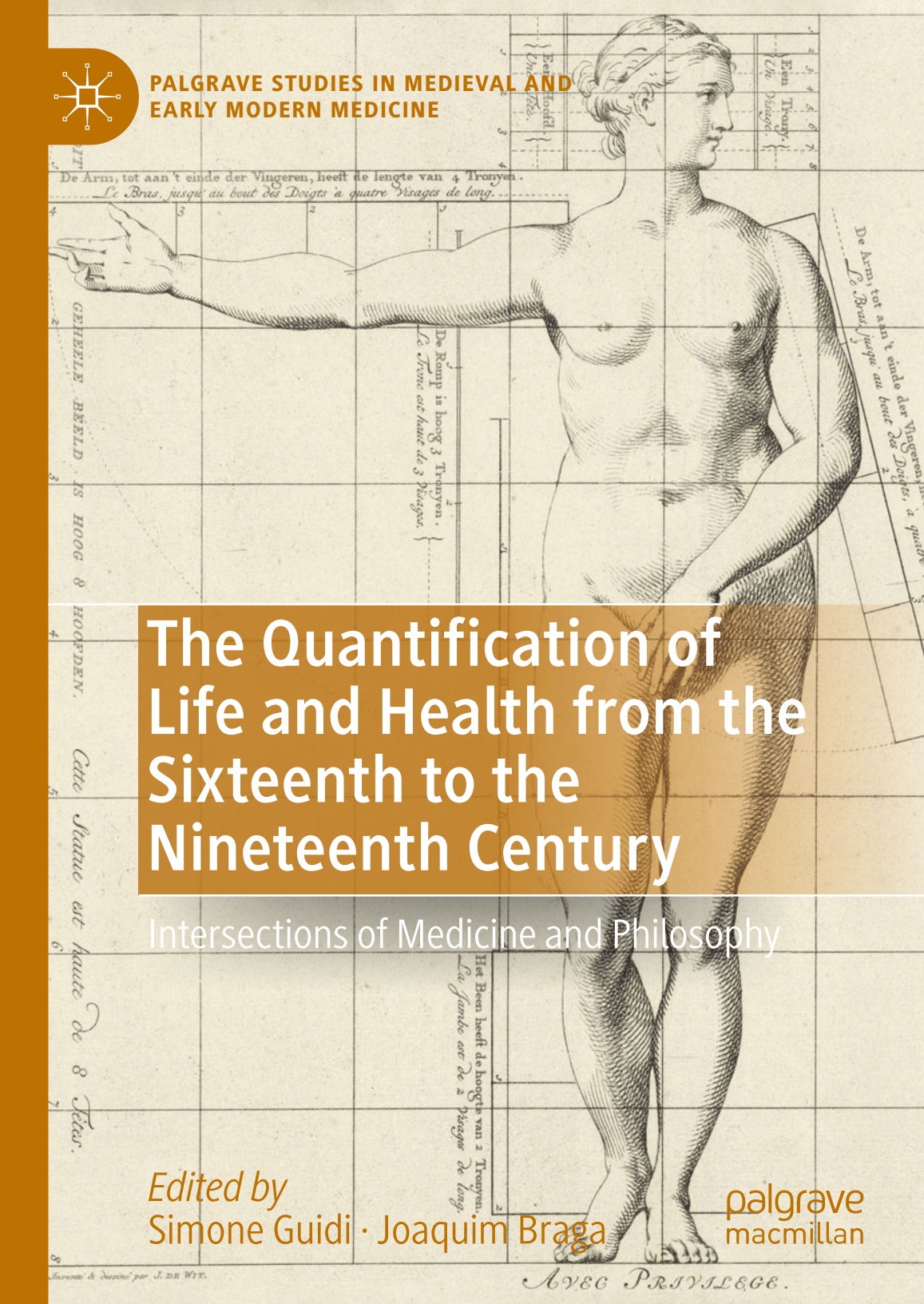

PALGRAVE STUDIES IN MEDIEVAL AND EARLY MODERN MEDICINE

The Quantification of Life and Health from the Sixteenth to the Nineteenth Century

Intersections of Medicine and Philosophy

Edited by
Simone Guidi · Joaquim Braga

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Editors

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Quali-quantitative Measurement in Francis Bacon's Medicine. Toward a New Branch of Mixed Mathematics

Silvia Manzo

1 Introduction

Different studies dedicated to re-examining the value and historiographical accuracy of the thesis of the mathematization of nature during the Scientific Revolution have held that mathematization acquired different forms throughout the history of science.[1] One of them is quantification, which, based on the work of Sophie Roux, we define as the capture in numerical form of certain aspects of material things, through measurements that are made with certain techniques, devices, and precise

[1] Sophie Roux, 'Forms of Mathematization (14th–17th Centuries)', *Early Science and Medicine*, 15, 4/5 (2010): 319–337; Geoffrey Gorham, Benjamin Hill, Edward Slowik, and C. Kenneth Waters, eds. 'Introduction', in *The Language of Nature: Reassessing the Mathematization of Natural Philosophy in the Seventeenth Century* (Minneapolis-London: University of Minnesota Press, 2016), 1–28.

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records.[2] As we shall see, Francis Bacon's (1561–1626) philosophy represents an early modern example that lies halfway between a purely qualitative and a tout court quantitative scientific outlook. Indeed, in his philosophy there is an experimental program that considers measurement as a key element to produce works useful to humans, that is, to transform nature through human intervention. This includes works aimed at the care of one's own body, the prevention and cure of diseases, and the prolongation of life.[3] However, not all variables that Bacon indicates should be measured are expressed through a metric and precise numbers.

In this chapter we will argue, firstly, that Bacon's engages in a peculiar form of mathematization of nature that develops a quali-quantitative methodology of measurement. Secondly, we will show that medicine is one of the disciplines where that dual way of measurement is practiced. In the first section of the chapter, we will expose the ontology involved in the Baconian proposal of measurement of nature. The second section will address the place that mixed mathematics occupies in Bacon's scheme of scientific branches and will suggest that a proper advancement of medicine can generate a new branch of mixed mathematics. The next section will reconstruct Bacon's approach to measurement and expose its quali-quantitative import. In the last section, we will show some examples of medicine in which this quali-quantitative measurement is applied.

[2] Roux, 'Forms of Mathematization (14th–17th Centuries)', 325. I agree with her approach that conceives mathematization in a wider sense embracing different forms and practices. Yves Gingras, 'What Did Mathematics Do to Physics?' *History of Science*, 39, 4 (2001): 383–416, 408 n10, distinguishes quantification (understood in terms similar as Roux) from mathematization (i.e., the writing of abstract geometric or algebraic formulations of physical phenomena).

