2.1 Science in medicine When, how, and what 33

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ESSENTIALS Science has always been part of Western medicine, although what counts as scientific has changed over the centuries, as have the con- tent of medical knowledge, the tools of medical investigation, and the details of medical treatments. This brief overview develops a his- torical typology of medicine since antiquity. It divides the ‘kinds’ of medicine into five sections: (1) Bedside medicine, developed by the Hippocratic doctors in classical times, has its modern counterpart in primary care. (2) Library medicine, associated with the scholastic mentality of the Middle Ages, still surfaces in the problems of information storage and retrieval in the computer age. (3) Hospital medicine, central to French medicine of the early 19th century, placed the diagnostic and therapeutic functions of the modern hospital centre stage in care and teaching. (4) Social medicine is about prevention, both communal and in- dividual, and is especially visible in our notion of ‘lifestyle’ and its impact on health. (5) Laboratory medicine has its natural home in the research es- tablishment and is a critical site for the creation of medical know- ledge, setting the standards for both medical science and scientific medicine. Introduction At least since the Hippocratic era, Western medicine has always as- pired to be scientific. What has changed is not so much the aspir- ations but what it has meant to be ‘scientific’. ‘Science is the father of knowledge, but opinion breeds ignorance’, opined the Hippocratic treatise The Canon, and Hippocratic practi- tioners developed an approach to health, disease, and its treatment based on systematic observation and cumulative experience. Even the word ‘physic’, whence physician as well as physicist, derives from the Greek for ‘nature’. Further, Hippocratic medicine was experi- mental, that word stemming from the same classical roots which gave us ‘experience’. Words, however, can be slippery, as philosophers as divergent as Francis Bacon and Ludwig Wittgenstein have stressed. The science and experiment of the Hippocratics can still inspire, but they are not our science and experiment. During the past two or three centuries, an armoury of sciences and technologies has come to underpin medical practice. This essay briefly describes these, within the con- text of distinctive and perennial features of medical practice (i.e. suf- fering individuals whose problems and diseases demand attention). A historical typology of Western medicine The history of Western medicine can be divided into five ‘kinds’ of medicine: bedside, library, hospital, social, and laboratory, with the latter extended to include technology (Table 2.1.1). Each approach to medical

care and knowledge emerged at a particular historical period, but each still has relevance to us today. Bedside medicine Bedside medicine can be equated with the vision of the Hippocratics, with its emphasis on the individual patient, a tendency towards holism, and an abiding concern with the patient within his or her own unique environment. These are some of the reasons why Hippocrates (Fig. 2.1.1) is still claimed as the dominant father figure by both orthodox and alternative medical practitioners. Library medicine What can be called ‘library’ medicine dominated in the Middle Ages, when learned medicine retreated into the universities and scholars sometimes assumed that everything worth discovering had been uncovered by the ancients, and everything worth being revealed could be found in the Bible. The millennium between the sacking of Rome and the discovery of the New World is often dismissed as a sterile period scientifically, but the physicians of the period, linguistically erudite and philosophically inclined, would have been surprised to be described as unscientific. They simply believed that the road to knowledge was through the book, and—were they able to—would point out that this so- called sterile period gave us the hospital and university. 2.1 Science in medicine: When, how, and what William F. Bynum

 These medical men also sometimes engaged with nature, although it is undeniable that nature rather than words became an increasing source of truth and knowledge during the Scientific Revolution, a period stretching roughly from just before Andreas Vesalius (1514– 1564) to Isaac Newton (1642–1727). Around 1600, it was becoming apparent to many that the Greeks had not left behind a complete and accurate account of the nature of the world, and that scientific knowledge was cumulative. This ‘Battle of the Books’, the debate over whether the ancients or the moderns knew more, was decided in fa- vour of the moderns. Many of the outstanding scientific achievements of the era were in astronomy and physics, but medicine, both in its theory and its practice, was also affected. Theory has always been easier to change than practice, of course, and it was famously remarked that William Harvey’s discovery of the circulation of the blood had no impact on therapeutics. Harvey (1578–1657) also notori- ously lamented that his practice fell off mightily following the discovery, his patients fearing that he was ‘crack-brained’. The fear that too close an identification with science was detrimental to patient confidence recurs in medical history, and is still part of the delicate negotiations between the profession and its public, and to the status of academic medicine. Within the discipline of medicine itself there have always been individuals—some of them, like Thomas Sydenham (1624–1689), eminently successful—who believed that experimental science had little to offer to patient care. But these ‘artists’ of medicine could still invoke the authority of Hippocrates, with its older connotations of knowledge and experience. Sydenham himself did not demur from his being dubbed ‘the English Hippocrates’. During the early modern period, the whole spectrum of the sciences—mathematics, physics, chemistry, the life sciences (not yet called biology)—made their ways into formulations of health and disease. Iatrophysics, iatromathematics, and iatrochemistry all had their advocates in the 17th and 18th centuries as approaches to medical theory and practice. That these systems tended to encourage speculation to run ahead of evidence was recognized at the time, and this was part of the reason why ‘hospital medicine’ had little recourse to those discip- lines we now call ‘basic medical sciences’. The founders of French hospital medicine, Xavier Bichat (1771–1802), J. N. Corvisart (1755–1821), and R. T. H. Laennec (1781–1826), often referred to chemistry, physiology, and the like as sciences that were ‘accessory’ to medicine. Hospital medicine The medicine that developed in the Paris hospitals, after the re- opening in 1794 of the medical schools closed by the Revolution a couple of years earlier, emphasized above all the study of disease in the sick patient. In a sense, this was Hippocratic medicine writ large, but with some significant

