PART I

Medicine and Disease: An Overview
Greece and Rome

Before the fifth century B.C., ancient Greece had physician-seers (iatromantis) who combined magical procedures and drug treatments, and wound healers deft at caring for battlefield trauma. Another group of practitioners were engaged in medical dietetics, a tradition that developed primarily in response to the needs of athletes. Ultimately, it encompassed not only questions regarding exercise, bathing, and relaxation, but the regulation of food and drink for all citizens. All of these traditions eventually merged around 500 B.C. into a techne iatriche, or healing science, that sought to define its own intellectual approach and methodology. For this purpose, the new medicine adopted a theoretical framework capable of explaining the phenomena of health and illness. The new techne was also heavily dependent on clinical observations from which careful inferences and generalizations were derived.

The foremost representative of classical Greek medicine was Hippocrates, a prominent practitioner and teacher who came to personify the ideal Western physician. Within a century of his death in 370 B.C., several unknown disciples wrote nearly 60 treatises, some clinical and some theoretical, on medical subjects differing widely in content and style. This collection of writings, which comprised a comprehensive and rational healing system usually known as "Hippocratic" medicine, emphasized the individual patient. Its practitioners focused exclusively on physical factors related to health and disease, including the immediate environment. Indeed, among the most famous works of the Hippocratic corpus was the treatise Airs, Waters, and Places, an early primer on environmental medicine. Another was Epidemics, a day-to-day account of certain patients, and a third was Regimen, a prescription of diet and life-style conducive to health.

For the ancient Greeks, health was a state of balance among four bodily humors: blood, phlegm, yellow bile, and black bile. Each had a specific bodily source, a pair of fundamental qualities, and a particular season in which it could be produced in excess. The blood, for example, was elaborated in the particular season in which it could be produced in excess. The blood, for example, was elaborated in the liver, was hot and moist, and was prone to overflow during the spring. Not only were humors the material and dynamic components of the body, but their ever-imperfect and labile mixture was responsible for a person's psychological makeup, or "temperament," as well as for deficiencies in bodily constitution that created susceptibilities to disease.

Illness thus occurred when the humoral balance was upset either by a lack of proper nourishment or by the imperfect production, circulation, and elimination of the humors. The physician's goal was to restore a healthy balance through the use of diet, rest, or exercise and a limited number of drugs, all capable of aiding the natural healing powers believed to exist in every human being.

This somewhat conservative approach of merely assisting nature and above all not harming the sick characterized the method of Hippocratic physicians. It was congruent with the rather tenuous social position of the early Greek healer, often an itinerant craftsman entirely dependent on his personal reputation because the country lacked an educational and licensing system for medical professionals. Given the elementary state of medical knowledge as reflected in the absence of properly identified disease entities, the demands made of Hippocratic healers were simple prognostications — will the patient live or die? — and ideally some amelioration of symptoms by complementing the healing forces. Unfettered by religious barriers, although coexisting with a religious healing system based on the cult of Asclepius (the god of medicine), the techne iatriche prospered within the flexible tenets of humoralism, a cultural system that was widely shared by healers and their patients and that allowed for the gradual inclusion of new clinical observations.

After the death of Alexander the Great in 323 B.C. and the partial dismembering of his empire, Egypt flourished under the rule of the Ptolemies. Alexandria, the chief cultural and commercial center, became famous for its library and museum, attracting manuscripts and scholars from the entire Hellenistic world. In addition to collecting medical literature, scholars such as Herophilus of Chalcedon and Erasistratus of Cos carried out systematic human dissections, identifying structures of the circulatory and nervous systems, the eye, and the female reproductive organs.

Given the limitations of contemporary medical knowledge, as the Hippocratic healing profession began to compete for upper-class patronage serious debates ensued about the value of medical theory and
knowledge and with their writings made Galen the central medical authority for the next 500 years.

In Rome, healing was essentially a popular skill practiced by heads of families, slaves, and foreigners. A lack of regulations and low social status contributed to a general mistrust of physicians. An exception, however, was the respect accorded to Galen of Pergamon of the second century, a well-educated follower of Hippocratic medicine who managed to overcome the schisms of sectarianism. A prolific writer who authored hundreds of treatises, Galen also carried out anatomic dissections and physiological experiments on animals. He successfully integrated his extensive clinical experience, which he acquired mainly as a surgeon to performing gladiators, into his basic theoretical knowledge, providing medicine with a comprehensive system destined to survive for nearly 1,500 years.

