seemed to seek out Englishmen even if potential Scottish, Irish, and Welsh victims were available.

According to Caius, a stricken town was fortunate if only half of all souls were claimed by the disease. After carefully evaluating the clinical pattern and natural history of the disease, he concluded that the sweating sickness was a new disease. Some historians believe that the disease was brought to London in 1485 when Henry VII's mercenaries returned from France and Flanders. The disease might have been a virulent form of influenza, ergotism (a reaction to fungal toxins), food poisoning, or a totally unknown and extinct disease, but the exact nature of these epidemics and the reason for their peculiar geographical distribution are still obscure.

AUTOPSIES, ART, AND ANATOMY

While the artists and anatomists of the Renaissance are inextricably associated with the reform of anatomy, the study of human anatomy—from bodies, as well as from books—had not been entirely neglected since the death of Galen. During the Middle Ages, human dissection was not pursued with the freedom and intensity so briefly enjoyed by Herophilus and Erasistratus, but it had not been absolutely forbidden or abandoned. Interest in dissection and vivisection increased slowly between the twelfth and the seventeenth centuries, but medieval autopsies were normally conducted to investigate suspicious deaths or outbreaks of plague, or even to search for special signs inside the bodies of purported saints. Such postmortems were probably about as informative as the rituals conducted in some primitive tribes to determine whether death was due to witchcraft.

Human dissection was practiced to a limited extent during the thirteenth and fourteenth centuries in those universities in southern Europe having medical faculties. Statutes of the University of Bologna dating back to 1405 recognized the practice of dissection. In 1442, the city of Bologna authorized the provision of two cadavers each year to the university for dissection. During the fifteenth century, similar provisions were made for most of the major European universities. Thus, medical students were able to observe a limited number of human dissections. However, they knew that examinations and dissertations required knowledge of accepted texts, not the ability to perform practical demonstrations. Students pragmatically attended dissections to confirm their readings of the ancient authorities and to prepare for examinations. Medieval and Renaissance students were probably not too different from students running a typical "cookbook" experiment today. Such experiments are performed to teach a standard technique or confirm some accepted fact, not to make novel observations.

Anatomical demonstrations throughout Europe varied considerably, but the typical public anatomy featured the corpse of a criminal guilty of a crime heinous enough to merit the sentence of "execution and dissection." After acknowledgment of the Papal Indulgence for the ceremony, a learned professor would read a great oration on the structure of the human body while a barber-surgeon attacked the cadaver. Generally, the debates between the Galenists of the medical faculty and the Aristotelians of the faculty of philosophy drew more attention than the mutilated corpse. Anatomical demonstrations continue to provide public education and entertainment, as indicated by public displays of transparent anatomical models. Transparent organs were on display at the First International Hygiene Exhibition (1911). Museums in Europe and the United States were exhibiting various Transparent Men and Transparent Women in the 1930s.

By about 1400, human dissection was part of the curriculum of most medical schools. Anatomies were also performed in some hospitals. However, well into the sixteenth century, medical students were in little danger of being forced to confront radically new ideas about the nature of the human body. The medical curriculum of the Renaissance university reflected a heavy commitment to the ancient authorities. Students were expected to master texts by Avicenna, Galen, and Hippocrates. The number of medical students was rather small, especially in northern Europe. Throughout the sixteenth century, the annual number of candidates for the degree of Bachelor of Medicine in Paris was less than 20.

For teachers as well as students, the purpose of dissection was to supplement the study of Galenic texts, but because of the complexity of Galen's writings, simplified guides were needed. One of the best-known early dissection manuals was the *Anatomy* (1316) of Mondino de Luzzi (ca. 1275–1326), who served as public lecturer at the University of Bologna from 1314 to 1324. Mondino's *Anatomy* was practical and succinct. The first printed edition of the popular text appeared in 1478 and was followed by at least 40 editions. But medical humanists rejected the work, and turned to newly restored editions of anatomical works by Galen, especially *On the Use of the Parts* and *On Anatomical Procedures*. Some of the early texts included simple diagrams, but these images did little to illuminate anatomical principles. Mastery of the principles of artistic perspective in the fifteenth century made the new art of anatomical illustration possible.

The development of a special relationship with the sciences, especially anatomy, mathematics, and optics, as well as the inspiration of classical Greek ideals, gave Renaissance art much of its distinctive character. Both artists and physicians sought accurate anatomical knowledge. Artists placed a new emphasis on accurately representing animals and plants, scientific use of perspective, and above all the idea

that the human body was beautiful and worthy of study. To make their art true to life and to death, artists attended public anatomies and executions and studied intact and flayed bodies in order to see how the muscles and bones worked.

While many Renaissance painters and sculptors turned to dissection, none exceeded Leonardo da Vinci (1452–1519)—painter, architect, anatomist, engineer, and inventor—in terms of artistic and scientific imagination. Leonardo's notebooks present a man of formidable genius and insatiable intellectual curiosity; they also reveal the problem of situating Leonardo within the history of science and medicine. His notebooks are full of brilliant projects, observations, and hypotheses about human beings, animals, light, mechanics, and more. Freud, who "psychoanalyzed" Leonardo, called the artist "the forerunner . . . of Bacon and Copernicus." But the grand projects were never completed, and thousands of pages of notes and sketches went unpublished. The secretive, left-handed artist kept his notebooks in code, a kind of mirror writing. It is tempting to speculate that if Leonardo had systematically completed his ambitious projects and conscientiously published and publicized his work, he might have revolutionized several scientific disciplines. Instead, Leonardo's legacy has been assessed as "the epitome of greatness in failure," because that which is unknown, incomplete, and disorganized cannot be considered a contribution to science. To regard Leonardo as typical of his era is of course unrealistic, although he had many brilliant contemporaries. Nevertheless, Leonardo's work indicates the scope of the ideas and work that a person of genius might achieve with the materials available in the fifteenth century.

Leonardo, who was the illegitimate son of a peasant woman and a Florentine lawyer, grew up in his father's house. At 14 years of age, Leonardo was apprenticed to Andrea del Verrochio (1435–1488), painter, sculptor, and the foremost teacher of art in Florence. Verrochio insisted that all his pupils learn anatomy. Within 10 years, Leonardo was recognized as a distinguished artist and had acquired wealthy and powerful patrons. Despite these advantages, Leonardo led a restless and adventurous life, serving various patrons, prosecuted on charges of homosexuality, beginning and discarding numerous projects for machines, statues, and books. It was art that first led Leonardo to dissection, but he pursued anatomical studies of animals and humans with almost morbid fascination for nearly 50 years, dissecting pigs, oxen, horses, monkeys, insects, and so forth. Granted permission to study cadavers at a hospital in Florence, the artist spent many sleepless nights surrounded by corpses. While planning a revolutionary anatomical treatise, Leonardo dissected about thirty bodies, including a seven-month fetus and a very elderly man.

