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PART I

OVERVIEW

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CHAPTER 1

THE MACHINE AT THE BEDSIDE: TECHNOLOGICAL TRANSFORMATIONS OF PRACTICES AND VALUES

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The landscape of modern health care is filled with machines. Its features are marked by their angles and metallic surfaces and enveloped by an atmosphere of mechanical bleeps and clicks, which denote a vital presence at the same time reassuring and distracting.

A technological dominance of health care has developed in the twentieth century, although some of its key ideological and pragmatic goals reach back in time to the Renaissance and the scientific revolution, which transformed the reigning view of medicine that had been shaped by the ancient Greeks.

The Greek physicians, steeped in the learning of the Hippocratic school, saw the natural world as an environment to live with and adapt to, rather than to conquer and dominate. Their theory of illness, the humoral theory, concerned an equilibrium that existed among the four basic constituents of the body (humors), which in turn were connected with environmental elements (physical, social, and personal) that surrounded and interacted with the humors and determined health and illness.

According to this view, illness occurred when one or more of the four humors became excessive or deficient and upset the equilibrium in which they existed. The resulting imbalance produced symptoms related to the particular humoral dysfunction. The idea that disruption of one aspect of this biological system would affect all connecting parts implied that illness involved the whole person, not just a segment of the body. Diagnosis consisted in specifying which of the humors had changed, and this meant making detailed analyses of the environmental factors likely to have produced the dysfunctional humoral state.

Seasons and humors were intimately connected. The season whose climate was closest in quality to a given humor was likely to be responsible for a given humoral imbalance. The humor blood, for example, with qualities of warmth and moistness, was most likely to be affected in the spring, whose climate had these characteristics. The humor phlegm, being cold and moist, was particularly vulnerable to the season marked by these traits, winter (Jones 1923). Accordingly, in this theory, the microcosm of one's biological makeup and the macrocosm of the physical world in which one lived were intimately linked.

Therapeutics were modest, in keeping with the power the Hippocratic Greeks attributed to nature and their recognition of how little they truly knew, or could do, to influence directly the course of events. Physicians viewed their task as assisting the natural powers of recovery by intervening at strategic and critical times in the course of illness. The ability to detect these moments was a central feature of Greek medical learning. To treat with harsh remedies in an attempt to overpower nature, and thereby to disregard the rational limits of one's therapeutic means, was to expose the practitioner to accusations of arrogance and to threaten the social standing of medicine. This approach to illness is epitomized in the Hippocratic essay "The Art" (Jones 1923, vol. 2):

> For if a man demand from an art a power over what does not belong to the art, or from nature a power over what does not belong to nature, his ignorance is more allied to madness than to lack of knowledge. For in cases where we may have the mastery through the means afforded by a natural constitution or by an art, there we may be craftsmen, but nowhere else. Whenever therefore a man suffers from an ill which is too strong for the means at the disposal of medicine, surely he must not expect that it can be overcome by medicine.

This point of view about nature began to be challenged in the sixteenth century. In biology, nature was assaulted first by the scalpel. Until this time, analysis of human anatomy had occurred basically through textual study. Professors read from the books of the learned ancients, usually Galen (A.D. 130–200). When the infrequent dissection of cadavers took place, students were supposed to see in the body what the book said was there. Nature was not interrogated during such lessons. Its form, in this case the body's, was thought to be inscribed in authoritative texts whose truths were accepted on faith. Medievalists did not believe that they could essentially improve on the views of revered, seemingly authoritative ancient geniuses. Although the Hippocratic Greeks had freely acknowledged their ignorance, they were committed to continual explorations of disease, mainly by bedside observation of the response of patients to illness. This spirit of inquiry became dulled in the Middle Ages, when scholars accepted as true what the ancients had written.

The Italian anatomist Andreas Vesalius challenged this medieval perspective. In a work published in 1543, *De corporis humani fabrica*, he demonstrated, by innovative dissection, over 200 errors in the accepted structure of the human body described by Galen. He proclaimed the necessity of studying nature by directly encountering and manipulating it, not by memorizing and memorializing existing texts. His words and actions penetrated and intermingled with the views of other scientists, who began actively to explore the natural world, seeking its truths by directly examining it (O'Malley 1965).

The metaphor of dissection, of separating wholes into parts in order to understand their working, became a central if not the most significant method of exploration as the scientific revolution took hold.