**Early Christian Era, East and West**

After the collapse of the Roman Empire, Western medicine experienced a period of retreatment and decline. Healing became an important act of Christian charity, a divine gift freely provided within the framework of the new church and not restricted to professional physicians. Given this religious orientation, Christians healed through the confession of sins, prayer, the laying on of hands, exorcisms, and miracles, occasionally performed by saints or church fathers.

In Byzantium, the Christian magical-religious healing flourished side by side with the earlier rational Greco-Roman medicine in spite of frequent tensions, especially because physicians often exacted exorbitant payments for their services. Several of them, including Oribasius of the fourth century, Aetius of Amida and Alexander of Tralles of the sixth century, and Paul of Aegina of the seventh century, compiled and preserved ancient medical knowledge and with their writings made Galen the central medical authority for the next 500 years.

Faced with a growing population and adverse economic conditions, the early Christian church created a number of philanthropic institutions. The provision of shelter and food for the poor and for strangers was extended to several forms of health care in houses called xenones (hostels) and more specifically nosokomeia (places for the sick). Among the first was an inn built by Bishop Basil around 375 in Caesarea, which was apparently staffed by nurses and physicians. Two decades later similar institutions opened their doors in Constantinople, and thereafter such hospitals proliferated in other major commercial cities of the Byzantine Empire.

In western Europe, monks played an important role in Christian healing as well as in the collection and preservation of medical manuscripts. Whereas Augustinian monks lived a life of isolation and prayer, the followers of Benedict created working communities that cared for their sick brethren as well as visitors and transients. Monasteries such as the cloister of Monte Cassino, founded in 529, and the cathedral schools after the year 800 became heirs to fragments of classical medical knowledge. Many Benedictine monasteries—such as St. Gall (c. 820)—continued both a hospitale pauperum for pilgrims and an infirmarium for sick monks and novices. Monasteries were constructed along important roads or in surviving Roman towns, notably in southern France and Italy. Sick care was dispensed as part of the traditional Christian good works. By contrast, medical treatment under the supervision of physicians remained sporadic.

**Islam**

Before the seventh century, Islamic healing consisted merely of a collection of popular health rules, or hadiths, known as "Muhammad's medicine" for use by devout Muslims living on the Arabic peninsula. In accordance with basic religious and philosophical ideas, this system was holistic, emphasizing both body and soul. However, as the Islamic Empire gradually expanded, a comprehensive body of Greco-Roman medical doctrine was adopted together with an extensive Persian and Hindu drug lore.

The collection, preservation, and eventual transmission of classical medical knowledge went on for several centuries. Even before the Arab conquest of 636, Nestorian Christians in Jundishapur, Persia, had played a prominent role in safeguarding Greek learning by translating many Greek works into the Syriac language. Later, under Islamic rule, these Nestorian physicians wielded great influence over the early caliphs, conducting searches for additional
Greek manuscripts in the Middle East and directing a massive translation program of scientific texts from Syriac into Arabic. Islam's political supremacy and commercial networks made possible the collection of medicinal plants from the Mediterranean basin, Persia, and India. The eleventh-century author Abu al-Biruni composed a treatise on pharmacy in which he listed about 720 drugs. In addition, Islamic alchemy furnished a number of metallic compounds for the treatment of disease. Such expansions in materia medica and the compounding of remedies led to the establishment of a separate craft of pharmacy.

In medical theory, authors writing in Arabic merely followed and further systematized classical humoralism. Whereas al-Razi, or Rhazes, of the ninth and early tenth centuries contributed a number of original clinical works such as his treatise on smallpox and measles, the *Canon of Medicine* composed in the early eleventh century by the Persian physician Ibn Sina, or Avicenna, became the leading medical encyclopedia and was widely used until the seventeenth century. Finally, Moses Maimonides, a Jewish physician and prolific author, wrote on clinical subjects and medical ethics.

