8 The Weight of Qualities

Quantifying Temperament in Early Modern British Mathematical Medicine

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In 1715, two years after his death, an English translation of the complete Latin works of the Scottish physician Archibald Pitcairne (1652–1713) appeared in London, furthering Pitcairne's role in the advancement of the new mathematical medicine.[1] "The Author of these *Dissertations* was one of the first, who leaving the *Old* Conjectural Method of Physical Writers, struck into a *New* and more Solid Way of Reasoning, grounded upon Observations and Mathematical Principles," the translator's preface proclaimed, noting Pitcairne's professorship in the practice of medicine at the University of Leiden, where at his inaugural lecture twenty-four years earlier he had called for a total reform of medicine on the model of Newtonian mathematical physics.[2]

Before taking up his professorship in April 1691, Pitcairne had read the first edition of Isaac Newton's *Principia Mathematica* and had resolved to mathematize medicine.[3] The need for this mathematization was obvious, Pitcairne declared in his lecture: only a mathematical method could secure certainty in medicine. Physicians needed to begin thinking, sensing, and reasoning like mathematicians and recover from their "addict[ion] to Philosophizing" about the essences or "physical causes" of material things.[4] On this point Pitcairne took his cue directly from Newton's *Principia:* there is an "unknown something" (*illud ignotum*) in a material body that accounts for all its observable actions in relation to other bodies.[5] The *Principia* had famously described the relations between bodies from a mathematical perspective based in observations of motions, and not, Newton warned the reader, as the causal explanations of those relations.[6] Such inner causes of material bodies are presently unknown, Pitcairne argued; what can be known about bodies is only what can be sensibly perceived in their motions in relation to one another. From this, the observer can induce the laws of governing these motions. For Pitcairne, physicians should thus observe and reason like astronomers:

> Physicians ought to propose the Method [*institutum*] of Astronomers as a Pattern for their Imitation [*imitandum*]: [astronomers] Never, in the Explication of the Motion of the Planets, call in the Assistance of a Romantic Hypothesis concerning the Structure of the World,

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> however pleasing and plausible, but by comparing the Observations which have been made at great Distances of Times and Places, and put together in a Method familiar to them, and useful to all the Phaenomena of the Celestial Motions, and to compute the Powers and Force which Bodies in Motion observe in their Tendency to other Bodies, either moveable or immoveable. Let us, if we are inclined to deserve well of the Republic of Physic … follow this excellent Rule of Theirs.[7]

For too long medicine had sought unobservable, and therefore hypothetical, causes or essences in animal bodies. If, instead, the living body was observed as extended parts in motion, both medical theory and practice could attain the absolute certainty of mathematical demonstration. From observing bodily motions, physicians would be able to induce the forces or powers (*vires*) governing them, and then from these powers the laws of motion of the animal body, or the "animal economy," as it was called, which would serve as the principles of demonstration in medicine.[8]

Pitcairne's inaugural lecture at Leiden was apparently well received; G. A. Lindeboom reports that the Leiden board of governors enthusiastically voted to increase Pitcairne's salary that same day.[9] Pitcairne immediately began publishing and presenting a program of mathematical medicine, which began with a dissertation on William Harvey's discovery of blood circulation.[10] In Pitcairne's view, Harvey had made it possible to apply a Newtonian "model of mathematical precision" to medicine: theoretically, blood circulation was the principle of life—the most fundamental motion of the living body—and practically, maintaining circulation was the principle of health.[11] Harvey had thus made mathematical certainty in medicine possible by discovering the observable and, in principle, measurable motions of the animal economy: the forces and speeds of blood circulation and the secretion of fluids from the blood at different parts of the body.[12]

Pitcairne was a member of what Theodore Brown has termed the "Newton-struck" generation of mathematicians and physicians—including Pitcairne's disciple and popularizer William Cockburn (1669–1739), the brothers John Keill (1671–1721) and James Keill (1673–1719), and the apothecary John Quincy (d. 1722)—who attempted to reform medicine into a certain mathematical science. Mathematizing medicine according to the practice of Newtonian astronomers, however, raised difficult theoretical and practical questions about its scientific object: How should mathematical physicians observe and measure the animal economy? How are the motions inside living bodies like or unlike the external motions of bodies observed in the sky or the laboratory? How are these motions best observed, measured, recorded, and communicated?

Harvey's discovery of blood circulation had in principle provided medicine with a new scientific object—the hydraulic forces and motions of circulation and secretion—but observing these motions to induce the laws of mathematical medicine proved more difficult than Pitcairne had proclaimed in his confident Leiden lecture. The attempt to *imitate* the systematic observation, induction, and mathematical demonstration of Newtonian astronomers was complicated by the necessity of *translating* medicine into a mathematically certain science and the method of observation and induction from physics into medicine.

In this chapter I explore one aspect of early modern mathematical medicine, the quantification of temperament—the balance of qualities or humors in the human body indicating a state of health or illness—as an example of this dynamic between the imitation and translation of a particular scientific practice. I use "translation" in Sven Dupré's expansive sense, as the transformative transfers of phenomena—linguistic, cultural, epistemic, sensory, or geographical—from one domain or place to another, both intentional and unintentional, that science "cannot avoid, not even when written in the universal language of mathematics." Translation, in this sense, involves the intended or unintended change of the phenomena in or by a transfer for testing, disseminating, or applying scientific knowledge.[13]

I argue that Pitcairne's Newtonian medicine is an example of a failed, or at least incomplete, translation from one scientific discipline to another, insofar as it aimed at imitation of the method of astronomical observation without sufficient determination of how its own scientific object—the human body as a hydraulic system of circulating fluids—should be systematically observed and measured. Pitcairne's Newtonian physician might attempt to imitate an astronomer, but he lacked a specific scientific norm to observe circulation and secretion inside the body as the Newtonian astronomer would observe planetary motion. Observing and quantifying temperament as an internal balance indicating a state of health or illness, therefore, remained an arbitrary and impracticable mathematization of qualitative properties of the blood.