[3] For studies on medicine in Bacon, see Helmut Minkowski, 'Einordnung, Wesen und Aufgaben der Heilkunst in dem Philosophisch-Naturwissenschaftlichen System des Francis Bacon: Zur Kenntnis der Beziehungen zwischen Medizin und Philosophie im 16. Und 17. Jahrhundert', *Sudhoffs Archiv für Geschichte der Medizin und der Naturwissenschaften* 27, 3/4 (1934): 299–327; Ian Box, 'Medicine and Medical Imagery in Bacon's "Great Instauration"', *Historical Réflections/Reflexions Historiques*, 16, 2/3 (1989): 351–365; Jeffrey Boss, 'The Medical Philosophy of Francis Bacon (1561–1626)', *Medical Hypotheses*, 4, 3 (1978): 208–220; Benedino Gemelli, 'Formation and Preservation of Life Between Speculation and Experiment in the Writings of F. Bacon', *Medicina nei secoli*, 15 (2003): 155–176; id, 'Francis Bacon: un riformatore del sapere tra filosofia e medicina', *Cronos. Cuadernos valencianos de Historia de la Medicina y de la Ciencia*, 7, 2 (2005): 227–275; Stephen Pender, 'Examples and Experience: On the Uncertainty of Medicine', *The British Journal for the History of Science*, 39, 1 (2006): 1–28. See also other studies cited in this chapter.

2 The Ontology of Measurement

Recent studies have insisted on the appetitive character of Baconian matter. This characterization is undoubtedly accurate and essential to understand both Baconian science in general and medicine as one of its branches.[4] However, there is another characteristic of Baconian matter that is fundamental and especially relevant to the analysis we will do in this chapter: its quantitative character.[5] What did Bacon think about quantity in nature in general? From an ontological point of view, *quantitas* is a form, the most abstract and separate from matter among all forms.[6] The conjunction of the conception of quantity plus the conception of matter entails that nature has variables that are measurable.

Throughout his various works, Bacon assumed and stated emphatically that the total amount of the material mass of the universe always remains the same. Once created by God, the total amount of matter did not increase or decrease. There is an appetite for self-preservation that accounts for this quantitative principle: the strongest appetite of every single particle of matter resists being annihilated. Since the 1590s, Bacon expressed certain intuitions regarding the distribution of matter in the cosmos and celestial movements according to the system of Alpetragius († ca1204). From there on, he was integrating throughout his different works ideas from different philosophical traditions that could complete all aspects and material levels of this world system. In this process, Bacon changed his mind regarding several questions, such as, for example, the nature of the causes to be investigated by natural philosophy, the atomic

[4] This interpretation of Baconian matter is found especially in Guido Giglioni, 'Mastering the Appetites of Matter. Francis Bacon's Sylva Sylvarum', in *The Body as Object and Instrument of Knowledge*, ed. by Charles T. Wolfe and Ofer Gal (Dordrecht: Springer, 2010).

[5] A monograph arguing for the quantitative aspect of Baconian matter is found in Silvia Manzo, *Entre el atomismo y la alquimia. La teoría de la materia de Francis Bacon* (Buenos Aires: Biblos, 2006). For specific points maintained in this section see Silvia Manzo, 'Holy Writ, Mythology, and the Foundations of Francis Bacon's Principle of the Constancy of Matter', *Early Science and Medicine*, 4, 2 (1999): 114–126; 'The Ethics of Motion: Self-Preservation, Preservation of the Whole, and the "Double Nature of the Good" in *Francis Bacon on Motion and Power*, ed. by Guido Giglioni, James Lancaster, Sorana Corneanu, and Dana Jalobeanu (Cham: Springer, 2016).

[6] Francis Bacon, 'De augmentis scientiarum', in *The Works of Francis Bacon*, ed. by James Spedding, Robert Leslie Ellis, and Douglas Denon Heath (London: Longman, 1867–1876), vol. I, 576–578.

constitution of matter, and the existence of the vacuum. However, despite these changes, the principle of the conservation of mass remained as an axis of unshakeable continuity both in the background and in the foreground of his conception of matter and nature.

Thus, again and again we find the categorical affirmation of the principle of constancy of the quantity of matter in different contexts: in the early *Cogitationes de natura rerum* (1604), in addition to his endorsement of the atomic hypothesis, he sketches his main ideas about matter and motion; in the allegorical works (*De sapientia veterum* (1609) and *De principiis atque originibus* (c. 1612?) where he presents the stages of the formation of the world through the myths of Coelum, Pan, and Cupid, and when he refers to the limits of the vexation of matter in experimentation through the figure of Proteus; in *Novum organum* (1620), regarding the classification of motion; in *Historia densi et rari* (1623), a work dedicated exclusively to the theme of the quantity of matter; in *Phaenomena universi* (1612), *Historia vitae et mortis* (1623), *Sylva Sylvarum* (1626), etc., when interpreting numerous experimental instances or establishing the provisional rules (*canones moviles*) obtained from natural history.

3 Mixed Mathematics, Physics, and Medicine

In the Baconian architecture of the sciences quantity is the object of mathematics, an appendix of natural philosophy that is divided into two kinds: pure mathematics and mixed mathematics. The first (composed of arithmetic and geometry) has as its object the abstract quantity, without any relation to matter. In turn, mixed mathematics considers quantity as it serves as an auxiliary to elucidate and prove the axioms of physics, and also to operate according to them. Mathematics is an inescapable tool for the success of science. Without its assistance, many parts of nature "can neither be invented with sufficient subtlety, nor demonstrated with sufficient perspicuity, nor accommodated to use with sufficient dexterity".[7]

Besides, the investigation of the extensions and motions of matter cannot be successfully applied to practice, without a prior quantitative inquiry of its different components. Consequently, the absence of a

[7] 'De augmentis scientiarum', in The Works of Francis Bacon, vol. I, 578; vol. IV, 431.

correct measurement generates sciences that perhaps will be "pretty as speculation, but fall flat in practice".[8]

Perspective, music, astronomy, cosmography, architecture, and machinery [*enginery*; *machinaria*] and "some other" belong to mixed mathematics.[9] Thus, Bacon integrates into the field of mixed mathematics the arts of the medieval quadrivium along with some of the mechanical arts of the Renaissance. However, he also believes that if research is conducted properly, scientific progress will make it possible for other branches of natural philosophy to take the form of mixed mathematics: "I predict that there will be more kinds of them [mixed mathematics], if men be not idle. For as physics advances farther and farther every day and develops new axioms, it will require new works [*opera nova*] from Mathematics in many things, and so the kinds of mixed mathematics will be more numerous".[10] We can assume that he believes that medicine will generate a new kind of mixed mathematics. This makes perfect sense because in the Baconian perspective medicine stands out for its great benefits in the material life of human beings, so that it is a discipline in which the instrumental aspect of mixed mathematics is very necessary. As Rees points out, the goal of prolonging life is the end of Baconian science as a whole. Medicine is the discipline in charge of fulfilling this objective, along with the objective of preserving health and curing diseases.[11]

It is noteworthy that this practical function seems to be the main reason why Bacon introduces mathematics into his scientific architecture.

