which time an interest in scientific description was cultivated. With the decline of the Roman Empire, Latin became a "dead language," but it retained its value in nomenclature because it remained unchanged throughout history. As a consequence, if one is familiar with the basic prefixes and suffixes (see the inside front cover of this text), many of the terms in the descriptive science of anatomy can be understood. Although the Greeks and Romans made significant contributions to anatomical terminology, it should be noted that many individuals from other cultures have also contributed to the science of human anatomy.

As a scientific field of inquiry, human anatomy has had a rich, long, and frequently troubled heritage. The history of human anatomy parallels that of medicine. In fact, interest in the structure of the body often has been stimulated by the desire of the medical profession to explain a body dysfunction. Various religions, on the other hand, have at one time or another stifled the study of human anatomy through their restrictions on human dissections and their emphasis on nonscientific explanations for diseases and debilitations.

Over the centuries, peoples' innate interest in their own bodies and physical capabilities has found various forms of expression. The Greeks esteemed athletic competition and expressed the beauty of the body in their sculptures. Many of the great masters of the Renaissance portrayed human figures in their art. Indeed, several of these artists were excellent anatomists because their preoccupation with detail demanded it. Such an artistic genius was Michelangelo, who captured the splendor of the human form in sculpture with the *David* (fig. 1.1) and in paintings like those in the Sistine Chapel.

Shakespeare's reverence for the structure of the human body found expression in his writings: "What a piece of work is a man! How noble in reason! how infinite in faculty! In form and moving, how express and admirable! In action how like an angel! In apprehension how like a god! The beauty of the world! The paragon of animals!" (*Hamlet* 2.2.315–319).

In the past, human anatomy was an academic, purely descriptive science, concerned primarily with identifying and naming body structures. Although dissection and description form the basis of anatomy, the importance of human anatomy today is in its functional approach and clinical applications. Human anatomy is a practical, applied science that provides the foundation for understanding physical performance and body health. Studying the history of anatomy helps us appreciate the relevant science that it is today.

Knowledge Check

1. What is the derivation and meaning of *anatomy?*
2. Explain the statement, Anatomy is a science based on observation, whereas physiology is based on experimentation and observation.
3. Why does understanding the biology of an organism depend on knowing its anatomy and physiology?
4. Discuss the value of using established Greek or Latin prefixes and suffixes in naming newly described body structures.

PRESCIENTIFIC PERIOD

Evidence indicates that a knowledge of anatomy was of survival value in prehistoric times and that it provided the foundation for medicine.

Objective 4 Explain why an understanding of human anatomy is essential in the science of medicine.

Objective 5 Define *trepanation* and *paleopathology.*

anatomy: Gk. *ana*, up; *tome*, a cutting
physiology: Gk. *physis*, nature; *logos*, study
biology: Gk. *bios*, life; *logos*, study
cadaver: L. *cadere*, to fall

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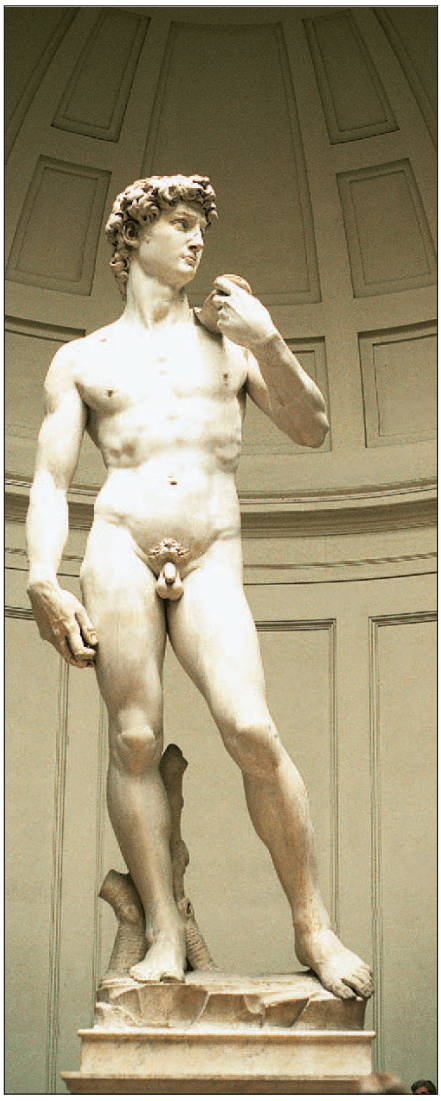

FIGURE 1.1 Michelangelo completed the 17-foot-tall *David* in 1504. Sculpted from a single block of white, flawless Carrara marble, this masterpiece captures the physical nature of the human body in an expression of art.

It is likely that a type of practical comparative anatomy is the oldest science. Certainly, humans have always been aware of some of their anatomical structures and how they function. Our prehistoric ancestors undoubtedly knew their own functional abilities and limitations as compared to those of other animals. Through the trial and error of hunting, they discovered the "vital organs" of an animal, which, if penetrated with an object, would cause death (fig. 1.2). Likewise, they knew the vulnerable areas of their own bodies.

The butchering of an animal following the kill provided many valuable anatomy lessons for prehistoric people. They knew which parts of an animal's body could be used for food,

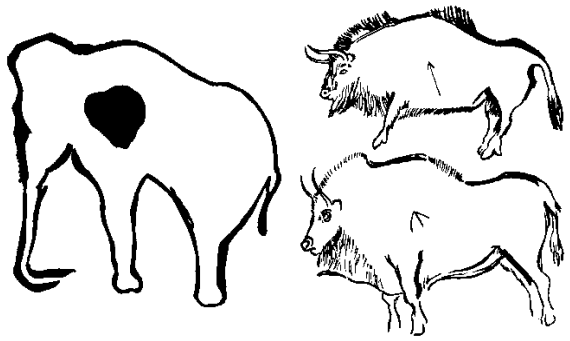

FIGURE 1.2 Contemporary redrawings of large game mammals that were depicted on the walls of caves occupied by early *Homo sapiens* in western Europe. Presumably the location of the heart is drawn on the mammoth, and vulnerable anatomical sites are shown on the two bison. Prehistoric people needed a practical knowledge of anatomy simply for survival.
From *A Short History of Anatomy and Physiology from the Greeks to Harvey* by C. Singer, 1957, Dover Publications, New York, NY. Reprinted by permission.

clothing, or implements. Undoubtedly, they knew that the muscles functioned in locomotion and that they also provided a major source of food. The skin from mammals with its associated fur served as a protective covering for their own sparsely haired skin. Early humans knew that the skeletal system formed a durable framework within their bodies and those of other vertebrates. They used the bones from the animals on which they fed to fashion a variety of tools and weapons. They knew that their own bones could be broken through accidents, and that improper healing would result in permanent disability. They knew that if an animal was wounded, it would bleed, and that excessive loss of blood would cause death. Perhaps they also realized that a severe blow to the head could cause deep sleep and debilitate an animal without killing it. Obviously, they noted anatomical differences between the sexes, even though they could not have understood basic reproductive functions. The knowledge these people had was of the basic, practical type—a knowledge necessary for survival.

Certain surgical skills are also ancient. **Trepanation** (*trep-ă-na′shun*), the drilling of a hole in the skull, or removal of a portion of a cranial bone, seems to have been practiced by several groups of prehistoric people. Trepanation was probably used as a ritualistic procedure to release evil spirits, or on some patients, perhaps, to relieve cranial pressure resulting from a head wound. Trepanated skulls have been found repeatedly in archaeological sites (fig. 1.3). Judging from the partial reossification in some of these skulls, apparently a fair proportion of the patients survived.

What is known about prehistoric humans is conjectured through information derived from cave drawings, artifacts, and fossils that contain paleopathological information. **Paleopathology** is the science concerned with studying diseases and causes of

trepanation: Gk. *trypanon*, a borer
paleopathology: Gk. *palaios*, ancient; *pathos*, suffering; *logos*, to study

FIGURE 1.3 The surgical art of trepanation was practiced by several prehistoric cultures. Amazingly, more than a few patients survived this ordeal, as evidenced by ossification around the bony edges of the wound.

death in prehistoric humans. A person's approximate age can be determined from skeletal remains, as can the occurrence of certain injuries and diseases, including nutritional deficiencies. Diets and dental conditions, for example, are indicated by fossilized teeth. What cannot be determined, however, is the extent of anatomical information and knowledge that may have been transmitted orally up until the time humans invented symbols to record their thoughts, experiences, and history.

Knowledge Check

5. Why would it be important to know the anatomy of the skull and brain before performing a surgery such as trepanation?
6. What types of data might a paleopathologist be interested in obtaining from an Egyptian mummy?

SCIENTIFIC PERIOD

Human anatomy is a dynamic and growing science with a long, exciting heritage. It continues to provide the foundation for medical, biochemical, developmental, cytogenetic, and biomechanical research.

Objective 6 Discuss some of the key historical events in the science of human anatomy.

Objective 7 List the historical periods in which cadavers were used to study human anatomy.

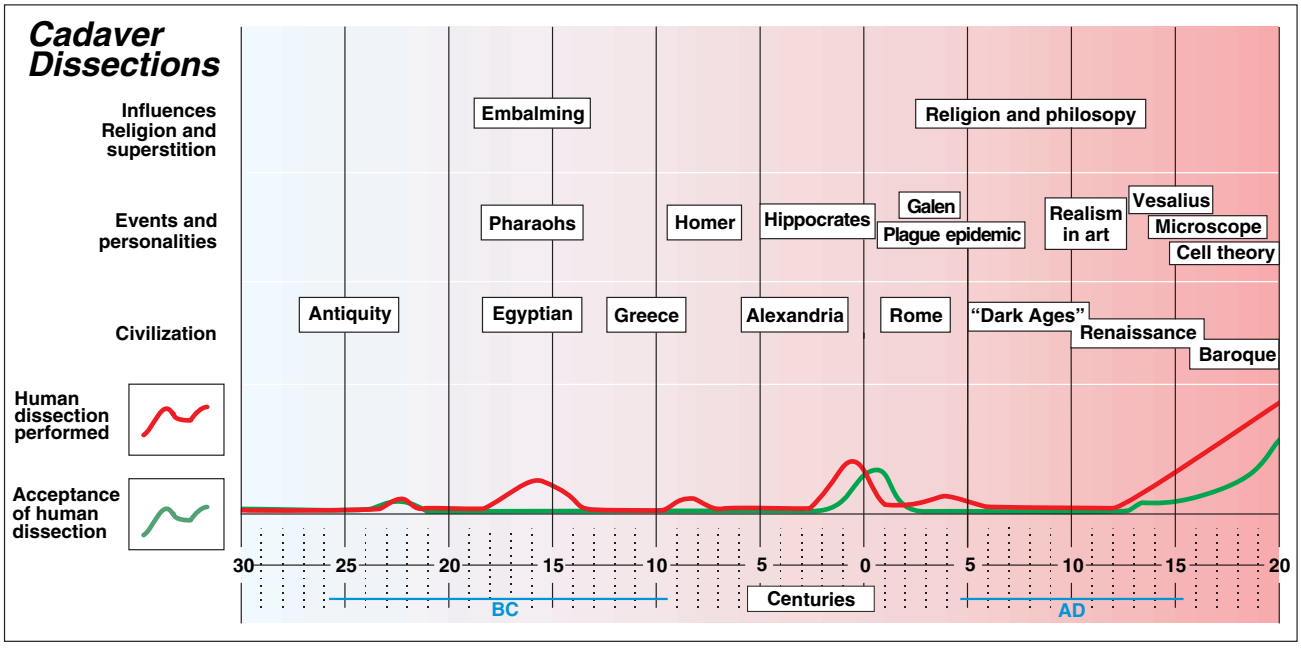

FIGURE 1.4 A timeline depicting the story of cadaver dissections.