At the turn of the sixteenth century, the newly invented microscope provided a tool for such efforts. An innovative user of this instrument, Robert Hooke, curator of experiments and member of the Royal Society of London, described in 1665 his examination of cork and the discovery of the cellular composition of living matter (Hooke 1665):

> I took a good clear piece of cork, and with a pen-knife sharpened as keen as a razor, I cut a piece off. . . . Examining it very diligently with a *Microscope* . . . I could exceedingly plainly perceive it to be all perforated and porous, much like a honey-comb. . . . [I] found that there were usually about three score of these small cells placed end-ways in the eighteenth part of an inch in length . . . more that a thousand in the length of an inch and therefore in a square inch above a million, or 1166400, and in a cubick inch, about twelve hundred millions, or 1259712000, a thing almost incredible, did not our *Microscope* assure us of it by ocular demonstration.

It was the breaking down of complex matter, or analysis, that was for Isaac Newton the cornerstone of scientific investigation. He wrote in *Opticks*, published in 1687 (Newton 1952):

> As in Mathematics, so in Natural Philosophy, the investigation of difficult things by the Method of Analysis, ought even to precede the method of composition. This analysis consists in making experiments and observations, and in drawing general conclusions from them by instruction, and admitting of no objections against the conclusions, but such as are taken from experiments, or certain truths. For hypotheses are not to be regarded in experimental philosophy. And although the arguing from experiments and observations by induction be no demonstration of general conclusions, yet it is the best way of arguing which the nature of things admits of. . . . By this way of analysis we may proceed from compounds to ingredients, and from motions to the forces producing them; and in general, from effects to their causes.

By this time, the idea was developing that nature was not merely to be lived with; it could be dominated by humans, who learned its secrets by the new experimental and analytic techniques of science.

Along with the ethos of dominance, the analytic, anatomic perspective generated a view of illness that segregated disease and disorder to specific places in the body. This concept replaced the ancient Greek notion of illness as a dynamic process involving place and lifestyle and affecting the whole person. It has become the prevailing concept of the nature of illness, and has influenced greatly the development and adoption of health care technology.

This view received its most comprehensive and influential formulation in the

1761 work of the Italian anatomist J. B. Morgagni, *The Seats and Causes of Diseases Investigated by Anatomy* (Morgagni 1960). This book synthesized concepts of structural changes produced by disease in parts of the body that had developed since the interest in the study of anatomy stirred two centuries before by Vesalius. Morgagni argued, as the title of his book states, that each disease had a seat, or anatomic resting place, in the body. The structural changes created by the disease in this place were unique, like fingerprints, and allowed those who inspected them to determine which sickness had affected the patient in life. They also explained the reason for the symptoms experienced by the patient.

Morgagni argued that these alterations were not merely of interest to the researcher seeking to understand disease processes, but critical for the learning and practice of clinicians. Only by examining changes in the body after death could those who worked at the bedside establish with certainty the veracity of their diagnostic conclusions. Morgagni advocated clinicopathologic correlation as a cornerstone of clinical education and evaluation. The clinicopathologic conference, now ubiquitous in health care, is one legacy of this view.

Anatomists developed a new perspective on Disease: It was a disorder of a bodily structure localized in a site. A small change in a vital part could result in serious damage to an otherwise normal body. Anatomists thus isolated diseases in places, and introduced into the discourse of health care what has become the principal question in the evaluation of patients: Where is the disease?

This concept is fundamentally different from the humoral-physiologic view of illness it replaced: that illness was the disruption of a balance among the basic constituents of the body, as well as with the total environment, and was thus a condition affecting the whole person. With the rise of anatomical thinking, illness became an event that basically affected an aspect of the body.

As the nineteenth century progressed, the acceptance of these views by clinicians paved the way for the modern specialization of health care. The rise of anatomical thinking and specialization are events inextricably bound. Specialization elevates the status of those who develop great knowledge about an aspect of things. Specialization of medical function did not begin with the acceptance of anatomy; it had existed since the earliest days of medicine. Specialists in the first half of the nineteenth century were largely informally trained people – midwives, bone setters, and so on. Those with a formal medical training, who so narrowed their practice, were looked down upon by their colleagues. The sage Philadelphia physician S. Weir Mitchell wrote that such doctors at this time, who practiced as specialists rather than generalists, were thought to be odd and misguided: ''I can remember when older physicians refused to recognize socially a man who devoted himself to the eye alone'' (Mitchell 1892).

But the logical justification for specialism, offered by an anatomically influenced perspective that isolated illness in specific bodily places, and the practical justification for specialism based on a need to create and master technology in order to detect and treat anatomical disruptions, combined to initiate the growth and acceptance of specialization in orthodox medicine during the nineteenth century. At this time the place of technology in practice became established, along with the multiple justifications for its use.