[8] Francis Bacon, 'Novum organum', in *The Instauratio magna. Part 2: Novum organum and Associated Texts*, ed. by Graham Rees, and Maria Wakely, in *The Oxford Francis Bacon* (hereafter OFB) vol. XI, book 2, aphorism XLIV (Oxford: Clarendon Press, 2004), 366–367.

[9] 'De augmentis scientiarum', in *The Works of Francis Bacon*, vol. I, 578; vol. IV, 371.

[10] Ibid. (translation slightly modified). See Dana Jalobeanu, '"The Marriage of Physics with Mathematics"': Francis Bacon on 'Measurement, Mathematics, and the Construction of a Mathematical Physics' in *The Language of Nature: Reassessing the Mathematization of Natural Philosophy in the Seventeenth Century*, ed. by Geoffrey Gorham, Benjamin Hill, Edward Slowik, and C. Kenneth Waters (Minneapolis—London: University of Minnesota Press, 2016). Jalobeanu argues that the prospect of an increasing number of branches of mixed mathematics was held by other authors at Bacon's time. She points out the case of Thomas Digges, author of *A Geometrical Practical Treatise Named Pantometria* (1571). For another interpretation of Bacon's mathematics see Giuliano Mori, 'Mathematical Subtleties and Scientific Knowledge: Francis Bacon and Mathematics, at the Crossing of Two Traditions', *The British Journal for the History of Science*, 50, 1 (2017): 1–21.

[11] Graham Rees, 'Introduction', in OFB, vol. VI, lxi–lxix.

He acknowledges the existence of precedents in this regard, expressly attributing to Aristotle the very idea that the union between "Physics and Mathematics produces Practice or Mechanics".[12] This attitude is in line with the tradition of mixed sciences and was a widespread position in the late sixteenth and early seventeenth centuries, in which a relationship is established between mathematics, mechanics, and practical utility.[13] The correct measurement of bodies and virtues becomes, therefore, a fundamental precept: "every thing to do with natural phenomena, be they bodies or virtues, should (as far as possible) be set down, counted, weighed, measured and defined. For we are after works not speculations, and, indeed, a good marriage of Physics and Mathematics begets Practice".[14] This product of the union of physics and mathematics is called "mechanics", which in Bacon's scheme is nothing but a form of "operational physics".[15] Physics is a part of natural philosophy, which investigates the efficient and material causes through the schematisms and latent processes of bodies (imperceptible configurations and motions of the microscopic particles of macroscopic bodies). By introducing measurements and calculations, mathematics has an instrumental value in permitting the low-level axioms discovered by physics to be translated into practical effects manipulating nature for human benefit. In this way, the measurement of nature's variables is not a secondary byproduct

[12] 'De augmentis scientiarum', in *The Works of Francis Bacon*, vol. I, 576; vol. IV, 369. It has already been noted since Ellis' edition, that here Bacon alludes to the Pseudo-Aristotelian. *Quaestiones mechanicae*, a work that circulated widely in Europe during the sixteenth and seventeenth centuries. On the early modern reception of this work see Paul Lawrence Rose and Stillman Drake, 'The Pseudo-Aristotelian Questions of Mechanics in Renaissance Culture', *Studies in the Renaissance* 18 (1971): 65–104; Joyce Van Leuween, *The Aristotelian Mechanics: Text and Diagrams*, chapter 6 (Cham: Springer, 2016).

[13] Gingras, 'What Did Mathematics Do to Physics?', 384; Jalobeanu, 'The Marriage of Physics with Mathematics', 55–60.

[14] Francis Bacon, 'Parasceve ad historiam naturalem', in OFB, vol. XI, 464–465; cf. 'Novum organum', in OFB, vol. XI, book 2, aphorism viii, 212–213.

[15] Sophie Weeks, 'The Role of Mechanics in Francis Bacon's Great Instauration', in *Philosophies of Technology: Francis Bacon and his Contemporaries*, 2 vols., ed. by Claus Zittel, Romano Nanni, Gisela Engel, and Nicole Karafyllis (Leiden: Brill, 2008), 176. She offers a very valuable interpretation of Bacon's mechanics in terms of "operative physics". However, she undervalues the importance of the role that mathematics plays in it. On the contrary, Cesare Pastorino, 'Weighing Experience: Experimental Histories and Francis Bacon's Quantitative Program', *Early Science and Medicine*, 16, 6 (2011): 542–570, notes the connection to mixed mathematics and underlines the operative role of measurement.

of the project of the restoration of learning, but a fundamental requirement to realize one of its most distinctive goals: the transformation of nature through human power for the well-being of human beings.

4 The Quali-quantitative Approach to Measurement

In different works, Bacon postulates a classification of "measures" (*mensurae*). They intend to measure different variables of what we would call "properties" of bodies and that Bacon calls motions (*motus*), forces (*vires*), and actions (*actiones*) of bodies. Already in the early *Valerius terminus* (1603), he regretted that "the calculating and ordination of the true degrees, moments, limits, and laws of motions and alterations (by means whereof all works and effects are produced)" had never been properly put into practice.[16] Later, in *Novum organum* the *mensurae* of motions are presented as "Mathematical Instances" and "Instances of Measure" (*Instantiae Mathematicae, Instantiae Mensurae*), which belong to a group of instances specifically useful for operation, namely "Practical Instances" (*Instantiae Practicae*).[17] In *Abbecedarium novum naturae* (1622) they are simply called "mathematics, or measures and scales of motions"[18] and in *De augmentis scientiarum* (1623) they are presented, like mathematics, as "appendix to [abstract] physics or measures of motions [*mensurae motus*]".[19]

Bacon argues that the motions of the universe at its various levels of complexity are nothing more than manifestations of the appetites of bodies, that is, desires or rejections of the inner parts of bodies with respect to other internal or external material units. Sometimes, the different types of tangible or pneumatic matter that reside within the same body have appetites opposed to each other; at other times, they oppose the appetites of the surrounding bodies. In this field of struggle between

[16] Francis Bacon, 'Valerius terminus', in *The Works of Francis Bacon*, vol. III, 243–244.

