

soon as possible. Those who early become and long remain apprentices ought to be the best masters.<sup>11-12</sup> Some cities provided schools to educate the young. A chronicler in Florence related that between 8,000 and 10,000 boys and girls between the ages of six and twelve attended the city's grammar schools, a figure that probably represented half of all school-aged children. Although grammar school completed education for girls, some 1,100 boys went on to six secondary schools that prepared them for business careers, while another 600 studied Latin and logic in four other schools that readied them for university training and a career in medicine, law, or the church. In the High Middle Ages, then, urban communities demonstrated a commitment to training the young.

As a result of the devastating effects of the plague and its recurrences, these same communities became concerned about investing in the survival and health of children. A number of hospitals existed in both Florence and Rome in the fourteenth century, and in the 1420s and 1430s, hospitals were established that catered only to the needs of foundlings, supporting them until boys could be taught a trade and girls could marry.

## New Directions in Medicine

The medical community comprised a number of functionaries. At the top of the medical hierarchy were the physicians, usually clergymen, who received their education in the universities, where they studied ancient authorities, such as Hippocrates and Galen. As a result, physicians were highly trained in theory but had little or no clinical practice. By the fourteenth century, they were educated in six chief medical schools—Salerno, Montpellier, Bologna, Oxford, Padua, and Paris. Paris was regarded as the most prestigious.

The preplague medicine of university-trained physicians was theoretically grounded in the Classical Greek theory of the “four humors,” each connected to a particular organ: blood (from the heart), phlegm (from the brain), yellow bile (from the liver), and black bile (from the spleen). Because the four humors corresponded in turn to the four elemental qualities of the universe—air (blood), water (phlegm), fire (yellow bile), and earth (black bile)—a human being was considered a microcosm of the cosmos. Good health resulted from a perfect balance of the four humors; sickness meant that the humors were out of balance. The task of the medieval physician was to restore proper order through a number of remedies, such as rest, diet, herbal medicines, or bloodletting.

Beneath the physicians in the hierarchy of the medical profession stood the surgeons, whose activities included performing operations, setting broken bones, and bleeding patients. Their knowledge was based largely on practical experience. Below surgeons were midwives, who delivered babies, and barber-surgeons, who were less trained than surgeons and performed menial tasks such as bloodletting and setting simple bone fractures. Barber-surgeons supplemented their income by shaving and cutting hair and pulling teeth. Apothecaries also constituted part of the medical establishment. They filled herbal prescriptions recommended by physicians and also prescribed drugs on their own authority.

All of these medical practitioners proved unable to deal with the plague. When King Philip VI of France requested the opinion of the medical faculty of the University of Paris on the plague, their advice proved worthless. This failure to understand the Black Death, however, produced a crisis in medieval medicine that resulted in some new approaches to health care.

One result was the rise of surgeons to greater prominence because of their practical knowledge. Surgeons were now recruited by universities, which placed them on an equal level with physicians and introduced a greater emphasis on practical anatomy into the university curriculum. Connected to this was a burgeoning of medical textbooks, often written in the vernacular and stressing practical, how-to approaches to medical and surgical problems.

Finally, as a result of the plague, cities, especially in Italy, gave increased attention to public health and sanitation. Public health laws were instituted, and municipal boards of health came into being. The primary concern of the latter was to prevent plague, but gradually they came to control almost every aspect of health and sanitation. Boards of public health, consisting of medical practitioners and public officials, were empowered to enforce sanitary conditions, report on and attempt to isolate epidemics by quarantine (rarely successful), and regulate the activities of doctors.



**A Medical Textbook.** This illustration is taken from a fourteenth century surgical textbook that stressed a how-to approach to surgical problems. *Top left*, a surgeon shows how to remove an arrow from a patient; *top right*, how to open a patient's chest; *bottom left*, how to deal with an injury to the intestines; *bottom right*, how to diagnose an abscess.

Paracelsus rejected the work of both Aristotle and Galen and attacked the universities as centers of their moribund philosophy. He and his followers hoped to replace the traditional system with a new chemical philosophy that was based on a new understanding of nature derived from fresh observation and experiment. This chemical philosophy was in turn closely connected to a view of the universe based on the macrocosm-microcosm analogy. According to this view, a human being was a small replica (microcosm) of the larger world (macrocosm). All parts of the universe were represented within each person. As Paracelsus said, "For the sun and the moon and all planets, as well as the stars and the whole chaos, are in man... For what is outside is also inside; and what is not outside man is not inside. The outer and the inner are one thing."<sup>12</sup> In accordance with the macrocosmic-microcosmic principle, Paracelsus believed that the chemical reactions of the universe as a whole were reproduced in human beings on a smaller scale. Disease, then, was not caused by an imbalance of the four humors, as Galen had argued, but was due to chemical imbalances that were localized in specific organs and could be treated by chemical remedies.