Studies of the superficial anatomy of the human body had inexorably led Leonardo to an exploration of general anatomy, comparative

anatomy, and physiological experiments. Through dissection and experimentation, Leonardo believed he would uncover the mechanisms that governed movement and even life itself. Leonardo constructed models to study the mechanism of action of muscles and the heart valves and carried out vivisections to gain insight into the heartbeat. For example, he drilled through the thoracic wall of a pig and, keeping the incision open with pins, observed the motion of the heart. Although he realized that the heart was actually a very powerful muscle, he generally accepted Galen's views on the movement and distribution of the blood, including the imaginary pores in the septum. Like so many of his projects, Leonardo's great book on the anatomy of "natural man" was left unfinished. When he died, his manuscripts were scattered among various libraries, and some were probably lost.

Convinced that all problems could be reduced to mechanics and mathematics, Leonardo was contemptuous of astrology and alchemy and distrustful of medicine. Indeed, he believed that preserving one's health was most easily accomplished by avoiding doctors and their drugs. Like Cato and Pliny, he denounced physicians as "the destroyers of life," who lusted after wealth despite their inability to make an informed diagnosis. Leonardo's notebooks, however, contain prescriptions as bizarre as any Galenical remedy, such as a mixture of nutshells, fruit pits, and chickpeas to break up stones in the bladder.

ANDREAS VESALIUS ON THE FABRIC OF THE HUMAN BODY

Just as Copernicus and Galileo revolutionized ideas about the motions of the earth and the heavens, Andreas Vesalius (1514–1564) transformed Western concepts of the structure of the human body. Vesalius' great treatise, *The Fabric of the Human Body* (*De humani corporis fabrica*), appeared in 1543, the year in which Nicolaus Copernicus (1473–1543) published the text that placed the sun, rather than the earth, at the center of the universe (*On the Revolutions of the Heavenly Spheres*). Vesalius was heir to the humanist medical tradition that had rediscovered the original writings of Hippocrates and Galen. He was a member of the first generation of scholars to enjoy access to the complete works of Galen. The *Fabrica*, which is considered the first anatomical treatise based on direct observation of the human body, is still regarded as a milestone in the history of anatomy. In honor of its place in the history of Western medicine, in 1998, scholars began publishing a five-volume English translation of the first edition of the *Fabrica*.

Given the scope of his work, Vesalius can be considered a classical scholar and humanist, as well as a physician, anatomist, and artist. Unlike Linacre and Caius, however, Vesalius was able to renounce

Andreas Vesalius, on the fabric of the human body.

the errors of the ancients clearly and publicly. Through his scholarship and his own observations, he came to realize that human anatomy must be read from the "book of the human body," not from the pages of Galen. With all due modesty, Vesalius regarded his work as the first real advance in anatomical knowledge since the time of Galen.

A horoscope cast by Girolamo Cardano, a Milanese physician, fixes the birth of Andreas Vesalius in Brussels, Belgium, on December 31, 1514, at 5:45 a.m. Vesalius was born into a world of physicians, pharmacists, and royal patronage. His father was imperial pharmacist to Charles V and often accompanied the Emperor on his travels. As a youth, Vesalius began to teach himself anatomy by dissecting mice and other small animals. Although he studied at both the University of Paris and Louvain, institutions notable for their extreme conservatism, his innate curiosity was not destroyed by the benefits of higher education.

While a student at the University of Paris, Vesalius served as assistant to Jacobus Sylvius (1478–1555), an archconservative who saw human dissection only as a means of pursuing Galenic studies. Unfortunately, the atmosphere in Paris became so threatening that Vesalius found it necessary to leave without a degree. In the fall of 1537, he enrolled in the medical school of the University of Padua, a venerable, but relatively enlightened institution. He was awarded the M.D. in December 1537, and appointed lecturer-demonstrator in anatomy and surgery. Abandoning the traditional professorial role, Vesalius lectured and dissected simultaneously. These dissection-lectures occupied the anatomist and his audience from morning to night for three weeks at a time. To minimize the problem of putrefaction, anatomies were scheduled for the winter term. Several bodies were used simultaneously so that different parts could be clearly demonstrated. Anatomies began with a study of the skeleton, and then proceeded to the muscles, blood vessels, nerves, organs of the abdomen and chest, and the brain.

By 1538, Vesalius was beginning to recognize differences between Galenic anatomy and his own observations, but when the young anatomist publicly challenged Galen, Sylvius denounced his former student as "Vesanus" (madman), purveyor of filth and sewage, pimp, liar, and various epithets unprintable even in our own permissive era. Vesalius in turn told his students that they could learn more at a butcher shop than at the lectures of certain blockhead professors. Referring to the dissection skills of his former teacher, Vesalius said that Sylvius and his knife were more at home at the banquet table than the dissecting room. In 1539, Marcantonio Contarini, a judge in Padua's criminal court, became so interested in Vesalius's work that he awarded the bodies of executed criminals to the university and obligingly set the time of execution to suit the anatomist's convenience.

Finally, to mark his independence from Galen, Vesalius arranged a public dissection lecture in which he demonstrated over two hundred differences between the skeletons of apes and humans, while reminding his audience that Galen's work was based on the dissection of apes. Hostile reactions from outraged Galenists were inevitable. Vesalian anatomists were vilified as the "Lutherans of Physic" on the grounds that the heresies of such medical innovators were as dangerous as Martin Luther's

(1483–1546) effect on religion. Tired of the controversy, Vesalius became court physician to Charles V, Holy Roman Emperor and King of Spain, to whom he dedicated the *Fabrica*. Soon Vesalius discovered that imperial service was almost as unpleasant as the stormy academic world.

The patronage of a king, pope, or wealthy nobleman might allow a scientist to continue his research, but such patrons were often difficult and demanding patients. Charles V suffered from gout, asthma, and a variety of vague complaints exacerbated by his predilection for quack remedies. Moreover, kings often loaned their physicians to other royal courts. Thus, when Henry II of France was injured while jousting, Vesalius and the French surgeon Ambroise Paré were among the medical consultants. Using the heads of four recently decapitated criminals, Paré and Vesalius carried out experiments to ascertain the nature of the injuries. They correctly predicted that the wound would be fatal. According to a doubtful, but persistent tradition, Vesalius went on a pilgrimage to the Holy Land to extricate himself from the Emperor's service, or as a penance for initiating a premature autopsy. Vesalius may have used the excuse of a pilgrimage to explore the possibility of returning to a professorship at Padua. Unfortunately, he died on the return voyage.

