Chapter 5
Quantification in Galenic Medicine

Abstract The central theme of this chapter is to identify and explore various forms of quantification in the medical tradition, on which Sanctorius might possibly have drawn for his quantitative approach to physiology. First, I address theories and practices connected to dietetics and pharmacology as well as the Galenic concept of a latitude of health, which assumed a certain graduation of the state of health. Second, I reconsider the relation of Sanctorius's work to two earlier authors who are commonly associated with Sanctorius and his static medicine: the Alexandrian physician Erasistratus (third century BCE) and the German cardinal and scholar Nicolaus Cusanus (1401–1464). Both were early proponents of quantitative approaches to medical problems. Third, I outline instances of quantitative physiological reasoning in Galen's work as well as in the works of Renaissance scholars, and I analyze their possible connection to Sanctorius.

Keywords Nicolaus Cusanus · Pharmacology · Quantification

As demonstrated in the previous passages, Sanctorius had a wide-ranging interest in various medical fields, was extremely well read in both ancient and contemporary literature, and promoted the use of various instruments, mostly to improve therapeutics, but also for demonstration purposes, as in the case of optics. He was a practicing physician, who unexpectedly and, it is alleged, only reluctantly took up the first chair in theoretical medicine at the University of Padua. While certainly not dissatisfied with the prestige and the money that went with the professorship, his true interest seems to have always been in medical practice and instrumentation. Yet, an integral aspect of Sanctorius's undertakings still remains to be considered: his quantitative approach to physiology based on the use of a series of measuring instruments.

In Chap. 3, the fusion of quality and quantity in Galenic medicine was clarified. Humoral theory, according to which balance was crucial to maintain health, necessarily involved a quantitative element, namely the proportions between the different variables involved, such as humors, qualities, ingestion, and excretion. Quantity was important also with regard to the six non-naturals. Given that these factors could change the primary qualities and thus influence the state of humoral balance, they had to be used in due quantity and quality. In order to fully appreciate

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Sanctorius's quantitative approach to physiology, it is necessary to scrutinize these forms of quantification in more detail. Some of them are dealt with in existing studies on Sanctorius, but a systematic analysis, bringing together the different threads of quantitative ideas and practices prevailing before, and contemporary to Sanctorius, is still lacking.[1] In the following, I provide such an analysis, and hope to thereby cover many different facets of quantification in Galenic medicine, although an exhaustive account is beyond my present means. The questions that guide this chapter are: Was there a mathematical tradition in Galenic medicine on which Sanctorius could draw? In what way was quantification part of medical theory and practice? In which medical fields was quantification used, and by whom?

5.1 The Quantification of Food and Drink

Out of the six non-natural things, discussions of food and drink, in particular, involved quantitative statements. As Melitta Adamson's study of medieval dietetics has shown, the quantity and proportion of food and drink was a standard topic dealt with in the *Regimen sanitatis* literature. While Adamson gave no example of the nature of these quantitative statements, their level of specification, or the measures used, Sanctorius referred in his *Commentary on Hippocrates* to a famous dietary discourse with the title *Trattato della vita sobria* (Treatise on the Sober Life, 1558), in which the author, Luigi Cornaro (ca. 1484–1566), had exactly specified the healthy quantities of food and drink to be consumed per day.[2] Cornaro determined a daily ration of twelve ounces of food and fourteen ounces of wine in order to conserve his health and lead a long life.[3] Sanctorius did not comment on the quantities given by Cornaro, but highlighted the importance of a steady routine. He thereby drew on Cornaro's report, that his friends had made him increase his daily food intake, arguing that he needed to adapt his eating habits to his old age. But this change in habits, so Cornaro, had a harmful rather than healthful effect, and provoked illness. In 1613, the Flemish Jesuit Leonardus Lessius (1554–1623) translated into Latin Cornaro's treatise, originally composed in the vernacular, and included it in his own treatise on hygiene, *Hygiasticon*. Echoing the themes mentioned by Cornaro, Lessius also included quantitative statements. Even while

[1] For studies dealing with some quantitative aspects related to Sanctorius, see e.g., Castiglioni 1931: 748, Bylebyl 1977, Grmek 1990: esp. 1–43, 71–89, Sanctorius and Ongaro 2001: 21 f., 42, Bigotti 2016a: 242–52.

[2] The *Trattato della vita sobria* was later published as part of the *Discorsi della vita sobria* (Discourses on the Sober Life, 1591) by Cornaro's grandson. In addition to the *Trattato,* this work contained three other essays written by Luigi Cornaro: a *Compendio della vita sobria* (Compendium on the Sober Life), a *Lettera al Sig. Barbaro* (Letter to Signor Barbaro) and an *Amorevole essortatione* (A Loving Exhortation) (Walker 1954: 529 f., Milani 2014: 3).

[3] The unit of measurement and of weight varied from one Italian state to another. The most common was the Roman *libra* (pound), which was equal to 327 g and divided into twelve *unciae* (ounces). See: Cardarelli 2003: 74.

acknowledging the difficulties in determining universally healthy amounts of nutrition, given the vast variations in human bodies, Lessius identified twelve to fourteen ounces of food and drink per day as the proper quantity, especially for the elderly and for those with a weak complexion (Cornaro 1591: 5v; Lessius 1613: 15; Sanctorius 1629a: 122; Gruman 1961: 225 f.; Adamson 1995).[4]

Moreover, the personal notes of the Italian artist Jacopo Pontormo (1494–1557) illustrate that measuring meals was not uncommon in the Renaissance. During the last years of his life, Pontormo systematically recorded his food intake along with other aspects of his daily routine, such as the weather and his medical condition. It is not entirely clear whether he used a balance to weigh the food before he consumed it, as he often referred to imprecise quantities. It is striking that he specified quantities especially for bread, as the following example shows: "Monday for dinner fourteen ounces of bread, pork loin, grapes and cheese and endive" (Pontormo and Nigro 1988: 43). Interestingly, Pontormo not only quantified bread in terms of weight, i.e., in ounces and pounds, but also in terms of price: "Friday evening salad, pea soup and one egg fish and bread for five kreutzer (quattrino)" (Pontormo and Nigro 1988: 37).[5] The inconsistent use of diverse measurements imply that Pontormo neither had a uniform measuring method for his food intake, nor considered this important. Yet, his notes reveal that he thought about nutrition in quantitative terms.