[17] 'Novum Organum', in OFB, vol., XI, book 2, aphorism xliv, 366–699.

[18] Francis Bacon, 'Abecedarium novum naturae', in *The Instauratio magna. Last Writing*, ed. by Graham Rees, in *The Oxford Francis Bacon*, vol. XIII (Oxford: Clarendon Press, 2000), 210–211.

[19] 'De augmentis scientiarum', in *The Works of Francis Bacon*, vol. I, 516; vol. IV, 357.

the appetites, different variables intervene in which motions are "circumscribed and measured": space (*Mensura Spatij* or *Instantiae Virgae*); time (*Instantiae Curriculli* or *Mensura Temporis*); quantity (*Instantiae Quanti sive Doses Naturae*, or *Mensura Quanti*); the degree of bonding of the inner parts of bodies (*Mensura Vinculi*); and the ascendancy of virtues over each other or their submission to each other (*Instantiae Luctae*). This last variable unfolds as follows in some classifications: on the one hand, the determination of the strength (*Mensura Fortitudinis/Vis aut Hebetudinis Rei*) of one motion with respect to others; on the other hand, the circumstances that cause the diminution or augmentation of the strength of the same motion by virtue of the friendly or enemy bodies that surround it (*Mensura Peristaeos/Stimulus Peristaeos*).[20]

Precision is considered fundamental for measurement to fulfill its instrumental purposes. Certainly, in most cases operations fail due to the "inaccurate determination and measurement of the forces [*vires*] and actions [*actiones*] of bodies".[21] Bacon regrets that in previous natural histories "we find nothing (…) duly examined, verified, counted, weighed and measured".[22] If motions are not "well counted and weighed and defined, the doctrine of motions, may falter and not be reliably translated into practice".[23] Measures "should be sought from the things themselves and not from likelihoods or conjectures".[24] This entails that the measurements of time, space, and quantity should be expressed numerically, with precision, and through a metric. No doubt, Bacon is engaged

[20] There are three systematic presentations of the different kinds of measures which appear in 'Novum organum', in OFB, vol. XI, book 2, aphorism xlv–xlviii, 368–417; 'Abecedarium novum naturae', in OFB, vol. XIII, 210–215; 'De augmentis scientiarum', in *The Works of Francis Bacon*, vol. I, 561. Besides slight linguistic variations, some conceptual differences between them are to be found. While the measures of time, space, and quantity appear in all three works, the measure of ascendancy presented in *Novum organum*, becomes unfolded into a measure of strength and a measure of surrounding circumstances (*peristaseos*) in *Abecedarium novum naturae* and *De augmentis scientiarum*. In addition, in *Abecedarium* a measure is added that is not in the other two, namely the measure of bonding.

[21] 'Novum organum', in OFB, vol. XI, book 2, aphorism xliv, 366–699: "male determinatas and mensuratas Corporum vires and actiones."

[22] 'Novum organum', in OFB, vol. XI, book 1, aphorism xcviii, 156–157.

[23] 'Abecedarium novum naturae', in OFB, vol., XIII, 110–111.

[24] 'Novum organum', in OFB, vol. XI, 382–383; cf. 'De augmentis scientiarum', in *The Works of Francis Bacon*, vol. I, 625.

in obtaining measurements of increasing precision. Accurate and definite calculations—whenever possible—must be produced. However, when the highest accuracy is not possible, rough estimates must be admitted, provided that they are precise enough to the goals of the investigation:[25] "where precise proportions are not available to us we must for sure fall back on rough estimates and comparisons".[26] A case in point is the calculation of "the abundance or paucity of the matter contained and spread out within the same space" (in other words, density and rarity). Bacon notices that the density and the rarity of different bodies can be "reduced to calculation": in some bodies, they can be reduced to "precise and certain" proportions; in others, to "indefinite proportions".[27]

In contrast, Bacon does not engage in the numerical and precise recordings of the other measurements. Regarding the ascendancy or submission of motions, their strength, and *peristasis,* he only proposes qualitative estimates.[28] In so doing, the general background is the goal to which each appetite and motion tends. Accordingly, he places them in a hierarchy according to certain rules that govern not only the natural order, but also the ethical and political order. The most general rule states that in nature those appetites and motions whose goal is the greatest good for the greatest amount will predominate.[29]

Something that is striking to contemporary eyes is that Bacon places these numerical measurements of time, space, and quantity of matter on the same level and hand in hand with the qualitative measurement of strength, ascendancy, or *peristasis*. Everything indicates that, while maintaining that these variables must be calculated and measured, he is not thinking of providing numerical values, but of roughly determining whether a motion is more or less "strong" than others, has more or less "vigor" than others. Since his theory of motion ultimately reduces all kinds of motion, even local motion, to the appetites of matter, it would

[25] In this interpretation, I follow Jalobeanu, 'The Marriage of Physics with Mathematics', 65–68. For a study noticing the value of precision in Baconian measurement, see Pastorino, 'Weighing Experience'.

[26] 'Parasceve', in OFB, vol. XI, 467.

[27] Francis Bacon, 'Phænomena universi', in OFB, vol. VI, 11.

[28] We can say little about the measure of bonding, since, as noted above, his presentation is too brief.

[29] On this this rule and its implications in nature and ethics, see Manzo, 'The Ethics of Motion'.

not come as a surprise that this peculiar way of measuring motions has a qualitative meaning.

If by a quantitative model of science, we conceive that the magnitudes contained in a scientific proposition must be able to be expressed exactly or approximately only under numerical expressions according to a given metric unit, it is obvious that Bacon did not apply this model universally for all the variables involved in his account of body properties. Regarding the measure of the quantity of matter, space, and time, Bacon's proposal tends to a quantitative model. In fact, he himself developed a method to measure specific gravities and constructed tables with defined values of different substances, after having compared the results obtained empirically.[30] Also in cases where he proposes to measure time and space, he does so with the intention of assigning precise numerical expressions to variables, although in practice—as we will see—he does not always apply the maximum degree of precision.We know that his method for the determination of specific gravities was objected by his lack of mathematical and experimental skills. However, this does not override the quantitative approach recognizable in his classification of the *mensurae* and in his own scientific practice, manifested not only in his much-studied research about specific gravities, but also in his investigations on a medical matter, that we will consider in the next section.