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TABLE 1.1 Survey of Some Important Contributions to the Science of Human Anatomy

Person	Civilization	Lifetime or Date of Contribution	Contribution
Menes	Egyptian	About 3400 B.C.	Wrote the first anatomy manual
Homer	Ancient Greece	About 800 B.C.	Described the anatomy of wounds in the *Iliad*
Hippocrates	Ancient Greece	About 460–377 B.C.	Father of medicine; inspired the Hippocratic oath
Aristotle	Ancient Greece	384–322 B.C.	Founder of comparative anatomy; profoundly influenced Western scientific thinking
Herophilus	Alexandria	About 325 B.C.	Conducted remarkable research on aspects of the nervous system
Erasistratus	Alexandria	About 300 B.C.	Sometimes called father of physiology; attempted to apply physical laws to the study of human function
Celsus	Roman	30 B.C.–A.D. 30	Compiled information from the Alexandrian school; first medical author to be printed (1478) in movable type after Gutenburg's invention
Galen	Greek (lived under Roman domination)	130–201	Probably the most influential medical writer of all time; established principles that went unchallenged for 1,500 years
de' Luzzi	Renaissance	1487	Prepared dissection guide
Leonardo da Vinci	Renaissance	1452–1519	Produced anatomical drawings of unprecedented quality based on human cadaver dissections
Vesalius	Renaissance	1514–64	Refuted past misconceptions about body structure and function by direct observation and experiment; often called father of anatomy
Harvey	Premodern (European)	1578–1657	Demonstrated the function of the circulatory system; applied the experimental method to anatomy
Leeuwenhoek	Premodern (European)	1632–1723	Refined the microscope; described various cells and tissues
Malpighi	Premodern (European)	1628–94	Regarded as father of histology; first to confirm the existence of the capillaries
Sugita	Premodern (Japanese)	1774	Compiled a five-volume treatise on anatomy
Schleiden and Schwann	Modern (European)	1838–39	Formulated the cell theory
Roentgen	Modern (European)	1895	Discovered X rays
Crick and Watson	Modern (English and American)	1953	Determined the structure of DNA
Collins and Venter	Modern (American)	2000	Instrumental in human genome research

Objective 8 Explain why an understanding of human anatomy is relevant to all individuals.

Objective 9 Discuss one way of keeping informed about developments in anatomical research and comment on the importance of this endeavor.

The scientific period begins with recorded anatomical observations made in early Mesopotamia on clay tablets in *cuneiform script* over 3,000 years ago and continues to the present day. Obviously, all of the past contributions to the science of anatomy cannot be mentioned; however, certain individuals and cultures had a tremendous impact and will be briefly commented on in this section.

cuneiform: L. *cuneus*, wedge; *forma*, shape

The history of anatomy has an interesting parallel with the history of the dissection of human cadavers, as is depicted in figure 1.4. A few of the individuals who made significant contributions to the field are listed in table 1.1. Some of their contributions were in the form of books (table 1.2) that describe and illustrate the structure of the body and in some cases explain various body functions.

Mesopotamia and Egypt

Mesopotamia was the name given to the long, narrow wedge of land between the Tigris and Euphrates rivers, which is now a large part of present-day Iraq. Archaeological excavations and ancient records show that this area was settled prior to 4000 B.C. On the basis of recorded information about the culture of the people, Mesopotamia is frequently called the Cradle of Civilization.

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TABLE 1.2 Influential Books and Publications on Anatomy and Related Disciplines

Aristotle. 384–322 B.C. *Historia animalium (History of animals), De partibus animalium (On the parts of animals),* and *De generatione animalium (On the generation of animals).* These classic works by the great Greek philosopher profoundly influenced biological thinking for centuries.

Celsus, Cornelius. 30 B.C.–A.D. 30. *De re medicina.* This eight-volume work was primarily a compilation of the medical data that was available from the Alexandrian school.

Galen, Claudius. 130–201. Nearly 500 medical treatises on descriptive anatomy. Although Galen's writings contained numerous errors, his pronouncements on the structure and function of the body held sway until the Renaissance.

de' Luzzi, Mondino. 1487. *Anathomia.* This book was used as a dissection guide for over 225 years, during which time it underwent 40 revisions.

Vesalius, Andreas. 1543. *De humani corporis fabrica (On the structure of the human body).* The beautifully illustrated *Fabrica* boldly challenged many of the errors that had been perpetuated by Galen. In spite of the controversies it provoked, this book was well accepted and established a new standard of excellence in anatomy texts.

Fabricius ab Aquapendente, Hieronymus. 1600–1621. *De formato foetu (On the formation of the fetus)* and *De formatione ovi et pulli (On the formation of eggs and birds).* These books marked the beginning of embryological study.

Harvey, William. 1628. *Exercitatio de motu cordis et sanguinis in animalibus (On the motion of the heart and blood in animals).* Harvey demonstrated that blood must be circulated, and his experimental methods are still regarded as classic examples of scientific methodology.

Descartes, René. 1637. *Discourse on method.* This philosophic thesis stimulated a mechanistic interpretation of biological data.

Linnaeus, Carolus. 1758. *Systema naturae.* The basis for the classification of living organisms is explained in this monumental work. Its anatomical value is in comparative anatomy, where the anatomy of different species is compared.

Haller, Albrecht von. 1760. *Elementa physiologiae (Physiological elements).* Some basic physiological concepts are presented in this book, including a summary of what was then known of the functioning of the nervous system.

Sugita, Genpaku. 1774. *Kaitai shinsho (A new book of anatomy).* This book adopted a European conceptualization of body structure and function and ushered in a new era of anatomy for the Japanese.

Cuvier, Georges. 1817. *Le règne animal (The animal kingdom).* This comprehensive comparative vertebrate anatomy book had enormous influence on contemporary zoological thought.

Baer, Karl Ernst von. 1828–37. *Über entwicklungsgeschichté der thiere (On the development of animals).* This book helped to pave the way for modern embryology by discussing germ layer formation.

Beaumont, William. 1833. *Experiments and observations on the gastric juice and the physiology of digestion.* Basic digestive functions are accurately described in this classic work.

Müller, Johannes. 1834–40. *Handbuch der physiologie des menschen für vorlesungen (Elements of physiology).* This book established physiology as a science concerned with the functioning of the body.

Schwann, Theodor. 1839. *Mikroskopische untersuchungen über die übereinstimmung in der struktur und dem wachstum der thiere und pflanzen (Microscopic researches into accordance in the structure and growth of animals and plants).* The basic theory that all living organisms consist of living cells is presented in this classic study.

Kölliker, Albrecht von. 1852. *Mikroskopische anatomia (Microscopic anatomy).* This premier textbook in histology laid the foundation for the emerging science.

Gray, Henry. 1858. *Anatomy, descriptive and surgical.* This masterpiece, better known as *Gray's anatomy,* is still in print and contains over 200 of the original illustrations. Thousands of physicians have used it to learn gross human anatomy.

Virchow, Rudolf. 1858. *Die cellularpathologie (Cell pathology).* Descriptions of normal and diseased tissues are presented in this book.

Darwin, Charles. 1859. *On the origin of species.* The ideas set forth in this classic took many years to be understood and accepted. Its importance to anatomy is that it provided an explanation for the anatomical variation evident among different species.

Mendel, Gregor. 1866. *Versuche über pflanzenhybriden (Experiments with plant hybrids).* Through observation and experimentation, Mendel demonstrated the basic principles of heredity.

Owen, Richard. 1866. *Anatomy and physiology of the vertebrates.* Some basic concepts of structure and function, such as homologue and analogue, are presented in this book.

Balfour, Francis M. 1880. *Comparative embryology.* This book was considered a primary source of information for the emerging science of experimental embryology.

Weismann, August. 1892. *Das keimplasma (The germplasm).* Weismann postulated the theory of meiosis, which states that a reduction in the chromosome number is necessary in the gametes of both the male and female for fertilization to occur.

Hertwig, Oskar. 1893. *Zelle and gewebe (Cell and tissue).* Important distinctions between the sciences of cytology and histology are made in this book.

Wilson, Edmund B. 1896. *The cell in development and heredity.* This book had a profound influence on the development of cytogenetics.

Pavlov, Ivan. 1897. *Le travail des glandes digestives (The work of the digestive glands).* The physiological functioning of the digestive system is described in this classic experimental work.

Sherrington, Charles. 1906. *The integrative action of the nervous system.* The basic concepts of neurophysiology were first established in this book.

Garrod, Archibald. 1909. *Inborn errors of metabolism.* Genetic defects are discussed in this pioneer book, and are shown to be caused by defective genes.

Bayliss, William M. 1915. *Principles of general physiology.* This book provided the synthesis that was needed for a newly emerging science.

Spemann, Hans. 1938. *Embryonic development and induction.* This masterful book provided the foundation for the science of modern experimental embryology.

Crick, Francis H. C., and James D. Watson. 1953. *Genetic implications of the structure of deoxyribonucleic acid.* This remarkable work explains the process of genetic replication and control of cellular functions.

Steindler, Arthur. 1995. *Kinesiology of the human body under normal and pathological conditions.* This contemporary text stimulated interest in biomechanics and functional anatomy as applied to clinical problems.

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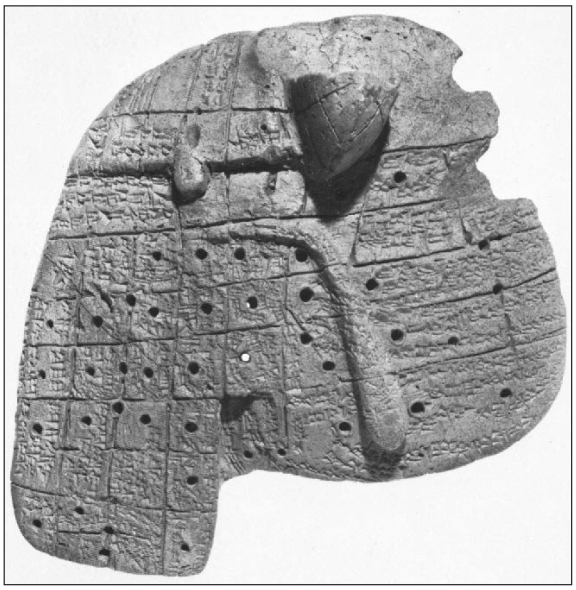

FIGURE 1.5 An inscribed clay model of a sheep's liver from the eighteenth or nineteenth century B.C. The people of ancient Mesopotamia regarded the liver as the seat of human emotions.

