Medical Thermometry—A Short History

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> *The instrument trains . . . it exacts accuracy and teaches care; it creates a wholesome appetite for precision, which, at last, becomes habitual.*
>
> SILAS WEIR MITCHELL, 1891

In their attempt to pinpoint the exact nature of disease, doctors throughout the ages have looked for idiopathic signs from which they might learn. Among those signs, fever has always held a central place.

Before the invention of the thermometer, physicians used three principal methods for ascertaining temperature: the patient's appearance, the patient's own perception of body heat and the use of the "educated hand" to determine the febrile state of the body. Of these methods the physician's hand remained the standard medical means for estimating temperature. In hand thermometry, doctors were taught to use several fingers or the whole hand, depending on the surface to be examined. The hand was not simply placed on the skin surface but

> remain[ed] hovering a while above or near, to perceive the heat exhaled therefrom; then enter[ed] upon a slight contact with this surface to receive the impression of its most superficial temperature; then by a firmer pressure receive[d] the full impression of the skin's temperature; then by gradually deeper pressures acquire[d] the impressions of the deeper seated combustions.

Each of these pressures with their varying impressions of heat was assessed separately in the artful science of medicine.[1(p255)]

Early History

Since the early Greeks, if not before, physicians identified preternatural heat as a disease entity in itself; only later did heat become a pathognomonic symptom of disease. Hippocrates had noted temperature as it affected different parts of the body and had insisted that physicians recognize its signs and use agents to elevate the temperature when depressed and lower it when raised. Subsequent physicians had also noticed its effect on the body in disease. Galen (131-201 AD), the founder of experimental physiology, described fever as preternatural heat, or *calor praeternaturam.* Few found fault with this description although some preferred to use terms such as "hot skin," "tissue change," "quick pulse," "turbid urine" and "continuous fever" to further delineate fever as heat. Although heat and cold played a significant role in the humoral theory of disease, ironically, aside from the simple recognition of the two separate states, little effort was made to measure either.[2,3]

Within a decade of the astronomer Galileo's invention of the open thermometer or thermoscope sometime between 1593 and 1597, efforts were undertaken to develop an instrument that measured the difference between normal and abnormal temperatures in the human body. Sanctorius of Justipolitanus (1561-1636), a forerunner of the iatromechanical school and professor of medicine at Padua from 1611 to 1624, took a keen interest in air and body temperatures and as early as 1612 had constructed a crude thermometer for use in disease. Patients either grasped the bulb of the thermometer and breathed into a hood or took the bulb by mouth. In his *Ars de Statica Medicina* (1614) and later in his *Commentaria in primam fen primi libri Canonis Avicennae* (1625), Sanctorius noted that both body heat and body weight affected the constitution.[4,5] Besides a thermometric instrument that measured the variations in temperature of the human body, Sanctorius also devised several medical instruments, including a pulsilogium, or pulse-clock, and a trocar.[6(p24)]

Following the invention of the mercury thermometer by Gabriel Fahrenheit in 1714, Hermann Boerhaave (1668-1738) and his pupils Gerhard van Swieten (1700-1772) and Anton de Haen (1704-1776) noted the instrument's potential usefulness in medicine. The thermometric scale of Anders Celsius, commonly known as the centigrade scale (1742), was in general use in France and Germany, whereas the Fahrenheit scale (1714) remained popular in England and the United States for both meteorologic and medical purposes. A third scale, developed by Reaumur, was used over large portions of eastern and southeastern Europe. While Boerhaave gave only passing reference to the thermometer, van Swieten, professor of medicine at the University of Vienna, recommended that fever should be measured with a thermometer rather than perceived by hand. Van Swieten recommended the mercurial thermometer and applied it to both the mouth and axilla following the technique used by Fahrenheit. In his *Commentaries Upon the Aphorisms of Dr Hermann Boerhaave* (1744), van Swieten remarked:

> When such a thermometer, first used on a healthy man, and marked accordingly on the scale, is either held in the hand of a fever patient, or the bulb placed in his mouth, or laid on his bare chest, or in his axillae . . . the ascent

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of the mercury to different elevations will show how far the fever heat exceeds the natural and healthy.[7(p26)]

Anton de Haen, a clinical teacher of medicine at the Vienna Hospital, was fully convinced of the thermometer's usefulness and drilled students in the importance of body temperature in fever disorders. He made his point at bedsides, teaching that the only safe way to determine fever lay in the use of the thermometer. No longer would a physician's touch or the patient's perception be adequate, especially when the shivering patient complained of extreme coolness while, in fact, registering a temperature three or four degrees above normal. De Haen's thermometric studies, scattered through the 15 volumes of his *Ratio Medendi* (1757-1773), noted the temperature of healthy as well as diseased persons, the increase in temperature in the aged, diurnal fluctuations, the discrepancies between pulse and temperature in certain diseases, the differences between actual temperature and a patient's perception, the changes in temperature as a sign of convalescence and the relation of heat and the action of certain drugs.[8] De Haen's observations were buried in his immense treatise, and little noted.