By contrast, the mathematical medicine of the Paduan physician Santorio Santori (Sanctorius) (1531–1636) offered physicians a means of observing and quantifying temperament. Now most often remembered as the first Western physician to use a medical thermometer and quantitative methods in medicine, Sanctorius was celebrated in the seventeenth century for establishing the "static" medical method of observing what is added to, and subtracted from, the body in order to measure its internal balance and for his design of instruments to measure signs of imbalance—thermometers, the weighing chair (*statera medica*), hygrometers to measure humidity, and pulsimeters (*pulsilogia*) to measure pulse rate.[14] In a series of weighing experiments using his specially designed chair, Sanctorius claimed to have systematically measured the difference between ingesta and excreta every day over the course of thirty years, through weighing himself and over ten thousand others, in order to track changes in the temperament influenced by environment and habit.[15] With more precise measurements of the balance or imbalance of intake and output given a specific location, age, and routine, Sanctorius argued, the physician could know with more certainty what to add or remove from a patient's regimen order to maintain or restore health.[16]

As Sanctorius left no detailed records of these experiments, later physicians wishing to replicate them were left with perplexing questions about when, what, and how often to weigh in order to quantify such differences. In this sense, Sanctorian static medicine offered an experimental norm of testing and recording quantities that required translation. Followers of Sanctorius who restaged the weighing experiments were forced to guess the correct method of Sanctorian measurement and recording. Yet the retrying of the Sanctorian experiments was productive, gathering a variety of experimental results from different locations, including England, Ireland, Scotland, and South Carolina. Observing and calculating the difference between ingesta and excreta in various places and translating them into a common frame allowed physicians to measure the effects of a variety of climates, cultures, and routines—including the patient's diet, sleeping habits, exercise, and sexual activity—on the temperamental balance.[17]

Early modern mathematical medicine has traditionally been cast as one of the exceptions to the "mathematization thesis" of nature in the seventeenth century.[18] According to the most famous twentieth-century formulation of that thesis, by Alexandre Koyré, the origins of modern science can be traced to the early modern shift from the medieval Aristotelian "closed" cosmos of hierarchically ordered natures, "qualitatively and ontologically differentiated," to an infinite world of quantities governed by universal laws of nature and represented geometrically.[19] Medicine remained one of the scientific domains in which "very little mathematization was successful or even attempted" in the seventeenth century, according to a recent reassessment of the mathematization thesis.[20] Modern histories of mathematization in medicine, while often citing Sanctorius as a pioneer of quantitative physiology, date the actual mathematization of medicine to the development of biomedical statistics and clinical diagnosis later in the nineteenth century.[21] Pitcairne's Newtonian medicine, in particular, enjoyed only a very short life before the turn of medicine and natural philosophy away from mathematical mechanism and towards vitalism later in the eighteenth century.[22]

The prevailing characterizations of "mathematization" in the standard historiographies as the direct application of mathematics to nature, however, have been increasingly critiqued for flattening out historically distinct translations between mathematical and non-mathematical domains and the emergence of new scientific objects. As Sophie Roux has argued, since the ideal of early modern mathematization was that "all the phenomena of nature can be in principle submitted to mathematics and that mathematical language is transparent; it is the language of nature itself," the history of that mathematization requires careful attention to the distinctions and relations between mathematical and non-mathematical languages, the construction of "mathematized" scientific objects, and the specific goals, instruments, and techniques of representing nature mathematically.[23] Rather than focusing on early modern mathematical medicine as an exception to the mathematization thesis, then, this chapter suggests that the attempt to imitate Newtonian mathematical physics in medicine was an incomplete translation of a new scientific object—the hydraulic body of circulating fluids—into an observable phenomenon, in the specific case of the internal balance of temperament.

A New Scientific Object: The Hydraulic Body in Pitcairne's Euclidean Medicine

Pitcairne's system, based on his Leiden lectures, was posthumously published in 1717 as *Elementa medicinae*, named after Euclid's *Elements*, which presented medical theory and practice as an extension of Euclidean geometry. The text begins with an explicit invocation of the *Elements* and positions itself as a continuation of its certain demonstrations. Given Proposition 117 from Book X on the incommensurability of the side and the diagonal of a square, it can be supposed that all matter is infinitely divisible.[24] The identification of geometrical magnitude and physical extension is assumed here rather than stated as an axiom or postulate: since there is no common measure that makes the side and the diagonal of a square commensurate lengths, magnitudes do not consist of indivisible parts and are therefore infinitely divisible. Thus matter is also infinitely divisible. The mathematician John Keill, the brother of James Keill and popularizer of Newton at Oxford, similarly appealed to Proposition 117 in his introduction to natural philosophy:

> If all Magnitude consisted of Indivisibles, an Indivisible would be an adequate and common Measure of all Magnitudes of the same kind; for it would be exactly contained some number of times in all, and therefore all Magnitudes would have a common Measure, and the Side of a Square would be commensurate to its Diagonal; [which is] contrary to the last Proposition of the tenth Book of Euclid's *Elements*.[25]

Unlike Pitcairne, however, Keill offered geometrical proofs for the infinite divisibility of quantity and explicitly addressed the distinction between a geometrical quantity and a material one. Philosophers who distinguished between mathematical and physical bodies, according to Keill, misunderstood the natures of extension and divisibility: a mathematical magnitude can be infinitely divided *because* it is extended insofar as extension is a property of both geometrical and physical space.[26]

The identification of geometry and physics, by contrast, is not justified or discussed at all in Pitcairne's *Elementa*. Indeed, the text seems addressed to a reader who already accepts this identification but needs instruction on how to conceive the human body as a geometrical object. Once thus conceived, the body could be properly observed as quantities in motion from which the physician could induce the laws governing those motions.[27] The divisibility of matter, according to Pitcairne, necessitates some action of dividing, which can only be a kind of motion. Physicians must be guided by their senses, moreover, and it would run contrary to everyday sense perception to deny that bodies are in motion: the most fundamental sense experiences of moving bodies reveal that some bodies are solid and others fluid.[28]

Combining the Newtonian axioms that all matter is subject to the same laws and that all matter is inert—that bodies have no internal principles of motion or change—with Harvey's discovery of blood circulation, the physician can thus begin with the following postulates for medical science: 1) All matter is divisible, and certain material bodies are solid and others are fluid; 2) certain bodies are alive; 3) a living body is defined as one in which blood circulates as a result of the force of the heart; 4) where blood circulates, there is life.[29] Since the basic motion of the living animal body is blood circulation, the most basic division of the body is between the moving parts that circulate (the contained fluids) and the moving parts that facilitate circulation (the containing solids of the vessels). All the "laws" of the solids and fluids in animal bodies can then be discovered "by a due Collection of Observations" of numbers, weights, speeds, thicknesses, and shapes.[30]

On this basis, according to Pitcairne, the physician can demonstrate the particulars of blood circulation, unknown to Harvey, by conceiving the body's solids and fluids as the quantifiable components of circulation and secretion: the solid vessels of specific number, sizes, elasticities, figures, and thicknesses (making up what are commonly identified as "arteries," "veins," "nerves," etc.) and the circulating fluids of measurable quantities, thicknesses, and velocities.[31] Charles Wolfe has noted that what was most important for Pitcairne was this "literal transposition" of Newtonian axioms and empirical method into medicine in order to achieve the certainty of mathematical physics.[32] Pitcairne remained agnostic on the nature of the "life" of the animal body beyond the claim that it is present wherever there is circulating blood; "life" as such is just the apparent movement of blood through a body.