These three examples illustrate that the quantification of food and drink was part of the Renaissance dietary literature, and occasionally quite specific. And indeed, nutrition was quantified already much earlier, long before the first *Regimina sanitatis* were written and the doctrine of the six non-naturals was systematized. As Sanctorius mentioned in the *Commentary on Hippocrates*, the author of the appendix to the Hippocratic treatise *De victus ratione in morbis acutis* (On Regimen in Acute Diseases) specified that patients should be given twelve cotyles of ass's milk.[6] Thus, even though Sanctorius certainly did not know of Pontormo's still unpublished notes and made no reference to Lessius's *Hygiasticon,* he was well acquainted with ancient as well as contemporary attempts to quantify and, as in the case of Cornaro, also to stabilize food intake (Sanctorius 1629a: 421; Hippocrates and Potter 1988: 235).

With respect to the three Renaissance authors mentioned, Cornaro, Lessius, and Pontormo, it is important to note that none of them was a physician. This testifies to the popularity of hygiene at the time, which extended well beyond medical circles. Sanctorius's use of the *Trattato della vita sobria* to support his argumentation reveals that Cornaro, a Venetian nobleman, was to him, the learned physician, a

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[4] Leonardus Lessius published his work *Hygiasticon* in Antwerp, so was very probably referring to Belgian units of weight. One Belgian *livre* (pound) was equal to 489.5 g and divided into sixteen *once* (ounces). However, Lessius compared his quantities to those mentioned by Cornaro without commenting on the possible discrepancies between the units of weight they used. See: ibid.: 84.

[5] A kreutzer (*quattrino*) was a small copper coin, the sixtieth part of one Tuscan lira. See: Pontormo and Nigro 1988: 36, fn. 16.

[6] Cotyle (*cotyla*, from the Greek for *cup*) was a measure used by the ancient Romans and Greeks, equivalent to nearly half an English pint, or ca. 250 ml. See: Smith 1848b.

trusted source. Thus, while management of the six non-natural factors was one of the most important tasks of the physician, it was also an area in which laypeople could gain a certain degree of authority. And so Cornaro wrote "a man can have no better doctor than himself, and no better medicine than the temperate life" (Cornaro 1591: 6v).[7] In this spirit, he offered simple rules to the general public without bothering with complex theoretical considerations of the body, or the properties of different food types. Instead, he placed his trust exclusively in his own common sense and self-knowledge, gained by means of trial and error. Accordingly, what he conveyed in his work was a kind of "self-help" approach to health suitable for everyone. This is in line with the public eager for self-improvement, mentioned earlier (Sect. 4.1.2). Yet, Cornaro's work was also subject to debate and criticism and Tessa Storey has cast doubt on Cornaro's popularity among the Italian public, by noting that his approach was not emulated in Italian vernacular health advice. But however popular Cornaro's work might have been, the fact that Pontormo, a contemporary of Cornaro, meticulously recorded his food intake implies that there was a general awareness, at the time, of the importance of regulating food intake not only in qualitative, but also in quantitative terms (Mikkeli 1999: 89–96; Storey 2017: 221–4).

What is more, the efforts of non-physicians to regulate their private hygiene raised the question of whether or not hygiene should be solely in the hands of the medical profession. Cornaro's answer to this was clear: physicians were necessary only for those who did not lead a sober life. Sanctorius, a university professor of medicine, writing a dietary treatise in Latin, the *De statica medicina*, could hardly have agreed. Can the *De statica medicina* therefore be seen as an attempt to reclaim authority in a medical field which was becoming more and more popularized? Was it influenced by his fear of losing patients, given that people were being encouraged to heal themselves? Or was the contrary the case: Did Sanctorius's instruments enable people to be their own physicians? I will resume these questions later, when more has been said on the material dimensions of Sanctorius's static medicine.

5.2 Degrees, Computation, and Proportions

In Galenic medicine one often encounters the term "degree" (*gradus*). It was used to express the range (*latitudo*) between health and disease (Sect. 3.1.2) as well as the range (*latitudo*) of qualities related to the properties of drugs. Thus, the Paduan professor of medicine Giambattista da Monte (1498–1551) wrote in his commentary on Galen's *Ars medica*: "Medicine is knowledge of all things in their latitude, from the first to the last degree" (Da Monte 1556: 151).[8] The idea of a latitude which permits of degrees was hotly debated by physicians in the Renaissance and had

[7] "Non havendo adunque l'huomo miglior Medico di se stesso, nè miglior medicina della vita ordinata, …." See: Cornaro 1591: 6v The English translation is taken from: Mikkeli 1999: 92.

[8] "est enim medicina scientia omnium in latitudine, & à primo gradu usque ad ultimum: …." See: Da Monte 1556: 151. For the English translation, see: Maclean 2002: 256.

given way in the fourteenth century to attempts to quantify qualitative changes by the so-called Oxford calculators. It is not my intention here to describe these complex discussions at any length, but rather to briefly point out certain aspects that I feel may better elucidate Sanctorius's quantitative approach to physiology.[9]