differences. First, the hospital offered the curious doctor a vast arena for observing disease. The equivalent of a lifetime's experience of a lone practitioner in the community could be experienced in a few Fig. 2.1.1 A statue of Hippocrates, originally from Kos Odeion but now in the Archaeological Museum of Kos. This is a late Hellenistic period copy of a classical prototype. No contemporary likeness of Hippocrates exists, but several busts and statues were created later on in the classical period. Copyright © D. A. Warrell. Table 2.1.1 A historical typology of Western medicine CHARACTERISTICS Object of inquiry Form and site of education Goal Example T Y P E S Bedside Whole patient Apprenticeship Therapy Hippocrates (c.460–370 bce) Library Text Scholastic, linguistic, University Preservation, recovery, commentary Constantine the African (d. before 1098) Hospital Patient, organ, lesion Hospital Diagnosis R. T. H. Laennec (1781–1826) Social Population, statistic Community Prevent John Simon (1816–1904) Laboratory Animal model Laboratory Understand Claude Bernard (1813–1878) Technology Molecule Automated laboratory The above + profit Kary Mullis (b. 1944) Adapted from W. F. Bynum, History of Medicine: a very short introduction, OUP, 2008.

2.1 Science in medicine: When, how, and what 35 months of hospital work. Hospitals offered the possibility of defining disease on the basis of hundreds of cases. Secondly, Hippocratic humoralism gradually disappeared as the dominant explanatory framework of health and disease, replaced by the primacy of the lesion, located in the solids: the organs and tissues, and by the mid-19th century, cells. In this new orientation, disease was literally palpable, its lesions to be discovered in life by the systematic use of physical examination—Corvisart rediscovered percussion, Laennec invented the stethoscope—and these findings to be correlated after death by routine autopsy. French high priests of hospital medicine brought diagnosis to a new stage and replaced the older symptom-based nosologies with a more objective, demon- strable one of lesions. The third feature of hospital medicine was what Pierre Louis (1787–1872) called the numerical method, the use of numbers to guide both disease classification and therapeutic evaluation. The philosophy underlying early 19th-century French medicine was most systematically expounded by one of the many American students who studied in Paris, Elisha Bartlett, in his Philosophy of Medical Science (1844). The medical science whose philosophy he chronicled was one of facts. Bartlett argued that all systems of medicine, past and present, were speculative, vague, and useless. Cullen, Brown, Broussais, and Hahnemann were all consigned to the historical dustbin. The new medicine was one of systematic observation and collection of facts, which, when properly com- pared and organized, could provide an objective understanding of disease and a rational basis for its treatment. Bartlett's philosophy was essentially undiluted Baconian inductivism applied to medi- cine. Unsurprisingly, he counted Hippocrates as well as Pierre Louis among his heroes. One consequence of the lesion-based medicine was the recogni- tion that not much of what doctors did actually altered the natural history of disease. Therapeutic scepticism, or even nihilism, flour- ished among doctors whose lives were spent, as Laennec put it, 'among the dead and dying'. It was less likely to be expressed among doctors concerned with earning a living treating private, paying pa- tients, but the concern with medicine's therapeutic impotency also fuelled the movement to prevent disease. Social medicine The fourth kind of medicine, social, also flourished in the 19th cen- tury. Just as hospitals existed long before 'hospital medicine', so epi- demics and preventive measures were not invented by the public health movement of the 1830s. Nevertheless, the preventive infra-structures developed partly in response to the cholera pandemics still exist, although of course much changed. The chief architect of the British public health movement, Edwin Chadwick (1800–1890), was a lawyer who thought that, on the whole, doctors were overrated (he was neither