Islam significantly influenced hospital development, creating secular institutions devoted to the care of the sick. The first *bimaristan* - a Persian term meaning "house for the sick" - was established in Baghdad before the year 803 by Ibn Barmak, the famous wazir of Harun al-Rashid. It was based on Byzantine models transmitted to Jundishapur. Unlike previous and contemporary Christian institutions devoted to medical care, *bimaristans* were private hospitals symbolizing royal prestige, wealth, and charity. Their selected inmates came from all sectors of the population and included mentally disturbed individuals. Operated by a director together with a medical staff, pharmacist, and servants, *bimaristans* offered comprehensive medical care and educational opportunities for students serving apprenticeships. In fact, the hospitals had their own libraries, which contained copies of medical texts translated from the Greek and Syriac.

In addition to providing clinical training, medical education became more formalized. Small private schools offered a flexible curriculum of lectures and discussions, generally under the direction of famous physicians. In recognition of these cultural apprenticeships, the state issued licenses for practicing medicine to students who had successfully completed a course of theoretical and clinical studies. The traditional Islamic *hisbah* system of codes and regulations designed to enforce law and order according to the mandates of the Koran gradually extended its jurisdiction over multiple healing activities. Physicians, surgeons, bonesetters, and pharmacists were examined by the caliph's chief physician or an appointed inspector before receiving permission to practice. Unquestionably, such official efforts to establish ethical and practical standards for medical conduct and action were important steps in the professionalization of medicine.

**Middle Ages**

After the twelfth century, medieval medical knowledge in the Occident ceased to be based solely on a number of scattered Greek and Latin manuscripts carefully collected and preserved for centuries in monasteries and schools. A rapidly growing number of classical medical texts, including the *Canon* of Avicenna and clinical treatises of Rhazes, were translated from Arabic to Latin. Nonetheless, the theory of four humors and qualities remained the basis for explaining health and disease. It was supplemented by the notion that an essential or "radical" moisture was needed to ensure proper mental and physical functioning. Based on the natural wetness of bodily tissues, this element played an important role in explaining disease, senility, and death.

The inclusion of medicine in early university studies had momentous consequences. Teachers devised formal curricula and identified a specific body of medical knowledge to be mastered by students. For the first time, physicians could acquire an academic degree in the field of medicine, thus laying claim to greater competency and legitimacy. Among the first schools to offer medical studies was in Salerno, around 985, but the real growth in medical education occurred in the thirteenth century with the founding of three major university centers: Montpellier and Paris in France, Bologna in Italy. Because a medieval medical education stressed theory, rhetoric, and philosophical speculation, graduates acquired an unprecedented degree of prestige and status. In contrast, the practical aspects of healing lacked intellectual standing, and surgery was therefore excluded from university studies. Graduates, in turn, created select medical organizations - often under royal patronage - and worked hard to achieve a monopoly on practice.

Teaching centers became focal points for medical investigations. Human dissection, for example, began at the University of Bologna toward the end of the thirteenth century, prompted by forensic as well as medical considerations: Both lawyers and practi-
tioners were interested in ascertaining the causes of death from foul play or epidemic disease. In 1316, a Bolognese professor, Mondino de Luzzi, wrote the first modern treatise on anatomy. This specific interest was continued at other universities, including those of Padua, Florence, and Pisa. All works on anatomy were designed to illustrate the descriptions of Galen, still the absolute authority on the subject.

In response to repeated and deadly plague epidemics – the first pandemic struck Europe between 1348 and 1350 – northern Italian city-states instituted a series of public health measures designed to protect the healthy elite from the ravages of the disease. Because poisonous miasma was blamed for the humoral imbalance that caused susceptibility to plague, authorities isolated ships whose crews and cargoes were suspected of carrying miasma. The isolation – or so-called quaranteneria – necessary to neutralize the offending particles lasted for 40 days. Venice and Ragusa were among the first cities to implement such measures, the former in 1348, the latter in 1377. Burial regulations, the control of water supplies, the cleansing or burning of contaminated possessions – all inaugurated a comprehensive sanitary program widely adopted by other European cities in ensuing centuries.