Many early investigations of the body represented an attempt to describe basic life forces. For example, people wondered which organ it was that constituted the soul. Some cuneiform writings from ancient Mesopotamia depicted and described body organs that were thought to serve this function. The liver, which was extensively studied in sacrificial animals (fig. 1.5), was thought to be the "guardianship of the soul and of the sentiments that make us men." This was a logical assumption because of the size of the liver and its close association with blood, which was observed to be vital for life. Even today, several European cultures associate the liver with various emotions.

The warm blood and arrangement of blood vessels are obviously a governing system within the body, and this influenced the search for the soul. When excessive blood is lost, the body dies. Therefore, some concluded, blood must contain a vital, life-giving force. The scholars of Mesopotamia were influenced by this idea, as was Aristotle, the Greek scientist who lived centuries later. Aristotle believed that the seat of the soul was the heart and that the brain functioned in cooling the blood that flowed from the heart. The association of the heart, in song and poetry, with the emotions of love and caring has its basis in Aristotelian thought.

The ancient Egyptian culture neighbored Mesopotamia to the west. Here, the sophisticated science of embalming the dead in the form of mummies was perfected (fig. 1.6). No known attempts were made to perform anatomical or pathological studies on the corpses, however, because embalming was strictly a religious ritual. It was reserved for royalty and the wealthy to prepare them for a life after death.

FIGURE 1.6
Perhaps the greatest contribution of the ancient Egyptian era to anatomy and medicine is the information obtained from the mummies. Certain diseases, injuries, deformities, and occasionally causes of death can be determined from paleopathogenic examination of the mummified specimens. Shown on the right is a congenital clubfoot from a mummy of a person who lived during the Nineteenth Dynasty (about 1300 B.C.).

The Egyptian techniques of embalming could have contributed greatly to the science of anatomy had they been recorded. Apparently, however, embalmings were not generally looked on with favor by the general public in ancient Egypt. In fact, embalmers were frequently persecuted and even stoned. Embalming was a mystic art related more to religion than to science, and because it required a certain amount of mutilation of the dead body, it was regarded as demonic. Consequently, embalming techniques that could have provided embalmed cadavers as dissection specimens had to wait until centuries later to be rediscovered.

Several written works concerning anatomy have been discovered from ancient Egypt, but none of these influenced succeeding cultures. Menes, a king-physician during the first Egyptian dynasty of about 3400 B.C. (even before the pyramids were built), wrote what is thought to be the first manual on anatomy. Later writings (2300–1250 B.C.) attempted a systematization of the body, beginning with the head and progressing downward.

embalm: L. *in*, in; *balsamum*, balsam

physician: Gk. *physikos*, natural

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Like the people of Mesopotamia and Greece, the ancient Egyptians were concerned with a controlling spirit of the body. In fact, they even had a name for this life force—the Ba spirit—and they believed that it was associated with the bowels and the heart. Food was placed in the tomb of a mummy to feed the Ba spirit during the journey to Osiris, Egyptian god of the underworld.

China and Japan

China

In ancient China, interest in the human body was primarily philosophical. Ideas about anatomy were based on reasoning rather than dissection or direct observation. The Chinese revered the body and abhorred its mutilation. An apparent exception was the practice of binding the feet of young girls and women in an attempt to enhance their beauty. Knowledge of the internal organs came only from wounds and injuries. Only in recent times have dissections of cadavers been permitted in Chinese medical schools.

The ancient Chinese had an abiding belief that everything in the universe depended on the balance of the two opposing cosmic principles of *yin* and *yang*. As for the circulatory system, the blood was the conveyor of the yang, and the heart and vessels represented the yin. Other structures of the body were composed of lesser forces termed *zō* and *fū*.

The Chinese were great herbalists. Writings more than 5,000 years old describe various herbal concoctions and potions to alleviate a wide variety of ailments, including diarrhea, constipation, and menstrual discomfort. Opium was described as an excellent painkiller.

Until recently, the Chinese have been possessive of their beliefs, and for this reason Western cultures were not influenced by Chinese thoughts or writings to an appreciable extent. Perhaps the best known but least understood of the Chinese contributions to human anatomy and medicine is acupuncture.

Acupuncture is an ancient practice that was established to maintain a balance between the yin and the yang. Three hundred sixty-five precise meridian sites, or vital points, corresponding to the number of days in a year, were identified on the body (fig. 1.7). Needles inserted into the various sites were believed to release harmful secretions and rid the tissues of obstructions. Acupuncture is still practiced in China and has gained acceptance with some medical specialists in the United States and other countries as a technique of anesthesia and as a treatment for certain ailments. The painkilling effect of acupuncture has been documented and is more than psychological. Acupuncture sites have been identified on domestic animals and have been used to a limited degree in veterinary medicine. Why acupuncture is effective remains a mystery, although it has recently been correlated with endorphin production within the brain (see chapter 11).

Japan

The advancement of anatomy in Japan was strongly influenced by the Chinese and Dutch. The earliest records of anatomical interest in Japan date back to the sixth century. Buddhist monks from Japan were trained in China where they were exposed to Chinese philosophy, and so Chinese beliefs concerning the body became prevalent in Japan as well. By the eighteenth century, Western influences, especially the Dutch, were such that the Japanese sought to determine for themselves which version of anatomy was correct. In 1774, a five-volume work called *Kaitai Shinsho (A New Book of Anatomy)*, published by a Japanese physician, Genpaku Sugita, totally adopted the Dutch conceptualization of the body. This book marked the beginning of a modern era in anatomy and medicine for the Japanese people.

For several hundred years, Western nations were welcome in Japan. In 1603, however, the Japanese government banned all contact with the Western world because they feared the influences of Christianity on their society. Although this ban was strictly enforced and Japan became isolated, Japanese scholars continued to circulate Western books on anatomy and medicine. These books eventually prompted Japanese physicians to reassess what they had been taught concerning the structure of the body.

Grecian Period

It was in ancient Greece that anatomy first gained wide acceptance as a science. The writings of several Greek philosophers had a tremendous impact on future scientific thinking. During this period, the Greeks were obsessed with the physical beauty of the human body, as reflected by their exquisite sculptures.

The young people of Greece were urged to be athletic and develop their physical abilities, but at about age 18 they were directed more to intellectual pursuits of science, rhetoric, and philosophy. An educated individual was expected to be acquainted with all fields of knowledge, and it was only natural that great strides were made in the sciences.

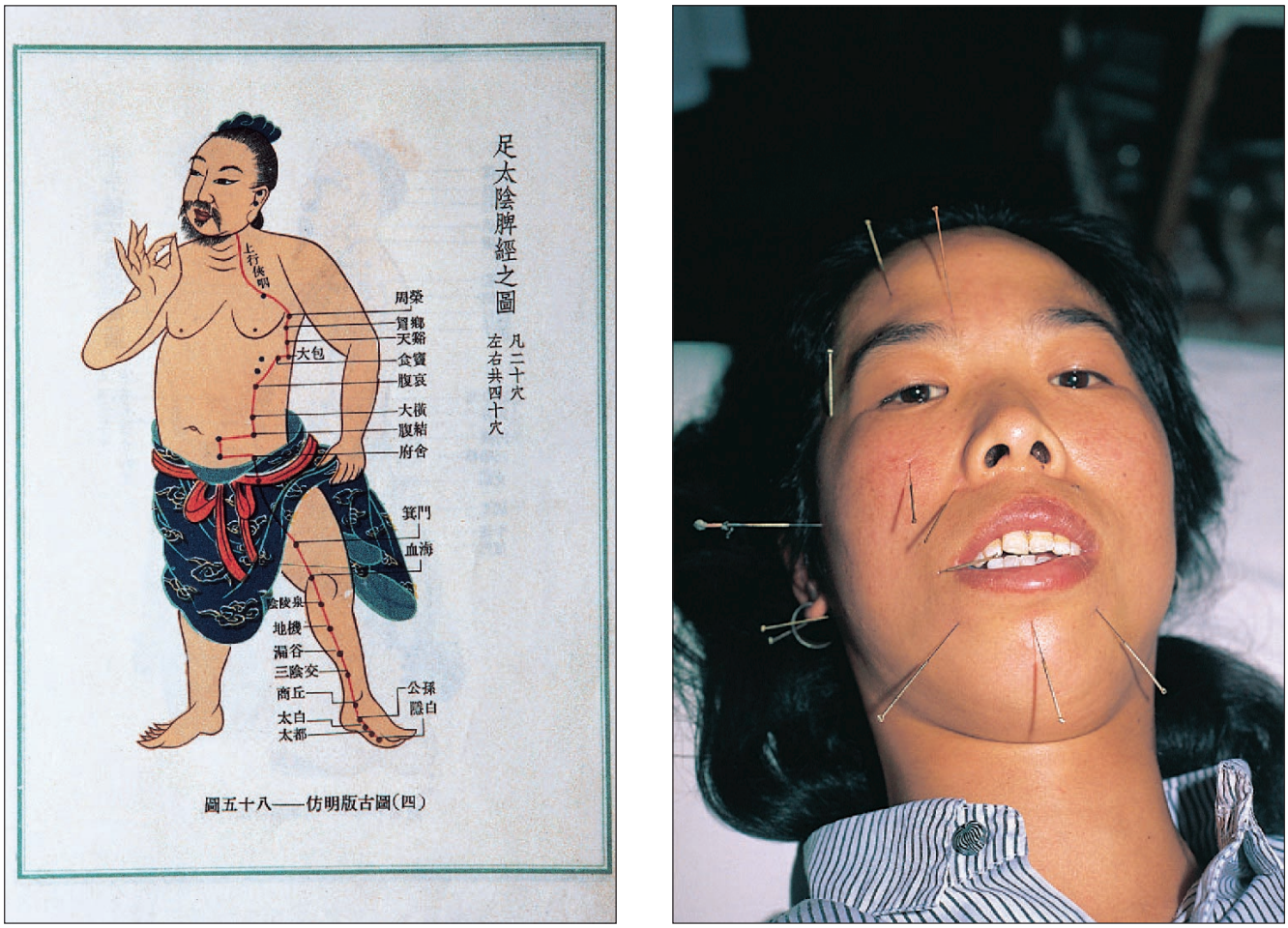
Perhaps the first written reference to the anatomy of wounds sustained in battle is contained in the *Iliad*, written by Homer in about 800 B.C. Homer's detailed descriptions of the anatomy of wounds were exceedingly accurate. However, he described clean wounds—not the type of traumatic wounds that would likely be suffered on a battlefield. This has led to speculation that human dissections were conducted during this period and that anatomical structure was well understood. Victims of human sacrifice may have served as subjects for anatomical study and demonstration.