Thus, the Baconian mixed mathematics develops a methodology of quali-quantitative measurement, which is perfectly compatible with the double character of matter mentioned above. Precisely because matter has appetites, and a constant amount that determines certain limits to transmutations, two forms of measuring nature coexist: a qualitative form—which notes the dynamics and tension between material appetites—and a quantitative form—which registers the quantity of matter, time, and space. This dual characteristic of both ontology and methodology is an important element to bear in mind when reconstructing the peculiar form of mathematization of nature proposed in Bacon's project of the reform

[30] See Pastorino, 'Weighing Experience', 55–62; Jalobeanu, 'The Marriage of Physics with Mathematics', 66–68.

of learning.[31] In the next section, we will see that medicine was a field in which Bacon applied this dual methodology for measurement.

5 Quali-Quantitative Measures in Medicine: Some Examples

5.1 General Quantitative Registers

In Bacon's medicine there are references to certain quantitative registers, such as pulse and body temperature, that are taken as symptoms for the detection of diseases and were part of the usual practices of his time. The pulse belongs to the "Summonsing Instances" (*Instantiae Citantes*) that "reduce the imperceptible to the perceptible". On the one hand, pulse is said to tell us about the condition of the human body, for it makes perceptible what lies "hidden by bodies in between, and which cannot be conveniently opened up".[32] The pulse speed, in fact, varies with age: young people have a strong and rapid pulse, while the elder have a fainter

[31] As Pastorino, 'Weighing Experience', 562–569, noticed, the importance given by Bacon to quantification and mathematics has been underestimated for a long time by scholarly studies. This reading was greatly influenced by the Kuhnian distinction into classical mathematical sciences and Baconian experimental sciences (Thomas S. Kuhn, 'Mathematical vs. Experimental Traditions in the Development of Physical Science', *Journal of Interdisciplinary History*, 7 (1976): 1–31). However, already in the 60's Mary Hesse, 'The Philosophy of Francis Bacon', in *A Critical History of Western Philosophy*, ed. by Daniel O'Connor (New York: The Free Press, 1964), argued that Bacon did not oppose radically to the use of mathematics in his project of reform of learning. Graham Rees' works, 'Quantitative Reasoning in Francis Bacon's Natural Philosophy', *News from the Republic of Letters*, 2 (1985): 32–33; 'Mathematics and Francis Bacon's Natural Philosophy', *Revue Internationale de philosophie*, 40, 159/4 (1986): 399–426 were pioneer in noticing that Bacon proposes an extensive quantitative research program and advocates the expansion of mixed mathematics (nevertheless, Rees argued that Bacon's cosmological model is qualitative, in 'Mathematics and Francis Bacon's Natural Philosophy', 418–421). Pastorino, 'Weighing Experience', showed that Bacon proposes a program of data quantification that could serve as a preliminary to the development of mixed mathematics. Jalobeanu, 'The Marriage of Physics with Mathematics', offered new arguments in favor of the existence of a mathematical research program in Bacon.

[32] 'Novum organum', in OFB, vol. XI, book 2 aphorism xl, 346–347.

and slower one.[33] In addition, it indicates not only the physical condition but also the emotions of the individual.[34]

As for the body temperature, we find only a few mentions of fever as a symptom. Bacon interprets the "burning fevers" as a sign that the heat of putrefied humor had overcome the native heat of the body to the point of extinguishing or dissipating it.[35] That notwithstanding, Bacon pays special attention to the relationship between life, age, and heat. He holds that "Heat is requisite to Growth: But after a Man is come to his Middle Age, Heat consumeth the Spirits".[36] Hence, he concludes that, to prolong life, it is necessary to contain that consumption by means of cold.[37] Since cold is hardly found in nature, opiates and niter serve as its succedanea: they prevent consumption by condensing the vital spirits.[38] Bacon proposes to investigate the different heats in different parts and members of the same animal and complains that no one has investigated "what degree of heat exists in the brain, the stomach, heart and other

[33] Francis Bacon, 'Historia Vitae & Mortis', in *The Instauratio magna Part III. Historia Naturalis and Historia Vitae*, ed. by Graham Rees, and Maria Wakely, in *The Oxford Francis Bacon* vol. XII (Oxford: Clarendon Press, 200), 342–343.

[34] Francis Bacon, 'Sylva sylvarum', in *The Works of Francis Bacon*, vol. II, Ex. 97, 380: "we see the affects and passions of the heart and spirits are notably disclosed by the pulse".

[35] 'Historia Vitae & Mortis', in OFB, vol. XII, 332–333. For more references to fever see pages 249, 55.

[36] 'Sylva sylvarum', in *The Works of Francis Bacon*, vol. II, Ex. 354, 458–459.

[37] Bacon's theory of the prolongation of life—that discusses Renaissance theories, among others Cornaro's—engages in a quantitative approach. Notably, he states: "age is nothing in itself (it is after all only a measure of time)" ('Historia Vitae & Mortis', in OFB, vol. XII, 164–165). Since the topic of longevity and prolongation of life has been already addressed by some scholars, I have preferred to focus my analysis on other aspects of Baconian medicine. See Giglioni, 'The Hidden Life of Matter: Techniques for Prolonging Life in the Writings of Francis Bacon'; Roger Marcus Jackson, 'The Prolongation of Life in Early Modern English Literature and Culture, with Emphasis on Francis Bacon', PhD Dissertation, University of North Carolina at Chapel Hill, 2010; Luciana Zaterka, 'Francis Bacon e a questão da longevidade humana', *Scientiae Studia*, 13, 3 (2015): 495–517; Marta Fattori, 'Prolongatio Vitae and Euthanasia in Francis Bacon', in *Francis Bacon on Motion and Power*, ed. by Guido Giglioni, James Lancaster; Sorana Corneanu, and Dana Jalobeanu (Cham: Springer, 2016).

[38] Bacon recommends the procedure of apothecaries, "who, when they do not have the appropriate simple, take its succedaneum". See 'Novum organum', OFB XI, book 2, aphorism i, 428–429. About niter and opiates, see 'Historia Vitae & Mortis', in OFB, vol. XII, 246–262.

organs".[39] Besides, he measures the activity of the body members by their heat, assuming that it diminishes with age.[40]

An important background against which Bacon discusses the variations of body's temperature across age is the theory of radical moisture, whose origins date back to Galenic medicine. Interestingly, Bacon's strictures on this theory include a quantitative concern. As Jackson has remarked:

> "He finds it 'very difficult to believe' that the same puny amount of primigenial moisture "which can only spread out but not increase in quantity" can come to occupy "a body in as great a diversity of mass as may between a tiny child and an adult". That a tiny bit of radical moisture can suffuse an animal's entire body is hard to swallow".[41]

The introduction of quantitative variables is most noticeable in Bacon's therapeutics.[42] We will focus on the case of purgatives.[43] Contrary to readings that held that their effects are derived from "a hidden propriety, a specifical virtue, and a fourth quality",[44] Bacon states that their true

[39] 'Novum organum', in OFB, vol. XI, book 2, aphorism xiii, 241.