Quantifying the New Scientific Object: Translating Temperament into Degrees of Blood Fluidity

Pitcairne's conceptualization of the body as a hydraulic system of circulating fluids and vascular solids, however, proved difficult to observe and measure for Newtonian physicians. When the physician William Cockburn attempted to apply the quantification of "temperament" as a specific value of blood fluidity for dosing purgative medicines, for example, his results were arbitrary and largely ignored.[33] Pitcairne had defined temperament as a specific blood fluidity that determined a proportionately greater secretion from the blood of bile, urine, and saliva—corresponding to three of the traditional temperaments, bilious (choleric), melancholic, and phlegmatic (pituitous).[34] The differences between the temperaments, according to Pitcairne, was just the difference in the size and "slipperiness" or "smoothness" of the smallest fluid particles. In fact,

> if the Blood of all Men consisted of Parts equally small and slippery, then all Men would have the same Temperament. The Temperament of every Man is a Change (whatsoever it be, and which is to be discovered by some sensible Appearance) of those Conditions in the Canals and Blood that are required to continue a Life destitute of all Pain. But since those Conditions may be infinitely varied (for the Proportions of different Bodies, constituting the same Fluid in any given Quantity, are without number) and which it is of the utmost moment for our Health to be acquainted with, although surpassing all our Industry [to discover]. … There are therefore three kinds only of Temperaments to be observ'd in the Fluids of a human Body, defined in terms of different fluidities of the Blood that … allow the Parts to be secreted from it, in any given Velocity of separation.[35]

Pitcairne's definition of temperament here is characteristic of his descriptions of the hydraulic body as the scientific object of mathematical medicine. Temperament is some kind of sensibly observable change in the "conditions" of the solids and fluids in the body. These conditions are quantifiable, if not directly measurable: they are the proportions of variously slippery and small particles, with varieties too numerous to count. There are three different *kinds* of fluidities in general, however, which correspond to the effect that the smallest parts of the blood have on the secretion of fluids at different places in the body.

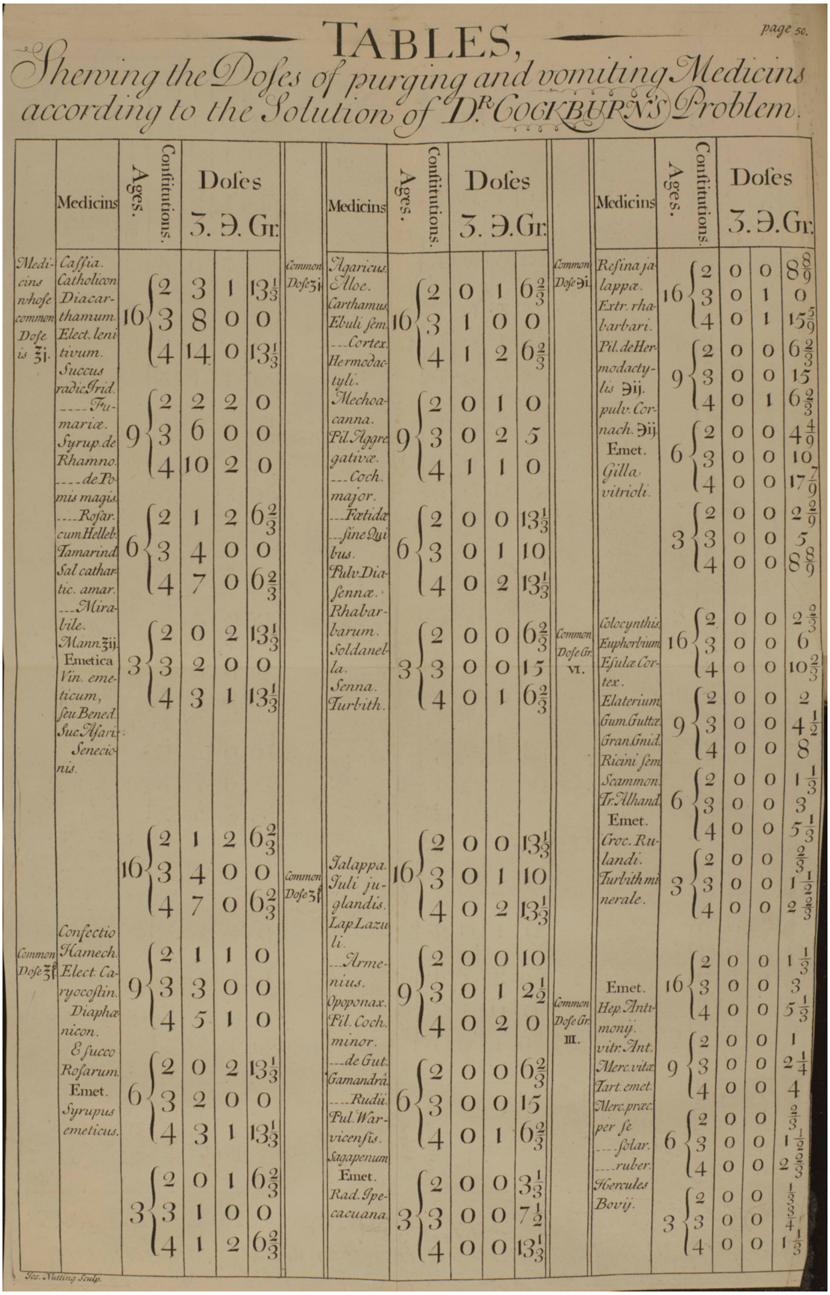
As Anita Guerrini has shown, Pitcairne's understanding of fluidity was directly influenced by a conversation with Newton in spring 1692 on matter theory that Pitcairne recorded and sent to friends.[36] According to Newton, Pitcairne recounted, fluidity was the resistance to flow—viscosity—as determined by the size and smoothness of the smallest parts: "Viscosity is either just a deficiency of fluidity (which is located in the smallness, and thus the separability of parts, understood as parts of last composition) or a deficiency of slipperiness or smoothness preventing the lowest parts from sliding over others."[37] Yet in Pitcairne's discussions of fluidity, the size and slipperiness of these minimal particles remained highly speculative and only abstractly quantifiable. Every circulating fluid, Pitcairne claimed, has specifically sized particles that only a particular force can separate out. A bilious or "choleric" temperament, for example, is one in which bile is secreted in greater proportion because of the greater quantity of particles that, with the requisite force and large enough orifices, are secreted from the rest of the blood in the liver. Pitcairne did not, however, elaborate on the precise sizes of these particles of different fluids, or how their slipperiness could be measured, beyond specifying that the three temperaments are different degrees of fluidity that allow different fluids to be secreted from the blood in greater proportion.[38]