Hippocrates

Hippocrates (460–377 B.C.), the most famous of the Greek physicians of his time, is regarded as the father of medicine because of the sound principles of medical practice that his school established (fig. 1.8). His name is memorialized in the Hippocratic oath, which many graduating medical students repeat as a promise of professional stewardship and duty to humankind.

Hippocrates probably had only limited exposure to human dissections, but he was well disciplined in the popular *humoral theory* of body organization. Four body humors were recognized,

humor: L. *humor*, fluid



(a) (b)

FIGURE 1.7 Acupuncture has long been practiced for diagnostic or therapeutic purposes. Acupressure is application of finger-point pressure at specific meridian sites to manage pain. (*a*) An acupuncture chart from the Ming dynasty of ancient China and (*b*) a patient receiving acupuncture.

and each was associated with a particular body organ: blood with the liver; choler, or yellow bile, with the gallbladder; phlegm with the lungs; and melancholy, or black bile, with the spleen. A healthy person was thought to have a balance of the four humors. The concept of humors has long since been discarded, but it dominated medical thought for over 2,000 years.

Perhaps the greatest contribution of Hippocrates was that he attributed diseases to natural causes rather than to the displeasure of the gods. His application of logic and reason to medicine was the beginning of observational medicine.

The four humors are a part of our language and medical practice even today. *Melancholy* is a term used to describe depression or despondency in a person, whereas melanous refers to a black or sallow complexion. The prefix *melano-* means black.

melancholy: Gk. *melan*, black; *chole*, bile

Cholera is an infectious intestinal disease that causes diarrhea and vomiting. *Phlegm* (pronounced flem) within the upper respiratory system is symptomatic of several pulmonary disorders. *Sanguine,* a term that originally referred to blood, is used to describe a passionate temperament. This term, however, has evolved to refer simply to the cheerfulness and optimism that accompanied a sanguine personality, and no longer refers directly to the humoral theory.

Aristotle

Aristotle (384–322 B.C.), a pupil of Plato, was an accomplished writer, philosopher, and zoologist (fig. 1.9). He was also a renowned teacher and was hired by King Philip of Macedonia to tutor his son, Alexander, who later became known as Alexander the Great.

cholera: Gk. *chole*, bile

phlegm: Gk. *phlegm*, inflammation

sanguine: L. *sanguis*, bloody

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The Hippocratic Oath

I swear by Apollo Physician and Aesculapius and Hygeia and Panacea and all the gods and goddesses making them my witnesses, that I will fulfill according to my ability and judgment this oath and this covenant:

To hold him who has taught me this art as equal to my parents and to live my life in partnership with him, and if he is in need of money to give him a share of mine, and to regard his offspring as equal to my brothers in male lineage and to teach them this art—if they desire to learn it—without fee and covenant; to give a share of precepts and oral instruction and all the other learning to my sons and to the sons of him who has instructed me and to pupils who have signed the covenant and have taken an oath according to the medical law, but to no one else.

I will apply dietetic measures for the benefit of the sick according to my ability and judgment; I will keep them from harm and injustice.

I will neither give a deadly drug to anybody if asked for it, nor will I make a suggestion to this effect. Similarly I will not give to a woman an abortive remedy. In purity and holiness I will guard my life and my art.

I will not use the knife, not even on sufferers from stone, but will withdraw in favor of such men as are engaged in this work.

Whatever houses I may visit, I will come for the benefit of the sick, remaining free of all intentional injustice, of all mischief, and in particular of sexual relations with both female and male persons, be they free or slaves.

What I may see or hear in the course of the treatment or even outside of the treatment in regard to the life of men, which on no account one must spread abroad, I will keep to myself, holding such things shameful to be spoken about.

If I fulfill this oath and do not violate it, may it be granted to me to enjoy life and art, being honored with fame among all men for all time to come; if I transgress it and swear falsely, may the opposite of all this be my lot.

FIGURE 1.8 A fourteenth-century painting of the famous Greek physician Hippocrates. Hippocrates is referred to as the father of medicine; his creed is immortalized as the Hippocratic oath (left).

Aristotle made careful investigations of all kinds of animals, which included references to humans, and he pursued a limited type of scientific method in obtaining data. He wrote the first known account of embryology, in which he described the development of the heart in a chick embryo. He named the aorta and contrasted the arteries and veins. Aristotle's best known zoological works are *History of Animals*, *On the Parts of Animals*, and *On the Generation of Animals* (see table 1.2). These books had a profound influence on the establishment of specialties within anatomy, and they earned Aristotle recognition as founder of comparative anatomy.

In spite of his tremendous accomplishments, Aristotle perpetuated some erroneous theories regarding anatomy. For example, the doctrine of the humors formed the boundaries of his thought. Plato had described the brain as the "seat of feeling and thought," but Aristotle disagreed. He placed the seat of intelligence in the heart and argued that the function of the brain, which was bathed in fluid, was to cool the blood that was pumped from the heart, thereby maintaining body temperature.

Alexandrian Era

Alexander the Great founded Alexandria in 332 B.C. and established it as the capital of Egypt and a center of learning. In addition to a great library, there was also a school of medicine in Alexandria. The study of anatomy flourished because of the acceptance of dissections of human cadavers and human **vivisections** (*viv″ĭ-sek′shunz*) (dissections of living things). This brutal procedure was commonly performed on condemned criminals. People reasoned that to best understand the functions of the body, it should be studied while the subject was alive, and that a condemned man could best repay society through the use of his body for a scientific vivisection.

Unfortunately, the scholarly contributions and scientific momentum of Alexandria did not endure. Most of the written works were destroyed when the great library was burned by the Romans as they conquered the city in 30 B.C. What is known about Alexandria was obtained from the writings of later scientists, philosophers, and historians, including Pliny, Celsus, Galen, and Tertullian. Two men of Alexandria, Herophilus and Erasistratus, made lasting contributions to the study of anatomy.

Aesculapius: Gk. (mythology) son of Apollo and god of medicine

Hygeia: Gk. (mythology) daughter of Aesculapius; personification of health; *hygies*, healthy

Panacea: Gk. (mythology) also a daughter of Aesculapius; assisted in temple rites and tended sacred serpents; *pan*, all, every; *akos*, remedy

vivisection: L. *vivus*, alive; *sectio*, a cutting

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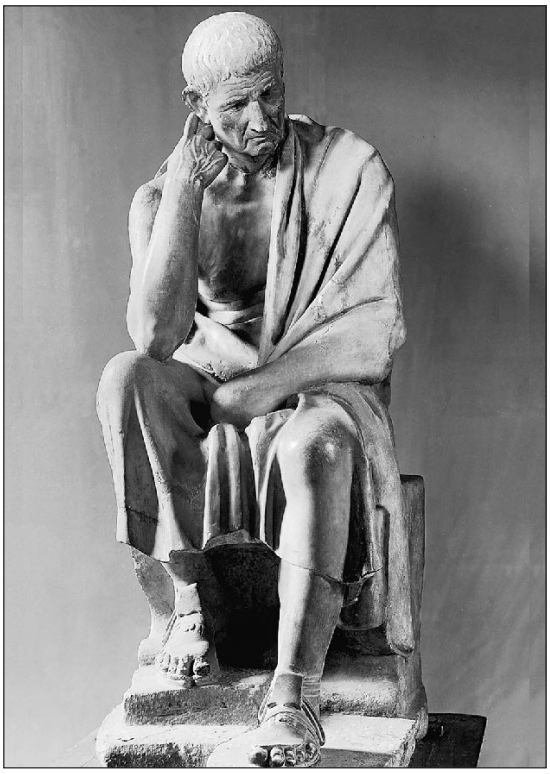

FIGURE 1.9 This Roman copy of a Greek sculpture is believed to be of Aristotle, the famous Greek philosopher.

Herophilus

Herophilus (about 325 B.C.) was trained in the Hippocratic school but became a great teacher of anatomy in Alexandria. Through vivisections and dissections of human cadavers, he provided excellent descriptions of the skull, eye, various visceral organs and organ relationships, and the functional relationship of the spinal cord to the brain. Two monumental works by Herophilus are entitled *On Anatomy* and *Of the Eyes*. He regarded the brain as the seat of intelligence and described many of its structures, such as the meninges, cerebrum, cerebellum, and fourth ventricle. He was also the first to distinguish nerves as either sensory or motor.

Erasistratus

Erasistratus (about 300 B.C.) was more interested in body functions than structure and is frequently referred to as the father of physiology. In a book on the causes of diseases, he included observations on the heart, vessels, brain, and cranial nerves. Erasistratus noted the toxic effects of snake venom on various visceral organs and described changes in the liver resulting from various diseases. Although some of his writings were scientifically accurate, he also had notions that were primitive and mystical. He thought, for example, that the cranial nerves carried animal spirits and that muscles contracted because of distention by spirits. He also believed that the left ventricle of the heart was filled with a vital air spirit (pneuma) that came in from the lungs, and that the arteries transported this pneuma rather than blood.

Both Herophilus and Erasistratus were greatly criticized later in history for the vivisections they performed. Celsus (about 30 B.C.) and Tertullian (about A.D. 200) were particularly critical of the practice of vivisection. Herophilus was described as a butcher of men who had dissected as many as 600 living human beings, sometimes in public demonstrations.

Roman Era

In many respects, the Roman Empire stifled scientific advancements and set the stage for the Dark Ages. The approach to science shifted from theoretical to practical during this time. Few dissections of cadavers were performed other than in attempts to determine the cause of death in criminal cases. Medicine was not preventive but was limited, almost without exception, to the treatment of soldiers injured in battle. Later in Roman history, laws were established that attested to the influence of the Church on medical practice. According to Roman law, for example, no deceased pregnant woman could be buried without prior removal of the fetus from the womb so that it could be baptized.

The scientific documents that have been preserved from the Roman Empire are mostly compilations of information obtained from the Greek and Egyptian scholars. New anatomical information was scant, and for the most part was derived from dissections of animals other than human. Two important anatomists from the Roman era were Celsus and Galen.

Celsus

Most of what is currently known about the Alexandrian school of medicine is based on the writings of the Roman encyclopedist Cornelius Celsus (30 B.C.–A.D. 30). He compiled this information into an eight-volume work called *De re medicina*. Celsus had only limited influence in his own time, however, probably because of his use of Latin rather than Greek. It was not until the Renaissance that the enormous value of his contribution was recognized.