Although others had used chemical remedies, Paracelsus and his followers differed from them in giving careful attention to the proper dosage of their chemically prepared metals and minerals. Paracelsus had turned against the Galenic principle that "contraries cure" in favor of the ancient Germanic folk principle that "like cures like." The poison that caused a disease would be its cure if used in proper form and quantity. Despite the apparent effectiveness of this use of toxic substances as treatment (Paracelsus did have a strong reputation for actually curing his patients), his opponents viewed it as the practice of a "homicide physician." Later generations came to regard Paracelsus more favorably, and historians who have stressed Paracelsus's concept of disease and recognition of "new drugs" for medicine have viewed him as a father of modern medicine. Others have argued that his macrocosmic-microcosmic philosophy and use of "like cures like" drugs make him the forerunner of both homeopathy and the holistic medicine of the postmodern era.

## Vesalius

The new anatomy of the sixteenth century was the work of Andreas Vesalius (1514–1564). His study of medicine at Paris involved him in the works of Galen. Especially important to him was a recently discovered text of Galen, *On Anatomical Procedures*, that led Vesalius to emphasize practical research as the principal avenue for understanding human anatomy. After receiving a doctorate in medicine at the University of Padua in 1536, he accepted a position there as professor of surgery. In 1543, he published his masterpiece, *On the Fabric of the Human Body*.

This book was based on his personal dissection of a body to illustrate what he was discussing. Vesalius's anatomical treatise presented a careful examination of the individual organs and general structure of the human body. The book would not have been feasible without both the artistic

advances of the Renaissance and technical developments in the art of printing. Together, they made possible the creation of illustrations superior to any done before.

Vesalius's hands-on approach to teaching anatomy enabled him to rectify some of Galen's most glaring errors. He did not hesitate, for example, to correct Galen's assertion that the great blood vessels originated from the liver since his own observations made it apparent that they came from the heart. Nevertheless, Vesalius still clung to a number of Galen's erroneous assertions, including the Greek physician's ideas on the ebb and flow of two kinds of blood in the veins and arteries. It was not until William Harvey's work on the circulation of the blood nearly a century later that this Galenic misperception was corrected.

## William Harvey

William Harvey (1578–1657) attended Cambridge University and later Padua, where he received a doctorate in medicine in 1602. His reputation rests on his book *On the Motion of the Heart and Blood*, published in 1628. Although questions had been raised in the sixteenth century about Galen's physiological principles, no major break from his system had occurred. Harvey's work, which was based on meticulous observations and experiments, led him to demolish the ancient Greek's erroneous contentions. Harvey demonstrated that the heart and not the liver was the beginning point of the circulation of blood in the body, that the same blood flows in both veins and arteries, and most important, that the blood makes a complete circuit as it passes through the body. Although Harvey's work dealt a severe blow to Galen's theories, his ideas did not begin to achieve general recognition until the 1660s, when capillaries, which explained how the blood passed from the arteries to the veins, were discovered. Harvey's theory of the circulation of the blood laid the foundation for modern physiology.

## Chemistry

Although Paracelsus had proposed a new chemical philosophy in the sixteenth century, it was not until the seventeenth and eighteenth centuries that a science of chemistry arose. Robert Boyle (1627–1691) was one of the first scientists to conduct controlled experiments. His pioneering work on the properties of gases led to Boyle's law, which states that the volume of a gas varies with the pressure exerted on it. Boyle also rejected the medieval belief that all matter consisted of the same components in favor of the view that matter is composed of atoms, which he called "little particles of all shapes and sizes" and which would later be known as the chemical elements.

In the eighteenth century, Antoine Lavoisier (AHN-twahn lah-vwah-ZYAY) (1743–1794) invented a system of naming the chemical elements, much of which is still used today. In helping to show that water is a compound of oxygen and hydrogen, he demonstrated the fundamental rules of chemical combination. He is regarded by many as the founder of