The emergence during the twelfth century of lay communities in which the principal focus of charitable work was care of the sick can be seen as a response to Europe’s growing burden of disease. The Knights of St. John, the Teutonic Knights, and the Augustinian Brotherhood played key roles in this evolution. Hospital foundations, sponsored by the rulers of newly created kingdoms or local bishops, provided the poor, elderly, unemployed, and sick with spiritual and physical care in the form of diet and nursing. The rising prevalence of leprosy after 1200 forced the establishment of nearly 20,000 shelters to separate these stigmatized sufferers from the general population. With the onset of plague after 1348, local authorities set up quarantine stations and pesthouses aimed at isolating those suspected of harboring the disease.

Renaissance

With the revival of classical Greek learning, or humanism, during the Renaissance, Western medicine was profoundly influenced by the replacement of corrupt and incomplete texts with new Latin translations of the original Greek. However, tensions developed between the old learning and contemporary insights into the phenomena of health and disease, some of which had been previously ignored or misunderstood. For example, the early-sixteenth-century findings of Andreas Vesalius of Padua, based on meticulous and systematic dissections that established the foundations of modern anatomy in the West, contradicted Galen’s descriptions. In fact, Vesalius demonstrated that Galen’s findings were based on animal dissections – especially of the barbary ape – instead of human dissections.

Another sixteenth-century attack on classical medicine came from a Swiss practitioner, Philippus von Hohenheim, better known by his adopted name, Paracelsus. His goal was to investigate nature directly and thereby discover the hidden correspondences between the cosmos and human beings. During his many travels, Paracelsus acquired a detailed knowledge of occupational diseases. For example, he observed the ailments contracted by European miners, an unprecedented pathology without adequate classical antecedents. On the basis of his alchemical education and clinical experience, Paracelsus formulated a new theory of medicine based on the notion that the body functioned chemically under the direction of an internal “archeus,” or alchemist, responsible for maintaining the proper balances and mixtures. Consequently, cures could be achieved only through the administration of chemically prepared remedies. Paracelsus strongly advocated the use of mercury in the treatment of syphilis, a potentially toxic therapy widely accepted by his contemporaries.

Equally important were the innovations in surgical technique and management of gunshot wounds by the sixteenth-century French surgeon Ambroise Paré. On the basis of new anatomic knowledge and clinical observations, Paré questioned a series of traditional assumptions concerning the treatment of injured soldiers, including venesection, cauterezation, and the use of boiling oil. Paré’s publications, written in the vernacular, profoundly influenced the surgical craft of his day, replacing ancient methods with procedures based on empirical knowledge.

Seventeenth Century

The classical assumptions of humoralism that had explained human functioning in health and disease for nearly two millennia in the Western world were severely challenged in the seventeenth century. During this century, the body came to be viewed as something like a machine governed by physical principles. This view was expressed by the philosopher René Descartes in a treatise published posthumously in 1662. Cartesian man had a dual nature: a physical body ruled by universal laws of matter and motion, and an immaterial soul or mind – a pure
thinking entity – located in the pineal body of the brain. The body was conceived of as a vast hydraulic network of hollow pipes, moving blood and nervous fluid in the circulatory and nervous systems under the influence of the mind.

Descartes’s mechanical theory spawned a mechanical school of human physiology located primarily in northern Italy, where Galileo Galilei, the great physicist, had already established a science of mechanics. Following in Galileo’s footsteps, a mathematician, Giovanni A. Borelli, analyzed the phenomenon of muscular contraction and a physician, Sanctorius of Padua, studied metabolic combustion and insensible perspiration.

In England, William Harvey’s experimental discovery of the blood circulation, announced in 1628, contributed to the mechanical view of living organisms while discrediting Galen’s fanciful hypothesis of a humor ebb and flow. The heart was now viewed as a pump, its chambers closing tightly with the help of valves. Blood was impelled into an intricate system of vessels according to the laws of hydrodynamics and traveled in a close circle through the arterial, venous, and capillary systems.

Not only did Harvey’s findings support a mechanistic view of the human organism, but his approach to the theory – which included dissections, animal experiments, and mathematical reasoning – demonstrated the potential usefulness of scientific research in resolving physiological questions. On the basis of the ideas of Pierre Gassendi, a seventeenth-century French philosopher, regarding the corpuscular nature of matter, various British investigators working in concert studied the phenomenon of respiration. By the 1670s, Robert Boyle, Robert Hooke, Richard Lower, and John Mayow had concluded that certain air particles entering the lungs and mixing with arterial blood were essential for all vital functions. At the same time, chemical fermentation studies by Jean Baptiste van Helmont and François de la Boé explained the nature of digestion. Microscopic studies, carried out by Anton van Leeuwenhoek in Holland using a single-lens instrument with a magnification of about 300 diameters, remained unequivocal.