Despite being steeped in the conservative academic scholarship of his time, Vesalius confronted and rejected Galen's authority and demanded that anatomists study only the "completely trustworthy book of man." Vesalius attributed his own disillusionment with Galen to his discovery that Galen had never dissected the human body. However, a minor work, known as the "Bloodletting Letter," suggests that practical problems concerning venesection forced Vesalius to question Galenic dogma. Venesection was the subject of violent controversy among sixteenth-century physicians. No one suggested abandoning bloodletting; rather, the medical humanists attacked what they called corrupt Arabist methods and demanded a return to the pure teachings of Hippocrates and Galen.

Unfortunately, even after "purification," Galen's teachings on the venous system remained ambiguous. When Hippocratic texts contradicted each other and Galen, which authority could tell the physician how to select the site for venesection, how much blood to take, how rapidly bleeding should proceed, and how often to repeat the procedure? Struggling with these questions, Vesalius began to ask whether facts established by anatomical investigation could be used to test the validity of hypotheses. Unable to ignore the implications of his anatomical studies and clinical experience, Vesalius became increasingly critical of the medical humanists. He could not tolerate the way they ignored the true workings of the human body while they debated "horse-feathers and trifles."

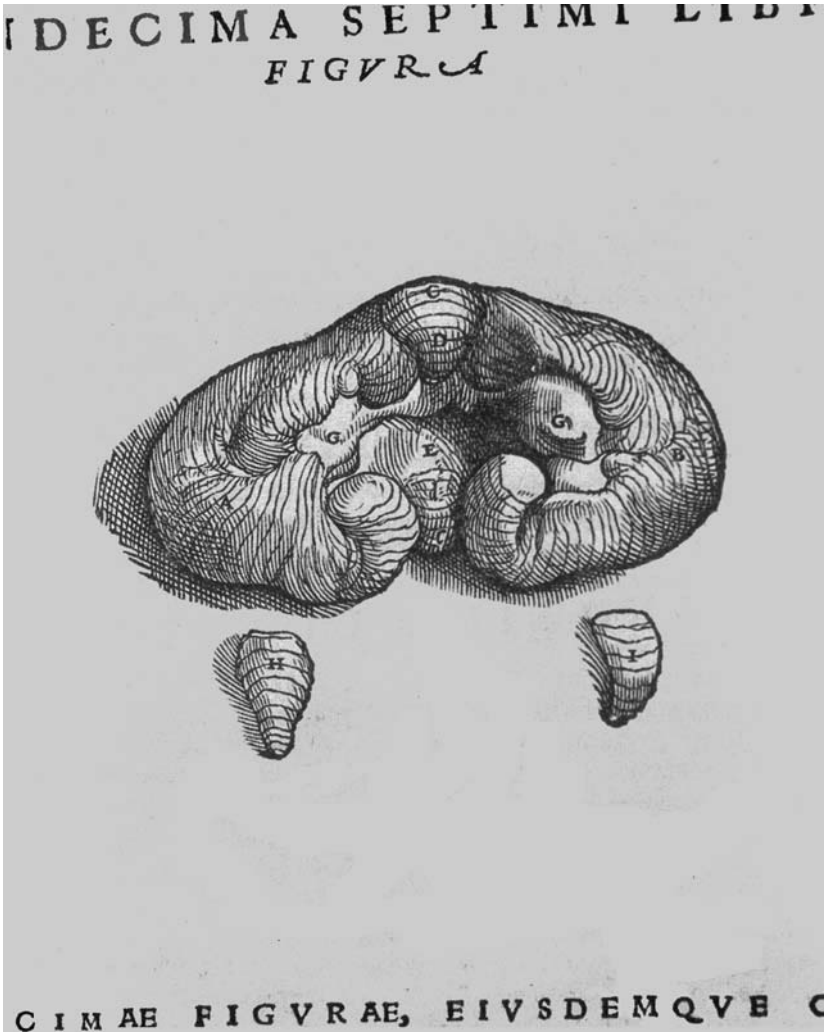
The Fabric of the Human Body was a revolutionary attempt to describe the human body as it really is without deferring to Galen when

the truth could be learned through dissection. Vesalius also demonstrated how well anatomical truths could be conveyed in words and illustrations. About 250 woodblocks were painstakingly prepared and incorporation into the text where their placement complemented and clarified matters described in the text. Ironically, critics of Vesalian anatomy attacked the *Fabrica* on the grounds that the illustrations were false and misleading and would seduce students away from direct observation. Actually, the importance of dissection is emphasized throughout the text and careful instructions were given on the preparation of bodies for dissection and the instruments needed for precise work on specific anatomical materials.

The *Fabrica* was intended for serious anatomists, but Vesalius also prepared a shorter, less expensive text, known as the *Epitome*, so that even medical students could appreciate the "harmony of the human body." The *Epitome* contained eleven plates showing the bones, muscles, external parts, nerves, veins, and arteries, and pictures of organs that were meant to be traced, cut out, and assembled by the reader. The Vesalian texts and illustrations were widely plagiarized and disseminated, often in the form of inferior translations and abstracts that failed to credit the originals.

In response to his critics, Vesalius denounced the "self-styled Prometheans" who claimed that Galen was always right and argued that the alleged errors in his works were proof that the human body had degenerated since the classical era. Galenists, Vesalius declared, could not distinguish between the fourth carpal bone and a chickpea, but they wanted to destroy his work just as their predecessors had destroyed the works of Herophilus and Erasistratus. Recalling how he had once been under Galen's influence, Vesalius admitted that he used to keep the head of an ox handy to demonstrate the *rete mirabile*, a network of blood vessels that Galen had placed at the base of the human brain. Unable to find the *rete mirabile* in human cadavers, anatomists rationalized this inconsistency by asserting that, in humans, the structure disappeared very soon after death. When Vesalius finally came to terms with Galen's fallibility, he openly declared that such a network was not present in humans.