Cockburn attempted to quantify Pitcairne's definition of temperament in a series of papers published in the *Philosophical Transactions* that began with two postulates directly adopted from Pitcairne's system and assigned numerical values to fluidity. First, because health is a function of the facilitation of circulation, medicines are only effective insofar as they are dissolved in the blood; second, medicines change the temperament of the blood, namely, the blood's fluidity or thickness.[39] In order to calculate the most effective doses of medicines for specific temperaments or "constitutions," Cockburn quantified Pitcairne's three temperaments according to greater and lesser degrees of fluidity:

> The quantity of any medicine affects us differently according to Quantity and Constitution of the Blood, or its thickness … [If the] thickness were the same the Dose should always be [the same] as its Quantity[.] There are only three healthy constitutions, which are numbered 2, 3, and 4. That of the most fluid Blood as the first number, and so on.[40]

Cockburn does not explain why, exactly, fluidity is quantified by integers of 2, 3, and 4, nor which temperament corresponds to which degree. Yet if the effect of medicines is ultimately a quantitative change to circulation, increasing or decreasing blood fluidity and the resulting secretions of fluids from the blood, some value of fluidity is necessary to calculate this change in relation to the quantity of the blood and the medicine administered. Cockburn listed such values in tabular form (Figure 8.1). Two patients having the same fluidity and the same quantity of blood—which Cockburn estimated by age—would receive the same dose; if two patients have the same quantity of blood, the doses will differ in proportion to the degree of fluidity, since the dose is proportional to the degree to which the medicine will affect fluidity (and thus the temperament).

Although Cockburn promoted a Newtonian approach to medicine as a mathematically certain science, his primary concerns in quantifying temperament as blood fluidity were the explanation of clinical observations and the improvement of drug therapies through more precise dosing.[41] The physician's "daily experience" that purging medicines, for example, take effect more quickly when ingested in a liquid form rather than a powder, and that patients with illnesses that thicken the blood such as edemas (dropsies) and jaundice require larger doses, is best explained by the inference to the proportional relation between the dose dissolved or mixed in the blood (as opposed to the administered dose) and the effectivity of the medicine.[42]



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TABLES, Shewing the Doses of purging and vomiting Medicins according to the Solution of Dr. COCKBURN'S Problem.

	Medicins	Ages.	Constitutions.	ʒ.	℈.	Gr.
Medicins whose common Dose is ℥i.	Cassia. Catholicon Diacarthamum. Elect. lenitivum. Succus radic. Irid. ---- Fumariæ. Syrup. de Rhamno. ---- de Pomis magis. ---- Rosar. cum Helleb. Tamarind. Sal cathartic. amar. --- Mirabile. Mann. ℥ij. Emetica Vin. emeticum, seu Bened. Suc. Asari. Senecionis.	16	2	3	1	13⅓
			3	8	0	0
			4	14	0	13⅓
		9	2	2	2	0
			3	6	0	0
			4	10	2	0
		6	2	1	2	6⅔
			3	4	0	0
			4	7	0	6⅔
		3	2	0	2	13⅓
			3	2	0	0
			4	3	1	13⅓
Common Dose ℥ß	Confectio Hamech. Elect. Caryocostin. Diaphænicon. & succo Rosarum. Emet. Syrupus emeticus.	16	2	1	2	6⅔
			3	4	0	0
			4	7	0	6⅔
		9	2	1	1	0
			3	3	0	0
			4	5	1	0
		6	2	0	2	13⅓
			3	2	0	0
			4	3	1	13⅓
		3	2	0	1	6⅔
			3	1	0	0
			4	1	2	6⅔

	Medicins	Ages.	Constitutions.	ʒ.	℈.	Gr.
Common Dose ʒi.	Agaricus. Aloe. Carthamus. Ebuli sem. --- Cortex. Hermodactyli. Mechoacanna. Pil. Aggregativæ. --- Coch. major. --- Fœtidæ --- sine Quibus. Pulv. Diasennæ. Rhabarbarum. Soldanella. Senna. Turbith.	16	2	0	1	6⅔
			3	1	0	0
			4	1	2	6⅔
		9	2	0	1	0
			3	0	2	5
			4	1	1	0
		6	2	0	0	13⅓
			3	0	1	10
			4	0	2	13⅓
		3	2	0	0	6⅔
			3	0	0	15
			4	0	1	6⅔
Common Dose ʒß	Jalappa. Juli juglandis. Lap. Lazuli. --- Armenius. Opoponax. Pil. Coch. minor. --- de Gut. Gamandrâ. ---- Rudii. Pul. Warvicensis. Sagapenum. Emet. Rad. Ipecacuana.	16	2	0	0	13⅓
			3	0	1	10
			4	0	2	13⅓
		9	2	0	0	10
			3	0	1	2½
			4	0	2	0
		6	2	0	0	6⅔
			3	0	0	15
			4	0	1	6⅔
		3	2	0	0	3⅓
			3	0	0	7½
			4	0	0	13⅓