Galen

Claudius Galen (A.D. 130–201) was perhaps the best physician since Hippocrates. A Greek living under Roman domination, he was certainly the most influential writer of all times on medical subjects. For nearly 1,500 years, the writings of Galen represented the ultimate authority on anatomy and medical treatment. Galen probably dissected no more than two or three human cadavers during his career, of necessity limiting his anatomical descriptions to nonhuman animal dissections. He

visceral: L. *viscus*, internal organ

pneuma: Gk. *pneuma*, air

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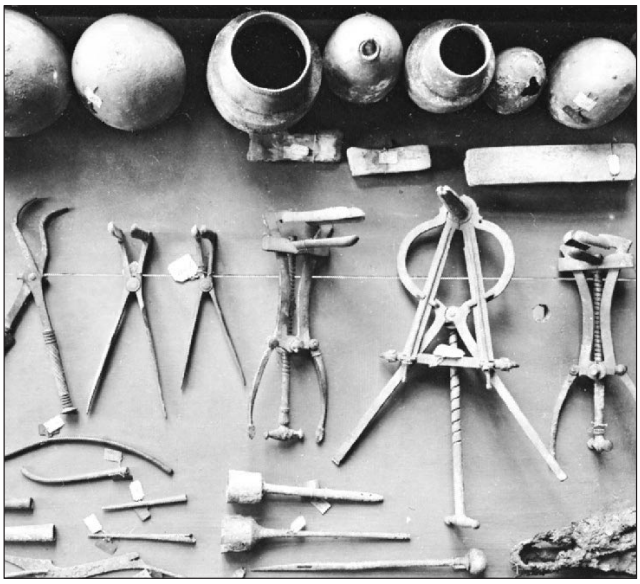

FIGURE 1.10 These surgical and gynecological instruments were found in the House of the Surgeon (about A.D. 67–79) in Pompeii. They are representative of the medical equipment used throughout the Roman Empire during this time.

compiled nearly 500 medical papers (of which 83 have been preserved) from earlier works of others, as well as from his personal studies. He perpetuated the concept of the humors of the body and gave authoritative explanations for nearly all body functions.

Galen's works contain many errors, primarily because of his desire to draw definitive conclusions regarding human body functions on the basis of data obtained largely from animals such as monkeys, pigs, and dogs. He did, however, provide some astute and accurate anatomical details in what are still regarded as classic studies. He proved to be an experimentalist, demonstrating that the heart of a pig would continue to beat when spinal nerves were transected so that nerve impulses could not reach the heart. He showed that the squealing of a pig stopped when the recurrent laryngeal nerves that innervated its vocal cords were cut. Galen also tied off the ureter in a sheep to prove that urine was produced in the kidney, not in the urinary bladder as had been falsely assumed. In addition, he proved that the arteries contained blood rather than pneuma.

Galen compiled a list of many medicinal plants and used medications extensively to treat illnesses. Although he frequently used bloodletting in an effort to balance the four humors, he cautioned against removing too much blood. He accumulated a wide variety of medical instruments and suggested their use as forceps, retractors, scissors, and splints (fig. 1.10). He was also a strong advocate of helping nature heal through good hygiene, a proper diet, rest, and exercise.

Middle Ages

The Middle Ages, frequently referred to as the Dark Ages, began with the fall of Rome to the Goths in A.D. 476 and lasted nearly 1,000 years, until Constantinople was conquered by the Turks in 1453. The totalitarian Christian Church suppressed science and medical activity stagnated. Human existence continued to be miserably precarious, and people no longer felt capable of learning from personal observation. Rather, they accepted life "on faith."

Dissections of cadavers were totally prohibited during this period, and molesting a corpse was a criminal act frequently punishable by burning at the stake. If mysterious deaths occurred, examinations by inspection and palpation were acceptable. During the plague epidemic in the sixth century, however, a few *necropsies* (*nek′rop-sēz*) and dissections were performed in the hope of determining the cause of this dreaded disease (see fig. 1.4).

During the Crusades soldiers cooked the bones of their dead comrades so that they could be returned home for proper burial. Even this act, however, was eventually considered sacrilegious and strongly condemned by the Church. One of the ironies of the Middle Ages was that the peasants received far less respect and had fewer rights when they were alive than when they were dead.

Contributions of Islam

The Arabic-speaking people made a profound contribution to the history of anatomy in a most unusual way. It was the Islamic world that saved much of Western scholarship from the ruins of the Roman Empire, the oppression of the Christian Church, and the onset of the Middle Ages. With the expansion of Islam through the Middle East and North Africa during the eighth century, the surviving manuscripts from Alexandria were taken back to the Arab countries, where they were translated from Greek to Arabic.

As the Dark Ages enshrouded Europe, the Christian Church attempted to stifle any scholarship or worldly knowledge that was not acceptable within Christian dogma. The study of the human body was considered heretical, and the Church banned all writings on anatomical subjects. Without the Islamic repository of the writings of Aristotle, Hippocrates, Galen, and others, the progress of centuries in anatomy and medicine would have been lost. It wasn't until the thirteenth century that the Arabic translations were returned to Europe and, in turn, translated to Latin. During the translation process, any Arabic terminology that had been introduced was systematically removed, so that today we find few anatomical terms of Arabic origin.

epidemic: Gk. *epi*, upon; *demos*, people
necropsy: Gk. *nekros*, corpse; *opsy*, view

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Renaissance

The period known as the Renaissance was characterized by a rebirth of science. It lasted roughly from the fourteenth through the sixteenth centuries and was a transitional period from the Middle Ages to the modern age of science.

The Renaissance was ushered in by the great European universities established in Bologna, Salerno, Padua, Montpellier, and Paris. The first recorded human dissections at these newly established centers of learning were the work of the surgeon William of Saliceto (1215–80) from the University of Bologna. The study of anatomy quickly spread to other universities, and by the year 1300 human dissections had become an integral part of the medical curriculum. However, the Galenic dogma that normal human anatomy was sufficiently understood persisted, so interest at this time centered on methods and techniques of dissection rather than on furthering knowledge of the human body.

The development of movable type in about 1450 revolutionized the production of books. Celsus, whose *De re medicina* was "rediscovered" during the Renaissance, was the first medical author to be published in this manner. Among the first anatomy books to be printed in movable type was that of Jacopo Berengario of Carpi, a professor of surgery at Bologna. He described many anatomical structures, including the appendix, thymus, and larynx. The most influential text of the period was written by Mondino de' Luzzi, also of the University of Bologna, in 1316. First published in 1487, it was more a dissection guide than a study of gross anatomy, and in spite of its numerous Galenic errors, 40 editions were published, until the time of Vesalius.

Because of the rapid putrefaction of an unembalmed corpse, the anatomy textbooks of the early Renaissance were organized so that the more perishable portions of the body were considered first. Dissections began with the abdominal cavity, then the chest, followed by the head, and finally the appendages. A dissection was a marathon event, frequently continuing for perhaps 4 days.

With the increased interest in anatomy during the Renaissance, obtaining cadavers for dissection became a serious problem. Medical students regularly practiced grave robbing until finally an official decree was issued that permitted the bodies of executed criminals to be used as specimens.

Corpses were embalmed to prevent deterioration, but this was not especially effective, and the stench from cadavers was apparently a persistent problem. Anatomy professors lectured from a thronelike chair at some distance from the immediate area (fig. 1.11). The phrase, "I wouldn't touch that with a 10-foot pole" probably originated during this time in reference to the smell of a decomposing cadaver.

The major advancements in anatomy that occurred during the Renaissance were in large part due to the artistic and scientific abilities of Leonardo da Vinci and Andreas Vesalius. Working in the fifteenth and sixteenth centuries, each produced monumental studies of the human form.

FIGURE 1.11 The scene of a cadaver dissection, 1500, from *Fasciculus Medicinae* by Johannes de Ketham. The anatomy professor removed himself from the immediate area to a thronelike chair overlooking the proceedings. The dissections were performed by hired assistants. One of them, the ostensor, pointed to the internal structures with a wand as the professor lectured.

Leonardo

The great Renaissance Italian Leonardo da Vinci (1452–1519) is best known for his artistic works (e.g., *Mona Lisa*) and his scientific contributions. He displayed genius as a painter, sculptor, architect, musician, and anatomist—although his anatomical drawings were not published until the end of the nineteenth century. As a young man, Leonardo regularly participated in cadaver dissections and intended to publish a textbook on anatomy with the Pavian professor Marcantonio della Torre. The untimely death of della Torre at the age of 31 halted their plans. When Leonardo died, his notes and sketches were lost and were not discovered for more than 200 years. The advancement of anatomy would have been accelerated by many years if Leonardo's notebooks had been available to the world at the time of his death.

Leonardo's illustrations helped to create a new climate of visual attentiveness to the structure of the human body. He was intent on accuracy, and his sketches are incredibly detailed (fig. 1.12). He experimentally determined the structure of complex body organs such as the brain and the heart. He made wax casts of the ventricles of the brain to study its structure. He constructed models of the heart valves to demonstrate their action.

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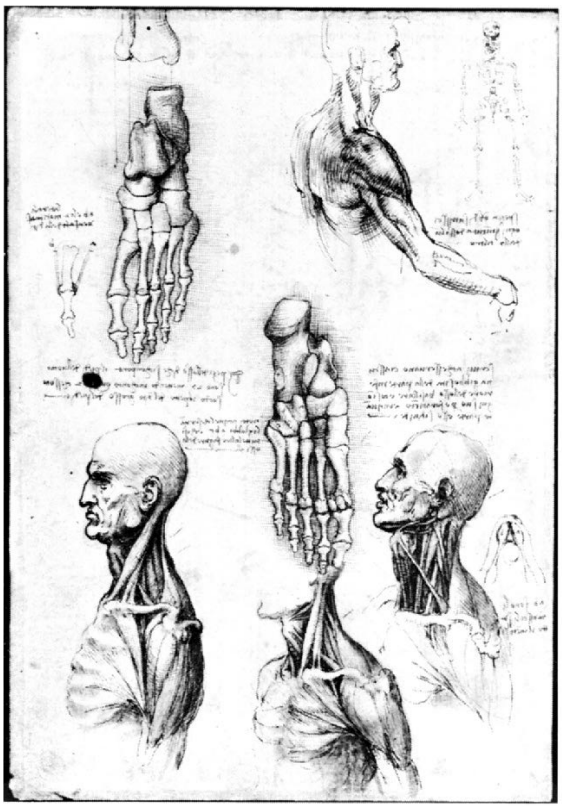

FIGURE 1.12 Only a master artist could achieve the detail and accuracy of the anatomical sketches of Leonardo da Vinci. "The painter who has acquired a knowledge of the nature of the sinews, muscles and tendons," Leonardo wrote, "will know exactly in the movement of any limb how many and which of the sinews are the cause of it, and which muscle by its swelling is the cause of the sinew's contracting.