When the nineteenth century began, technology was not a part of diagnosis. In addition, its use in therapeutics was basically confined to the cutting instruments of surgery, a discipline not practiced by most university-trained physicians. This antitechnological bias in medicine can be traced to the thirteenth century, when the medieval universities, which were just beginning, became the locus of formal medical training. Learning their skills alongside theologians and lawyers in graduate faculties of the university, physicians came to accept and adopt the belief of these disciplines that the use of tools and manipulation lowered the esteem and social standing of scholars and physicians. Learning in the university was book learning. In pursuing their activities, scholars could not act like tradesmen, with whom the use of instruments was associated. This prejudice caused surgery to become disconnected from medicine. Surgeons were forced to set up their own schools outside of the framework of the university. Those physicians who lowered themselves to establish manual contact with patients were derisively labeled "body physicians."

This antitechnological, antimanual tradition was one Vesalius had to combat when he launched his campaign urging students and physicians who wanted to learn about the body to engage it actively. He decried physicians who, "despising the use of the hands," delegated to others "those things which had to be done manually for their patients and to stand over them like architects" (O'Malley 1965).

With the acceptance of the importance to research and practice of dissecting the dead body, through the work between the sixteenth and eighteenth centuries of anatomists such as Vesalius and Morgagni, a crucial blow was dealt to the bias against technology and manual contact with patients. Dissection involved both touching patients and using tools for the clearly important purpose of locating and understanding the nature of structural changes caused by disease. In the nineteenth century, the desire to evaluate and treat such structural changes in the living overwhelmed the antitechnological, antimanual bias and transformed medicine.

In diagnosis, techniques were introduced such as percussion of the chest, together with instruments such as the stethoscope, laryngoscope, and ophthalmoscope, which established the first half of the nineteenth century as the age of physical diagnosis. Physicians, using these simple tools, attempted to perceive the living body's interior. Indeed, they became so enraptured by the evidence produced by applying their own senses to the evaluation of illness that they increasingly disregarded the sensations experienced and described by the patient as unreliable, unconfirmable, and inferior by comparison.

The decision to accept manipulation reintegrated the surgical approach to illness into the armory of practice. However, the rise of surgery to its modern status was dependent on two discoveries of the mid-nineteenth century. The first was proof by the dentist William Morton in 1846 that ether could eliminate operative pain. This was followed by the development of a technique to reduce infection by the surgeon Joseph Lister, who introduced sterile operating procedures (antisepsis) in the mid-1860s. These discoveries, and the possibility they carried of greatly improving surgical success, achieved real acceptance only when Robert Koch and others in the 1880s demonstrated the causal role of bacteria in disease. The germs in the air and on the wound that Lister insisted be eliminated were now shown to have a real effect on infection.

The great interest in identifying the nature of the different bacterial agents now implicated in disease causation led to the development of sophisticated instruments for the visual and chemical analysis of body fluids and tissues. Microscopes, incubators, staining agents, colorimeters, and other such devices were gathered together to form the diagnostic laboratory. This institution depended increasingly on technicians with the time and skill to apply the new techniques. Physicians, impressed with the connection of these instruments and techniques to science, and thinking of themselves as practicing scientifically by using them, increasingly turned from the judgments of their own senses and the techniques of physical diagnosis to the impressive data of the laboratory.

This change was in keeping with the original emphasis of the scientific revolution of the seventeenth century. One of its tenets was to place inquiry on an objective basis. In the investigation of nature, it sought to eliminate evidence influenced by human values or bias. It attempted to establish a rigorous set of methodologies to establish facts, such as experimentation, and to describe the facts wherever possible in objective ways, such as through the use of numbers.

Developments in medicine in the second half of the nineteenth century had made possible the statement of medical facts in objective forms. The chemical tests coming out of the diagnostic laboratory often expressed results in numbers. Further, instruments being invented in this period such as the sphygmograph, spirograph, and electrocardiograph made it possible to depict the motions of muscles, nerves, and blood in a graphic format. With such evidence, many physicians hoped that they could now take their place among the men and women of science. As the twentieth century began, the mathematician and philosopher Karl Pearson, in his well-known book *The Grammar of Science* (1900), called on the scientist ''above all things to strive at self-elimination in his judgments, to provide an argument which is as true for each individual mind as for his own.'' He insisted that judging facts ''unbiased by personal feeling is characteristic of what may be termed the scientific frame of mind.'' Doctors strove to establish this image.

The nineteenth century ended with technology firmly linked to diagnosis, and with surgery reunited with medicine, enjoying an enhanced status and forming the vanguard of therapeutics. However, these developments created three crucial problems for the twentieth century: first, how to organize rationally this growing technologic armory; second, how to distribute its goods among the increasing number of patients whom it would benefit; and third, how to construct a fruitful relationship among patients, practitioners, and medical technology.