Several 18th-century English contemporaries of de Haen, most notably Sir Charles Blagden (1748-1820), John Fordyce, Sir Joseph Banks and Solander, carried out experiments on animal temperatures that were subsequently published in 1775 in *Philosophical Transactions*. Placing themselves in heated chambers, they were able to establish that animal heat is independent of external temperature.[9,10] Also exemplary of the early fascination with the distinction between animal heat and external temperature was Governor Henry Ellis of Georgia, a naturalist who noted that "a thermometer standing at the end of my nose would often stand at 105 degrees, while in close contact with my body I would never get it above 98 degrees."[2(p433)] Then, too, Ben Franklin had observed about 1750 that although the outside temperature was 100°F, his own body remained at 96°F, proving to his satisfaction that warm-blooded animals had the ability to maintain a fixed temperature regardless of the climate or season.[11,12]

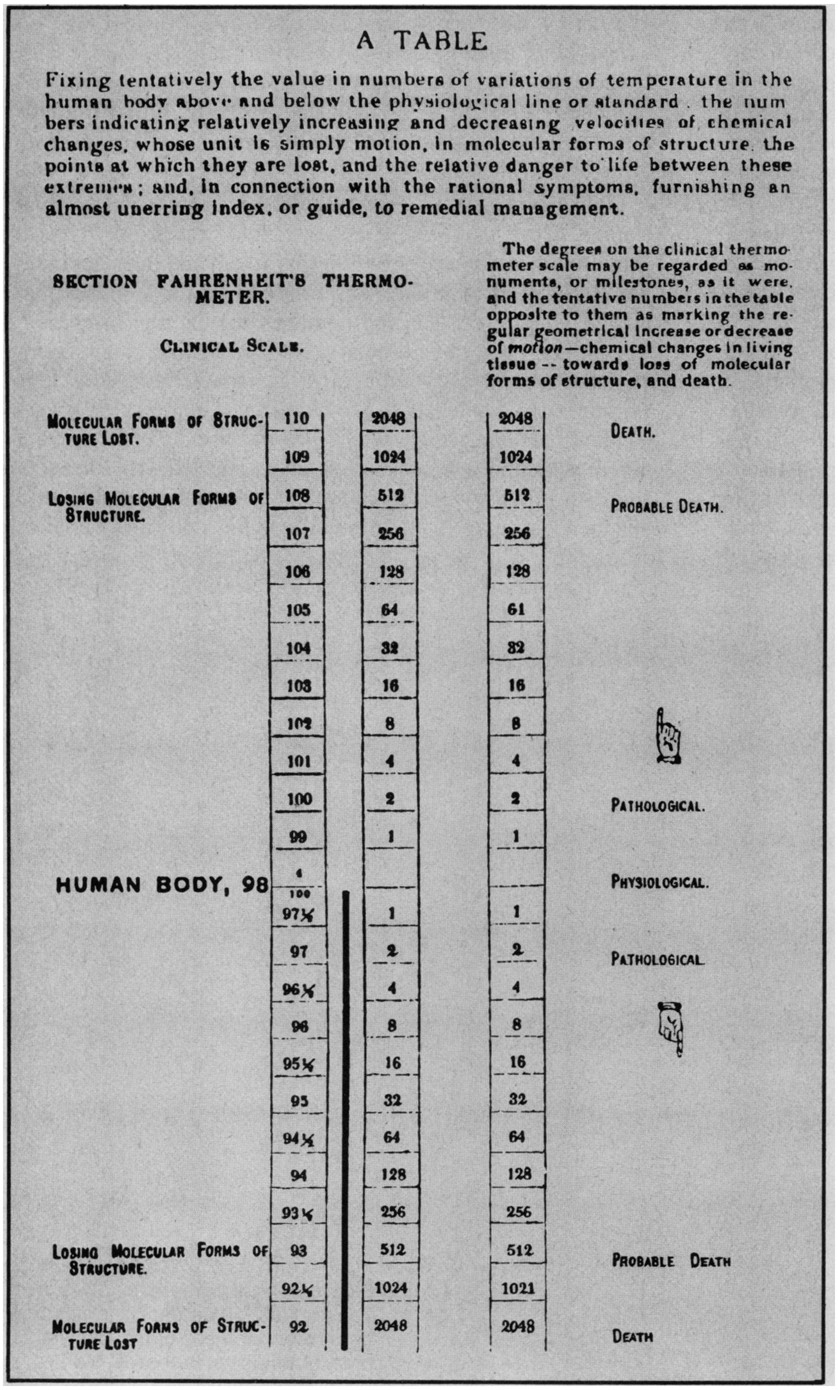
The most accurate 18th-century observations of healthy people and animals were found in the published works of George Martine (1702-1741), a graduate of Edinburgh and Leiden and a member of the mechanical school, who theorized that animal heat resulted from the velocity of the blood moving through the vessels.[13,14] His *Essays Medical and Philosophical* (1740)[13] spurred the subsequent work of Macard in 1741[15] and the experiments of Georg Pickel (1751-1838) in 1778.[16] Observations by George Cleghorn (1716-1789) in 1768[17] and John Lining (1708-1760) in 1748[18] on temperature among victims of malarial fever, of Charles Blagden in 1775,[12] of John Hunter (1728-1793) in 1793[19] and of James Currie in 1797 indicated a steady, albeit limited, interest in the temperature of healthy persons and the changes brought on by disease.