Vesalius

The contribution of Andreas Vesalius (1514–64) to the science of human anatomy and to modern medicine is immeasurable. Vesalius was born in Brussels into a family of physicians. He received his early medical training at the University of Paris and completed his studies at the University of Padua in Italy, where he began teaching surgery and anatomy immediately after graduation. At Padua, Vesalius participated in human dissections and initiated the use of live models to determine surface landmarks for internal structures (fig. 1.13).

Vesalius apparently had enormous energy and ambition. By the time he was 28 years old, he had already completed the masterpiece of his life, *De Humani Corporis Fabrica,* in which the various body systems and individual organs are beautifully illustrated and described (fig. 1.14). His book was especially important in that it boldly challenged hundreds of Galen's teachings. Vesalius wrote of his surprise upon finding numerous anatomical errors in the works of Galen that were taught as fact, and he refused to accept Galen's explanations on faith. Because he was so outspo-

FIGURE 1.13 A painting of the great anatomist Andreas Vesalius, as he dissects a cadaver. From his masterpiece *De Humani Corporis Fabrica.*

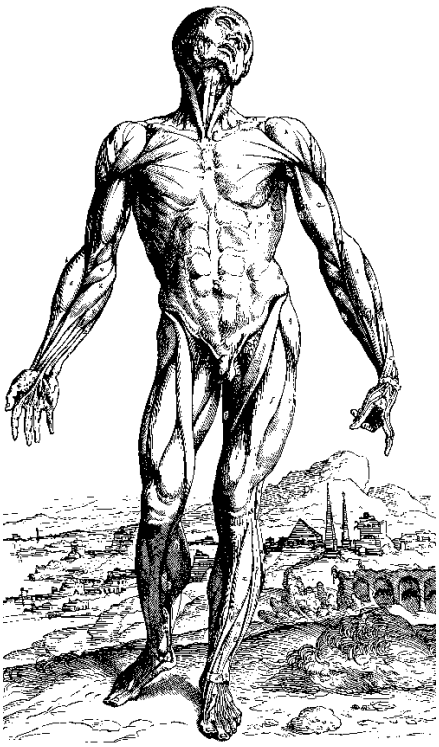

FIGURE 1.14 A plate from *De Humani Corporis Fabrica,* which Vesalius completed at the age of 28. This book, published in 1543, revolutionized the science of anatomy.

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FIGURE 1.15 *The Anatomy Lesson of Dr. Tulp,* a famous Rembrandt painting completed in 1632, depicts one of the public anatomies that were popular during this period. Dr. Nicholas Tulp was a famous Dutch anatomist who described the congenital defect in the spinal column known as spinal bifida aperta.

kenly opposed to Galen, he incurred the wrath of many of the traditional anatomists, including his former teacher Sylvius (Jacques Dubois) of Paris. Sylvius even went so far as to give him the nickname Vesanus (madman). Vesalius became so unnerved by the relentless attacks that he destroyed much of his unpublished work and ceased his dissections.

Although Vesalius was the greatest anatomist of his epoch, others made significant contributions and to an extent paved the way for Vesalius. Michelangelo pursued anatomy in 1495, being supplied with corpses by the friar of a local monastery. Mondino de' Luzzi and the surgeon Jacopo Berengario of Carpi also corrected many of Galen's errors. Fallopius (1523–62) and Eustachius (1524–74) completed detailed dissections of specific body regions.

Seventeenth and Eighteenth Centuries

During the seventeenth and eighteenth centuries, the science of anatomy attained an unparalleled acceptance. In some of its aspects, it also took on a somewhat theatrical quality. Elaborate amphitheaters were established in various parts of Europe for public demonstrations of human dissections (fig. 1.15). Exorbitantly priced tickets of admission were sold to the wealthy, and the dissections were performed by elegantly robed anatomists who were also splendid orators. The subjects were usually executed prisoners, and the performances were scheduled during cold weather because of the perishable nature of the cadavers.

Fortunately there were also serious, scientific-minded anatomists who made significant contributions during this period. Two of the most important contributions were the explanation of blood flow and the development of the microscope.

Harvey

In 1628, the English physician William Harvey (1578–1657) published his pioneering work *On the Motion of the Heart and Blood in Animals*. Not only did this brilliant research establish proof of the continuous circulation of blood within contained vessels, it also provided a classic example of the scientific method of investigation (fig. 1.16). Like Vesalius, Harvey was severely criticized for his departure from Galenic philosophy. The controversy over circulation of the blood raged for 20 years, until other anatomists finally repeated Harvey's experiments and concurred with his findings.

Leeuwenhoek

Antoni van Leeuwenhoek (*la'ven-hook*) (1632–1723) was a Dutch optician and lens grinder who improved the microscope to the extent that he achieved a magnification of 270 times. His many contributions included developing techniques for examining tissues and describing blood cells, skeletal muscle, and the lens of the eye. Although he was the first to accurately describe sperm cells, Leeuwenhoek did not understand their role in

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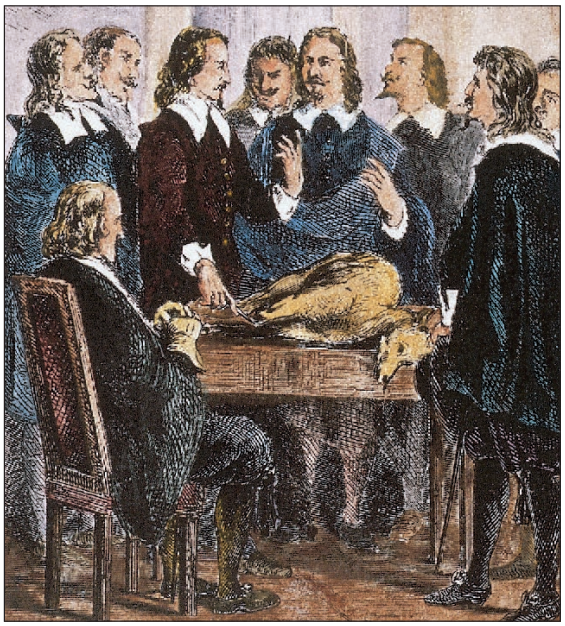

FIGURE 1.16 In the early seventeenth century, the English physician William Harvey demonstrated that blood circulates and does not flow back and forth through the same vessels.

fertilization. Rather, he thought that a spermatozoan contained a miniature human being called a *homunculus*.

The development of the microscope added an entirely new dimension to anatomy and eventually led to explanations of basic body functions. In addition, the improved microscope was invaluable for understanding the etiologies of many diseases, and thus for discovering cures for many of them. Although Leeuwenhoek improved the microscope, credit for its invention is usually given to the Dutch spectacle maker, Zacharius Janssen. The first scientific investigation using a microscope was performed by Francisco Stelluti in 1625 on the structure of a bee.

Malpighi and Others

Marcello Malpighi (*mal-pe′ge*) (1628–94), an Italian anatomist, is sometimes referred to as the father of histology. He discovered the capillary blood vessels that Harvey had postulated and described the pulmonary alveoli of lungs and the histological structure of the spleen and kidneys.

Many other individuals made significant contributions to anatomy during this 200-year period. In 1672, the Dutch anatomist Regnier de Graaf described the ovaries of the female reproductive system, and in 1775 Lazzaro Spallanzani showed that both ovum and sperm cell were necessary for conception. Francis Glisson (1597–1677) described the liver, stomach, and intestines, and suggested that nerve impulses cause the emptying of the gallbladder. Thomas Wharton (1614–73) and Niels Stensen (1638–86) separately contributed to knowledge of the salivary glands and lymph nodes within the neck and facial regions. In 1664, Thomas Willis published a summary of what was then known about the nervous system.

A number of anatomical structures throughout the body are named in honor of the early anatomists. Thus we have *graafian follicles, Stensen's* and *Wharton's ducts, fallopian tubes, Bartholin's glands,* the *circle of Willis,* and many others. Because these terms have no descriptive basis, they are not particularly useful to a student of anatomy.

Nineteenth Century

The major scientific contribution of the nineteenth century was the formulation of the cell theory. It could be argued that this theory was the most important breakthrough in the history of biology and medicine because all of the body's functions were eventually interpreted as the effects of cellular function.

The term *cell* was coined in 1665 by an English physician, Robert Hooke, as he examined the structure of cork under his microscope in an attempt to explain its buoyancy. What Hooke actually observed were the rigid walls that surrounded the empty cavities of the dead cells. The significance of cellular structure did not become apparent until approximately 150 years after Hooke's work.

With improved microscopes, finer details were observed. In 1809, a French zoologist, Jean Lamarck, observed the jellylike substance within a living cell and speculated that this material was far more important than the outside structure of the cell. Fifteen years later, René H. Dutrochet described the differences between plant and animal cells.

Two German scientists, Matthias Schleiden and Theodor Schwann, are credited with the biological principle referred to as the *cell theory*. Schleiden, a botanist, suggested in 1838 that each plant cell leads a double life—that is, in some respects it behaves as an independent organism, but at the same time it cooperates with the other cells that form the whole plant. A year later, Schwann, a zoologist, concluded that all organisms are composed of cells that are essentially alike. Nineteen years later, the addition of another biological principle seemed to complete the explanation of cells. In 1858, the German pathologist Rudolf Virchow wrote a book entitled *Cell Pathology* in which he proposed that cells can arise only from preexisting cells. The mechanism of cellular replication, however, was not understood for several more decades.

Johannes Müller (1801–58), a comparative anatomist, is noted for applying the sciences of physics, chemistry, and psychology to the study of the human body. When he began his teaching career, science was sufficiently undeveloped to allow him to handle numerous disciplines at once. By the time of his death, however, knowledge had grown so dramatically that several professors were needed to fill the positions he had held alone.

Twentieth Century

Contributions to the science of anatomy during the twentieth century have not been as astounding as they were when little was known about the structure of the body. The study of anatomy

homunculus: L. diminutive form of *homo*, man

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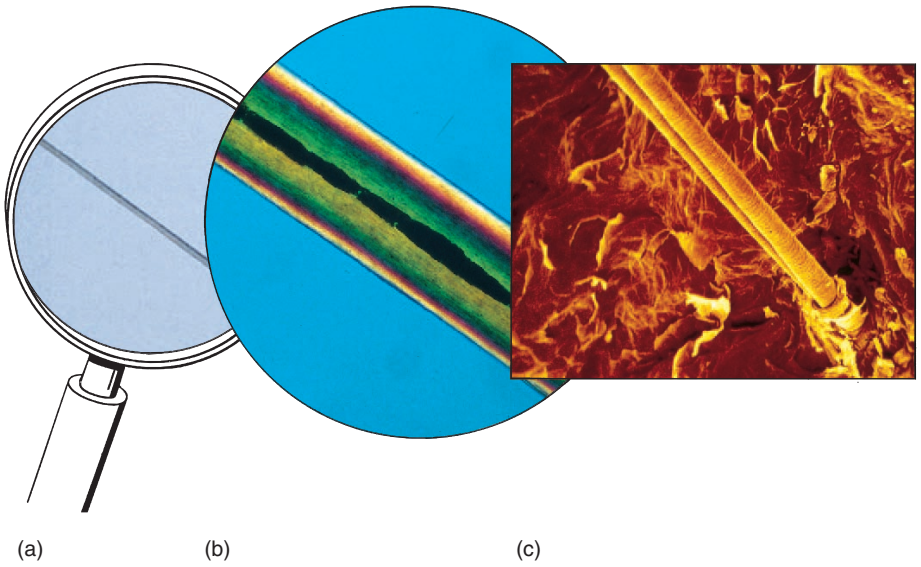

FIGURE 1.17 Different techniques for viewing microscopic anatomy have greatly enhanced our understanding of the structure and function of the human body. (*a*) The appearance of hair under a simple magnifying glass, (*b*) an observation of a stained section of a hair through a light microscope, and (*c*) a hair emerging from skin as viewed through an electron microscope (340×¨at 35-mm size).

grew increasingly specialized, and research became more detailed and complex.