the first nor the last lawyer to hold that opinion). He held that filth spread via the foul smells (miasma) of rotting organic matter caused epidemic dis- eases. His solutions were engineering ones—clean water and effi- cient waste disposal—which he argued would leave the world an altogether more pleasant and healthier place. His ideas were formed during the 1830s and early 1840s, and they remained more or less fixed for the rest of his long life, which extended well into the bac- teriological age. Nevertheless, Chadwick also invoked science in his public health reform programme, above all the science of statistical investigation. His use of statistics can easily be shown to have been naive, but it was ardent. In his own sphere of enquiry, Chadwick was as much in awe of the unadorned 'fact' as was his contemporary Bartlett. A later generation of Medical Officers of Health and others concerned with disease prevention (or containment) would develop new investigative techniques, more sophisticated statistics and, es- pecially, new theories of disease causation and transmission. But the early public health movement was firmly based on the science of its time. Laboratory medicine The final locus of medicine, the laboratory, was also largely a product of the 19th century, though of course laboratories (a place where one worked, especially to mutate lead into gold) had existed for much longer. A leading exponent of the laboratory, and one of its most thoughtful philosophers, had experienced Paris hospital medicine as a medical student. Claude Bernard's Introduction to the Study of Experimental Medicine (1865) is at once an intriguing account of his own brilliant career and a sophisticated analysis of the philosophy of experimentation within the life sciences (Fig. 2.1.2). Hospitals, he argued, are merely the gateways to medical knowledge, and bed- side clinicians can be no more than natural historians of disease. To understand the causes and mechanisms of disease, it is necessary to go into the sanctuary of the laboratory, where experimental con- ditions can be better controlled. There are in nature no uncaused causes: determinism is the iron law of the universe, extending equally to living systems and inorganic ones. However, organ- isms present special experimental problems, and it is only through isolating particular features, and holding other parameters as con- stant as possible, that reliability and reproducibility can be achieved. Bernard identified three primary branches of experimental medi- cine: physiology, pathology, and therapeutics. His own research programme touched all three pillars: his research on the roles of the liver and pancreas in sugar metabolism contributed to under- standing normal physiology as well as diseases such as diabetes; his investigations of the sites of action of agents such as curare and carbon monoxide foreshadowed structural pharmacology and drug receptor theory; his work on the functions of the sympathetic nerves buttressed his own more general notion of the constancy of milieu interieur as the precondition to vital action (and freedom), a pre- cursor of Walter Cannon's concept of homeostasis. Bernard stands supreme as the quintessential advocate of the laboratory. Who was the first modern medical experimentalist? When Bernard wrote, experimental medical science was still a fledgling activity, best developed in the universities of the German states and principalities. The German university ideal of medical education was to be extolled by the American educational re- former Abraham Flexner (1866–1959) in the early 20th century. It was in the reformed and newly created German universities that the forms of modern scientific research were established. Research careers were created; copublication in specialist journals became common; scientific societies flourished. The microscope became the symbol of the medical scientist even as the stethoscope was becoming the hallmark of the forward-looking clinician. In the

 hands of scientists like Schwann, Virchow, and Weismann, the modern cell theory was developed and applied to medicine and biology more generally. These researchers established the drive to push units of analysis further and further. Eduard Buchner's

identification of cell-free ferments in 1897 firmly established the importance of subcellular functions. Pasteur, Koch, Ehrlich, von Behring, and others advanced new notions of the causes of disease, the body's response to infection, and the possibilities of new drugs to combat disease. Any of these scientists might arguably be the answer to the parlour-game question: Who was the first modern medical scientist? The German-speaking lands perfected the modern forms of sci- entific research, but a good case can be made for a Frenchman to be crowned the first thoroughly modern experimentalist within medicine. François Magendie (1783–1855) (Fig. 2.1.3) was a child of the Enlightenment and product of the French Revolution. One of several eminent individuals (Thomas Malthus was another) raised according to the anarchic principles espoused by Jean- Jacques Rousseau, Magendie did not learn to read or write until he was 10. His subsequent precocity was such that he was ready for medical studies by the age of 16, learned anatomy and surgery as an apprentice, and made his way through the Paris hospital system. Although he never lost interest in practical medical issues, his reputation was established primarily within the laboratory. Fig. 2.1.2 Claude Bernard and his pupils. Oil painting, 1889 by Léon Augustin Lhermitte. Courtesy of the Wellcome Collection, Creative Commons Attribution (CC BY 4.0). Fig. 2.1.3 François Magendie. Lithograph by N. E. Maurin. From Burgess R (1973). Portraits of doctors and scientists in the Wellcome Institute, London, no. 1870.2, by courtesy of the Wellcome Library, London.