	Medicins	Ages.	Constitutions.	ʒ.	℈.	Gr.
Common Dose ℈i.	Resina jalappæ. Extr. rhabarbari. Pil. de Hermodactylis ℈ij. pulv. Cornach. ℈ij. Emet. Gilla vitrioli.	16	2	0	0	8 8/9
			3	0	1	0
			4	0	1	15 5/9
		9	2	0	0	6⅔
			3	0	0	15
			4	0	1	6⅔
		6	2	0	0	4 4/9
			3	0	0	10
			4	0	0	17 7/9
		3	2	0	0	2 2/9
			3	0	0	5
			4	0	0	8 8/9
Common Dose Gr. VI.	Colocynthis. Euphorbium. Esulæ Cortex. Elaterium. Gum. Guttæ. Gran. Gnid. Ricini sem. Scammon. Tr. Alhand. Emet. Croc. Rulandi. Turbith minerale.	16	2	0	0	2⅔
			3	0	0	6
			4	0	0	10⅔
		9	2	0	0	2
			3	0	0	4½
			4	0	0	8
		6	2	0	0	1⅓
			3	0	0	3
			4	0	0	5⅓
		3	2	0	0	⅔
			3	0	0	1½
			4	0	0	2⅔
Common Dose Gr. III.	Emet. Hep. Antimonij. vitr. Ant. Merc. vitæ. Tart. emet. Merc. præc. per se ---- solar. ---- ruber. Hercules Bovij.	16	2	0	0	1⅓
			3	0	0	3
			4	0	0	5⅓
		9	2	0	0	1
			3	0	0	2¼
			4	0	0	4
		6	2	0	0	⅔
			3	0	0	1½
			4	0	0	2⅔
		3	2	0	0	⅓
			3	0	0	¾
			4	0	0	1⅓

Jos. Nutting Sculp.

Figure 8.1 William Cockburn, Tables of Purging and Vomiting Medicines According to Age and Constitution. *Philosophical Transactions* 26 (1708), 53.

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Changing the degree of "most fluid" blood requires a smaller dose, to be sure, but in assigning this fluidity the number 2, Cockburn combined his adoption of Pitcairne's definition of temperament, his translation of the degree into a specific value for use in calculating doses, and his and other physicians' clinical experiences of discerning blood fluidity in relation to other signs and symptoms. For Cockburn, in other words, blood fluidity was defined not principally as subvisible minimal particles of specific sizes and smoothness, but as a clinically observable phenomenon of a more or less viscid state. When thick, for example, the blood was condensed, sticky, slowly moving through contracted vessels, and indicated by pale skin, a weak pulse, and tremors.[43] The geometrical conception of the hydraulic animal body was the theoretical foundation of Cockburn's quantification of fluidity, but it seemed secondary to the clinical usefulness of quantifying qualitative characteristics of the blood that the physician was already trained to observe in practice.

Despite the relative historical insignificance of Cockburn's quantification of temperament as degrees of blood fluidity, the table of ages, doses, and temperaments ("constitutions") reproduced in Figure 8.1 indicates one of the central epistemic and phenomenological transformations of quantification in early modern medicine: the abstraction of specific qualitative assessments of the physician's trained senses into numerical values that generated new experiential data and scientific objects. Even though Cockburn's practicing physician, calculating doses, still discerned temperament through expert sensing, that sensing was at least conceptually restricted to observing the thickness or viscosity of blood, which became a discrete value referring to new categories of patients (those with the least, average, and most fluid blood) as the basis for therapeutic interventions. Temperament in the tables—as a "constitution" of 2, 3, or 4—remained a subjective assessment by the individual physician that Cockburn translated into an arguably arbitrary numerical value.

More specifically, the quantification of blood fluidity simplified and reduced temperament to a state of the blood. A fundamental notion in Galenic medicine, temperament or complexion (*temperamentum* and *complexio*, both translations of the Greek *crasis*, or mixture) referred to a particular physiological balance of Aristotelian qualities—hot/cold and wet/dry—in a particular organ, individual body, species, food, or drug, either as an innate and natural condition or a temporary and mutable one.[44] Latin Scholastic medicine made "complexion" both central and polysemous, variously indicating a permanent or temporary qualitative state or a predominant humor. A male physician in his thirties, the old woman he is treating, the dog at his feet, the drink on his table, the bee bothering him, and the plant in his window will all have different natural complexions. In the course of treatment, the physician might look at and touch various parts of the woman's body for the sensible signs of the complexionate balance of various parts—the thermal temperature, humidity, color, and resistance of her skin; the volume, weight, color, and viscosity of her saliva, sweat, vomit, urine, and feces; the rate and strength of her pulse; and the shape, position, and function of organs. These signs may be substantial and certain, such as immediate sensations of hot, cold, wet, or dry, or accidental and more conjectural, such as color, texture, resistance, and function.

A perfectly balanced complexion—*temperamentum ad pondus*—was considered a theoretical construct, the precise indivisible midpoint between qualitative extremes marking the perfect quantitative balance, and was regarded as relatively useless in practical medicine. The physician instead sought the "just" equality of a specific complexionate entity—*temperamentum ad iustitiam*—of a range or "latitude" with specific degrees proper to a part or a whole organism, within which the part or whole was able to exercise its natural function.[45] Medieval commentators often characterized this complexionate latitude as a continuum between the qualitative contraries along which the part or whole was always moving.[46]

Determining the temperaments of the patient as a whole, as well as the different body parts (particularly the brain, heart, and liver), was thus a complex and often speculative task even for the physician's trained gaze, touch, and clinical reasoning. Signs, symptoms, and causes as diverse as the color, temperature, texture, and shape of the body and face, the position and shape of organs, sleep patterns, excreta, pulse, eating and drinking habits, geographical area of residence and travel, age, and the time of year, among many others, were traditionally listed as criteria that the physician should take into account.[47] Once defined only as a degree of blood fluidity in Pitcairne's mathematical medicine, however, the physician's senses and focus contracted to a quantified state of the blood and what that state implied about circulation and secretion. More importantly, temperament conceptually became a single value (if not an actual measurement) of blood fluidity rather than a dynamic system of qualitative latitudes in one organism.

If Pitcairne's and Cockburn's Newtonian physician thought of temperament quantitatively, there is little indication that his practical assessments of temperament changed as a result. Cockburn's (and Pitcairne's) quantifications of temperament are thus historically significant perhaps less as examples of the "mathematization" of medicine than as attempts to imitate Newtonian physics in Harveyan medicine without a consensus on how to observe the motions of circulation or on how such observations would be practically useful to the physician.