One innovation that gained momentum early in the twentieth century was the simplification and standardization of nomenclature. Because of the proliferation of scientific literature toward the end of the nineteenth century, over 30,000 terms for structures in the human body were on record, many of which were redundant. In 1895, in an attempt to reduce the confusion, the German Anatomical Society compiled a list of approximately 500 terms called the *Basle Nomina Anatomica (BNA)*. The terms on this list were universally approved for use in the classroom and in publications.

Other conferences on nomenclature have been held throughout the century, under the banner of the *International Congress of Anatomists*. At the Seventh International Congress held in New York City in 1960, a resolution was passed to eliminate all eponyms ("tombstone names") from anatomical terminology and instead use descriptive names. Structures like Stensen's duct and Wharton's duct, for example, are now properly referred to as the parotid duct and submandibular duct, respectively. Because eponyms are so entrenched, however, it will be extremely difficult to eliminate all of them from anatomical terminology. But at least there is a trend toward descriptive simplification.

In this text, the preferred descriptive terms are used in both the text narrative and the accompanying illustrations. Where the term first appears in the narrative, however, the preferred form is followed by a parenthetical reference to the traditional name honoring an individual—for example, **uterine** (fallopian) **tube.** The terminology used in this text is in accordance with the official anatomical nomenclature presented in the reference publication, *Nomina Anatomica,* Sixth Edition.

In response to the increased technology and depth of understanding in the twentieth century, new disciplines and specialties have appeared in the science of human anatomy in an attempt to categorize and use the new knowledge. The techniques of such cognate disciplines as chemistry, physics, electronics, mathematics, and computer science have been incorporated into research efforts.

There are several well-established divisions of human anatomy. The oldest, of course, is **gross anatomy,** which is the study of body structures that can be observed with the unaided eye. Stringent courses in gross anatomy in professional schools provide the foundation for a student's entire medical or paramedical training. Gross anatomy also forms the basis for the other specialties within anatomy. **Surface anatomy** (see chapter 10) deals with surface features of the body that can be observed beneath the skin or palpated (examined by touch).

Microscopic Anatomy

Structures smaller than 0.1 mm (100 μm) can be seen only with the aid of a microscope. The sciences of **cytology** (the study of cells), or **cellular biology, developmental anatomy** (the study of prenatal development) and **histology** (the study of tissues) are specialties of anatomy that have provided additional insight into structure and function of the human body. One can observe greater detail with the *electron microscope* than with the *light microscope* (fig. 1.17). New techniques in staining and histochemistry have aided electron microscopy by revealing the fine details of cells and tissues that are said to compose their *ultrastructure*.

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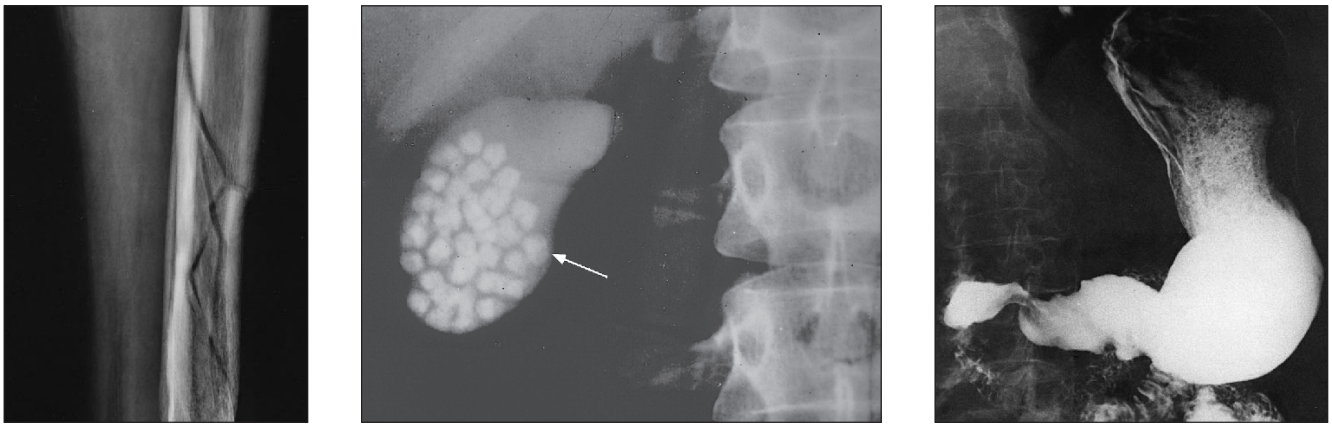

(a) (b) (c)

FIGURE 1.18 The versatility of radiology makes this technique one of the most important tools in diagnostic medicine and provides a unique way of observing specific anatomical structures within the body. (*a*) A radiograph of a healing fracture, (*b*) a radiograph of gallstones within a gallbladder, and (*c*) a radiograph of a stomach filled with a radiopaque contrast medium.

Radiographic Anatomy

Radiographic anatomy, or *radiology*, provides a way of observing structures within the living body. Radiology is based on the principle that substances of different densities absorb different amounts of X rays, resulting in a differential exposure on film. Radiopaque substances such as barium can be ingested (swallowed) or injected into the body to produce even greater contrasts (fig. 1.18). **Angiography** involves making a radiograph after injecting a dye into the bloodstream. In *angiocardiography*, the heart and its associated vessels are x-rayed. *Cineradiography* permits the study of certain body systems through the use of motion picture radiographs. Traditional radiographs have had limitations as diagnostic tools for understanding human anatomy because of the two-dimensional plane that is photographed. Because radiographs compress the body image with an overlap of organs and tissues, diagnosis is often difficult.

X rays were discovered in 1895 by Wilhelm Konrad Roentgen (*rent'gen*). The radiograph image that is produced on film is frequently referred to as a *roentgenograph.* The recent development of the computerized axial tomography technique has been hailed as the greatest advancement in diagnostic medicine since the discovery of X rays themselves.

The **computerized axial tomography** technique (**CT,** or **CAT,** scan) has greatly enhanced the versatility of X rays. It uses a computer to display a cross-sectional image similar to that which could only be obtained in an actual section through the body (fig. 1.19*a*).

Another technique of radiographic anatomy is the **dynamic spatial reconstructor (DSR)** scan (fig. 1.19*b*). The DSR functions as an electronic knife that pictorially slices an organ, such as the heart, to provide three-dimensional images. The DSR can be used to observe movements of organs, detect defects, assess the extent of a disease such as cancer, or determine the extent of trauma to tissues after a stroke or heart attack.

Magnetic resonance imaging (MRI), also called **nuclear magnetic resonance (NMR),** provides a new technique for diagnosing diseases and following the response of a disease to chemical treatment (fig. 1.19*c*). An MRI image is created rapidly as hydrogen atoms in tissues, subjected to a strong magnetic field, respond to a pulse of radio waves. MRI has the advantage of being noninvasive—that is, no chemicals are introduced into the body. It is better than a CT scan for distinguishing between soft tissues, such as the gray and white matter of the nervous system.

A **positron emission tomography (PET)** scan is a radiological technique used to observe the metabolic activity in organs (fig. 1.19*d*) following the injection of a radioactive substance, such as treated glucose, into the bloodstream. PET scans are very useful in revealing the extent of damaged heart tissue and in identifying areas where blood flow to the brain is blocked.

Human anatomy will always be a relevant science. Not only does it enhance our personal understanding of body functioning, it is also essential in the clinical diagnosis and treatment of disease. Human anatomy is no longer confined to the observation and description of structures in isolation, but has expanded to include the complexities of how the body functions as an integrated whole. The science of anatomy is dynamic and has remained vital because the two aspects of the body—structure and function—are inseparable.

One of the important aspects of human anatomy and medicine is the *autopsy*—a thorough postmortem examination of all of the organs and tissues of a body. Autopsies were routinely performed in the early part of the twentieth century, but their frequency has declined significantly in the last three decades. Currently, only

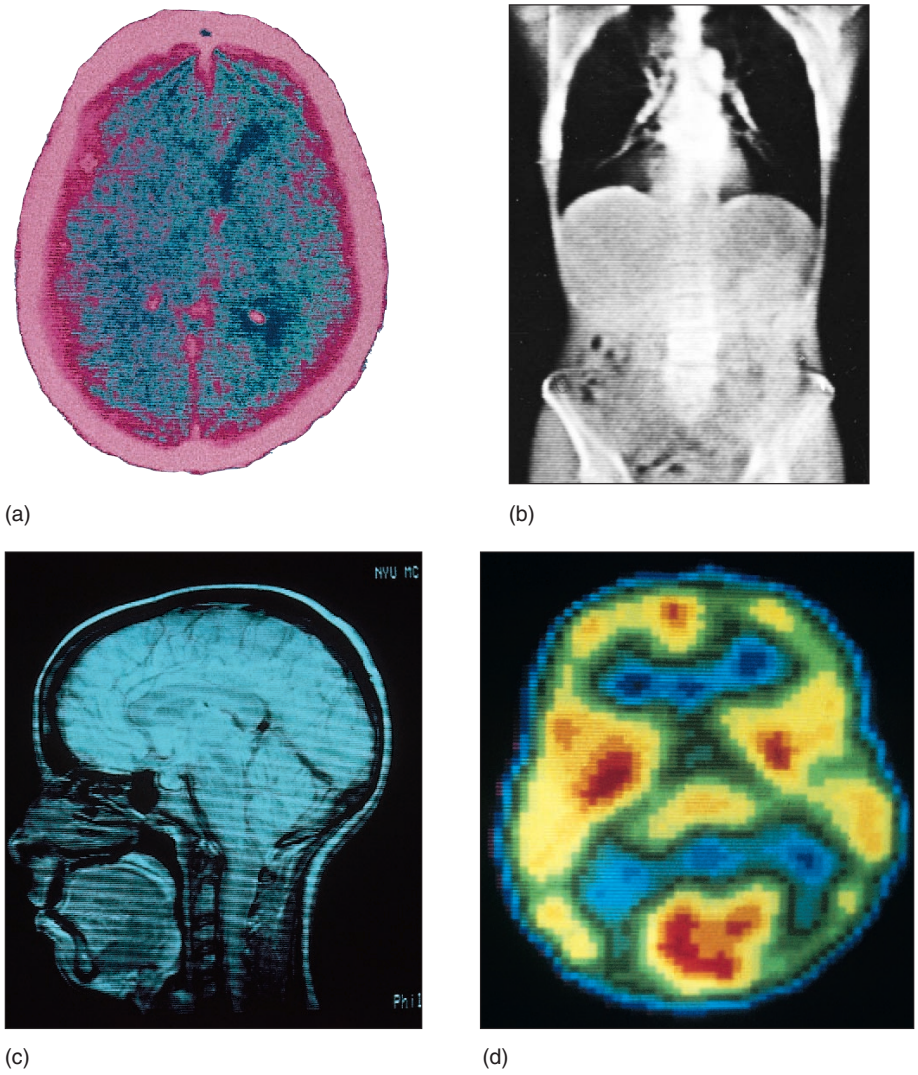

FIGURE 1.19 Different techniques in radiographic anatomy provide unique views of the human body. (*a*) A CT scan through the head, (*b*) a DSR scan through the trunk (torso), (*c*) an MRI image through the head, and (*d*) a PET scan through the head.