John Hunter in his *Observations on Certain Parts of the Animal Economy* (1792)[20] believed that heat arose from "a principle so connected with life that it can and does act independently of circulation, sensation and volition, and is that power which preserves and regulates the internal machine." The surgeon and physiologist added to existing data on temperature when he argued against Martine's theory that temperature was produced by the blood's circulation. "It is very evident," Hunter countered, "that warmth depends on a different principle, which is intimately connected with life itself, and is a power which maintains and regulates the machine, independent alike of the circulation, the will, and of sensation."[19(p338)]

Figure 1.—Lithography by Jules Abel Faivre (1867-1945) depicting use of a barometer (courtesy of the National Library of Medicine, Bethesda, Md).

Concurrent with the speculations of physicians were the chemical explanations of Antoine-Laurent Lavoisier and Pierre-Simon Laplace who in 1780 attributed animal heat to the combustion of oxygen with hydrogen and carbon during respiration.[21] Their views, however, were not received warmly by the medical profession. Sir Benjamin Brodie (1783-1862) of St George's Hospital, for example, reported in 1812 that, as a result of experiments carried out on the spinal column of animals, he had determined the source of animal heat to be the nervous system.[22,23] Brodie's theory and the earlier observation by de Haen on the brief rise in temperature after death caused the views of Lavoisier and Laplace to remain outside the mainstream of medical thinking until the later works of George von Liebig (1827-1903), Jules Robert von Mayer (1814-1878), Hermann von Helmholtz (1821-1894) and James P. Joule (1818-1889) finally carried the day.[24-27] Only after the experiments of Rudolph Virchow (1821-1902) and Claude Bernard (1813-1878) was the role of the nervous system in the production of fever defined.[28,29]

In the meantime, James Currie (1756-1805) built on the earlier observations of Martine by testing the effects of warm and cold baths, digitalis, opium, alcohol and diet on body temperature in typhoid fever. Known as the father of hydrotherapy, he advocated cold effusions in treating fevers but cautioned that they be used only when the heat of the body was elevated considerably above the natural body temperature.



A TABLE

Fixing tentatively the value in numbers of variations of temperature in the human body above and below the physiological line or standard . the numbers indicating relatively increasing and decreasing velocities of chemical changes, whose unit is simply motion, in molecular forms of structure. the points at which they are lost, and the relative danger to life between these extremes; and, in connection with the rational symptoms, furnishing an almost unerring index, or guide, to remedial management.

SECTION FAHRENHEIT'S THERMOMETER.

CLINICAL SCALE.

The degrees on the clinical thermometer scale may be regarded as monuments, or milestones, as it were, and the tentative numbers in the table opposite to them as marking the regular geometrical increase or decrease of *motion*—chemical changes in living tissue -- towards loss of molecular forms of structure, and death.

MOLECULAR FORMS OF STRUCTURE LOST.	110	2048	2048	DEATH.
	109	1024	1024	
LOSING MOLECULAR FORMS OF STRUCTURE.	108	512	512	PROBABLE DEATH.
	107	256	256	
	106	128	128	
	105	64	61	
	104	32	82	
	103	16	16	
	102	8	8	
	101	4	4	
	100	2	2	PATHOLOGICAL.
	99	1	1	
HUMAN BODY, 98	4/100			PHYSIOLOGICAL.
	97½	1	1	
	97	2	2	PATHOLOGICAL
	96½	4	4	
	96	8	8	
	95½	16	16	
	95	32	32	
	94½	64	64	
	94	128	128	
	93½	256	256	
LOSING MOLECULAR FORMS OF STRUCTURE.	93	512	512	PROBABLE DEATH
	92½	1024	1021	
MOLECULAR FORMS OF STRUCTURE LOST	92	2048	2048	DEATH

Figure 2.—An 1872 table of the Fahrenheit scale (from McElroy[43]; courtesy of California State University, Long Beach).