Although corpuscular dynamics replaced traditional humors and their qualities in the explanation of human physiology, clinical medicine failed to benefit from the new medical theories. Practitioners treating the sick could not readily apply these views to the therapeutic tasks at hand, preferring instead to prescribe their traditional cures by adhering to obsolete ideas of humoral corruption and displacement. Thomas Sydenham, a prominent English physician, urged his colleagues to ignore the conflicting theoretical views, proposing instead the careful study of individual diseases at the bedside. Sydenham’s goal was the establishment of complete clinical descriptions of particular diseases, their subsequent classification, and the development of specific remedies for each identified ailment.

Eighteenth Century
In the occidental world, the Enlightenment created an optimistic outlook concerning the role and benefits of medicine. Most contemporary thinkers believed that health was a natural state to be attained and preserved. Society had to be made aware of medical possibilities through the employment of professionals who could deal expertly with all health-related problems. Governments increasingly sought to develop social policies that included the physical well-being of the public. A new medical elite took charge and began to play a more prominent role in European society.

Among the requirements of national power perceived by European authorities was a healthy and expanding population. Greater emphasis was placed on environmental health, infant and maternal welfare, military and naval hygiene, as well as mass treatment of the poorer sectors in newly erected hospitals and dispensaries. Absolutist governments established systems of “medical police.” These organizations were responsible for establishing and implementing programs, such as that designed by the German physician Johann P. Frank, to monitor and enforce public and private health regulations from cradle to grave. In Britain, private philanthropy substituted for governmental action in matters of health. Although frequently utopian in its goals, the medical police movement created greater awareness of the social and economic factors conducive to disease. In turn, physicians and reformers were successful in establishing charitable institutions for care of the sick, including mothers and children. Needy ambulatory patients were seen in dispensaries and polyclinics. Although often crowded and a source of contagion, such establishments provided shelter, food, and a modest medical regimen designed to manage illness.

Efforts to control smallpox focused on a practice popular in the Orient: smallpox variolation. The virus, taken from pustules of an active case, was inoculated in healthy individuals on the assumption that this transfer would attenuate the agent and produce only a mild case of the disease in exchange for permanent immunity. In England the procedure was pio-
neered in 1721, but it remained controversial because of its potential for causing full-fledged, often fatal cases of smallpox and thus triggering unexpected epidemics. After the 1760s, however, simplified and safer inoculation methods found popular acceptance, and these were replaced in the 1790s by cowpox vaccination, introduced by Edward Jenner.

On the theoretical front, the eighteenth century became the age of medical systems in the Western world. It was clear that a synthesis of the isolated physical and chemical discoveries of the preceding century into a comprehensive system would be necessary to provide a rationale for and guidance to clinical activities. Spurred by success in the physical sciences, especially Newton's formulation of the laws of gravity, physicians set out to establish principles governing the phenomena of health and disease. Such efforts were as old as medicine itself. However, new models of anatomy and physiology based on Vesalius's dissections and Harvey's experiments, coupled with chemical and microscopic findings, demanded placement into an updated scaffolding.

Most eighteenth-century systematists tended to be prominent academics. As teachers and famous practitioners, they zealously promoted and defended their creations, fueling bitter controversies within the medical profession. System building conferred status and a mantle of intellectual respectability conducive to patient patronage and separation from quacks. Among those who adhered to mechanical theories in explaining clinical events were the Dutch professor Herman Boerhaave of Leyden and the German Friedrich Hoffmann of Halle. By contrast, a colleague of Hoffmann, Georg Stahl, tried to remedy the apparent inadequacies of iatromechanism by postulating the existence of a vital principle, a soul or "anima," capable of harmoniously directing all mechanical activities in the body and thus ensuring organic unity. Two subsequent systems elaborated by the Scottish physicians William Cullen and John Brown assumed that a properly balanced and stimulated nervous system played a pivotal role in the maintenance of human health.