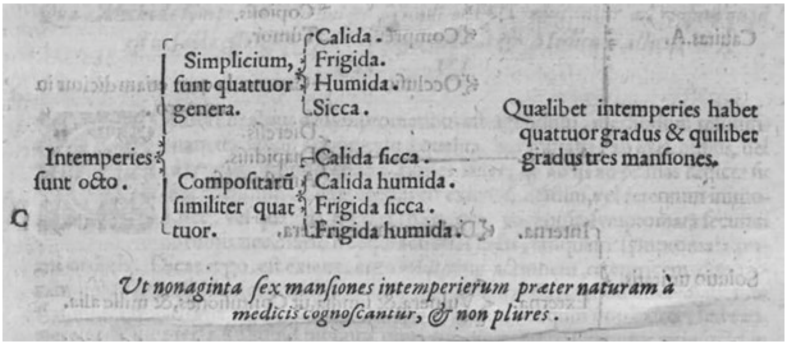
5.2.1 The Latitude of Health

In the Galenic corpus, the most important formulation of a gradual intension or remission of health, the so-called *latitude of health*, appears in the *Ars medica*. Thus, in his *Commentary on Galen*, Sanctorius referred to this idea and explained, for example, that the primary and optimal degree of health was the body *simpliciter salubre semper* (healthy in a general sense always), which served as the norm for all other complexions. The second degree of optimal health was to be found in bodies that were *salubri ut multum* (healthy for the most part). This terminology relates to Galen's categorization of the latitude of health, according to which a body could be healthy, morbid, or neutral, either *simpliciter* (in a general sense) or *ut nunc* (with application to the present). Moreover, the body could be in these states either *semper* (always) or *ut multum* (for the most part). But it is not fully clear how Galen understood these terms, or how they were received, since his *Ars medica*, gave rise to different interpretations. Without going into the latter in detail, it is of interest here to note that the latitude of health pertained to gradual differences between *types of body*, which were introduced in the *Ars medica* but were not described in numerical values. Hence, the degrees of health, of disease, and of a neutral state were not defined quantitatively—they were labeled rather than measured (Sanctorius 1603: 4r; 1612a: 102, 116).

However, the graduation of health and disease involved certain forms of computation and diagrammatic representation, as illustrated for example by Sanctorius's count of ninety-six degrees of contra-natural bad complexions (Fig. 5.1) (Sanctorius 1603: 4r; 1612a: 121, 133).

In fact, similar combinatory calculations were used to determine the many variables involved in medicine. Thus, Girolamo Cardano (1501–1576) calculated that considering astronomical, environmental, and physiological variables in diagnosis and prognosis would amount to taking 2936 (later recalculated as 3194) equiprobable outcomes into account and, even then, there would be exceptions. Along similar lines, Sanctorius tried to compute the number of combinations of two, three, and four corrupted humors in animals, of which there were, according to him, 165 in all. He put forward the figure of 80,084 possible equiprobable mixtures of up to four

[9] For more information on the concept of the "latitude of health" and especially on the problem of the neutral state of health, see Joutsivuo 1999, who also analyzed Sanctorius's view on the issue as expressed in his *Commentary on Galen* and his *Commentary on Avicenna*. See also Ottosson 1984: 178–94, Maclean 2002: 139 f., 177–81, 256–9. On the Oxford calculators see, for example: Sylla 1973, Trzeciok 2016.



Intemperies ſunt o&to.

Simplicium, ſunt quattuor genera. Calida. Frigida. Humida. Sicca.

Compoſitarũ ſimiliter quattuor. Calida ſicca. Calida humida. Frigida ſicca. Frigida humida.

Quælibet intemperies habet quattuor gradus & quilibet gradus tres manſiones.

Ut nonaginta ſex manſiones intemperierum præter naturam à medicis cognoſcantur, & non plures.

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There are eight bad complexions.

- Of the simple there are four types.
  - warm
  - cold
  - wet
  - dry
- Similarly of the composite, four.
  - warm and dry
  - warm and wet
  - cold and dry
  - cold and wet

Any bad complexion has four grades and any grade has three degrees (mansiones).

So that 96 degrees of contra-natural bad complexions are recognized by physicians and not more.

Fig. 5.1 Table illustrating Sanctorius's count of ninety-six degrees of contra-natural bad complexions (Sanctorius 1603: 4r). The English translation of the table is taken from: (Wear 1973: 352)

(out of 165) corrupted humors.[10] The enormous numbers show that such forms of quantification were purely intellectual and had no practical application (Sanctorius 1603: 149r–151r; Maclean 2002: 175 f.).

5.2.2 *Pharmacology and the Latitude of Qualities*

Another area in which degrees, computation, and proportions were important is pharmacology. It was connected to the concept of a latitude of qualities, according to which there existed four degrees of strength, or intensity of the primary qualities. These degrees were introduced by Galen in order to understand the interactions

[10] Ian Maclean has shown that Sanctorius employed a wrong method for his calculation and that the real figure is even much higher. See: Maclean 2002: 176, fn. 120.

between body and drug, as well as to classify the powers and effects of drugs. As was mentioned earlier (Sect. 3.1.3), drugs were complexionate, meaning that they were characterized by the four primary qualities of hot, cold, moist, and dry. In addition, according to the Galenic doctrine, they possessed so-called *derivative* qualities, which are the effects a substance can be observed to have on the body: heating and cooling, drying and moistening, but also purging, burning, or the like. These effects cannot be determined in themselves, but only in relation to a body. Pepper, for example, is cold to the touch but has a hot taste and a heating effect on the body. So, just like the complexion of human bodies (Sect. 3.1.2), the complexion of medicines was relative. Therefore, the effect of a drug could change from body to body, too, and a drug could be hotter in relation to one patient than it was in relation to another. Its effect depended on the complexion of the body it acted on and was thus determinable solely in relation to this body. According to Galen's pharmacology, it was therefore necessary that the physician not only detect the properties of a drug (e.g., hot or cold), but also ascertain the individual strength of the substance.[11] These were defined in terms of four degrees of intensity: (1) weak, (2) obvious, (3) strong, (4) massive. Hence, in choosing the healing drug, it was not enough for the physician to find a substance matching that of the patient's state of complexional imbalance; in order to guarantee a healing effect, he also had to ensure that the degree of intensity between the two of them was inversely equal. So if a drug was characterized as hot in the first degree and dry in the third, a physician would have known that it helps against a cold and moist disease, if the moisture strongly predominated. Attention to the intensities was also important with regard to preserving health. While cure was effected by contraries, similars were thought to preserve health and it was necessary, therefore, that their degree of intensity be equal to that of the patient's normal complexion. Accordingly, Sanctorius wrote in the *Commentary on Hippocrates*: "If something is warm in the second degree it will certainly not be preserved in the same state by something that is warm in the first degree, but cooled down" (Sanctorius 1629a: 407 f.).[12]

However, given the variability and relativity of complexions, how could the physician determine the complexional balance, or imbalance of a patient and the degree of intensity of a drug? For Galen, the yardstick was the normal temperate complexion of a human body. As the most temperate part of the body was, according to Galen, the skin which covers the hands, the only means to decide complexion a patient had was touch. Likewise, the hand provided the standard by which medicinal complexions could be evaluated. As the physician would normally take his own hand as the reference point for assessing a remedy, or the complexion of a patient,

[11] In using the term "Galen's pharmacology," I follow Sabine Vogt, who has argued that even though the word "pharmacology" in today's sense was unknown to Galen and his contemporaries, it is correct to speak of Galen's "pharmacology," in view of his theoretical approach to drug-lore. See: Vogt 2008: 305.