"In taking the heat of the patient," Currie wrote, "I have generally used a small mercurial thermometer of great sensibility, with movable scales . . . and I have introduced the bulb under the tongue, with the lips closed, or under the axilla, indifferently. . . ."[30(pp35-36)-32]

The early years of clinical thermometry suffered from the lack of accurate instruments (Figure 1). Temperatures as high as 118°F were recorded in the 19th century—records that were not especially rare. According to one physician, a patient who had fallen from a horse registered a temperature of 110°F for several consecutive days, attaining on one occasion 122°F![33] However, the availability of more accurate instruments led to the work of Antoine Cesar Becquerel and Gilbert Breschet who, in 1835, established the mean temperature of a healthy adult at 37°C or 98.6°F.[1(p2),34]

By 1840 investigations had begun in earnest on the temperature of the body in both health and disease. No longer were experiments viewed in isolation; indeed, they became clinically important. Thermometric observations were prominently recorded in medical articles and comparisons were made with temperatures taken at various periods of the day and with previous variations noted in the same disease among other persons. Exemplary of these efforts were the investigations of Gabriel Andral (1797-1876),[35,36] August Gierse,[37] Edward Hallman (1813-1855),[38] Henri Roger (1809-1891)[39] and Jean-Nicolas Demarquay (1814-1875).[12,40]

Although thermometric investigations had provided a wealth of information on temperature in health and disease, there were as yet no laws derived from those studies that clearly justified to general practitioners the practical application of the thermometer. To be sure, the elevation of temperature had been noted in disease but formulations of any fixed rules regarding specific diseases were still to come. What prevented these early observations from becoming guiding medical principles were the still-little-understood laws of heat and the realization that the human body was at one in its movements with the forces outside it. These impediments were put aside in 1842 to 1845 when surgeon Robert Mayer laid down the essential work for the unity and correlation of forces in physiologic processes. Mayer's findings were followed by the investigations of Hermann von Helmholtz, James P. Joule of Manchester and Gustave A. Hirn (1815-1890) of Colmar, whose theories of heat production made body temperature as a convertible force subject to set laws more understandable. Following their efforts, physicians found it easier to translate the findings of the thermometer to both physiologic and pathologic processes.[41(p8),42]

By the mid-1860s, use of the clinical thermometer had led to certain conclusions. For one thing, doctors recognized the importance of body temperature and the physiologic significance of its variations (Figure 2). Body heat was admitted to result from chemical transformations occurring in the normal waste and repair of the body tissues; the temperature produced by this action was recognized as uniform—rarely varying from one person to another. In *Physiological Researches*, published in 1863, John Davy (1790-1868) had determined that variations occurred as a result of exercise, the ingestion of food or drink, external temperature and from the greater activity of the bodily processes in infants and children.[44,45] By the 1860s, too, physicians had concluded that the temperature was a better clinical guide than the pulse because it was not easily affected by nervous debility or excitement.[46,47]