15% of corpses are autopsied in the United States, which is down from over 50% 30 years ago. Autopsies are of value because (1) they often determine the cause of death, which may confirm or disconfirm preliminary death statements; (2) they frequently reveal diseases or structural defects that may have gone undetected in life; (3) they check the effectiveness of a particular drug therapy for a patient or the success of a particular surgery; and (4) they serve as a means of training medical students.

An interesting piece of information regarding the value of an autopsy in confirming the cause of death was revealed in a study of 2,557 autopsies conducted over a 30-year period to determine the accuracy of physicians' diagnoses of deaths (see "Autopsy," S. A. Geller, *Scientific American,* March 1983). In this study, the causes of death had been improperly or inaccurately recorded in 42% of the cases. This means that because of a decline in the number of autopsies, there may be over a million death certificates filed in the United States each year that are in error. This has important implications for criminal justice and medical genetics, as well as for the insurance industry.

An objective of this text is to enable students to become educated and conversant in anatomy. An excellent way to keep up with anatomy during and after completing the formal course is to subscribe to and read magazines such as *Science*, *Scientific American*, *Discover*, and *Science Digest*. These publications and others include articles on recent scientific findings, many of which pertain to anatomy. If you are to be an educated contributor to society, it is essential to stay informed.

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Knowledge Check

7. Briefly discuss the impact of each of the following on the science of human anatomy: the humoral theory of body organization, vivisections, the Middle Ages, human dissections, movable type, the invention of the microscope, the cell theory, and the development of X-ray techniques.
8. Explain why knowledge of anatomy is personally relevant.
9. Why is it important to stay abreast of new developments in human anatomy? How might this be accomplished?

Clinical Case Study Answer

In this case, the doctor made the right diagnosis and provided a therapy that helped the patient. However, he did so with a flawed understanding of human anatomy and physiology and disease. The application of sound scientific methods has corrected classic misconceptions of disease, such as the humoral theory.

Chapter Summary

Definition of the Science (p. 2)

1. Human anatomy is the science concerned with the structure of the human body.
2. The terms of anatomy are descriptive and are generally of Greek or Latin derivation.
3. The history of human anatomy parallels that of medicine and has also been greatly influenced by various religions.

Prescientific Period (pp. 2–4)

1. Prehistoric interest in anatomy was undoubtedly limited to practical information necessary for survival.
2. Trepanation was a surgical technique that was practiced by several cultures.
3. Paleopathology is the science concerned with diseases of prehistoric people.

Scientific Period (pp. 4–19)

1. A few anatomical descriptions were inscribed in clay tablets in cuneiform writing by people who lived in Mesopotamia in about 4000 B.C.
2. Egyptians of about 3400 B.C. developed a technique of embalming. It was not recorded, however, and therefore was not of value in furthering the study of anatomy.
3. The belief in a balance between yin and yang was a compelling influence in Chinese philosophy and provided the rationale for the practice of acupuncture.
4. The advancement of anatomy in Japan was largely due to the influence of the Chinese and Dutch.
5. Anatomy first found wide acceptance as a science in ancient Greece.
   (a) Hippocrates is regarded as the father of medicine because of the sound principles of medical practice he established.
   (b) The Greek philosophy of body humors dominated medical thought for over 2,000 years.
   (c) Aristotle pursued a limited type of scientific method in obtaining data; his writings contain some basic anatomy.
6. Alexandria was a center of scientific learning from 300 to 30 B.C.
   (a) Human dissections and vivisections were performed in Alexandria.
   (b) Erasistratus is referred to as the father of physiology because of his interpretations of various body functions.
7. Theoretical data was deemphasized during the Roman era.
   (a) Celsus's eight-volume work was a compilation of medical data from the Alexandrian school.
   (b) Galen was an influential medical writer who made some important advances in anatomy; at the same time he introduced serious errors into the literature that went unchallenged for centuries.
   (c) Science was suppressed for nearly 1,000 years during the Middle Ages, and dissections of human cadavers were prohibited.
   (d) Anatomical writings were taken from Alexandria by Arab armies, and thus saved from destruction during the Dark Ages in Europe.
8. During the Renaissance, many great European universities were established.
   (a) Andreas Vesalius and Leonardo da Vinci were renowned Renaissance men who produced monumental studies of the human form.
   (b) *De Humani Corporis Fabrica*, written by Vesalius, had a tremendous impact on the advancement of human anatomy. Vesalius is regarded as the father of human anatomy.
9. Two major scientific contributions of the seventeenth and eighteenth centuries were the explanation of blood flow and the development of the microscope.
   (a) In 1628, William Harvey correctly described the circulation of blood.
   (b) Shortly after the microscope had been perfected by Antoni van Leeuwenhoek, many investigators added new discoveries to the rapidly changing specialty of microscopic anatomy.
10. The cell theory was formulated during the nineteenth century by Matthias Schleiden and Theodor Schwann, and cellular biology became established as a science separate from anatomy.
11. A trend toward simplification and standardization of anatomical nomenclature began in the twentieth century. In addition, many specialties within anatomy developed, including cytology, histology, embryology, electron microscopy, and radiology.

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Review Activities

Objective Questions

1. *Anatomy* is derived from a Greek word meaning
   (a) to cut up. (c) functioning part.
   (b) to analyze. (d) to observe death.
2. The most important contribution of William Harvey was his research on
   (a) the continuous circulation of blood.
   (b) the microscopic structure of spermatozoa.
   (c) the detailed structure of the kidney.
   (d) the striped appearance of skeletal muscle.
3. Which of the following listings is in correct chronological order?
   (a) Galen, Hippocrates, Harvey, Vesalius, Aristotle
   (b) Hippocrates, Galen, Vesalius, Aristotle, Harvey
   (c) Hippocrates, Aristotle, Galen, Vesalius, Harvey
   (d) Aristotle, Hippocrates, Galen, Harvey, Vesalius
4. Anatomy was first widely accepted as a science in ancient
   (a) Rome. (c) China.
   (b) Egypt. (d) Greece.
5. The establishment of sound principles of medical practice earned this man the title of father of medicine.
   (a) Hippocrates (c) Erasistratus
   (b) Aristotle (d) Galen
6. Which of the four body humors was believed by Hippocrates to be associated with the lungs?
   (a) black bile (c) phlegm
   (b) yellow bile (d) blood
7. The anatomical masterpiece *De Humani Corporis Fabrica* was the work of
   (a) Leonardo. (c) Vesalius.
   (b) Harvey. (d) Leeuwenhoek.
8. What event of about 1450 helped to usher in the Renaissance?
   (a) the development of the microscope
   (b) an acceptance of the scientific method
   (c) the development of the cell theory
   (d) the development of movable type
9. The body organ thought by Aristotle to be the seat of intelligence was
   (a) the liver. (c) the brain.
   (b) the heart. (d) the intestine.
10. X rays were discovered during the late nineteenth century by
    (a) Roentgen. (c) Schleiden.
    (b) Hooke. (d) Müller.

Essay Questions

1. Define the terms *anatomize*, *trepanation*, *paleopathology*, *vivisection*, and *cadaver*.
2. Discuss the practical nature of anatomy to prehistoric people.
3. Why were the techniques of embalming a corpse, which were perfected in ancient Egypt, not shared with other cultures or recorded for future generations?
4. What is acupuncture? What are some of its uses today?
5. Why is Latin an ideal language from which to derive anatomical terms? What is the current trend regarding the use of proper names (eponyms) in referring to anatomical structures?
6. Why do you suppose the Hippocratic oath has survived for over 2,000 years as a creed for medical practice? What aspects of the oath are difficult to conform to in today's society?
7. What is meant by the humoral theory of body organization? Which great anatomists were influenced by this theory? When did it cease to be an influence on anatomical investigation and interpretation?
8. Discuss the impact of Galen on the advancement of anatomy and medicine. What circumstances permitted the philosophies of Galen to survive for such a long period?
9. Briefly discuss the establishment of anatomy as a science during the Renaissance.
10. Herophilus popularized anatomy during his time but was severely criticized by later anatomists. Why was his work so controversial?
11. Who invented the microscope? What part did it play in the advancement of anatomy? What specialties of anatomical study have arisen since the introduction of the microscope?
12. Discuss the impact of the work of Andreas Vesalius on the science of anatomy.
13. Give some examples of how culture and religion influenced the science of anatomy.
14. List some techniques currently used to study anatomy and identify the specialties within which these techniques are used.

Critical-Thinking Questions

1. Discuss some of the factors that contributed to a decline in scientific understanding during the Middle Ages. How would you account for the resurgence of interest in the science of anatomy during the Renaissance?
2. Homeostasis is a physiological term that was coined by the American physiologist Walter Cannon in 1932. It refers to the ability of an organism to maintain the stability of its internal environment by adjusting its physiological processes. Discuss the similarities of the humoral theory of body organization and the philosophy of yin and yang as ancient attempts to explain homeostasis.
3. You learned in this chapter that Galen relied on dissections of animals other than human in an attempt to understand human anatomy. Discuss the value and limitations of using mammalian specimens (other than human) in the laboratory portion of a human anatomy course. What advantages are gained by studying human cadavers?
4. Students studying law at European Universities during the Early Renaissance were required to take a course in human anatomy. Considering the breadth of law practice during those times, explain why it was important for a lawyer to understand anatomy.
5. Just as geography describes the topography for history, anatomy describes the topography for medicine. Using specific examples, discuss how discoveries in anatomy have resulted in advances in medicine.

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for chapter-by-chapter quizzing, additional study resources, and related web links.