[40] 'Historia Vitae & Mortis', in OFB, vol. XII, 316–317.

[41] Jackson, 'The Prolongation of Life', 163. He quotes Francis Bacon, 'De vijs mortis', in *Philosophical Studies*, ed. by Graham Rees, in OFB VI (Oxford: Clarendon Press, 1996), 270–273; cf. 'Historia Vitae & Mortis', in OFB, vol. XII, 144–146; 342. The quantitative aspect of Bacon's criticism of radical moisture is conjoined with qualitative aspects. See, for instance, the following passage: "For in animals all things are completely repaired while they are growing up and still youthful; indeed for a time they increase in size and improve in quality [*Quantitate augentur, Qualitate meliorantur*], so that the matter of repair could be practically everlasting, if the means of repair did not break down" ('Historia Vitae & Mortis', in OFB, vol. XII, 146–147). A detailed analysis of Bacon's confutation of the radical moisture is beyond the scope of this article. For an excellent historical study of the evolution of the theory of radical moisture and Bacon's stance, see Jackson, 'The Prolongation of Life', 158–168.

[42] According to Richard Shryock, 'The History of Quantification in Medical Science', *Isis*, 52, 2 (1961): 215–237, the quantitative approach of therapeutics was a common practice from ancient medicine on.

[43] For an exposition on purgatives of one source with which Bacon was probably familiar, see Jean Fernel, 'Therapeutices Universalis [Methodi Medendi]', in *Universa Medicina*, book III, *De purgandi ratione* (Paris: Andreas Welchem, 1567). Bacon mentions critically Fernel in 'Temporis partus masculus', in *The Works of Francis Bacon*, vol. III, 531.

[44] In describing this property as "fourth quality" Bacon alludes to the medical tradition that distinguished a kind of scale of qualities, namely, *qualitates primas, secundas, tertias*

causes can be easily known through experience. He lists a number of processes that can happen in the internal parts of the human body by ingestion or topical application of purgatives: "expulsion" of substances by vomits, diarrhea, etc., when the stomach is overloaded; "mordication" (that is, corrosion) of orifices of body parts, especially the mesentery veins; "attraction" of humors; "flatulency" caused by the spirits of the purgative; "compression or crushing" out of purulent matter, etc.; "lubrifaction and relaxation" of the stomach and "abstersion" or scouring the more viscous humors.[45] In explaining these processes carried out by the purgatives, Bacon appeals to the different kinds of measurements mentioned in the previous section. We will have a look at each of them.

5.2 *Mensura Quanti*

Bacon points out that a "great" quantity of purgative is needed to bring about the expulsion by vomits, diarrhea, etc.: "As we see in a great quantity of new milk from the cow; yea and a great quantity of meat; for surfeits many times turn to purges, both upwards, and downwards".[46] Again, several medicines "in greater quantity move stool, and in smaller quantity urine".[47] These cases are examples of the *mensura quanti* or *doses naturae*, which measures "virtues according to the Quantum of

et quartas. According to the Leuven professor of medicine Fortunatus Plempius, some physicians called the "occult" qualities "qualitates quartas". A case in point is the purgative property: "Quartas denique ajunt esse, quae effectus edunt abdita & imperceptibili quadam ratione: ut *purgatrices facultates*." Vopiscus Fortunatus Plempius, *Fundamenta medicinae*, book II, chapter 3 (Leuven: H. Nempaeus, 1654), 39 (italics in the original). Keith Hutchison, 'What Happened to Occult Qualities in the Scientific Revolution?', *Isis*, 73, 2 (1982): 233–253, pointed out that in "Renaissance science 'occult' qualities were commonly characterized as insensible, as opposed to 'manifest' qualities, which were directly perceived", 233. Bacon criticizes the distinction into manifest and occult qualities. See, for instance, in 'Novum Organum', in OFB, vol. XI, book 1, aphorism lxvi, 104–105.

[45] The most detailed exposition on purgatives is to be found in 'Sylva sylvarum', Ex. 36–44, in *the Works of Francis Bacon*, vol. II, 355–358. When possible, I had modernized Bacon's medical terminology in this passage.

[46] 'Sylva sylvarum', ex. 36, in *The Works of Francis Bacon*, vol. II, 355.

[47] Ibid., ex. 44, 358. We see a similar idea in Fernel, *Therapeutices*, liber III, cap. X, 397: "Sua autem est & definita cuiusque quantitas, qua id conuenientem atque moderatum purgationis modum praestare solet (…). Quantitatem vel augere vel minuere pro purgandi facilitate difficultateve cogimur."

bodies, and show what the Quantum of a Body does to influence the Mode of the Virtue". Every inquiry must note the "dose" of the body needed to produce a given effect, and "add a guidance concerning Too Much and Too Little".[48]

Certainly, this example does not show a precise numerical quantification. In contrast, in his personal pharmacopoeia, collected in the text known as *Medical remains,* are found in precise amounts.[49] There Bacon collects a series of recipes indicating precise doses of different medicines, the exact amount of the ingredients required for their preparation, intervals and hour to take the medicine, etc. We also find further indications for corporeal self-care, including diets, exercises, baths, etc. Regarding purgatives, for example, there is a recipe "to open the liver":

> Take rhubarb two drams, agaric trochiscat one dram and a half, steep them in claret wine burnt with mace; take of wormwood one dram, steep it with the rest, and make a mass of pills with *syrup acetos* simplex. But drink an opening broth before it, with succory, fennel, and smallage roots, and a little of an onion.[50]

It is not by chance that the first two "provisory rules" (*canones moviles*) of *Historia vitae & mortis* refer to the quantity of matter and the weight variations resulting from internal bodily processes, imperceptible to the naked eye. The first provisory rule expresses the principle of the constancy of the quantity of matter in the specific case of the human body: "Consumption does not happen unless what is lost from one body takes up

[48] 'Novum organum', in OFB, vol. XI, book II, aphorism, xcvii, 380–383; 'De augmentis scientiarum', in *The Works of Francis Bacon*, vol. I, 576; 'Abecedarium novum naturae', in OFB, vol. XIII, 210–211. Bacon says that he takes from medicine the label "doses naturae". This label was common in the pharmacological literature of his time, such as the *Antidotarium* by Johannes Wecker (Basle, 1588), which is conjectured to be one of the sources consulted by Bacon. See Spedding ('Historia Vitae & Mortis', in *The Works of Francis Bacon*, vol. II, 155) and Rees ('Historia Vitae & Mortis', in OFB, vol. XII, 440). "Much and little" are introduced as "common adiuncts of things" in Francis Bacon, 'The Advancement of Learning', in OFB, ed. by Michael Kiernan, vol. IV (Oxford: Clarendon Press, 2000), 76–77; 'De augmentis scientiarum', in *The Works of Francis Bacon*, vol. I, 543–544; 'Abecedarium novum naturae', in OFB, vol. XIII, 216–219.