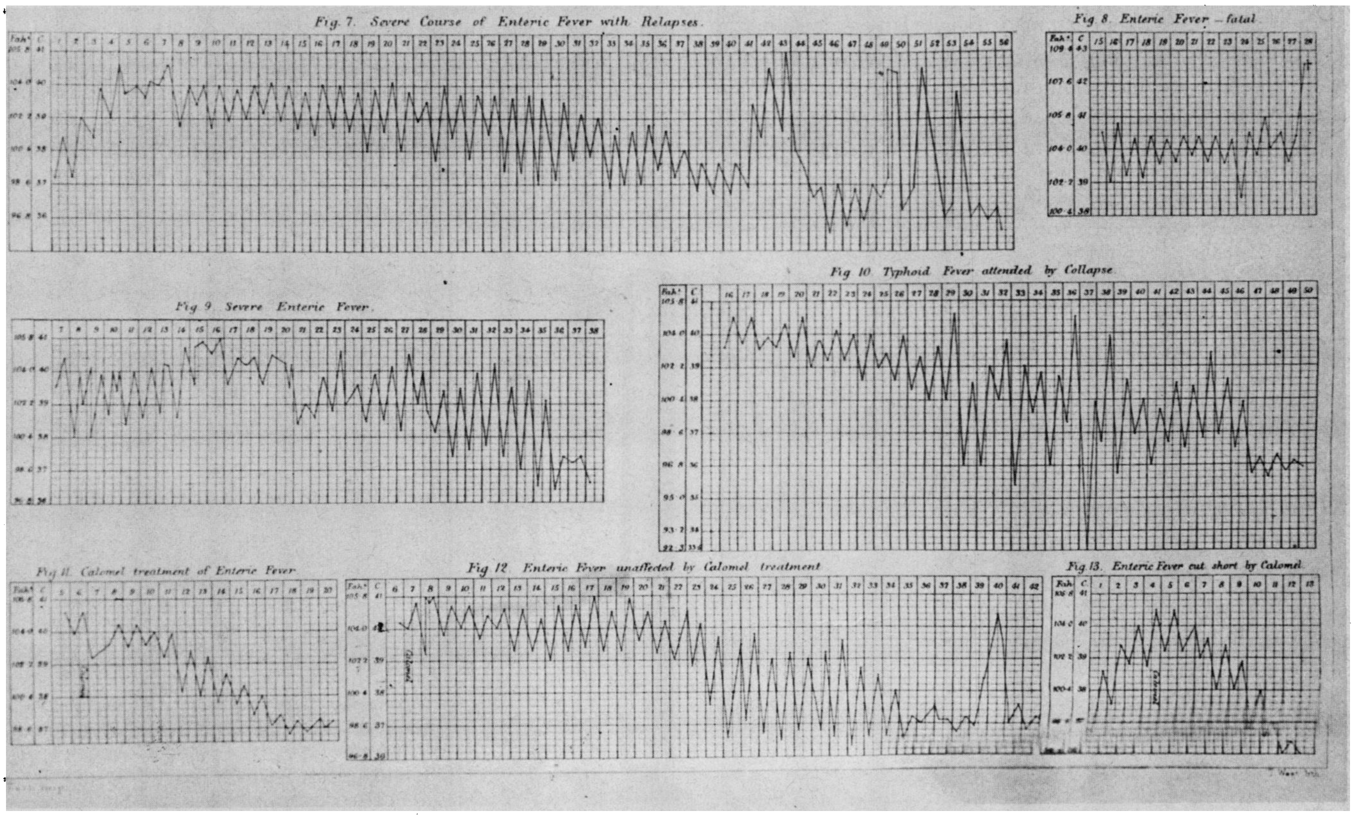


Figure 3.—Temperature charts (from Wunderlich[41]; courtesy of California State University, Long Beach).

Carl Wunderlich

By the second half of the 19th century, noted physicians and surgeons had begun to show more than casual interest in thermometry. Although significant studies had been published by Claude Bernard in France, by John Davy, Daniel Blair[48] and Sidney Ringer (1835-1910) in England[49] and by Barensprung[50] and Ludwig Traube (1818-1876) in Germany,[51] the first truly classical study of the thermometer in clinical practice came with the publication in 1868 of Wunderlich's *Das Verhalten der Eigenwärme in Krankheiten.* The first English edition of this work was published in 1871.[41] Carl Reinhold Wunderlich (1815-1877) of Wurttemberg had first introduced the use of the thermometer in his clinic in 1851 at the recommendation of Traube, whose work on the antipyretic effects of digitalis on body temperature Wunderlich found beneficial. Over a period of 15 years and with an increased appreciation for the value of the thermometer in clinical medicine, Wunderlich noted that there were "no patients in my hospital wards whose temperature has not been taken; and, although at first this was only done twice a day, for the last ten years from four to six daily observations have been made in cases of fever, and in special cases even more frequently."[41(pp38-39)] After obtaining nearly 100,000 observations, Wunderlich discerned certain traits which, when charted, showed that disease obeyed fixed laws that could be shown by the course of the temperature (Figure 3). In all, Wunderlich estimated having taken several million observations of some 25,000 specific cases.

The care with which Wunderlich had accumulated his statistics and the careful tabulation of his results convinced the medical profession of the importance of accurate knowledge of temperature in clinical diagnosis, prognosis and the treatment of disease. Wunderlich made the decisive determination for pathology—that there was constancy of temperature in a healthy person and variation of temperature in disease. What followed from these two ascertainable facts were some 40 principles that he derived from his experiments and observations.[41(pp1-18)]

From his studies Wunderlich was able to trace the natural history of specific diseases and establish the unquestioned foundation of thermometric change and the distinguishing features of typhoid fever. Soon, observations of temperature during pregnancy, delivery and the postpartum period and in various internal diseases became widely acknowledged. And after Theodor Billroth's proofs in 1868 of the importance of temperature in the diagnosis of surgical diseases, the thermometer was seldom out of sight of surgeons.[52,53] "A physician who carried on his profession without employing the thermometer," concluded Wunderlich, "was like a blind man endeavouring to distinguish colours by feeling."[54(p451)]

Medical Response to Clinical Thermometry

Wunderlich's findings received enthusiastic support throughout Europe and America. Indeed, many of the early studies that had taken place were not justified in the light of the principles laid down by Wunderlich and his followers. From Jean-Martin Charcot (1825-1893)[55] and Sigismond Jaccund (1830-1913) in France,[56] to Sidney Ringer and William Aitken in England,[57,58] to John C. Draper (1835-1885),[59,60] Bennet Dowler (1797-1879)[61] and Edward Seguin in America, medical thermometry assumed an intelligent application that firmly established its practical value in medicine. Use of the thermometer facilitated the clinical recognition of disease, aided practitioners in arriving at certain and safe conclusions regarding the nature of disease, allowed physicians to understand the natural history of diseases in which fever was present and provided an accurate means for monitoring various therapeutic regimens.