The Trials of Quantified Temperament: "Such Troublesome Experiments"

A much more useful quantification of temperament for Newtonian physicians came from a distinctly non-Newtonian source: Sanctorius's weighing experiments. Assiduously committed to clarifying the medical canon and improving medical practice, Sanctorius's works, including commentaries on Galen's *Ars medica*, Avicenna's *Canon*, and the Hippocratic *Aphorisms*, were both profoundly traditional and innovative. They combined new quantitative practices and measuring instruments with a dynamic Galenism and expertise in academic medicine.[48] Sanctorius's most famous and popular work, *De statica medicina*, is a collection of medical aphorisms based on weighing experiments he had performed over the course of thirty years, using a specially designed steelyard chair (Figure 8.2), to measure the effects of the Galenic non-naturals or external factors impacting complexionate balance—air, food and drink, exercise and rest, sleep, excretions, and the passions or emotions.

Promoting this book to Galileo soon after its publication, Sanctorius described his "static" method as the experimental perfection of Hippocratic medicine, based in two certain first principles: the Hippocratic definition from *De flatibus* of medicine as the addition of what was missing and the subtraction of excess, and experience, through which the physician could track the bodily changes indicating privation or excess.[49]

De statica medicina quantified the effects of the six non-naturals on what Sanctorius claimed was the most fundamental index of health, the amount of "insensible perspiration" in addition to other excreta.[50] Citing Hippocrates and Galen as authorities, Sanctorius centralized and elaborated their notion of an invisible vapor or exhalation through the pores or mouth, and declared that he had invented a new art of medical statics based on its accurate measurement.[51] By systematically and regularly weighing the body, consumed food and drink, and urine, stool, and sweat, Sanctorius calculated the amount of insensible perspiration as the differences between the weights of sensible ingesta and sensible excreta. In a perfectly balanced state of health, ingesta (food and drink) and excreta (including sensible evacuations and insensible perspiration) were proportionate; insensible perspiration, Sanctorius claimed, was the most plentiful bodily excretion.[52] A physician who only observed a patient's sensible evacuations would know so little about their state of health, in fact, that their therapies would be deceptive and destructive: only by measuring the amount of insensible perspiration as the differences between body weight, ingesta, and sensible excreta could the physician observe the effects of the non-naturals on the patient and how these should be regulated through the proper diet, drugs, and habits.[53]

The centrality of the non-naturals in static medicine supported a particular understanding of temperament that was thus easily quantified both conceptually and practically in experimental measurement. The specific complexionate balance measured through weighing was what Sanctorius termed the *external* or *adventitious* temperament: a balance that was always in flux as a result of the influence of the non-naturals, and with which the physician was principally concerned in diagnosis and treatment.[54] This temperament was both directly measurable by weighing and mutable by changes in environment and habit. Whereas

Figure 8.2 Sanctorius, The Weighing Chair. *Ars de statica medicina* (1625). Wellcome Collection, CC BY 4.0

an innate temperament might be relatively permanent and less amenable to medical treatment, adventitious temperament was measurable by systematic weighing and could be corrected through the regulation of the non-naturals.

Sanctorius famously left no explicit record of his experiments, however, much to the chagrin of many eighteenth-century followers, such as the Scottish physician Francis Home, who praised Sanctorius's measurement of insensible perspiration but lamented the laconic aphoristic style of the *De statica medicina:*

> There is no discovery, next to that of the circulation of the blood, that has so much affected our reasoning in medicine, as that of insensible perspiration. The origin of most diseases, and the operation of most medicines are accounted for from it. Sanctorius, to whom we are indebted for the discovery, would have done more service to the science of medicine, had he simply narrated the different experiments that he made, with the proper circumstances belonging to each, and allowed the reader to be a proper judge of the conclusions which he drew from them. By neglecting this, his particular conclusions meet with less credit.[55]

In the preface to his retrials of the weighing experiments in *Medicina statica Britannica*, the Newtonian physician James Keill similarly complained that Sanctorius's aphoristic style in the *De statica medicina* had breached the scientific conventions of collective witnessing and judgment of experiments. Keill included tables recording his own experiments so that "whosoever looks over the Tables, will be as it were present at the Experiments, and will seem to be made his own judge of the truth of the Aphorisms. He may also draw other more useful Observations from them, which escaping in the Aphoristical way of writing, would have lain hid in perpetual darkness."[56] And the physician John Lining (1708–1760), writing to Royal Society physician James Jurin (1684–1750) about the experiments he conducted in South Carolina, complained that Sanctorius had left behind obscure aphorisms rather than explicit experimental instructions and results: "hence we are not only deprived of the Authorities from whence he deduced his Aphorisms, but likewise of a long-continued Series of Experiments; from whence the Changes induced upon the human Frame, in the different Seasons, might have experimentally appeared."[57]

Sanctorius's experiments, then, proved easier to translate than to imitate. As Teresa Hollerbach has noted, Sanctorius described his experiments as trials or risks (*periculum feci*) in the preface to *De statica medicina*, invoking Latin translations of the Hippocratic aphorism "experience [is] treacherous" (*experimentum periculosum*), a contrived event with an uncertain and possibly dangerous result.[58] Because Sanctorius only communicated his experiments as aphorisms, however, later static experimenters were left to guess their subject and aim: Who should weigh what, how, how often, and why?