In contrast to his revolutionary treatment of anatomy, Vesalius did not go much further than Galen and Aristotle in physiology and embryology. He gave an exhaustive description of the structure of the heart, arteries, and veins, and was skeptical of the Galenic claim that the blood moved from right heart to left heart through pores in the septum, but the motion of the blood remained obscure. Thus, while Galen was challenged on anatomical details, his overall anatomical and physiological doctrines remained intact. For example, having ruled out the presence of the *rete mirabile* in humans, Vesalius had to find an alternative site for the generation of the animal spirits. By interpreting Galen's various



Inferior view of the cerebellum as depicted in *De Humani Corporis Fabrica*, 1543.

accounts of the process that generated them, Vesalius concluded that Galen thought that only part of this process occurred in the *rete mirabile*; the final modifications may have involved the brain and its ventricles. Vesalius could, therefore, ascribe the function of the nonexistent *rete mirabile* to the general vicinity of the cerebral arteries.

Historians generally agree that anatomical research has been the cornerstone of Western medicine since the sixteenth century. Inspired by the new Vesalian anatomy, physicians focused on direct observation of the body as the only means of generating valid anatomical knowledge. But anatomical knowledge and the right to perform human

dissection also served as a means of establishing a unique professional identity and asserting power over life and death. The emphasis on human dissection as an essential aspect of medical education, however, led to increasing tension between the apparently insatiable need for cadavers and the widespread prejudice against human dissection. Until recent times, anatomists were often forced into dangerous and illegal methods of obtaining human bodies. As a medical student in Paris, Vesalius fought off savage dogs while collecting human bones from the Cemetery of the Innocents. In Louvain, he stole the remains of a robber chained to the gallows and brought the bones back into the city hidden under his coat. Grave-robbing incidents were reported wherever Vesalius conducted his famous lecture-demonstrations. One ingenious group of medical students reportedly obtained a corpse, dressed it, and walked their prize into the dissecting room as if it were just another drunken student being dragged into class. Despite anecdotes that feature the bravado of enterprising anatomists, being associated in the popular mind with hangmen and grave robbers was humiliating and dangerous to anatomists. When anatomists were fortunate enough to obtain cadavers, they faced grave dangers during routine dissections, because even the smallest cut could result in a fatal infection.

Long after most European nations had made legal provisions for anatomical studies, body snatching provided the bulk of the teaching material for gross anatomy in Great Britain, Canada, and the United States. Anatomists too timid to obtain cadavers themselves turned to entrepreneurs known as "Resurrectionists" or "Sack-Em-Up Men," who procured bodies by grave robbing, extortion, and murder. In England, under the Murder Act of George II, the bodies of criminals considered vile enough to be worthy of death and dissection were awarded to the Royal College of Surgeons as a "peculiar mark of Infamy added to the Punishment." When England's 1832 Anatomy Act allowed the state to give the unclaimed bodies of paupers to medical schools, poverty became virtually as deeply stigmatized as criminality. It is interesting to note that the Visible Human Project began with the use of a 39-year-old criminal executed by lethal injection in 1993. The body was frozen, sectioned, and transformed into the first fully digitized human being. Today, the National Library of Medicine's Visible Human Project provides invaluable radiological scans and digitalized photographs of cross-sections of a male and a female cadaver.

American physicians also attempted to establish a professional identity through anatomical knowledge. This created an infamous black market for cadavers. Following the example set in England, physicians successfully lobbied for laws that allocated paupers' bodies to medical schools. But scandalous stories of body snatching and dissection-room pranks continued to inflame the public. Advocates of improved medical and surgical training were obliged to remind legislators and laymen that

if doctors did not practice on cadavers, they would have to learn the art at the expense of their patients. The Latin motto used by Medical Examiners and Pathology Departments around the world—"*Hic locus est ubi mors gaudet succurrere vitae*" (This is the place where death delights to help the living)—stresses the insights physicians and researchers gain through human dissection.

By the beginning of the twentieth century, gross anatomy had become an essential part of the curriculum at every American medical school. By the end of that century, the hours devoted to formal anatomy training had sharply declined and the shortage of instructors had become more significant than the problem of obtaining cadavers. Many medical educators argued that computerized scans and three-dimensional representations of the human body provided better teaching tools than traditional dissections, although standardizing models ignores the variability of human anatomy. Others insist that human dissection is an essential aspect of conveying the lesson of human mortality and the meaning of being a doctor. The French anatomist Marie François Xavier Bichat (1771–1802) stressed the importance of conducting autopsies. "Open up a few corpses," he wrote, "you will dissipate at once the darkness that observation alone could not dissipate."

MEDICINE AND SURGERY

On at least one important point Galen and Vesalius were in full agreement. Both argued that medicine and anatomy had degenerated because physicians had given up the practice of surgery and dissection. During the Middle Ages, the distinction between theoretical and practical medicine had been exaggerated by learned physicians, and power plays within university faculties exacerbated this tension. To enhance the dignity of the medical faculty, theoretical, logical, and universal ideas concerning the nature of human beings were emphasized at the expense of empirical and mechanical aspects of the healing art. While the Scientific Revolution produced little change in medical practice, even the most highly educated physician was becoming susceptible to the germs of skepticism. Instead of admitting their limitations, physicians tried to maintain the illusion of the infallibility of the rules and principles of medicine, while blaming failures on errors made by patients and apothecaries.

During this period, however, patients could still select specific kinds of practitioners out of a diverse field in order to fit their budget and their own perception of their medical condition. There is evidence that patients expected the healers they hired to produce significant results. The records of the Protomedicato, the judicial arm of the College of Medicine in Bologna, for example, contain cases where patients sued

practitioners for breach of contract. That is, healers entered into contracts that promised to cure patients within a specific time. However, when the healers were actually physicians, the courts endorsed payment for services rather than for results, because physicians were professionals rather than craftsmen.

Physicians might have been engaged in increasingly sophisticated debates about the nature and cause of disease, but their therapeutics lagged far behind their most novel theories. Wise or cynical laymen noted that life and death appeared to be unaffected by medical treatment. A king might have the best physicians in the world, but when ill, his chances of recovery were not really any better than those of a poor peasant with no doctor at all. When therapeutics was the weakest link in medicine, psychological comfort was the practitioner's major contribution. Under these conditions, the quack might provide more comfort, at lower cost.

Although surgery and medicine could not be totally disentangled, traditions and laws delineated the territorial rights of practitioners. As a general rule, surgeons were expected to deal with the *exterior* of the body and physicians dealt with its *interior*. Surgeons dealt with wounds, fractures, dislocations, bladder stones, amputations, skin diseases, and syphilis. They performed bleedings under the direction of physicians, but were expected to defer to physicians in the prescription of postoperative care. Surgical practice was itself divided into separate areas of status, competence, and privilege among surgeons, barber-surgeons, and barbers.