[12] "calidum ut duo certè per calidum ut unum non conservari in eodem statu, sed refrigerari: …." See: Sanctorius 1629a: 407 f. Sanctorius discussed the Galenic degrees of intensity also in his *Commentary on Galen*, see e.g., Sanctorius 1612b: 224–7.

he had to take into account his own remoteness from the temperate condition. This he could learn, so Galen, only through a long experience of touching different bodies. There remained, however, the problem of finding some sort of objective reference, by which to judge whether a complexion was temperate. Regarding the primary qualities of hot and cold, Galen proposed measuring the temperate complexion as the midpoint between the extremes found in reality—ice and boiling water or fire. With regard to dry and moist, the temperate was that which appeared neither hard nor soft to the touch. Hence, determining the intensities of qualities, be they in a drug or in a human body, was a difficult calculation involving several rather vaguely determined factors. This shows that Galen tried to quantify drug action and recognized the need for a point of reference when comparing complexions, but also that he did not go so far as to develop methods to measure the underlying qualities, such as heat, by constructing measuring instruments, for example, the thermometer (Ottosson 1984: 134–210; Vogt 2008: 308–10).

As Galen's pharmacological theory was restricted to the so-called *simple remedies*, consisting in a single substance, attempts were made in the Middle Ages to devise mathematical rules to determine the complexion of a compound medicine. The two central problems were (1) to account for the degree of intensity and (2) to determine the effect of varying the weight of each of the ingredients. At the end of the thirteenth century, Arnold of Villanova developed a theoretical system which enabled him to calculate both variables, the degree of intensity of, and the quantity of the ingredients in a compound drug.[13] However, Villanova himself seems to have thought his rules too complicated for any practical application. The nature of qualitative change and the problem of expressing the intensive effect of a qualitative force in quantitative terms were discussed by also philosophers of nature. In fact, Michael McVaugh has argued that Villanova's system had a strong natural-philosophical orientation and that the medical tradition on which it was based might have anticipated developments in natural philosophy. According to McVaugh, Villanova's system either directly, or indirectly influenced the so-called Oxford calculators, a group of thinkers at Oxford University in the mid-fourteenth century, most but not all of whom were associated with Merton College, and hence were earlier called the Merton School. They developed different concepts of a "latitude of forms," understood as an abstract range within which a given form, *complexio*, quality, or quantity can vary. These theories have been ably described elsewhere and need no further analysis here.[14] What must be stressed, however, is that the late medieval debates on the latitude of forms were intellectual endeavors, which did not consider the possibilities of practical application (Sylla 1973: 228–76; Temkin 1973: 111–4; Siraisi 1990: 146; Villanova et al. 1992; Sylla 2011: 903).

To sum up, the concept of a latitude of qualities put forward by Galen in relation to the properties of drugs led in the Middle Ages to attempts to quantify qualitative

[13] For a detailed analysis of Arnold of Villanova's system, published in the *Aphorismi de gradibus*, and for the development of medieval pharmacological theory, see: Villanova et al. 1992. For the relation of Villanova's theory to medical practice, see: McVaugh 1969.

[14] On the Oxford calculators and medieval theories of the latitude of forms, see: Sylla 1973, 2011.

changes. But these attempts were purely theoretical: the latitude of a quality or form remained a conceptual or abstract construct. Still, they may well have influenced Sanctorius in his quantitative approach to physiology, even though I was unable to find in his work a direct reference to any of the Oxford calculators.[15] I did find a reference to Arnold of Villanova, however. It is interesting to note that the Catalan physician published his pharmacological theory in aphorisms (*Aphorismi de gradibus*, Sect. 4.1.1)—the very form used by Sanctorius in the *De statica medicina*. Yet, it is difficult to detect any direct influence of Villanova's aphorisms on Sanctorius's static medicine, as Sanctorius neither referred to the *Aphorismi de gradibus* nor dealt specifically with the pharmacological theory it contained. Instead, as will be shown below, Sanctorius connected his quantification efforts with Galen and the concept of the latitude of health (Sanctorius 1625: 410; 1629a: 389).

5.2.3 Pharmacological Practice

In pharmacological practice, the quantification of medicinal substances by weight was an integral part of the daily work not only of pharmacists, but also of physicians; indeed, both professions were often practiced by one and the same person. In sixteenth century Venice, pharmacies were at the heart of medical practice. It was herethat doctors and surgeons met and, in all likelihood, also received their patients. Thus, physicians and pharmacists were in day-to-day contact and doubtless provided a mutual stimulus. Moreover, merchants and traders in *materia medica* from all over the world met in Venice, making it a hub of botanical and pharmacological exchange. Padua, too, was an important center for pharmacological research and practice, thanks to its botanical garden and the foundation there, in 1533, of the first ever chair of simples in Europe. In this light, it is no surprise that Sanctorius had a sound knowledge of medicines and presented them in his works. In the *Commentary on Galen* he wrote, for example:

> Apart from paracentesis, I use three ounces of juice of irises with two ounces of manna, dissolved in water, and flowers of citrus, to evacuate dropsical fluid. In this use, the root of jalapa which has been recently brought from India miraculously effectuates evacuation by a drachm.[16] These [things] evacuate water more safely than paracentesis. For the same use, medicated wine is prepared from jalapa, which is the most pleasing for the removal of dropsical fluid. For its preparation I use the work and diligence of the pharmacopoeia at the "sign of the ostrich" [pharmacy] of Albertus Stechinus, who in the preparation of this and

[15] Fabrizio Bigotti has argued that Sanctorius based his practice and conclusions with regard to the *pulsilogium* and the thermoscope on developments of the scholastic theory of the latitude of forms. See: Bigotti and Taylor 2017: 60, 65 f., 74, Bigotti 2018: 94 f.