In his translation of *De statica medicina* into English, the physician and apothecary John Quincy argued that readers had misunderstood the aphorisms as cryptic instructions for further experiments rather than as dietetic recommendations for a general readership. Quincy had also translated Pitcairne's *Elementa*, and criticized the Latinisms and academic jargon of contemporary medicine. Readers of Sanctorius's aphorisms were not meant to restage the experiments themselves, he argued, but rather, considering the purpose of static medicine to measure and regulate the non-naturals, to become more aware of the effects of such external factors on the state of their health. Quincy's translation of Sanctorius from Latin into English thus aimed to popularize the importance of regulating the non-naturals in everyday life:

> I have endeavoured only to bring [the aphorisms] into a larger Acquaintance, both by rendering them in our own Language, and giving such Explanations of some of the most difficult, as may make them easie and intelligible, almost to any Person who has given himself the Leisure to reflect at all, upon the Nature of his Constitution, and the Changes it is most apt to undergo by the Influence of external Causes.[59]

Quincy made these arguments in the Preface to his translations of *De statica medicina* and James Keill's *Medicina statica Britannica* in one volume; by offering both translations together, Quincy hoped that a wider lay readership would learn the importance and influence of location, custom, and climate on their health.[60]

This was precisely Quincy's understanding of the benefit of Sanctorian static medicine, namely, to promote the importance of self-regulation in preserving and restoring health rather than obsessive self-tracking. He complained that weight-obsessives inspired by Sanctorius would only "eat and drink by the Ounce," compulsively weigh themselves, and record their excreta. The aim of static medicine, according to Quincy, was self-control and the regulation of the non-naturals rather than constant (and ultimately useless) measurement: "any person may soon be a judge of the present State of his Constitution without going into a Pair of Scales."[61] Lucia Dacome has persuasively argued that for Quincy, replicating these experiments was largely worthless, first, because the "exactness" of Sanctorius's calculations was immaterial to the text's didactic purpose of educating the literate public about the medical significance and influence of the non-naturals, and second, because Sanctorius's Paduan environment and lifestyle would have yielded very different results, "both our Climate and Way of Living being so very different from his."[62]

In this sense, Sanctorian statics offered Newtonian physicians a practical quantification of observable motion as body weight, ingesta, and excreta, differently measured according to their interpretation of the nature and purpose of Sanctorius's original experiments. This different mathematization, emerging from Sanctorius's attempt to make Galenic diagnosis more precise and systematized in his static weighing experiments, thus practically enabled the quantification of temperament through the translation and comparison of experimental measurements. For the Newtonian physicians who had embraced Harvey's law of circulation, translating Sanctorius's weighing experiments both quantified and externalized temperament by connecting the observable quantities of weight with the internal motions of circulation. Since the life of the animal body was a function of the motions of circulation, a healthy body was one in which these motions were unobstructed and could be measured directly by weighing.[63]

Adventitious temperament was therefore translated and materialized as and through the scale itself—or, in Quincy's interpretation, self-control and moderation of one's regimen—and the changes in body weight. In his 1747 account of retrials undertaken in England, Ireland, and South Carolina, for example, the physician Bryan Robinson (1680–1754) argued that had Sanctorius recognized blood circulation as the principle of life, he might have made the important connection between measuring and regulating the non-naturals and the internal motions of the heart, circulation, and secretion—that is, between the inner quantities of motion and the external quantities of weight.[64] Introducing his comparison of the retrials, Robinson connected the geometry of circulation with static experimental data and the measurement of the effects of the non-naturals:

> As the Discharges of human Bodies depend upon, and are regulated by, the Motion of the Blood; so it may be proper to premise a short account of Motion, by which the Nature of the Discharges by Perspiration, Urine, and Stool, will be more clearly understood than they would be without it. … The disturbing Causes of the Motion of the Heart are the Changes in the sensible qualities of the Air, Heat and Cold, Dryness and Moisture, Errors in Food, in Exercise of Body, in the Times of sleeping and waking, and the Passions of the Mind; that is, a wrong Use of the *Non-naturals* is the common disturbing Cause of the motion of the Heart.[65]

For Keill and Robinson, in particular, Sanctorian statics provided a bridge between the hydraulics of circulation and secretion (the mathematical foundation of medicine, according to Pitcairne) and systematically observable and measurable quantities. This bridge, however, was not so much built as begun and abandoned: as Keill wryly remarked, he gave up his ten-year static retrials without finding a clearer connection between the hydraulics of blood circulation and static measurements, since systematic static measuring required such "a constant and certain way of living" that "a man of business cannot find leisure to pursue [it] with sufficient diligence."[66]

Conclusion

Pitcairne's program to induce the laws of the animal economy from systematic observations "after the rule" of astronomers attempted to imitate Newtonian mathematical physics without due consideration of how theoretical and practical medical concepts would be transformed once they were translated into quantities. On the other hand, for physicians eager to mathematize medicine in order to secure its epistemic authority, the appeal of Sanctorius's static experimentalism was its translatability into different methods of quantifying excess and privation as the measure of health. Sanctorius's lack of experimental instruction meant that his experimental program was, in a sense, inimitable; readers and experimenters had to translate, rather than virtually witness or precisely replicate, his experimental practices. Yet because the Sanctorian notion of static balance was based on an externalized definition of adventitious temperament as the state of being influenced by the non-naturals, the "balance" being measured in static experiments was both materially concrete (in the form of the scale or weighing chair itself and the difference in weights of ingesta and excreta) and transferable. It could be compared across different geographic locations, different physicians as experimental subjects and objects, and more or less precise and repeated measurements. In this sense, the quantification of temperament in static experimentalism was arguably part of the longer transformation of temperament from a dynamic interplay of complexionate parts and wholes in the individual body into new scientific objects—such as the systematic observation and recording of body weight—that both externalized and collectivized temperament as measurable quantities.[67]

Notes

1 Pitcairne, "An Oration," in *The Whole Works* (the original Latin is in Pitcairne, *Oratio*).
2 Ibid., 5. After receiving his medical degree from the University of Reims in 1680, Pitcairne was introduced to Newton's *Principia Mathematica* by the Edinburgh mathematics professor David Gregory. On Pitcairne's reading of Newton, see Brown, "Medicine"; Cunningham, "Syndenham versus Newton," 88; Guerrini, "James Keill"; Guerrini, "Archibald Pitcairne"; Guerrini, "Isaac Newton.' "
3 On Newton's metaphysical agnosticism about physical causes, see Janiak, *Newton as Philosopher*, 14–25.
4 Pitcairne, "An Oration," 7.
5 Ibid., 9.
6 Newton, *Principia*, def. VIII, trans. Cohen and Whitman, 4–5.
7 Pitcairne, "An Oration," 10–11.