The first major twentieth-century issue was to organize specialized personnel, technology, and patients to treat illness. The hospitals became the key agents to accomplish this integration and, accordingly, greatly increased in number and significance. Statistics tell the story: In 1875, the number of hospitals in the United States was between 200 and 600. By 1909, there were over 4,000; by 1928, almost 7,000.

The growth of hospitals was accompanied and influenced by medical specialization. The decline of the generalist approach to health care in this century is epitomized in the 1912 comment of William Mayo, a founder of the Rochester, Minnesota, clinic bearing his name: "So vast is the extent of knowledge to be gained of disease that no one man can hope to accomplish more than a small share during his lifetime. The old-time family practitioner has passed away and with him has passed individualism in medicine."

This prediction would soon be realized. By 1930, one physician in four in the United States was a specialist; by 1980, more than four in five. Specialism has been growing not only within medicine but also within other health care disciplines. At the start of the twentieth century, for example, there were about 345,000 health care providers, of whom about one in three were physicians. Most of the others were nurses. But gradually, as the century progressed, the demand for the expeditious performance of specialized tasks introduced into health care a new cadre of people to run the burgeoning technology and to perform new tasks generated by the acquisition of knowledge. In the mid-1960s, this heterogeneous group of individuals became called *allied health personnel*; by the mid-1970s, their number in the United States had reached some 1.8 million. Included within their ranks were 152 different specialists – such as cytotechnologist, health physics technician, dietitian, and rehabilitation therapist. The health care force at this time numbered about 5.1 million people, of whom only 1 in 13 was a physician (National Commission on Allied Health Education 1982). If one now adds the 152 allied health specialties to the 23 major specialties among physicians and the 8 among dentists, and then takes account of the specialties of nursing, optometry, and other health professions, one finds that there exist today over 200 specializations (Wilson and Neuhauser 1980), whose practitioners must somehow focus on the object of this whole enterprise – the patient.

How to marshall the expertise of this array of technology and people to meet the needs of an individual, not only efficiently but also humanely, is a central problem of modern health care. A significant issue in meeting this challenge is an organizational one: What is the best arrangement of personnel and machines? The main response of the twentieth century has been the hospital, which has gradually assumed the major role in Western societies to provide health care. Whereas in the United States, as the century began, the vast majority of births and deaths occurred outside of the hospital, they now occur mostly within its walls. The offices of physicians at the turn of this century, spread throughout cities and towns, are now largely located in or near hospitals. Insurance companies are more likely to pay for therapy programs conducted within rather than outside of hospitals. And not surprisingly, the cost of hospital care now represents the major portion of medical expenditures: In 1981 it was approximately $118 billion, or 41.2 percent of the total.

The hospital thus is a crucial means of integrating and centralizing health services. The hospital is the place in which agents of health care, their technology, and their patients meet; the hospital is the locus of medical care. But the organization of medical services requires something more. It is critical that the hospital provide a means of linking the separate medical interventions of diverse people. This is the function of the medical record.

If the hospital is the geographic locus, the record is the information locus of medical care. In an age of specialization, the record becomes central to organization. How else can the myriad actions the patient experiences daily be evaluated and altered unless an accurate and orderly account of them exists? Hospital records were somewhat randomly kept and unevenly supervised in the United States until reforms were initiated by the newly organized American College of Surgeons in the second decade of this century. This group inaugurated an annual inspection of hospitals and began to publish yearly lists of those that met agreed-upon standards. Certification by the college gradually became a mark of distinction, and failure to gain it a stigma. A significant aspect of its certification review was the state of the medical record. Through the work of the College of Surgeons and that of others, the medical record steadily improved. However, this improvement has been inadequate to meet the burdens it must bear. Its handwritten format, bulkiness, and general disorder, which make it difficult to find and at times to read data, tend to dishearten clinicians and encumber care.

The hospital and its system of integrating staff and medical data replaced a decentralized system of care. Before the twentieth century, medical care took place mainly in the home. Hospitals were for the poor, who could not afford home attendance and maintenance. Technology, which helped the hospital to rise to its present status, now makes possible the reinstitution of home care for many patients. During this century, we have developed increasingly sophisticated forms of communication, which permit detailed monitoring of most body functions at a distance. This capacity began with Alexander Graham Bell's invention in 1876 of the telephone, which linked doctors to patients' homes. It was furthered when Willem Einthoven, inventor of the modern electrocardiograph, developed in 1905 a technique of sending these electric records of heart actions a distance of 1.5 km between his laboratory and the local hospital; he called these transmissions *telecardiograms*.

Today we possess capabilities of transmitting over distance virtually every form of visual representation of illness, such as the interior of the retina, an x-ray film of the chest, and the actions of the heart expressed as numbers and graphs. We can monitor the physiological activities of the body as it changes over time, and transmit the physical examination findings of doctors and nurses