[16] The *Mirabilis jalapa* plant, also known as the four o'clock flower, is named after Xalapa, the capital city of the Mexican state of Veracruz. It was already used by the Aztecs for medicinal purposes and was grown commercially in India. See: Neumann 1752: 149–63, Anagnostou 2008: 125. One Roman *drachma* (drachm) was equal to 3.39 g and the eighth part of one ounce (Robens et al. 2014: 57).

> other medicines is so learned and diligent that he deserves the highest praise ever bestowed in this most distinguished city (Sanctorius 1612b: 315).[17]

The citation illustrates how specific quantities were carefully weighed out when preparing remedies for which the proportion and the quantity of the different ingredients were integral. A pair of scales (or: a balance) was a vital piece of equipment in any apothecary and certain physicians—not the least, Sanctorius—probably had one of their own. In preparing his remedies, as explained above, he relied on the pharmacopeia of Alberto Stecchini (life dates unknown). Stecchini worked at one of the most celebrated pharmacies of the later sixteenth century in Venice, namely, the aforementioned *ad Signum Strutij* or Struzzo pharmacy. The book to which Sanctorius referred, *Avvertimenti nelle compositioni de' medicamenti per uso della spetiaria* (Advice on the composition of medicines for use in pharmacy) was originally published in 1575 by the Struzzo founder Georg Melich (life dates unknown). Alberto Stecchini published revised editions of it in 1605 and 1627, adding new recipes and his own opening discourse on the art of the apothecary. Given Sanctorius's great admiration for Stecchini, it seems likely that he consulted not only his published works but also the man himself, frequenting the *Struzzo* pharmacy to this end. According to Richard Palmer, physicians in sixteenth century Venice often attached themselves to particular pharmacies and it seems that Sanctorius chose to buy the ingredients for his remedies from the Struzzo. Maybe this was also the place where he first learned about the exotic root of jalapa and its purgative effects, which he mentioned in the above citation. In any case, it is remarkable that Sanctorius praised Stecchini's pharmacopeia to the skies, in all three of his commentaries; and, too, it is indicative of the, often, close relationships between physicians and pharmacists, and the accordingly intense exchange of knowledge and experience between the two professions. In this context, optimal dosage was ascertained not by means of mathematical theories, but rather by hands-on testing paired with text-based knowledge. This included common knowledge acquired during the pharmacist's apprenticeship as well as knowledge gained from reading the work of predecessors, both ancient and medieval (Sanctorius 1625: 748 f.; 1629a: 489 f.; Palmer 1985: 101–16; Parrish 2015: 7; Leong and Rankin 2017: 157; Pugliano 2017: 249).

[17] "Ego omissa paracentesi pro aqua hydropicorum evacuanda utor uncijs tribus succi ireos cum duabus uncijs mannae dissolutae in aqua è floribus citri: in hunc usum radix salapae nuper ex India delatae ad drachmam mirificam efficit evacuationem: tutiusq; his evacuari poterit aqua, quam paracentesi. Ad eundem usum paratur vinum medicatum ex salapa iucundissimum in auferenda hydropicorum aqua; in eo conficiendo utor opera, & diligentia Alberti Stechini pharmacopeia ad Signum Strutij, qui in hac, & in alijs praeparandis medicinis adeo eruditus, & diligens est, ut hactenus summas laudes in amplissima hac Civitate meritus sit." See: Sanctorius 1612b: 315.

5.2.4 Pharmacology and Dietetics

As explained in Sect. 3.1.3, there was a close connection between drugs and foodstuffs. The latter were used not only to preserve health, but also to heal diseases. Accordingly, Galen applied the degrees of intensity for the potency of drugs also to food and drink. Parsley, for example, was thought to be hot in the third degree and dry in the third degree and could therefore strongly alter the body. Similarly to compound drugs, different foods were combined in a single meal, either to guarantee that it was temperate and would therefore not change the complexion of a body, or to counteract an imbalanced complexion of a body. Thus, while hot and dry pepper could be used to treat a phlegmatic person, it could also be used to render cold and moist fish more temperate. Ken Albala has argued that, even though the mathematical theories developed in the Middle Ages in order to quantify qualitative changes (Sect. 5.2.2) were not used in dietetics, Renaissance dieticians did comprehend the basic idea of varying amounts having varying effects and applied it informally in their work. Without using mathematics, they knew, for example, that pepper, which was hot in the fourth degree and cinnamon, hot in the first degree, together formed a condiment somewhat less intense than the same amount of pepper alone. Similarly, they were aware that in combinations of opposite qualities, the food in the greater quantity would remain predominant (Albala 2002: 84–91).

The preceding paragraphs have shown that Galenic medicine as practiced in the early modern period involved certain ideas of quantification related to degrees, computation, and proportions. In the Middle Ages and the Renaissance, there was an increasing desire to quantify data and, especially with regard to therapeutics, the concept of a latitude of qualities led to the elaboration of a quantified medical theory, which was, however, not applied in practice. Still, the daily work of physicians, pharmacists, and dieticians was shaped by the management of quantities, be it in the composition of a remedy or the compilation of a balanced diet. The close connection between drugs and foodstuffs and the applicability of pharmacological theory to food and drink probably inspired non-physicians like Pontormo and Cornaro to quantify their food intake. What is more, these aspects might well have given Sanctorius the idea of using a balance not only to weigh the ingredients of drugs, but also to measure the effects of the six non-natural things on insensible perspiration. Yet this assumption is thrown into doubt by the fact that Sanctorius referred neither to quantification nor to his measuring instruments in his last publication dealing with the invention of remedies (*De remediorum inventione*). Instead, he made recourse to Aristotelian syllogistic logic and directed the reader to his first published work *Methodi vitandorum errorum*, in which he described his method for finding the specific differences in diseases (*affectus*), which were, he claimed, the only indication for remedies.[18] Whether he actually used this method rather than quantitative examinations in his medical practice is, of course, a different question entirely, and will be addressed later (Sanctorius 1629b: 1–12).