8 Ibid., 9–10.
9 According to Lindeboom in "Pitcairne's Leyden Interlude," 280–82. See also Guerrini, "Archibald Pitcairne," 75.
10 Pitcairne, "A Dissertation upon the Circulation of the Blood," in *The Whole Works*, 33–65.
11 Guerrini, "Isaac Newton,' " 224.
12 Pitcairne, "A Dissertation," 34–35.
13 Dupré, "Introduction," 303; see also the articles in the Focus section of that volume.
14 On Sanctorius, see especially Dacome, "Living with the Chair"; Hollerbach, "Weighing Chair"; Hollerbach, "Sanctorius Reconsidered."
15 Sanctorius, *De statica medicina*, "Ad lectorem."
16 Ibid., aph. 1, 1.
17 On these retrials, see Dacome, "Living with the Chair."
18 See, e.g., Gingras, "Mathematics"; Gorham, Hill, and Slowik, "Introduction"; Jalobeanu and Vida, "Introduction"; Tomazella Ferreira and Celestino Silva, "Roles of Mathematics."
19 Koyré, *Newtonian Studies*, 7. In Dijksterhuis's account, modern science began with Newton's distinction between rational mechanics, which expressed motion in "exact proportions and demonstrations," and the inexact, practical art of constructing useful machines. See Dijksterhuis, *Mechanization*, 3; Newton, *The Principia*, trans. Cohen and Whitman, 381. See also Kuhn, "Mathematical vs. Experimental," 28. For an overview of the mathematization thesis, see Mahoney, "Mathematical Realm."
20 Gorham, Hill, and Slowik, "Introduction," 15.
21 Magnello and Hardy, *Road to Medical Statistics*, iv; Matthews, "Probabilistic and Statistical Methods," 1372–73; Matthews, *Quantification*, chs. 1–2; Reiser, *Medicine*, 110.
22 Guerrini, "James Keill," 259; Guerrini, "Archibald Pitcairne," 82.
23 Roux, "Forms," 320 and 325. See also Lorraine Daston's critique of E. A. Burtt's metaphysical presumptions about mathematization and mechanization in Daston, "History of Science."
24 Pitcairne, *Elementa medicinae*, 1. 1. This proposition from Euclid was most likely a later interpolation.
25 John Keill, *Introduction to Natural Philosophy*, 30. On Keill's interpretation of Newton, see Guerrini, "James Keill," 253–54.
26 Keill, *Introduction to Natural Philosophy*, 31.
27 Pitcairne, *Elementa medicinae*, xxiii.
28 Ibid., 1. 1.
29 Ibid., "Postulata."
30 Pitcairne, "An Oration," xxiii.
31 Pitcairne, *Elementa medicinae*, 1. 4.
32 Wolfe, "Newtonian Analogies," 227.
33 Cockburn and Southwell, "Gulielmi Cockburni M. D. Solutio Problematis De Purgantium"; Cockburn, "Problema medicinæ cultoribus solvendum proponit Guilielmus Cockburn"; Cockburn, "Practice of Purging and Vomiting Medicines."
34 Pitcairne rejected "sanguine" as a temperament, claiming that it was only a plethora or "greater quantity" of fluid than were present in the other three. See *Elementa medicinae*, 1. 3. 6.

35 Ibid., 1. 3. 3.
36 Guerrini, “Archibald Pitcairne,” 70 and 74–76.
37 Isaac Newton, “Pitcairne with Newton at Cambridge, 1691/2, Cambridge, 2nd March 1691/2,” in *Correspondence*, 3:211.
38 Pitcairne, *Philosophical and Mathematical Elements of Physick*, 13.
39 Cockburn and Southwell, “Solutio Problematis De Purgantium,” 2119–20.
40 Cockburn, “Practice of Purging and Vomiting Medicines,” 48–49.
41 Cockburn’s quantification of fluidity and calculations of doses found little support at the Royal Society at the time, and in Edinburgh the physician Charles Alston derided Cockburn’s method as arbitrary, “hypothetical,” and of little use in estimating doses. See Alston, *Lectures*, 2:565–67.
42 Cockburn, “Practice of Purging and Vomiting Medicines,” 47–48.
43 See Cockburn’s discussions of treating sailors in *Sea Diseases*, 76–79. Cockburn’s varied career indicates that “it is probably much too simple to divide turn-of-the-century physicians into theorists and experimenters, … or Newtonians and Baconians-Sydenhamians,” Cook, “Practical Medicine,” 21–22 n. 107.
44 On the reception of Galenic complexion in Latin Scholastic medicine, see Thorndike, “De Complexionibus”; Jacquart, “De crasis à complexio”; Ottosson, *Scholastic Medicine*, 120–200; Siraisi, *Medieval Medicine*, 101–4; Groebner, “Complexio/Complexion.”
45 Galen, *De complexionibus* 1. 6, ed. Durling, 30.
46 On the concept of latitude in medieval commentaries on Galen and Avicenna, see Kaye, *History of Balance*, ch. 4.
47 See, e.g., Nance, “Determining.”
48 Hollerbach, “Sanctorius Reconsidered,” ch. 3. On the vibrancy of Galenism in sixteenth- and seventeenth-century academic medicine, see Maclean, *Logic, Signs and Nature*.
49 Quoted in Castiglione, “Life and Work,” 773; see Hollerbach’s discussion of this letter in “Sanctorius Reconsidered,” 41–42.
50 On the history of insensible perspiration, see Renbourn, “Natural History.”
51 Quoted in Castiglione, “Life and Work,” 773; Sanctorius, *De statica medicina,* “Ad lectorem.”
52 Sanctorius, *De statica medicina*, aph. III, 2.
53 Ibid., aph. II, 2.
54 Sanctorius, *Commentaria in Artem medicinalem Galeni*, 117.
55 Home, *Medical Facts and Experiments*, 234–35.
56 James Keill, *Essays on Several Parts of the Animal Oeconomy*, Preface.
57 Lining, “Extracts of Two Letters,” 492; on Lining, see Dacome, “Living with the Chair,” 484–85.
58 Hollerbach, “Sanctorius Reconsidered,” 211.
59 Quincy, *Medicina Statica*, Preface, iii.
60 Ibid., Preface, vii.
61 Ibid.
62 Ibid; Dacome, “Living with the Chair,” 477–78.
63 Keill, *Essays on Several Parts of the Animal Oeconomy*, Preface.
64 Robinson, *Dissertation on the Food and Discharges of Human Bodies*, iii–iv and 11.
65 Ibid., 1 and 11.

66 Keill, *Essays on Several Parts of the Animal Oeconomy*, Preface.
67 On the change from internal *complexio* to external complexion over the course of the late fifteenth and early sixteenth century, see Groebner, "Complexio/Complexion."

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