The earliest thermometers used in the British Isles were imported from Leipzig by Griffin. The first instruments manufactured in England were those of instrument maker Louis P. Casella, under the direction of William Aitken of the Royal Victoria Hospital. For general practice, however, the curved nonregistering thermometer by Casella was considered too cumbersome (Figure 4). As one physician at Guy's Hospital recalled, "I think it was nearly a foot long and was so great a novelty that it was taken to a southeastern meeting of the

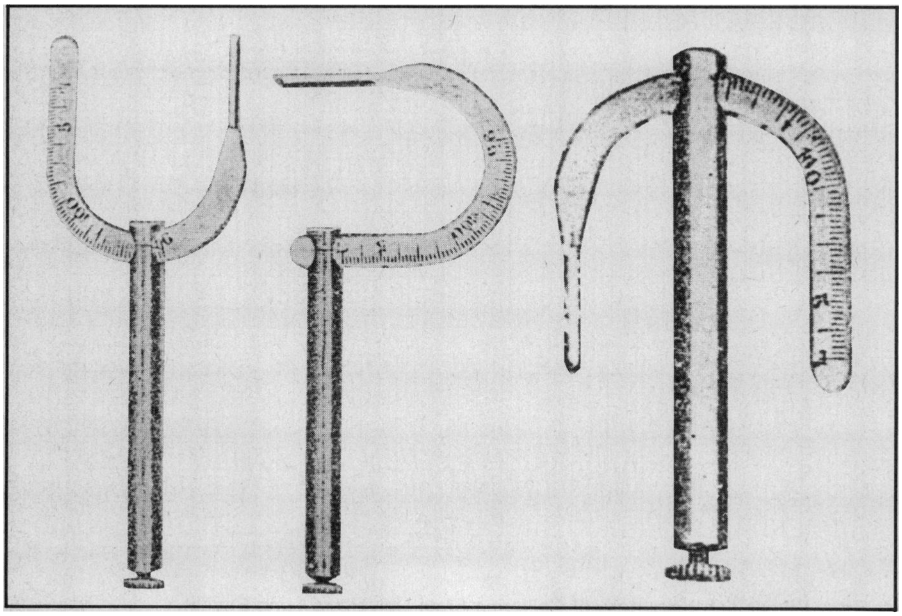


Figure 4.—Curved thermometers designed for insertion under patient's tongue; made for T. Wilson Parry by Francis Cooper of Tottenham Lane, Hornsey (from Br Med J 1912; 1:1137; courtesy of California State University, Long Beach).

British Medical Association for exhibition, where the members regarded it with much curiosity and interest, although, I am sorry to say, one or two with ridicule."[11]

Having recognized the need for a more portable instrument, T. Clifford Allbutt asked Casella to make a pocket thermometer. When Casella showed no interest in the undertaking, Allbutt then worked with Harvey and Reynolds of Leeds to manufacture an accurate thermometer that could be carried in a safe and portable case. With the size of the instrument reduced, clinical thermometry became a regular part of medical practice and firms such as Harvey and Reynolds and Hawksley of London supplied registering thermometers that were easily portable.[2(p437),62]

The special laws of thermopathology required that thermometers be designed specifically for physicians and correlated with the variations in physiologic functions. This in turn implied a need for thermometers that were adaptable to the body cavities—whether the axilla or groin, mouth, rectum, urethra, vagina or hand. By the 1860s, the axilla had become the most universally adopted, convenient and reliable point of application. Recognition of the mouth as a source of disease transmittal acted as a restraint on its use for thermometic measurement. "I have seen the thermometer used when the amount of mucus accumulated on it was so great as to make it almost difficult to see the register," commented one physician in 1891.[63] He noted that most practitioners simply wiped the instrument with a handkerchief, towel or even bedclothing, thereby preserving the germs "to be conveyed to the next unfortunate, who may be the first patient called upon." Not until doctors recognized the importance of alcohol, bichloride of mercury, hydrogen peroxide, potassium permanganate and other germicidal agents in the late 1890s did oral thermometry begin to replace the axilla as the most popular point of application.[63-65]

One of the early problems the manufacturers of clinical thermometers faced was that of glass shrinkage, which distorted the thermometer's accuracy.[66] To avoid this, thermometers were "seasoned" or stored for two or three years before being put into use; any subsequent calibration was generally good for the life of the instrument. English physicians who wanted greater precision in thermometric measurement could purchase seasoned thermometers certified by the observatory at Kew Gardens, London. The certificate provided a scale of readings corrected with standardized instruments. For obvious reasons, the certificate proved highly marketable for manufacturers; but the demand worldwide for accurate thermometers tempted less scrupulous manufacturers to sell certified—but unseasoned—instruments that lost most of their utility within a year. In 1880 the Winchester Observatory at Yale College established a thermometric bureau under the management of Dr Leonard Waldo to serve the needs of the American market. Within a short time the observatory at Harvard University offered a similar service.[67,68]

As doctors became more sophisticated in using the thermometer, they divided diseases into distinct periods reflective of thermometric change. The first period, known as the initial, effervescent or pyrogenetic stage, marked the gradual increment of body heat; the second stage of full febrile development was known as the fastigium. The third or final period, known as defervescence, marked the decline of the temperature to normal. When viewed on a thermometric chart, the entire course of a disease—from pyrogenesis to defervescence—was brought into view. Especially during prolonged illnesses in which changes were gradual rather than sudden, the chart became an important guide to diagnosis and prognosis. In its entirety, the chart was a visual record of the history of a given disease (see Figure 3).[69,70]