Efforts to classify diseases were intensified. Nosology, the systematic division of disease entities, prospered side by side with similar taxonomic efforts directed at plants and animals. Physicians such as Carl von Linné (Linnaeus), Boissier de Sauvages, and Cullen established complex classification systems designed to bring order to the myriad symptom complexes found at the bedside as well as to provide guidelines for treatment. Unfortunately, these systems remained highly subjective and dependent on the clinical experience of the nosologist who produced them. Greater accuracy and uniformity were achieved as bedside experiences were linked to structural changes observed at postmortem dissections, an approach pioneered by the Italian physician Giovanni B. Morgagni but not fully implemented until decades later in France.

**Nineteenth Century**

**French Clinical School**

Modern Western medicine emerged in France at the Paris Medical School during the first half of the nineteenth century. After the French Revolution, political developments and a new philosophical outlook radically changed the theoretical and institutional bases of medicine. Given the population explosion and urbanization, hospitals became the key locations for medical advances. Housing thousands of poor patients, the Parisian hospitals offered unique opportunities for the observation of a large number of sick individuals.

The French medical revolution was ushered in by an important change in approach. Arguing that it was not necessary to discover the ultimate causes of health and disease, early leaders of the Paris Medical School, such as Pierre J. Cabanis and Philippe Pinel, postulated that physicians could perceive the effects of disease and apprehend the relationships between the disease and the patient, accessible to observation only at the bedside. Thus, only the incontestable truths of sensory perception had validity in any attempt to understand health and disease. These phenomena were too complex and variable to be placed into the straitjacket of a specific medical theory. Stress was to be placed on practical problem solving, with sense impressions providing the only reliable data.

This skeptical empiricism gave rise to a new method: "analysis." Disease was composed of many symptoms and signs, and these confusing combinations appeared sequentially at the sickbed. The most important task was to record the regular order of such manifestations, correlate them with physical signs, and thus recognize simple patterns. Eventually, practitioners would be able to discern specific disease entities and finally classify them. Pinel urged physicians to walk the hospital wards frequently, notebook in hand, recording the hourly and daily progression of illness. The goal was better diagnosis and prognosis based on clinical events.
Emphasis on the physician’s powers of observation increased the importance of physical diagnosis and expanded the techniques employed in eliciting physical signs of illness. Until this time, practitioners had relied almost entirely on their patients’ accounts to reach a diagnosis. Although the clinical history remained important, French physicians began to apply new methods starting with Jean N. Corvisart’s direct percussion in 1808, the employment of a stethoscope by René T. H. Laennec in 1816, and indirect percussion of the body with a plessimeter designed by Pierre A. Piorry in 1826. These procedures were, of course, also based on the premise that certain organs in the patient’s diseased body suffered a number of structural changes.

Thus, another fundamental development of the Paris Medical School was pathological anatomy, the study of localized changes in bodily organs accomplished through systematic postmortem examinations of the thousands of patients who died in hospitals. Correlating clinical symptoms and signs with specific organic lesions enabled practitioners to redefine particular disease entities and understand the underlying structural defects. Such clinicopathological correspondences expanded medicine’s knowledge of diseases, their effects, and natural evolution. As a corollary, French physicians became more interested in improving their diagnostic rather than their therapeutical skills.

Another tool, the “numerical method,” was introduced in 1828 by Pierre C. A. Louis to compare clinical findings and identify through medical statistics general disease characteristics as well as the efficacy of traditional therapies. Although this approach initially raised a storm of protest among practitioners who felt that statistical calculations tended to obscure the significance of individual clinical variations, the method launched a new era of clinical investigation, replacing intuitive and impressionistic decision making at the bedside.

By the mid-nineteenth century, however, the French school lost its undeniable leadership in Western medical practice. Although tremendously fruitful, the clinical approach based on bedside observations and postmortem findings had its limitations. Conscious ignored were questions concerning the causes of disease and the nature of biological events surrounding the phenomena of health and disease. What had been a realistic approach in an era of speculative chemistry and physiology, imperfect microscopes, and nonexistent pharmacological knowledge around 1800 became an anachronism 50 years later. Further answers had to be sought in the laboratory, not just at the sickbed.