[49] It is conjectured that this text was composed around 1623, or after that date.

[50] Francis Bacon, 'Medical remains', in *The Works of Francis Bacon*, vol. III, 827. Cf. 'Historia Vitae & Mortis', in OFB, vol. XII, 298.

residence in another".[51] This rule is later explained by stating that things are never destroyed and that whatever is consumed either escapes into the air or is absorbed by some other body nearby.

Let's see how this quantitative statement intervenes in the explanation of the physical process involved in the medical use of cupping glasses. Bacon rejects the explanation that, due to the heat of the cupping glass applied on the skin, the air inside rarifies and escapes through the pores of the glass, thereby reducing its amount. From this assumption, the suction of flesh was said to be brought about by the reduction of the air's quantity. And this would happen on account of matter's appetite of connection ("motion of connection") by which bodies do not put up with being separated from another body, rejoice in mutual connection, and avoid a vacuum. While Bacon fully endorses the existence of the appetite of connection, he points out that the suction does not occur by the escape of rarefied air, but by the air's contraction once it has been cooled down. As the air occupies less space, the flesh is suctioned by the appetite of connection.[52] Notably, this case clearly shows the quali-quantitative approach, by conjoining quantitative (changes in space, matter's quantity, temperature) with qualitative variables (material appetite of connection).

The second provisory rule of *Historia vitae & mortis* resorts to a quantitative measurement, the weight, as an outstanding way to interpret the internal changes of the pneumatic matter inside tangible bodies. By an operation called "attenuation", spirits enclosed in tangible bodies destroy the tangible parts, and "preyed on the moisture of the body and whatever else it could digest into new spirit; after which the pre-existing and new-made spirit gradually escape together". These internal changes in bodies are not directly perceived, but they can be "reduced to the senses", and can be proved or demonstrated ("Hoc ex probatione ea, instar omnium, euincitur") by registering weight changes: "We see this very well in the weight loss of bodies dried out by perspiration. For whatsoever is given out it was not spirit when it had weight, nor was it other than spirit when

[51] 'Historia Vitae & Mortis', in OFB, vol. XII, 346–347.

[52] 'Novum organum', in OFB XI, book 2, aphorism i, 422–423; cf. 'De vijs mortis', in OFB, vol. VI, 348–350. For Bacon definition of the motion of connection see 'Novum organum', in OFB, vol. XI, book 2, aphorism xlviii, 382–383.

it escaped".[53] Furthermore, Bacon points out that it is necessary to evaluate whether and to what extent variations of quantity entail variations of degree in the body's properties (variations of quality): "Now we must not dwell on indefinite quantities but we must also look into the Relationship of the Quantity of a body to the mode of its virtue".[54]

5.3 *Mensura Temporis*

The case of rhubarb leads us to another relevant variable of medical measurement: time. Rhubarb has several internal particles with opposed medicinal properties: some of them are purgatives, while others are astringents. Which of these properties will predominate in medical treatment? It depends on the duration of the infusion of the rhubarb in water. If the infusion lasts only one hour, then its purgative power will be more powerful and the astringent effect will be mild. In contrast, if the infusion lasts twenty-four hours its purgative effect will be less intense.[55] In addition, Bacon draws attention to the lapse of time required in order to obtain the intended effects in the human body: "generally (…) the working of purging medicines cometh two or three hours after the medicines taken".[56] These cases are obvious examples of what Bacon calls *mensura temporis,* that measures nature by moments of time. For "every natural motion or action takes place in time –some more quickly, others more slowly– but, at all events, in definite [*certis*] intervals which are known to nature". In addition, the measure of time involves an estimation of the "intervals in which the beginnings, ends, returns, or periods and so on of motions happen".[57]

[53] 'Historia Vitae & Mortis', in OFB, vol. XII, 346–349; cf. ib. 172–174.

[54] 'Novum organum', in OFB, vol. XI, 382–383; cf. 'De augmentis scientiarum', in *The Works of Francis Bacon*, vol. I, 625. See for instance, Francis Bacon, 'Historia ventorum', in OFB, vol. XII, 72–75: "In vapours quantity [*copia*] and quality [*qualitas*] are significant. A small quantity produces gentle breezes; a moderate quantity stronger ones, and a large quantity burdens the air and produces rains either with or without winds."

[55] 'Novum organum', in OFB, vol. XI, book 2, aphorism xlvi, 380–381; Francis Bacon, 'Sylva sylvarum', ex.19, in *The Works of Francis Bacon*, vol. II, 345; cf. ib. ex. 98, 381.

[56] 'Sylva sylvarum', ex. 36, in *The Works of Francis Bacon*, vol. II, 355–356.

[57] 'Novum organum', in OFB, vol. XI, book 2, aphorism xlvi, 374–375. Cf. 'Abecedarium novum naturae', in OFB, vol. XIII, 212–213.

5.4 Mensura Spatii

Like time, space also plays a role in medicine. The measure of space is related to the "orb of virtue" *(orbis virtutis)*, namely, the "distance which the forces [*vires*] of bodies may travel to, stop at, build up to and die down from. Whether the operation occurs by contact alone, or at a [greater or] lesser distance, whether it be not excited well over the shortest distances, or slacken off over the longest, and the like".[58] These distances have "degrees" (*gradus spatiii*) which are "neither indefinite nor random, but definite and certain". It should be added that the limits of the extent of virtue may be a consequence of the quantity of matter, the intensity of the virtue, or the conditions imposed by the medium. All these factors must also be subjected to calculations when determining the specific limits of each property in several circumstances.[59]

Again, the use of purgatives provides examples of the measurement of this variable. Some purgatives act at a distance, as they draw humors down from above when they are at a certain distance from them. In contrast, other medicines, like ointments and plasters, produce therapeutic effects through direct contact with the epidermis.[60] Another interesting example of the measurement of space in a medical context is observed in the functioning of the sense organs. In perception the need for distance varies depending on the sense organ and the perceived object. Generally, Bacon claims, in hearing the closer the source of sound, the better the reception in the ear, while in vision a certain distance between the eye and the object to be seen is necessary.[61] However, the ear also requires some distance, as "the Caue of the Eare doth hold off the Sound a little from the Organ".[62] In turn, the eye needs light and a medium to perceive, so that it cannot see an object that is in direct contact with it. Larger bodies can be seen accurately "at the point of a cone, when the rays of an object converge at

[58] 'Abecedarium novum naturae', in OFB, vol. XIII, 210–213 (translation slightly modified).