American Thermometry

According to Edward Seguin, an avowed disciple of Wunderlich, America could claim Josiah S. Lombard,[71] Lucius D. Bulkley,[72] H. C. Daguin, Bennet Dowler, Abraham Jacobi (1830-1919),[73] Austin Flint (1812-1886),[74] Joseph Jones (1833-1896)[75] and Jacob DeCosta (1833-1900)[76] as men who aided measurably in the understanding of medical thermometry.[1(p9)] Except for the work of Dr Jones of Georgia, however, whose experiments were published in the *Transactions* of the American Medical Association in 1859, clinical thermometry had few American adherents before the mid-1860s.[77,78] During the Civil War, John Shaw Billings recalled having used a thermometer when caring for the wounded in Richmond in 1862, and in 1866 the *Army Medical Department Reports* included the earliest series of temperature charts published by a medical officer in the public services.[12,79]

American hospital thermometry was introduced in the mid-1860s in the New York Hospital and later in the Bellevue Hospital. In 1866 Seguin and William H. Draper carried out tests in the New York Hospital on the application of thermometry in disease. Both recognized disease as "a disorder of the mathematics of life" and were anxious to transform thermometry into thermography by way of "medical mathematism."[1(pp309,384)] Of interest to Seguin and Draper were the distinctions that the use of the thermometer allowed them to make between typhus, typhoid and remittent and intermittent fevers. Draper prepared his own chart of the vital signs, which he attached to the beds of his patients in the New York Hospital; Austin Flint borrowed a similar chart developed by Jacob DeCosta, which Flint introduced at Bellevue.[80,81]

Although hospital physicians and their staffs laid the foundations of medical thermometry in America, it quickly spread into the hands of family practitioners and from there to nurses and the family circle. By the 1870s, Seguin was encouraging the development of "family thermometry."[82] His espoused purpose was to encourage family practitioners to gain "intelligent cooperation of women in the mechanical part of positive diagnosis" and also to rescue women "from the clutches of quackery and of medical theurgism." Mothers who could read thermometers could render invaluable service to their families in times of illness, provide important information for physicians and serve notice to quacks and assorted mediums that their suspect therapeutics were no longer accepted in the home circle. Thermometry, Seguin concluded, "is not only knowledge, but social power."[83]

At the height of the discussion in America on the implications of medical thermometry, Ohio physician Z.C. McElroy, a follower of the materialistic interpretation of Ernst Haeckel and Thomas H. Huxley, placed the thermometer's use within a broader philosophic framework.[43] McElroy praised the thermometer as an instrument of precision but argued that only when understood in its relationship to the totality of organic life could the thermometer be given its appropriate significance in the diagnosis, prognosis and

treatment of disease. Philosophy with its broader vision confirmed that the thermal state of the body was due to changes of matter and that "in organic life temperature is wholly due to retrograde chemical metamorphosis, and, with almost certainty, to the retrograde metamorphosis of solid tissue." Physiology encompassed an understanding of definite molecular forms of structure, each capable of specific functions and each with its own specific rate of waste and repair. Pathology, on the other hand, consisted of variations in the "physiological velocities of repair and waste" above or below the standard; and, finally, therapeutics consisted of remedial agencies designed "to promote, retard, or change the velocity of the chemical changes of matter in either or both the interest of repair or waste." The purpose of the clinical thermometer was to measure the physiologic or pathologic velocity of chemical change occurring in the human body and express that change in the form of a number.[43]

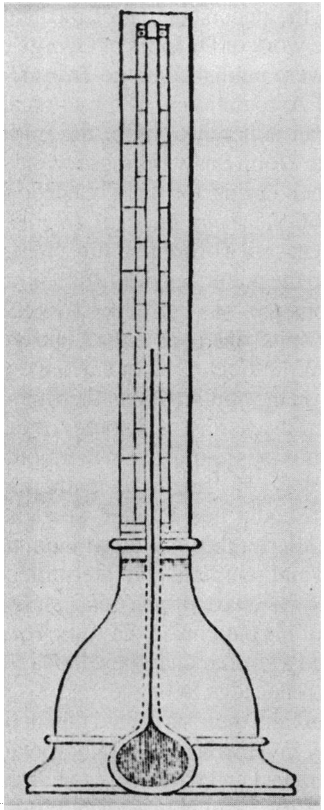


Figure 5.—A surface thermometer used for examination of tumors and diseased joints (from Spurgin[84]; courtesy of California State University, Long Beach).

Medical therapeutics, insofar as it approached being an exact science, explained McElroy, made use of remedial agencies for their sole ability to influence motion—"chemical changes of matter, ascending to or descending from molecular forms of structure of living beings."[43] The thermometer permitted physicians to evaluate the condition of molecular change in the body as a means of diagnosing a pathologic state, of making an accurate prognosis of the pathologic state and in guiding therapeutic measures designed to correct the condition of molecular motion in the body.