**German Scientific Medicine**

Before the eclipse of the Paris Medical School, German medicine began to emerge from its earlier, speculative period, frequently labeled “romantic.” From 1800 to 1825 physicians in the politically divided German states made a serious attempt to establish a “science” of medicine using criteria from the critical philosophy of Immanuel Kant. But their efforts were doomed given the elementary state of knowledge of what we consider to be the “basic” medical sciences: anatomy, physiology, biochemistry, pathology, and pharmacology.

By the 1830s, however, the foundations had been laid for less ambitious but more fruitful investigations into the phenomena of health and disease. The 1834 Prussian-German Customs Union and extensive railroad network brought a measure of economic prosperity to the German states, enabling them to support the reform of their autonomous university system. Armed with an ideology of pure research and lack of concern for immediate practical results, German physicians went to work in academic laboratories and dissecting halls. The emphasis on and prestige accorded to the pursuit of intellectual activities was eagerly supported by the highest authorities, who perceived such scientific enterprises as enhancing national prestige.

Studies in physiology, microscopic anatomy, embryology, as well as comparative and pathological anatomy flourished. One of the key figures promoting these studies was Johannes Mueller, a physiologist searching for the ultimate truths of life behind empirical data. Although his philosophical goals remained elusive, Mueller had trained a whole generation of outstanding German scientists by the time of his death in 1858. They included Theodor Schwann, proponent of the cell theory; Emil DuBois Reymond, and Hermann von Helmholtz, famous for their discoveries in nerve electrophysiology and the physics of vision; Jakob Henle, the founder of histology; and Rudolf Virchow, the founder of cellular pathology. Indeed, these men rejected a general philosophical framework and adopted a purely reductionist viewpoint, attempting to explain all biological phenomena as merely following the laws of physics and chemistry.

Germany’s university system played a central role in the development of scientific medicine in the West after 1840. Unlike the near monopoly of
French academic studies in one city, Paris, there were more than 20 institutions of higher learning scattered throughout the German states, each self-governing and intensely competitive. Since degree requirements included the submission of dissertations based on original research, the stage was set for a spectacular increase in scientific activity once the universities had established prestigious professorships and built adequate laboratory facilities. Medical research became a respectable career, made possible by the proliferation of fellowships and assistantships. Successful individuals were rewarded with academic posts and further facilities, leading to a dramatic rise in scientific professionalization and specialization.

Even in clinical disciplines German academics with proper research experience edged out outstanding practitioners. A whole generation of physicians who had trained abroad — especially in Paris — returned with a knowledge of physical diagnosis and pathological anatomy. A new bedside approach combined the French methods with German chemical and microscopic examinations based on a growing understanding of human physiology and physiopathology. Although the first key step of disease description and identification had taken place in Parisian hospitals, German physician-scientists sought to understand the mechanisms that caused pathological changes. Here the laboratory became important for biochemical analyses, microscopic observations, and animal experiments.

The quest for greater diagnostic precision was aided by the design of new tools for visualizing disease. In 1851, Helmholtz described the ophthalmoscope, an instrument capable of directly exposing eye disorders and testing visual acuity. The successful assembly of a laryngoscope by Johann N. Czermak in 1857 permitted inspection of the throat, especially the larynx and vocal cords. Visualization of the esophagus was accomplished in 1868 by Adolf Kussmaul with an esophagoscope, and the bladder came to be observed with the help of the cystoscope, invented by Max Nitze in 1877. Finally, in 1895, Wilhelm C. Roentgen, a physicist, discovered the rays that carry his name. Henceforth, X-ray photography and fluoroscopes became common features in clinical diagnosis, especially that of chest diseases.

German advances in the basic medical sciences and clinical diagnosis were not matched at the therapeutic level. In fact, a better understanding of disease processes often led to skepticism — even nihilism — regarding possible cures. To be sure, the conceptual advances in understanding disease were impressive and promised further breakthroughs. At the same time, greater technological assistance and diagnostic complexity shifted medical care to hospitals and clinics, significantly raising costs. But the actual practice of medicine remained unaffected. Although the fledgling pharmaceutical industry began to purify a number of traditional remedies and develop a few new drugs, therapeutics lagged. Translating scientific understanding into convincing practical results had to await the development of vaccines, sera, and antisepsis based on a knowledge of bacteriology.