[18] On Sanctorius's first work *Methodi vitandorum errorum* and his medical logic, see: Maclean 2002.

5.3 Erasistratus and Nicolaus Cusanus—Two Early Quantitative Approaches

In addition to the quantitative tendencies just outlined, there are two names which are more closely associated with Sanctorius and his static medicine: Erasistratus (third century BCE) and Nicolaus Cusanus (1401–1464). The former was a major exponent of the ancient medical school of Alexandria and was already mentioned above, in connection with early ideas on *perspiratio insensibilis* (Sect. 3.2.1). The latter was one of the most important German thinkers of the fifteenth century, whose activities ranged from theology, law, and philosophy to mathematics and astronomy. Due to the fact that both men were early proponents of quantitative approaches to medical problems, the secondary literature has often related their undertakings to Sanctorius and his use of quantification. In the following, I reconsider such possible links, in chronological order.

5.3.1 Erasistratus

Around the third century BCE, the physician and anatomist Erasistratus demonstrated that animals give off invisible emanations:

> If one were to take a creature, such as a bird or something of the sort, and were to place it in a pot for some time without giving it any food, and then were to weigh it with the excrement that visibly has been passed, he will find that there has been a great loss of weight, plainly because, perceptible only to the reason, a copious emanation has taken place (Anonymus and Jones 1968: 127).

The similarity to Sanctorius's description of his own weighing procedures is instantly striking. Although separated by nearly two thousand years, the two physicians were interested in the same physiological phenomenon and used a balance to examine it. At first glance, it seems obvious: Sanctorius built his static medicine on the findings of Erasistratus. At second glance, however, the picture changes. As all of Erasistratus' works have been lost, they are known solely thanks to the references made by his successors, primarily Galen. But even though Galen referred to the problem that Erasistratus had tackled he made no mention of Erasistratus's quantitative observation. In his work *De naturalibus facultatibus* (On the Natural Faculties), Galen wrote:

> Now, the amount of urine passed every day shows clearly that it is the whole of the fluid drunk which becomes urine, except for that which comes away with the dejections or passes off as sweat or insensible perspiration. This is most easily recognized in winter in those who are doing no work but are carousing, especially if the wine be thin and diffusible; these people rapidly pass almost the same quantity as they drink. And that even Erasistratus was aware of this is known to those who have read the first book of his *General Principles* (Galen and Brock 1916: 109 ff.).

Hence, the lack of a reference on Galen's part to Erasistratus's demonstration of insensible perspiration provides strong evidence that Sanctorius was ignorant of it.[19] In fact, it was only at the end of the nineteenth century that a Greek papyrus from the second century CE, in which an anonymous author wrote of Erasistratus and his examination of weight changes in fowls, was rediscovered in the British Museum. The papyrus contains nothing but the brief paragraph cited above: the observation made by Erasistratus. From the evidence at hand, it seems that the Alexandrian physician'sconcern was to prove the existence of insensible perspiration rather than to systematically measure it. This would explain the absence of numerical values in the account of his observation. To summarize, long before Sanctorius, Erasistratus had put forward the idea of measuring insensible perspiration by means of weighing procedures. Yet, Sanctorius was most probably unaware of Erasistratus' quantitative procedure and it can therefore be assumed that their undertakings were not related. Moreover, the two physicians followed different approaches. Contrary to Erasistratus, Sanctorius was not out to prove the existence of *perspiratio insensibilis*, which, for him, was beyond any doubt. However, he did try to establish its quantity by means of systematic observation (Grmek 1990: 36 ff.; Bigotti 2016b: 5, fn. 14).

5.3.2 *Nicolaus Cusanus*

A more contemporary author, who might have been a reference point for Sanctorius, is Nicolaus Cusanus. His name often appears in historical accounts of the work of Sanctorius, but the question of a possible relation between Cusanus and Sanctorius is usually dealt with only briefly, in a few sentences.[20] However, in my opinion, the issue is by no means trivial and deserves a more in-depth look. As the following analysis will show, there are striking similarities in the work of the two authors, which hence good reason to assume that their quantitative approaches were closely related. Before addressing this point, I briefly examine Cusanus and his work, with a focus on the aspects I consider relevant with regard to Sanctorius. Furthermore, I compare their quantitative methods and, on this basis, review the likelihood of a connection between their efforts.

The Quantitative Approaches of Cusanus and Sanctorius Compared The son of a prosperous German merchant, Nicolaus Cusanus first studied at the University of Heidelberg before moving to the University of Padua in 1417, from where he graduated six years later as a doctor in canon law (*decretorum doctor*). The

[19] As will be shown below, Sanctorius knew Galen's work *De naturalibus facultatibus* and was familiar with Galen's statement, quoted here, that the entirety of any drink consumed became urine, except for those parts of it excreted as feces, sweat, or insensible perspiration (Sect. 5.4.1).