University-trained physicians were a tiny minority of those who professed knowledge of the healing arts, but they were especially concerned with the status of the medical profession. Physicians considered themselves men of letters. Still echoing Galen, physicians contended: "He that would be an excellent physician must first be a philosopher." Physicians argued that medicine was a science that must be learned from classical texts, not a craft to be learned by experience. Elite physicians could command a salary many times greater than that of surgeons. The status differential between physicians and surgeons is also apparent in the services they were willing to provide. For example, judiciously appraising service in plague pesthouses as a potential death sentence, physicians remained outside and shouted advice to the surgeons, who examined and treated the patients. Despite such hazardous duty, surgeons were poorly paid. For example, a young surgical apprentice appointed to a pesthouse in 1631 (after two surgeons died of the plague) was later awarded just enough money to buy new clothing so that he could burn the clothes he had worn for eight months while in the pesthouse. If the sick could not afford physicians or surgeons they could consult apothecaries, practitioners who had secured the right to a monopoly on preparing and selling drugs.

In many areas, a license to practice medicine could be obtained on the basis of education or by an examination measuring practical skills. Learned physicians saw the latter form of licensing as a loophole through which their unlettered, ignorant competitors gained legal recognition. This "loophole"—the demonstration of skill and experience—was especially important to women, because they were denied access to a university degree. Most women practitioners seem to have been the widows of physicians or surgeons, but some were licensed for their skill in treating particular problems. Female practitioners were occasionally recruited by the public health authorities to care for female patients quarantined in pesthouses during plague outbreaks.

Today, specialization is regarded as a sign of maturity in the evolution of a profession. However, in premodern times, "specialists" such as oculists, bonesetters, and cutters of the stone were more likely to be uneducated empirics than learned physicians. Licensed physicians constantly complained about competition from great hordes of ignorant empirics. Not all educated laymen agreed with the physicians' assessment of the distinction between physicians and the empirics. In particular, the plague years convinced many observers that much that had been written by learned doctors produced "much smoke" but "little light."

AMBROISE PARÉ AND THE ART OF SURGERY

Of course, the education, training, status, and legal standing of surgeons and physicians varied considerably throughout Europe. But almost everywhere, warfare provided golden opportunities for enterprising surgeons; the battlefield has always been known as the ultimate medical school. In such an environment, it was possible for Ambroise Paré (1510–1590), an "unlettered" barber-surgeon, to think his own thoughts, learn by experience, and bring pride and dignity to the art of surgery. To Paré surgery was a divine calling, despite the lowly status of its practitioners. Described by his contemporaries as independent, gentle, impetuous, and ambitious, Paré was honest enough to admit that his major contributions to surgery were simple and not necessarily original. Nevertheless, his willingness to break with tradition and courageously follow methods suggested by his own observations pointed the way towards a general renaissance in surgery. Unlike previous generations of innovative craftsmen, Paré and his peers could emerge from obscurity because the printing press allowed them to publish popular texts in the vernacular. Paré's writings were collected and reprinted many times during his lifetime and translated into Latin, German, English, Dutch, and Japanese. Always willing to learn from ancient authorities, contemporary physicians and surgeons, or even quacks with

a promising remedy, Paré was a deeply religious man, who acknowledged only one final authority.

Little is known about Paré's background and early life. Even the date of his birth and his religion are uncertain. Paré rarely discussed his training and apprenticeship, other than the fact that he had lived in Paris for three years during the nine or ten years he had studied surgery. Although apprenticeship was ostensibly a time for learning, pupils were all too often exploited by cruel masters who neglected their obligation to teach. To obtain more practical experience, Paré worked at the Hôtel Dieu, a hospital that provided examples of a great variety of disorders, as well as opportunities to participate in autopsies and anatomical demonstrations. Conditions at the hospital were so miserable that during one winter, four patients had the tips of their noses frozen and Paré had to amputate them.

Paré's surgical texts provide vivid and moving accounts of the horrors of war, as well as accounts of the kinds of wounds caused by weapons unknown to Hippocrates and Galen. After a battle, the stench of rotting corpses seemed to poison the air; wounds became putrid, corrupt, and full of worms. All too often, injured soldiers died from lack of food and attention, or from the economy measures used to treat them. For example, surgeons believed that mild contusions were best treated with bed rest, bleeding, wet cupping, and sweat-inducing drugs. Such gentle and time-consuming treatments were fine for officers and nobles, but a common soldier was more likely to be wrapped in a cloth, covered with a little hay, and buried in manure up to his neck to encourage sweating.

Gunpowder weapons were, as Francis Bacon noted, among the world-shaking inventions unknown to the ancients. Although gunpowder was referred to in Europe as early as the thirteenth century, it was not until the fourteenth century that pictures of primitive cannons appeared. Thus, to rationalize the treatment of gunpowder wounds, physicians had to argue from analogies. John of Vigo (1460–1525), one of the first to write specifically on the surgical problems of the new warfare, argued that wounds made by firearms were poisoned. Traditionally, poisoned wounds, such as snakebites, were neutralized by cauterization. To assure that deep, penetrating gunpowder wounds were thoroughly cauterized, Vigo recommended the use of boiling oil. When Paré began his career in military surgery, he followed Vigo's methods until his supply of oil was exhausted and he was forced to treat the rest of his patients with a wound dressing made of eggs, oil of roses, and turpentine. In comparing the outcome of these treatments, Paré discovered that the patients who had received the mild dressing healed better than those cauterized with boiling oil. Based on these observations, Paré promised himself that he would never again rely on books when he

could learn from experience. In his writings, Paré urged other surgeons to follow his example.

When cauterization was necessary, Paré preferred the "actual cautery" (red hot irons) to the "potential cautery" (strong acids or bases, boiling oil). To aid the healing of burned flesh, Paré recommended a dressing of raw onions and salt. An elderly female healer taught Paré about the use of raw chopped onion in the treatment of burns. After conducting his own tests, Paré determined that the remedy was effective. In the 1950s, scientists reported that onions contain a mild antimicrobial agent. Thus, in the absence of modern antibiotics, onion might be valuable in preventing bacterial superinfection of burns. In some cases, however, Paré recommended the use of his famous puppy oil balm. He had procured the secret recipe for puppy oil at great trouble and expense, but he openly published it for the benefit of all surgeons and patients. To prepare puppy oil dressing, the surgeon began by cooking two newborn puppies in oil of lilies until the bones dissolved. The oil was mixed with turpentine and a pound of earthworms, and then cooked over a slow fire. Paré was convinced that puppy oil soothed pain and promoted healing.