 His monographs on physiology and pharmacology marked new beginnings, and his life manifests three emblematic qualities which make him one of us. First, he valued facts above theories, evidence above rhetoric. However, he went beyond Bartlett and the high priests of hospital medicine in insisting that in experiment, and not simply observa- tion, lay the real future of medical knowledge. Like his pupil Claude Bernard, Magendie was a deft experimentalist. He used animals (and occasionally patients) to probe into a whole range of prob- lems in physiology, pathology, and pharmacology: the functions of the spinal nerves, the physiology of vomiting, important facets of absorption, digestion, circulation, nutrition, and the actions of drugs and poisons. He described anaphylaxis a century before it was named. He was as philosophically naive as Bernard was sophisti- cated: of course he had theories, but his image of himself as a rag- picker with a spiked stick, gathering isolated experimental facts where he found them, is a telling one. Secondly, he was modern in sometimes backing the wrong horses. He judged cholera and yellow fever to be noncontagious, was suspi- cious of anaesthesia, and sometimes claimed more than we might for his newly introduced therapeutic substances, such as strychnine and veratrine. Magendie could often be mistaken in his beliefs; so can we. Thirdly, Magendie was the scientist who first expunged the double-faced Janus from the medical mentality. William Harvey worshipped Aristotle, Albrecht von Haller was steeped in his- tory, and Isaac Newton popularized the pious conceit of pygmies standing on the shoulders of giants. Until the 19th century, doc- tors routinely looked to the past, not simply for inspiration but for useful information. Magendie looked only in one direction: the future. He had no sense of history and no use for it. He meant what he said when he insisted that most physiological 'facts' had to be verified by new experiments, and he undertook to provide a beginning. He made the laboratory the bedrock of medicine. With Magendie, the history of medicine became an antiquarian discipline. What happened next? Like everyone, Magendie was of his time. Nevertheless, his values were symptomatic of important themes within 19th-century medi- cine and medical science. By the beginning of the First World War, most of the structures and the fundamental concepts of modern medicine were in place. Of course, both medical science and med- ical practice have been utterly transformed since. But the impulse of experimentation and its variable translation into practice

were there. We have gone far beyond the cell in our analytical procedures, and our medical, surgical, and therapeutic armamentaria are vastly more sophisticated and powerful.
Technological medicine Our medicine is fundamentally different in one important respect, even if the trend was already evident in the 19th century: the fusion of science and technology. Science and technology have become so intertwined that the older distinctions between them are blurred. Technology made a real but minimal impact on 19th-century medicine. Some instruments, such as Helmholtz's ophthalmoscope, came into clinical medicine through the labora- tory; and German experimental scientists were eager to exploit the latest equipment such as kymographs, sphygmographs, and the profusion of artefacts (Petri dishes, autoclaves, and so on), which Koch and his colleagues devised for the bacteriological laboratory. Most important of all was probably X-rays, discovered by Roentgen in late 1895. This made an immediate impact on med- ical diagnosis, and the associated science of radioactivity soon was felt within therapeutics (Fig. 2.1.4). Significantly, perhaps, the pi- oneers of the radioactive phenomena—Roentgen, Becquerel, the Curies—got their Nobel Prizes in physics or chemistry. Hounsfield and Cormack got theirs for computer-assisted tomography in medicine or physiology. More recently, Kary Mullis's Nobel Prize was for a technological development within molecular biology. Both medical science and medical practice are now inseparably rooted in technology. So is modern life, another reflection of a per- ennial historical truth: medical knowledge and medical practice are products of wider social forces with unique historical individualities. Fig. 2.1.4 Photograph of a radiograph (x-ray negative) taken on
22 December 1895 by Wilhelm Röntgen, the discover of x-rays. It shows his wife's left hand; she wears a large ring on her 4th digit. Courtesy of the Science Museum, London, Creative Commons Attribution
(CC BY 4.0).

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