[20] See e.g., Del Gaizo 1889: 21, Castiglioni 1931: 748, Ettari and Procopio 1968: 27, Sanctorius and Ongaro 2001: 21 f., 41 f.

nomination as cardinal in the late 1440s marked the climax of his career and was soon followed by the publication of his famous series of papers under the title *Idiotae libri quatuor* (The Idiot in Four Books, 1450), which was written in the form of a dialogue between a layman (*Idiota*) and a Roman orator (*Orator*). Interestingly, the work included a paper on static experiments (*Idiota de staticis experimentis*).[21] This title alone, *de staticis experimentis*, sounds suspiciously as if it may have inspired the title of Sanctorius's *De statica medicina*. Both titles feature the New Latin word *staticus*, which can be translated as "relating to weighing," and derives directly from the Greek term *statikós*. This implies that weighing and, thus, the use of a balance was fundamental not only to Sanctorius's treatise, but played an important part in Cusanus's work, too. In fact, perusal of the latter's text shows that the similarities between the two works go well beyond their titles. At the beginning of the dialogue, the idiot, who is understood to be not a foolish person, but simply a layman, explained:

> It seems to me that by reference to differences of weight we can more truly attain unto the hidden aspects of things and can know many things by means of more plausible surmises (Cusanus 1983: 222).[22]

And a few lines later, the idiot continued:

> For identical sizes, of whatsoever different things, are not at all of the same weight. Accordingly, since the weight of blood or the weight of urine is different for a healthy man and for a sick man or for a youthful man and an elderly man or for a German and an African, wouldn't it be especially useful to a physician to have all these differences recorded? (Cusanus 1983: 222).[23]

The orator strongly agreed with the idiot who, in addition to the weighing of blood and urine, also proposed to record the weight of herbs. According to him, comparing the weights of the herbs administered with the weight of the patient's blood or urine would enable the physician to determine the correct dosage of a drug. Whether he meant absolute or relative weights is unclear, however. Thus, through the voice of the idiot, Cusanus had already postulated the importance of quantitative studies in medicine and suggested weighing procedures to realize them. These involved not only the fluids of the human body, but also medicaments. Notwithstanding that neither the idiot nor the orator explicitly referred to pharmacological theories, the close connection to contemporary discussions on the latitude of qualities outlined above is obvious (Sect. 5.2.2). Moreover, historiographical studies have shown that Cusanus was influenced by the works of the Oxford calculators, which gives grounds

[21] The following account of Cusanus's paper *Idiota de staticis experimentis* is based on the English translation of the work by Jasper Hopkins, see: Cusanus and Hopkins 2001: 602–30.

[22] "Per ponderum differentiam arbitror ad rerum secreta verius pertingi et multa sciri posse verisimiliori coniectura." See: Cusanus 1983: 222. The English translation is taken from: Cusanus and Hopkins 2001: 606.

[23] "Nam nequaquam est eiusdem ponderis identitas magnitudinis quorumcumque diversorum. Unde cum aliud sit pondus sanguinis et urinae hominis sani et infirmi, iuvenis et senis, Alemanni et Afri, nonne maxime conferret medico habere has omnes differentias annotatas?" See: Cusanus 1983: 222. The English translation is taken from: Cusanus and Hopkins 2001: 607.

to assume that his quantitative ideas were informed by discussions on the latitude of forms. In any case, in the *De staticis experimentis*, weighing became the crucial method for the physician to find the proper remedy. By adding “experiments done with weight-scales” to common methods of diagnosis based on the examination of, for example, color or taste, the physician was able to achieve greater precision in his judgements (Lohr 1988: 556–94; Vescovini 2002: 93; Miller 2017; Dictionary.com 2020).

Cusanus also considered the possibility of weighing a whole man in order to compare his weight with the weight of other animals. To this purpose, man and animal were to be placed successively on a balance-scale. Then, in a second round of measurements, both animal and man, were to be immersed in water and the differences in weight noted. Regardless of the difficulties entailed by such a procedure, it is interesting to note that Cusanus applied here to living bodies the by then well-known Archimedean principle of specific gravity. As specific gravity is the ratio of the weight of a body to its volume, Cusanus's suggestion of weighing bodies in water implies that he intended to compare not only the absolute weights of animals and men, but also their densities, i.e., their composition. This is further indicated by his proposal of an alternative way to assess the weights of men and animals. After having measured their bodyweights outside of water by means of a balance, the man and the animal were to be submerged in a tub of water and the water thereby displaced and caused to overflow was to be collected and weighed. Here again, Cusanus drew on a widely known Archimedean principle to compare the composition of human and animal bodies. In fact, in a later passage of the *De staticis experimentis*, the German thinker even suggested a method of measuring the elements contained in an object by means of a balance. It seems that he thought that this method, too, could be applied to men and animals, although he did not explicitly state this. Without going into the details of this method, which would be too great a digression from the present topic, it is pertinent to mention that Cusanus regarded the weighing procedures as a means to elaborate the average weight of a temperate man respectively of various species of animal, and did not foresee any diagnostic use of them, such as determining complexional imbalances.

Although Sanctorius made no reference in the *De statica medicina* to weighing human bodies (*viventia corpora*) in water, he did so in his *Commentary on Avicenna*. This, he ventured, would enable one to find out how much air such bodies contained. However, instead of amplifying this idea, Sanctorius referred to Archimedes' the famous experiment to determine the gold content of a crown. In the *De statica medicina,* in one of the aphorisms in the section on the non-natural pair air and water, Sanctorius likewise addressed the principle of specific gravity. He explained that the weight of water could be easily determined by weighing a heavy body in water. the deeper the body sank, the lighter and therefore healthier was the water; conversely, if the body sank only a little, the water was heavier and unhealthier. Thus, contrary to Cusanus, Sanctorius used the Archimedean principle here to measure the density of the water, and not of the body immersed in it. Yet, in another passage of the *De staticis experimentis*, Cusanus wrote about the weight of water, drawing on the Roman architect Vitruvius (fl. first century BCE), to assert that light waters were healthier than heavy waters. The similarities between these two treatises pertain to issues that were common knowledge among scholars both in the fifteenth and the seventeenth century, so their relevance should not be overestimated—but nor should their existence be neglected (Sanctorius 1614: 21r–21v; 1625: 152 f.).[24]