When the Faculty of Physicians challenged Paré to explain why so many men died of minor gunpowder wounds, Paré examined the components of gunpowder to see whether the ingredients contained a special venom or fire. He concluded that there was neither fire nor venom in gunpowder. Indeed, soldiers, blessedly ignorant of medical theory, drank gunpowder in wine to stimulate healing, or applied gunpowder to wounds as a drying agent. Quoting Hippocrates' *On Airs, Places, and Waters*, Paré argued that the noxious air of the battlefield corrupted the blood and humors so that after a battle even small wounds became putrid and deadly. Finally, Paré suggested that many of these deaths were due to the will of God. If it seems unfair for Paré to blame wound infection on God, it should be remembered that when a patient recovered, Paré invariably said that he dressed the wound, but God healed the patient.

Battlefield surgery often included the amputation of arms or legs, an operation that could lead to death from hemorrhage. Many patients died after amputations because cauterization destroyed the flaps of skin needed to cover the amputation site and increased the danger of infection. The use of the ligature for the repair of torn blood vessels was an old but neglected technique when Paré brought it to the attention of his contemporaries and demonstrated its value in amputations. If the surgeon had performed his task with skill, wealthy patients could be fitted with ingenious and beautifully ornamented prosthetic devices that allowed for various degrees of movement. Paré also devised wooden legs suitable for the poor.

When Paré suffered a compound fracture of the leg, he was fortunate to avoid the usual treatment, which was amputation. (In a simple fracture, there is no external wound. Compound fractures involve a break in the skin; the existence of this external wound often leads to complications.) In 1561, Paré was kicked by his horse; two bones in his left leg were broken. Afraid of being kicked again, he stepped back and fell to the ground, causing the fractured bones to break through flesh, hose, and boot. The only medicaments that could be found in the village—egg whites, wheat flour, oven soot, and melted butter—did nothing to assuage the excruciating pain, which Paré suffered with quiet dignity. Knowing the usual course of such injuries, Paré feared that he must lose his leg to save his life, but the fracture was reduced, the wound was bandaged, the leg was splinted, and rose ointment was applied until the abscess drained.

Despite Paré's reputation for kindness, he had a consuming curiosity that made him willing to use human beings as experimental subjects. When Charles IX praised the virtues of a bezoar stone (a hard indigestible mass found in the stomach or intestinal tract of animals) he had received as a gift, Paré argued that such stones were not really effective antidotes to poisons. To settle the argument, one of the king's cooks, who was about to be hanged for stealing two silver plates, was allowed to participate in Paré's experiment. The condemned man was given the bezoar stone and a poison provided by the court apothecary. Unfortunately for the cook, Paré was correct about the uselessness of bezoar stones, as well as many other widely prescribed and fearfully expensive remedies and antidotes, such as unicorn horn and mummy powder. Noblemen drank from vessels made of unicorn horn and carried unicorn horn with them when traveling in order to ward off illness, much as modern tourists rely on quinine, Dramamine, and Kaopectate. True unicorn horn was very expensive because the bashful creature could only be captured by a beautiful virgin, but the major sources of unicorn horns were the rhinoceros and the narwhale.

Expressing skepticism about the existence of the unicorn, Paré conducted a series of experiments on alleged unicorn horns, such as examining the effect of unicorn preparations on the behavior and survival of venomous spiders, toads, scorpions, and poisoned pigeons. In no case did unicorn horn demonstrate any medicinal virtues. Despite Paré's work and the questions raised by other skeptics, apothecaries vigorously defended the virtues of "true" (high quality, high price) unicorn horn. On aesthetic and medical grounds, Paré rejected the use of mummy powder; he said it was shameful for Christians to consume remedies allegedly derived from the dead bodies of pagans. Ever skeptical, Paré revealed that expensive preparations sold as the mummies of ancient Egyptians were actually fabricated in France from bodies that had been dried in a furnace and dipped in pitch. But some physicians

recommended mummy in the treatment of bruises and contusions, because of its alleged power to prevent blood from coagulating in the body. Advocates of mummy as a medicine urged physicians to select high quality, shiny black preparations, because inferior products that were full of bone and dirt, and gave off an offensive odor, were not effective. Well into the seventeenth century, physicians were still prescribing a variety of disgusting remedies, including mummy preparations, bezoar, powdered vipers, dried animal parts, human placentas, the entrails of moles, and filings or moss from an unburied human skull. Such remedies were also found in various editions of the London Pharmacopoeia.

Opposing the use of established remedies required courage and independence. When Paré published his studies of poisons and antidotes, physicians and apothecaries attacked him for trespassing on their territory. One critic claimed that one must believe in the medical virtues of unicorn horn because all the authorities had proclaimed its efficacy. Paré replied that he would rather be right, even if that required standing all alone, than join with others in their errors. Ideas that had been accepted for long periods of time were not necessarily true, he argued, because they were often founded upon opinions rather than facts.

Although Ambroise Paré was the exemplar of sixteenth-century French medicine, thanks to Louis XIV's (1638–1715) fistula-in-ano, Charles-François Félix (1635?–1703) had a rare opportunity to demonstrate the efficacy of the art of the surgery. For many months, physicians had subjected the king to emetics, purges, leeches, bleedings, and other futile and dangerous remedies. The king's distress was caused by a seed or fecalith that had lodged itself in the royal rectum, causing inflammation, abscesses, and a fistula. On November 18, 1686, the desperate king turned from medicine to surgery. According to Félix's enemies, the surgeon had been practicing for the operation in a Parisian hospital. Some of his human guinea pigs did not survive, but their deaths were attributed to poisoning and the corpses were disposed of secretly. In any case, the operation on the king was entirely successful. A much relieved and grateful monarch granted royal rewards and favors to the surgeons, much to the displeasure of the physicians.

THE OCCULT SCIENCES: ASTROLOGY AND ALCHEMY

Scientists and scholars once looked at the sixteenth and seventeenth centuries as the period in which "rationalism" began to replace magical and even religious thinking, or at least push occultism to the periphery. Since the 1970s, many historians have labored mightily to find evidence that the great figures once regarded as founders of a rational, experimental, scientific method were actually more interested in astrology, alchemy, and other forms of mysticism and occult phenomena. To be

historically accurate, it is anachronistic to use the terms "science" and "scientist" for this time period, but historians note that astrology and natural magic could be considered proper examples of "applied science."