[59] 'Novum organum', in OFB, vol. XI, book 2, aphorism xlv, 368–369; aphorism xlvi, 374–375.

[60] Ibid.; cf. 'Sylva sylvarum', ex. 38 in *The Works of Francis Bacon*, vol. II, 356.

[61] 'Novum organum', in OFB, vol. XI, aphorism xlv, 370–373; *Sylva Sylvarum*, in *The Works of Francis Bacon*, vol. II, ex. 272, 431.

[62] 'Sylva sylvarum', ex. 272, in *The Works of Francis Bacon*, vol. II, 431.

some distance".[63] However, in certain very exceptional circumstances, a tiny object can be seen by contact and Bacon's explanation appeals to the difference between the pupil size and object size. Bacon also notes the distance needed to see tiny objects increases, especially at advanced age.

5.5 *Mensura Fortitudinis, Mensura Peristaseos*

Finally, in purgatives we also find qualitative measurements, which, of course, articulate with quantitative ones. Let's look at examples of the measurement of the strength of a motion (or appetite) as compared to others. Vomits or diarrhea (i.e., different sorts of "expulsion") are brought about either "by the quality" or "by the quantity" of the purgative used in the medical treatment. The qualities might be (a) extreme bitterness, (b) loathsome and horrible taste, and (c) "secret malignity and disagreement towards man's body not appearing much in the taste". Moreover, Bacon adds that, if a substance has only the quality (c) and neither of the other two qualities (a and b), it acts by corrosion or "by a secret malignity and enmity to nature". Hence, that substance "is to be held suspected as a kind of poison".[64] Notably, terms like "disagreement", "enmity", etc., suggest a conflict between the material appetites of the purgative and those of the human body. The "strongest" appetites involved in such conflict will prevail over the weaker ones.

A case of *mensura peristaseos* is found in Bacon's considerations about purgatives working by attraction. He claims that purgatives have a "direct force of attraction" by which they draw several humors of the human body. But different purgatives attract differently; some purgatives draw one humor more, some another. The difference lies in the "sympathy" existing between the purgative and the respective humor: while rhubarb draws choler, agaric draws phlegm.[65] The sympathy between the members of each pair enforces the attraction exerted by the purgative. This is precisely what peristasis consists of according to Bacon's typology. Many medical examples are found, where therapeutic effects are explained in terms of sympathy and antipathy exerted in herbal medicines, diets,

[63] 'Novum organum', in OFB, vol. XI, book 2, aphorism xlv, 370–373; Sylva Sylvarum, in *The Works of Francis Bacon*, vol. II, ex. 272, 431.

[64] 'Sylva sylvarum', ex. 36, in *The Works of Francis Bacon*, vol. II, 355.

[65] Ibid., ex. 38, vol. II, 356.

ointments, stones, bracelets, etc.[66] As he says in the introduction to the natural history of sympathy or antipathy: "Fight and amity in nature are stimuli of motions and keys of works".[67]

To conclude this section, it is worth citing the following passage from *De viis mortis* which exhibits the quali-quantitative approach informing Bacon's medicine:

> The vigour and quality [*qualitas*] of a Spirit is no less important than its quantity [*ipsum quantum*], for whenever we find a sharp and impetuous spirit in any thing and if it is nevertheless mingled with the thing sparingly in a scanty and meagre quantity [*quantitate*], the action it performs is weak.[68]

6 Conclusion

In this chapter we have shown that the form of mathematization promoted by Francis Bacon's project of the reform of learning is committed to the creation of new branches of mixed mathematics, whose main task is to build a bridge between the axioms reached by the theoretical part of science and the practical application of that knowledge. We maintain that medicine, noted for its great usefulness in promoting the physical well-being of the human being, is one of the scientific branches with special potential to generate its own branch of mixed mathematics.

We have further argued that while the key to mixed mathematics is measurement, it is not limited to exclusively quantitative terms. Bacon promotes the measurement of different variables, some that he expresses—or tries to express—with the greatest numerical precision (quantity of matter, space, time), and others that he presents through qualitative estimates (strength, peristasis). Both types of variables are not mutually exclusive and often appear conjoined. In this way, Bacon develops a quali-quantitative measurement methodology. In medicine we find this dual methodology put into practice. Thus, for example, certain

[66] Ibid., ex. 95–97, vol. II, 379–380, ex. 960–998, vol. II, 660–671.

[67] 'Historia sympathiae & antipathiae rerum', in *The Works of Francis Bacon*, vol. II, 81: "Lis et amicitia in nature stimuli are motuum, et claves operum."

[68] 'De vijs mortis', in OFB, vol. VI, 346–345. To make the reading easier, this quotation does not transcribe the typographical additions to the MS introduced by the OFB edition.

purgatives attract certain bodily humors more than others because they have "greater sympathy" with them (qualitative measurement); in turn, a higher dose—e.g. one more grain of the purgative—will have a more potent effect, and that also depends on the time that passes after it has been ingested, on how long the purgative was prepared in an infusion, etc. (quantitative measurement).

The coexistence of qualitative and quantitative measurements is directly related to the ontology of matter that shapes Baconian nature. Matter has an ample variety of both harmonic and conflicting appetites and has a total amount that remains constant and sets limits for transmutations between bodies. The appetitive (qualitative) and quantitative character of matter informs the quali-quantitative methodology that constitutes Baconian mixed mathematics. That is why medicine studies and intervenes in the human body and its relationship with the environment and with the different therapeutic means in two ways. On the one hand, it measures and puts exact numbers or rough estimates to the doses and ingredients of medicines, times and intervals, distances, temperature, pulse, changes in weight of the individual, etc. On the other hand, it measures in comparative and approximate terms the field of dispute in which life takes place, the conflicts and harmony between the internal appetites of the different members of the human body—without ignoring the affections and emotions of the individual—and the appetites of the surrounding environment, medicines, diets, and other therapeutic resources.