Germ Theory
Since the time of Hippocrates, Western practitioners had blamed factors in the atmosphere for the appearance of infectious disease. A “miasma” composed of malodorous and poisonous particles generated by the decomposition of organic matter was implicated in a broad array of fevers, including plague, malaria, and yellow fever. Speculations about the nature of these miasmatic specks waxed and waned, from Girolamo Fracastoro’s *seminaria*, or “seeds of disease,” in 1546, to microscopic “worms,” or multiplying ferments, *zymes*, proposed by William Farr in 1842. However, physicians remained generally skeptical of theories that implicated microscopic substances in the genesis of complex disease entities. Moreover, their rudimentary microscopes only added to the confusion by revealing myriad objects.

Given the clinical behavior of the most common nineteenth-century diseases such as typhus, cholera, typhoid, and yellow fever, most physicians accepted the notion that they were not directly contagious and could occur only because of specific environmental conditions. This anticontagionist posture was strongly reinforced by political and economic groups that sought to avoid the imposition of costly quarantines. But others argued that certain contagious diseases, such as smallpox, measles, and syphilis, were indeed transmitted by living parasites.

In the 1840s, chemists, including Justus von Liebig, proposed that both contagion and miasma were actually “ferments,” consisting of self-reproducing particles of a chemical nature spontaneously generated during the decomposition of organic matter. At about the same time, Henle, a German anatomist, suggested that such particles were actually alive and behaved like parasites after invading the human organism. He believed that the causes of infectious disease could be found by a careful search for these parasites, believed to be members of the plant kingdom. The proof for this causal relation-
ship between disease and parasites was contained in Henle’s three “postulates”: constant presence of the parasite in the sick, its isolation from foreign admixtures, and reproduction of the particular disease in other animals through the transmission of an isolated parasite.

Thanks to the work of Louis Pasteur, a French chemist, fermentation and putrefaction were shown to be indeed mediated by living microorganisms. In 1857 Pasteur claimed that the yeast responsible for lactic fermentation was such a microorganism. In the early 1860s, Pasteur disposed of the doctrine of spontaneous generation, proving through a series of clever experiments that only by exposure to tainted air would processes of fermentation and putrefaction take place.icrobial life could not exist in any organic medium that had been sterilized and subsequently protected from outside contamination.

With the existence of microscopic germs and some of their actions firmly established, researchers such as Pasteur and the German physician Robert Koch began to study specific diseases. In 1876 Koch published his findings on anthrax, a deadly illness of animals, especially cattle and sheep. He provided the first proof that a specific microorganism could cause a particular disease in an animal. Koch’s new techniques for obtaining pure cultures and staining pathogenic bacteria further advanced the fledgling field of microbiology and led to a reformulation of Henle’s postulates. According to Koch, three criteria were needed to implicate a particular microorganism in the etiology of a certain disease. First, the parasite must be present in every case of the disease and under circumstances that could account for the clinical course and pathological changes of that disease. Second, this agent should not be present in any other disease as a fortuitous and nonpathogenic parasite. Finally, after being fully isolated from the sick organism and repeatedly grown in pure culture, the parasite should be able to induce the same disease if inoculated into another animal.

The last two decades of the nineteenth century witnessed an unprecedented string of bacteriological discoveries based on the Henle–Koch postulates, including the agents responsible for typhoid fever, leprosy, and malaria (1880), tuberculosis (1882), cholera (1883), diphtheria and tetanus (1884), pneumonia (1886), plague and botulism (1894), dysentery (1898), and syphilis (1905). Whereas Koch and his co-workers devoted much time to the development of technical methods for cultivating and studying bacteria, Pasteur and his collaborators turned their efforts toward determining the actual mechanisms of bacterial infection and host resistance. By 1900 not only were physicians able to diagnose the presence of specific microorganisms in the human body and hence diagnose an infectious disease, but they possessed some knowledge concerning natural and acquired immunity. In several instances, the latter could be successfully induced, a belated triumph of modern laboratory medicine.

Guenter B. Risse

Bibliography


Ben David, E. G. J. 1960. Medical productivity and academic organization in 19th century medicine. Scient-