Historians once emphasized the artistic and scientific triumphs of the Renaissance, but recently scholars have focused on the many ways in which superstition and the occult sciences flourished. Medicine, along with the other arts and sciences, remained entangled with astrology, alchemy, and other varieties of mysticism. Out of this mixture of art, science, and magic arose new challenges to medical theory, philosophy, and practice. One form of prognosis known as astrological medicine was based on the assumption that the motions of the heavenly bodies influenced human affairs and health. More broadly, astrology was a form of divination. In practice, astrological medicine required knowing the exact time at which the patient became ill. With this information and a study of the heavens, the physician could prognosticate the course of illness with mathematical precision and avoid dangerous tendencies. In therapeutics, astrological considerations determined the nature and timing of treatments, the selection of drugs, and the use of charms. For example, the sun ruled the chronic diseases, Saturn was blamed for melancholy, and the moon, which governed the tides and the flow of blood in the veins, influenced the outcome of surgery, bloodletting, purging, and acute illness. The putative relationships between the heavenly bodies and the human body were so complex, numerous, and contradictory that in practice it was impossible to carry out any operation without breaking some rule. While medical astrology occupies a prominent place in the Renaissance, it can be seen as a continuity of popular medieval doctrines that were not necessarily linked to scholarly medical theory. Physicians may have continued to study and utilize medical astrology, but many Renaissance medical treatises ignored or even explicitly condemned astrology.

Even in the twenty-first century, a quick survey of shelves in most major bookstores indicates that astrology attracts many more readers than astronomy. Chemists, secure in their knowledge that alchemy has few devotees today, have long been amused at the continuous battle against superstition waged by astronomers. Alchemists, however, occupy an ambiguous position in the history of medicine and science, praised as pioneers of modern chemistry, damned as charlatans, or treated reverently as purveyors of an alternative way of knowing the universe.

It is generally assumed that the primary goal of alchemy was to transform base metals into gold, but alchemy is a term that encompasses a broad range of doctrines and practices. Particularly in Chinese medicine, alchemy encompassed the search for the elixirs of health, longevity, and immortality. In Western history, the idea that the task of alchemy

was not to make gold or silver, but to prepare medicines, can be found in the writings of Philippus Aureolus Theophrastus Bombastus von Hohenheim (1493–1541), alchemist, physician, and pharmacologist. Fortunately, he is generally referred to as Paracelsus (higher than Celsus), the term adopted by the Paracelsians of the seventeenth century, who believed that therapeutics could be revolutionized by the development of chemical or spagyric drugs. (Spagyric comes from the Greek words meaning "to separate" and "to assemble.") Little is known with any certainty about his early life and education. Although he left behind a large, if disorganized, collection of writings in medicine, natural philosophy, astrology, and theology, only one authentic portrait exists. His place in the history of medicine is ambiguous, but in modern German history, Paracelsus served a major cultural icon during the Nazi era.

After a brief period as a student at the University of Basel, Paracelsus became tired of academic dogmatism and immersed himself in the study of alchemy. Instead of consulting scholars and professors, Paracelsus sought out the secret alchemical lore of astrologers, gypsies, magicians, miners, peasants, and alchemists. Although there is no evidence that he ever earned a formal academic degree, Paracelsus bestowed upon himself the title "double doctor," presumably for honors conferred on him by God and nature. Nevertheless, Paracelsus secured an appointment as Professor of Medicine and city physician of Basel. Despite his new academic credentials, he seemed more interested in staging scenes that would now be called media events. To show his contempt for ancient dogma, he burned the works of Avicenna and Galen while denouncing orthodox pharmacists and physicians as a "misbegotten crew of approved asses." Wearing the alchemist's leather apron rather than academic robes, he lectured in the vernacular instead of Latin. Although these public displays enraged his learned colleagues, it was a dispute over a fee for medical services that forced him to flee from Basel. His enemies happily noted that he died suddenly in a mysterious, but certainly unnatural, fashion when only 48, while Hippocrates and Galen, founders of the medical system he rejected, had lived long, productive lives.

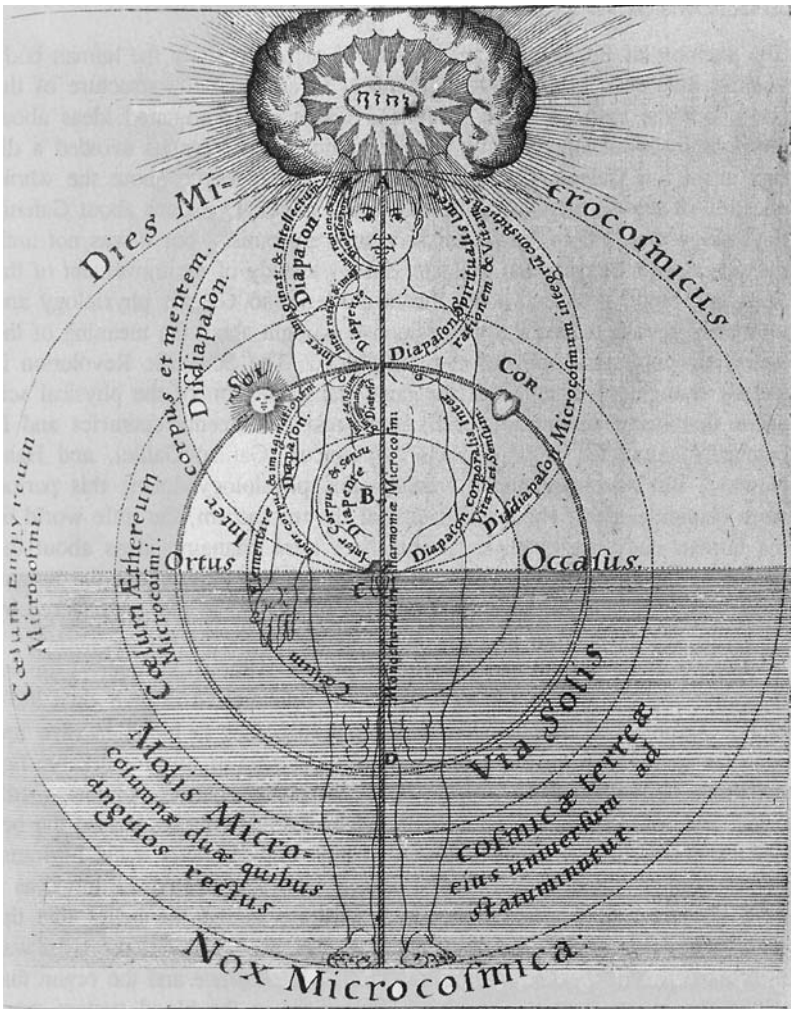
In opposition to the concept of humoral pathology, especially the doctrines of Galen and Avicenna, Paracelsus attempted to substitute the doctrine that the body was essentially a chemical laboratory, in which the vital functions were governed by a mysterious force called the *archaeus*, a sort of internal alchemist. Disease was, therefore, the result of derangements in the chemical functions of the body rather than a humoral disequilibrium. Physicians should, therefore, study the chemical anatomy of disease rather than gross anatomy. Anatomical research itself was, therefore, irrelevant to understanding the most profound questions about the vital functions of the human body. Because life

