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Review

Early evolution of the thermometer and application to clinical medicine

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ABSTRACT

By the time of Hippocrates and Galen the notion of fevers and temperature were known. Through ensuing centuries, ancient Greek, Roman, and medieval savants and physicians made additional contributions to the understanding of fever, temperature, and thermometry. By the end of that era, there was a working definition of what constitutes a rationale temperature scale, the distinction between fever as a symptom and fever as a disease, an elaborate classification scheme for temperature, hypotheses as to the causes of fever, and methods for measuring fevers. Based on the definition of fever at that time, the 16th century scientist Galileo promulgated production of thermometric instruments hundreds of years before they were routinely used in the clinical setting. In this work we examine the history of fever and clinical thermometry in the ancient world through the end of the eighteenth century with descriptions of instruments for its measure and human relationship to fever.

Contents

1. Introduction and early temperature concepts without instruments

Talmudic medicine originating in Babylonia can be traced to Akkadian cuneiform inscriptions from sixth century BCE, for which the single term "*ummu*" and Sumerian pictographic symbol of a flaming brazier denoted fever and local warmth of inflammation (Atkins, 1982; Mackowiak, 1998; Majno, 1975). Inflammation and fever among early Mesopotamian societies involved supernatural interpretations of disease and was blamed on gods and ghosts quite freely (Majno, 1975). Medical epistemology in Hellenistic Palestine and Greco-Roman societies from fifth century BCE embodied the philosophical notion that body temperature involved a harmonious balance among four corporeal elements known as humors – blood (*sanguis*), phlegm (*flegma*), black bile (*melanchole*), and yellow bile (*chole*); proposed by Hippocrates of Kos (460–377 BCE) based upon Pythagorean natural composition of four balanced elements (e.g. water, earth, wind, and fire) (Mackowiak, 1998). Fever and heat, known as "*puretos*" and "*therme*" respectively, originated with excess yellow bile; a concept consistent with many infections of that era associated with fever and jaundice (Bessemans, 1938; Mackowiak, 1998). According to

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Hippocrates:

"…wherever bile or phlegm is heated, all the rest of the body is heated along with them,

and this is called *puretos* [Greek; fever]" (Jones, 1868).

Before Herophilus of Chalcedon (335–260 BCE) Hippocratic physicians articulated fever and elevated body temperature through direct cutaneous palpation rather than in relation to pulse rates (Jones, 1868; Sajadi et al., 2012).

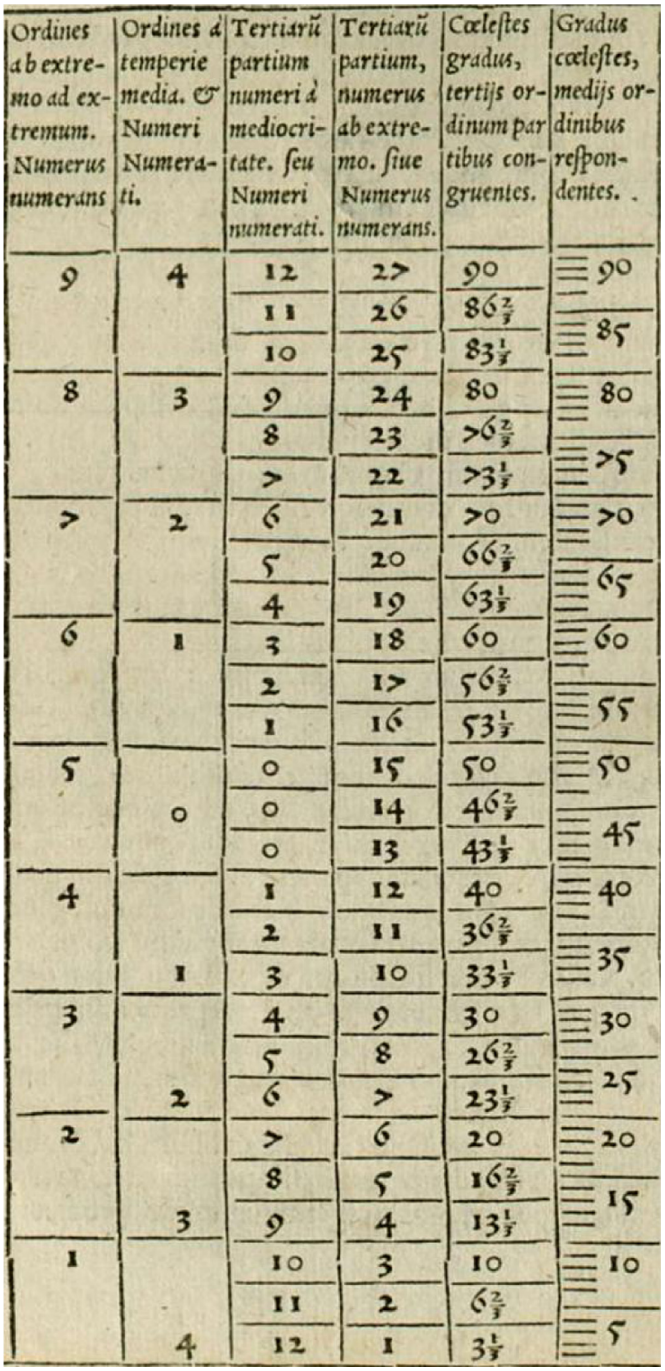
Claudius Galen of Pergamum (131–201 CE) further defined medicine for Medieval Western Europe based upon teachings from both Aristotle of Stagirus (384–322 BCE) regarding the physical sciences and classic theory of humors introduced by Hippocrates in his treatise *Of the nature of man* (Barnett, 1956; Fullerton and Silverman, 2009; Taylor, 1942). In his treatise *On the nature of faculties*, Galen endorsed humoral physiology and proposed excessive body heat as a primary disease (termed *dyscrasia* for abnormal humoral mixture [*eucrasia* represents health and the best possible humoral mixture]) that originated from movement, putrefaction, proximity to another body of excess heat, constriction, and certain foods with the necessary capability to produce heat (e.g. garlic, leeks, and onions) (Galen, 2006). According to Galen:

> "…if [the heat] is spread to the whole body, the disease is called *febris* [Latin; fever], which is excessive heat of the entire animal" (Galen, 2006).

Romans of this era emphasized the importance of this disease through its deification and envisioned a goddess of fever, *Febris*, with the dedication of a temple on Palatine Hill for the means of propitiation (Sajadi et al., 2012).

The description of heat and cold qualities by a number and establishment of a neutral temperature by a mixture of equal quantities of the hottest possible material (boiling water) and coldest possible material (ice) is Galen's contribution to clinical thermometry (Barnett, 1956; Taylor, 1942). Four degrees of heat and four degrees of cold were proposed based upon the capacity of pharmaceutical agents to affect appropriate changes among individual patients (Barnett, 1956; Taylor, 1942). The assignment of degrees was a qualitative estimate by physicians based on direct sense-perception and comparison to standard cases followed by relegation to particular degrees (level) of heat or cold (e.g. 1st, 2nd, 3rd, or 4th degree) (Barnett, 1956; Taylor, 1942). Galen's work represents the earliest notion to a standard temperature.

Further theoretical constructs concerning a standard temperature scale in relation to combinations of pharmaceutical agents were promulgated in the *De Logistica Medica* [Latin; about the logic of medicine] of Johannes Hasler of Berne (1548–1593 CE), published in 1578 (Hasleri and Problema, 1578; Taylor, 1942). Hasler's pertinacious manner to calculations, intended to ascertain degrees of heat or cold, introduced a temperature-scale incorporating degrees of latitude (Fig. 1) (Hasleri and Problema, 1578; Taylor, 1942). Column one (starting from the left-hand side) represents the "medical scale" with his succession [order; rank] of nine degrees set against Galen's scale with four degrees of heat and four degrees of cold (column two), division by thirds of these scales within columns four and three, respectively, and latitude scales within columns five and six (Hasleri and Problema, 1578; Middleton, 1966; Taylor, 1942). Mixtures of pharmaceuticals could then be prepared by physicians based upon the determination of normal temperatures expected with inhabitants of various latitudes. During this period, concepts espoused by Galen and Hasler continued and were consonant with contemporary medical philosophy to a reasonable subdivision of temperature despite no formulation to an instrument for direct measurement of heat and cold.



Ordines ab extremo ad extremum. Numerus numerans	Ordines à temperie media. & Numeri Numerati.	Tertiarũ partium numeri à mediocritate. seu Numeri numerati.	Tertiarũ partium, numerus ab extremo. siue Numerus numerans.	Cœleſtes gradus, tertijs ordinum partibus congruentes.	Gradus cœleſtes, medijs ordinibus reſpondentes.
9	4	12	27	90	90
		11	26	86⅔	
		10	25	83⅓	85
8	3	9	24	80	80
		8	23	76⅔	
		7	22	73⅓	75
7	2	6	21	70	70
		5	20	66⅔	
		4	19	63⅓	65
6	1	3	18	60	60
		2	17	56⅔	
		1	16	53⅓	55
5	0	0	15	50	50
		0	14	46⅔	
		0	13	43⅓	45
4	1	1	12	40	40
		2	11	36⅔	
		3	10	33⅓	35
3	2	4	9	30	30
		5	8	26⅔	
		6	7	23⅓	25
2	3	7	6	20	20
		8	5	16⅔	
		9	4	13⅓	15
1	4	10	3	10	10
		11	2	6⅔	
		12	1	3⅓	5

Fig. 1. Hasleri temperature scale (*De Logistica Medica* [1578, p 2]; courtesy of the Wellcome Institute Library, London).

2. Developmental precepts for early thermometers

Pneumatic experiments (expansion of air by heat) performed in antiquity represent the oldest known references of instruments utilized for quantitative measurements of heat and cold (Barnett, 1956; Mackowiak, 1998; Middleton, 1966; Taylor, 1942). Among the earliest writings concerned with heat expanded air are attributed to the works authored by Philo of Byzantium (240–200 BCE), also known as Philo Mechanicus (Middleton, 1966; Taylor, 1942). With some conjecture, his most important work is a large compendium, entitled *Mechanike syntaxis* [Greek; Mechanical Collection], containing a collection of treatises on mechanics (Middleton, 1966). The original Greek manuscript is largely lost