Surface Thermometry

Not all medical thermometry was limited to the measurement of the body's internal temperature. Recognizing variations of temperature in different parts of the body and believing that those surface variations would be helpful in diagnosing disease, J. Spurgin, MD, constructed in 1857 a "thermoscope," consisting of a common thermometer whose glass bulb was suspended in a hollow cone of wood, the glass shaft rising out of the cone and fixed to a graduated ivory index (Figure 5).[84] By comparing surface temperatures, Spurgin was able to treat breast tumors, having discerned that the heat of the tumor was several degrees higher than surrounding tissue. Satisfied with the results of the instrument, he recommended the thermoscope in the diagnosis and treatment of tumors and diseased joints.

A few years later, Pierre Paul Broca's (1824-1880) interest in the cephalic index was expanded to "cerebral thermometry."[85] Using a graduated thermometer (Figure 6), Broca found it possible to obtain the mean temperature of the brain, of the right hemisphere compared with the left and of the frontal, temporal and occipital lobes. On the basis of observations on interns and students in his wards at the Hôpital des Cliniques, Broca concluded that the temperature was higher on the left side of the brain at repose, but when at

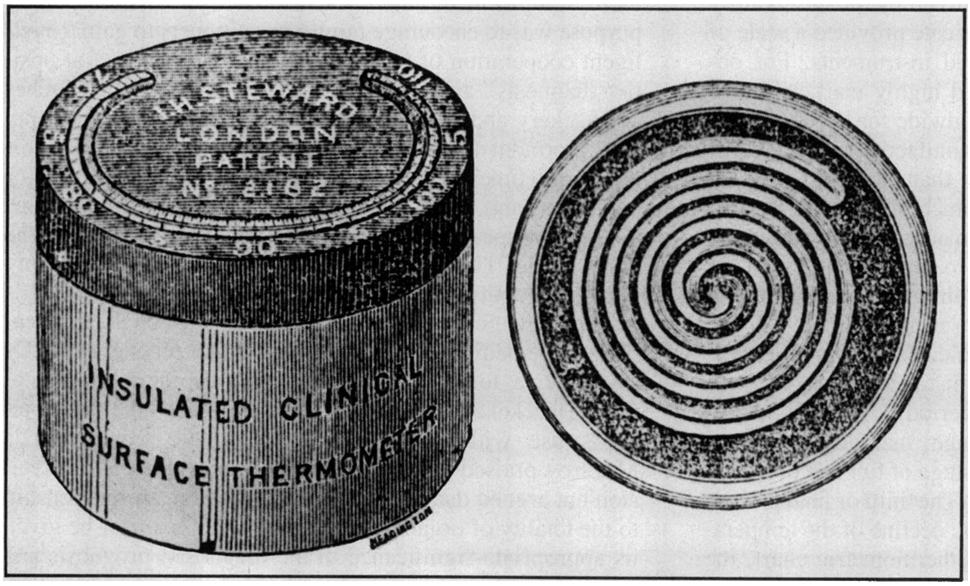


Figure 6.—A surface thermometer for cranial thermometry. **Left,** Steward's surface thermometer, side view. **Right,** View of undersurface, representing flatly coiled tube containing mercury. (From Hart[85]; courtesy of California State University, Long Beach.)

work, equilibrium was established. Although he began his investigations in 1869, Broca did not apply his research to the diagnosis of cerebral afflictions until 1873 when cerebral thermometry became a means of determining the existence of a cerebral embolism.[85]

Soon after notice of Broca's published work appeared in 1877, Landon Carter Gray, MD, of Brooklyn repeated the experiments of Broca on physicians and medical students at the Long Island College Hospital.[86] His conclusions, which were remarkably similar to those of Broca, enabled him to diagnose the existence of an intracranial tumor, afterward verified by postmortem examination.

Conclusion

In his address before the Congress of American Physicians and Surgeons in 1891, Silas Weir Mitchell noted that medical instrumentation forced physicians "to learn, to be rapid, and at the same time [to be] accurate." As in factories where machines were lifting a generation of workers to the "general level of acuteness of observation," the use of diagnostic instrumentation had lifted the medical intellect beyond all previous boundaries.[87(p164)] From Hippocrates who first recognized the importance of temperature as a sign of acute disease, to Sanctorius who first applied the thermometer to the human body, medicine had made a significant departure from art to science. And, again, with de Haen who demonstrated the practical application of thermometry in clinics, Becquerel who discovered the norm in mathematical diagnosis and Wunderlich who demonstrated the rules of ustion in disease, medicine could look back on a progression of events that ultimately placed clinical thermometry among the more significant achievements in medical science.

Although recognizing the ability of precision instruments to heighten levels of knowledge and provide an additional aid to diagnosis, Mitchell warned of the potential risks that instruments could bring "to the lazy or the unthoughtful." Physicians could become so dependent on instruments as to lose the power or even the desire to reason on the complex phenomenon of disease. Unless doctors "keep ahead of their instrumental aids," he remarked, they "will merely dementalize them, and but measurably lift the mass without in proportion advantaging the masters of our art, who were so easily masters in days when the erudite touch was more uniquely advantageous than it is today."[87(p165)] As Mitchell so rightly understood, true medical science resided not in the instrument, however precise, but in the intellect.

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