Paracelsus.

and disease were chemical phenomena, specific chemical substances must serve as remedies. The specific healing virtue of a remedy would depend on its chemical properties, not on the qualities of moistness, dryness, and so forth associated with humoral theory.

In a burst of optimism, Paracelsus declared that all diseases could be cured when, through alchemy, one came to understand the essence of life and death. The challenge of finding a specific remedy for each disease seemed overwhelming, not because of a scarcity of medicines, but because nature was one great apothecary shop. Confronting nature's embarrassment of riches, the alchemist could be guided by the method of separation, the Doctrine of Signature, and the astrological correspondences among the seven planets, seven metals, and the parts of the body.

Rejecting the Galenic principle of curing by the use of contraries, Paracelsus favored the concept that like cures like. But, discovering



The Microcosm—a seventeenth-century alchemical chart showing the human body as world soul.

the true nature of the remedy, which was traditionally a complex mixture, could only be accomplished by alchemically separating the pure from the impure, the useful from the useless. Within the vast *materia medica* already known to sixteenth-century healers, poisons had always been of particular interest, because they were obviously very powerful agents. Paracelsus argued that alchemy made it possible to separate out the curative virtues hidden within these perilous substances. Galenists denounced Paracelsians as dangerous radicals who used poisons as remedies. In response to these accusations, Paracelsus ridiculed his critics for their use of unsafe purgatives, exorbitantly priced theriacs, and noxious mixtures made with mummy powder, dung, and urine. All things could act as poisons, he declared, but the art of alchemy could "correct" poisons.

In place of traditional complex herbal preparations, Paracelsus and his followers favored the use of purified drugs, especially minerals such as mercury, antimony, iron, arsenic, lead, copper, and their salts, and sulfur. Determining whether new chemical remedies actually had specific therapeutic virtues could, obviously, be very risky. Fortunately, many toxic materials cause such rapid purgation that not enough would be absorbed to provide a lethal dose. Moreover, in some cases, the alchemical purification processes probably removed everything but the solvent. On the other hand, some attempts at purification produced interesting new substances. For example, attempts to distill off the essence of wine created "strong liquors" that were made into medicinal cordials. On occasion, entirely new and interesting drugs emerged from the chaos of the alchemical laboratory. Of special interest is the possibility that Paracelsus was one of the first to discover the narcotic effects of ethyl ether, which was known as "sweet vitriol." Not all Paracelsian drugs were derivatives of toxic metals; his "laudanum," a preparation used to induce restful sleep and ease pain, was essentially opium in wine.

Although Paracelsus ridiculed traditional uroscopy, he accepted the underlying idea that since urine contains wastes collected from the whole body it must harbor valuable diagnostic clues. Instead of uroscopy by ocular inspection, he proposed diagnosis by chemical analysis, distillation, and coagulation tests. Given the state of qualitative and quantitative analysis, however, his chemical dissection was likely to be about as informative as ocular inspection. In urine analysis, as in studies of potential remedies, many Paracelsians ignored the important residues and concentrated all their attention on the distillate. A work attributed to Paracelsus, but generally regarded as spurious, provided instructions for the chemical examination of urine by the measurement of volume and specific gravity, using a measuring cylinder ingeniously designed as a replica of the human body.

To replace humoral categories of disease, Paracelsus attempted to develop a system based on analogies to chemical processes. While generally obscure and inconsistent, his chemical concepts were peculiarly appropriate to metabolic diseases, dietary disorders, and certain occupational diseases. For example, in classifying gout as a "tartaric disease," he had indeed chosen an example of a metabolic disease in which body chemistry has gone wrong: in gouty individuals, a metabolic product forms local deposits, primarily in the joints, in a manner very roughly analogous to the way in which tartrates sediment out of wine. He also pointed to a relationship between cretinism in children and goiter in adults (disorders caused by a lack of iodine in the diet). According to Paracelsus, miners, smelter workers, and metallurgists exhibited a variety of symptoms because their lungs and skin absorbed dangerous combinations of unwholesome airs and clouds of poisonous dust. This noxious chemical mixture generated internal coagulations, precipitations, and sediments. Such examples can create the impression that Paracelsus had valid reasons for his attack on Galenism and actually held the keys to a new system of therapeutics, but it is easy to read too much into the Paracelsian literature and confuse obscurity with profundity. Nevertheless, later advocates of chemical or Paracelsian medicine were involved in the transformation of pharmacology and physiology, diagnostics, and therapeutics. The Society of Chemical Physicians was founded in 1665. Successful examples of chemical medicines forced even the most conservative physician to think about the limits of Galenism and tempted many orthodox physicians to experiment with the new remedies. Despite the opposition of the College of Physicians and its attempts to suppress the use of the new chemical remedies, the English Paracelsians achieved considerable recognition. By the mid-1670s, even those who rejected Paracelsian philosophy were beginning to accept the new chemical remedies. Moreover, debates about the chemical philosophy of life served as an alternative to the mechanistic systems that invaded the medical sciences in the wake of the Newtonian revolution. Debates between "mechanist physicians" and "chemical physicians" continued into the eighteenth century.

Despite evidence of intellectual continuity, Renaissance scholars seemed to believe that they were making a major break with the medieval and Arabic past, primarily by recapturing and assimilating classic Greek texts. Similarly, many physicians were convinced that medicine was undergoing rapid and significant changes. Physicians and surgeons were acquiring anatomical and pharmacological knowledge and ideas that promoted increasingly sophisticated debates about the nature of the human body and the cause of disease. This did not automatically change the nature or efficacy of their prescriptions and procedures, but it made the search for further knowledge possible and highly desirable.