Many of the static experiments mentioned by Cusanus were based not on the balance, but on the water-clock, which the ancient Greeks used to measure specific intervals of time. It is one of the oldest time-measuring instruments and consisted, in its basic form, of a vessel with a small opening near the bottom. A measured amount of water was poured into it, which then flowed out through the hole. Given the consistent use of the same instrument and the same quantity of water the time it took for the vessel to empty was always the same. Cusanus suggested a slightly different use of the instrument in order to compare the pulse in healthy and in sick adolescents, and in young and in elderly people. Instead of pouring a fixed amount of water into the vessel, he proposed to weigh the water that traversed the clock during the time of one hundred pulse beats. Recording the different weights of water, he believed, would make it possible to establish the respective weights of different illnesses. According to Cusanus, the same method could be used with regard to respiration; and he explained, thus, that if a person had fever, the physician should measure the respiration by means of the water-clock during "the sudden episodes of feeling hot and of feeling cold," in order to gain more precise knowledge of the gravity of the disease and of the right moment to administer medication (Cusanus and Hopkins 2001: 609). What is more, this would also help the physician to better judge the course of the disease, so Cusanus.[25] As will be seen below (Sect. 7.2), Sanctorius, too, engaged in attempts to measure the pulse and respiration. However, instead of using a water-clock to determine changes in his patients' rates of pulse and respiration, he devised several instruments of his own, most of which were based on the swing of a pendulum. Thus, Cusanus and Sanctorius both proposed to measure the pulse and respiration with instruments whose fundamental property was to record equal intervals of time. In fact, Sanctorius's *pulsilogia* served him also as a timekeeper. Furthermore, both scholars related their methods to medical practice, with the aim of helping the physician conduct diagnosis, prognosis, and therapy.

Two further aspects have to be noted with regard to the *De staticis experimentis*. While exploring possible means to measure the "weight of air," Cusanus suggested

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[24] For more information on ancient hydrostatics and pneumatics, see: Valleriani 2016.

[25] Before Cusanus, the Alexandrian physician Herophilus is said to have used a water-clock in the early third century BCE, to measure his patients' pulse. Drawing on his own experience, he had determined which natural pulse rate for persons of different age groups should occur during the time period measured by his water-clock. The amount by which his patients' pulse beats exceeded or fell below the normal rate for their respective age group indicated the gravity of their disease. As there is only one reference to Herophilus's use of the water-clock in the treatise *De pulsibus* (On the Pulse, date uncertain) published (probably in the second century) by the otherwise unknown physician Marcellinus, it can be assumed that Cusanus was unaware of it. See: Landels 1979: 32 f., Von Staden 1989: 354, Lewis 2015: 197 f., 200 f.

putting desiccated wool on one side of a pair of scales and stones on the other side, as a counterbalance.[26] If the balance was located outdoors in a temperate location, the weight of the wool would come to indicate the humidity or dryness of the air: growing heavier, if the air were moist, the wool would increase in weight: if the air were dry, the wool would become lighter. Writing about the weight of the air in the *De statica medicina*, Sanctorius stated:

> The weight of the air can be gathered first from the bigger or smaller weight of the sediment of alum, which is first dried in the sun and then exposed to nocturnal air (Sanctorius 1614: 20v–21r).[27]

Hence, here again Cusanus and Sanctorius put forward similar methods, in this case to determine the weight of air by measuring its humidity. Yet, while for Sanctorius, the physician, this was clearly related to the influence on insensible perspiration of the non-natural factor air, Cusanus did not relate his *experimentum* to medicine. Furthermore, as will be shown below (Sect. 7.4), Sanctorius dealt with the issue much more extensively than Cusanus and proposed also three other ways of determining the humidity of the air. In the *Commentary on Avicenna*, he even depicted two instruments for this purpose (Figs. 7.19 and 7.20) (Sanctorius 1625: 23, 215).

The last interesting point of comparison between Cusanus and Sanctorius under consideration here refers to their measurement of the impetus of wind. In the *De staticis experimentis*, Cusanus mentioned the possibility of investigating "the strength of winds … from experiments done with weight-scales" (Cusanus and Hopkins 2001: 617). He gave no further description of how these procedures should be conducted and made no reference to any medical application. However, he did correlate determining the strength of a wind and that of a man, stating that the latter could be ascertained by having a man lift a weight sufficient to bring a balance into equilibrium. In the *Commentary on Avicenna*, Sanctorius presented a special balance to measure the impetus of winds (Fig. 7.1). This was important, so Sanctorius, because of the different effects that rainy and windy air could have on the body. Noisy wind, for example, sometimes hindered sleep and sometimes induced it. What is more, the instrument helped predict sea storms and thus minimize the risks of flooding. Without going into the details of Sanctorius's apparatus and its operation, it should have become clear by now, that there are similarities not only between the *De staticis experimentis* and the *De statica medicina*, but also between the respective authors' quantitative endeavors, as indeed Sanctorius did mention in his other works (Sanctorius 1625: 246 f.).

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[26] The idea that air has weight was much debated toward the end of the sixteenth century and was a topic of interest also for Sanctorius. The notion of determining the weight of the air by measuring its humidity must be seen in the light of the Aristotelian doctrine of the interconvertibility of air and water. For more information, see: Middleton 1964: 4, Middleton 1969: 3, 81. For an analysis of Sanctorius's concept of the weight of the air, see Bigotti (2018), who has argued that Sanctorius already recognized atmospheric pressure, an interpretation that I, however, do not share.

[27] "Quanta sit aeris ponderositas, colligitur primo ex maiori, vel minori gravitate aluminis faecum prius exiccati in sole, & deinde aeri nocturno expositi." See: Sanctorius 1614: 20v–21r.

The Accusation of Plagiarism In fact, these similarities did not go unnoticed by Sanctorius's contemporaries. In his attack on the *De statica medicina* (Sect. 3.1, fn. 2), Ippolito Obizzi (b. second half of the sixteenth century), a physician and philosopher from Ferrara, accused Sanctorius of plagiarism. After claiming that Sanctorius had learned about "static reasoning" from Cardinal Cusanus, he concluded that the *De statica medicina* was "deceptive and by no means a truthful experiment and cannot be called an original work" (Obizzi 1615: 71). Besides these general denunciations, Obizzi gave a rather detailed account of those arguments in Cusanus's treatise which he considered similar to those employed by Sanctorius, and asserted that Sanctorius had derived his *pulsilogium* from Cusanus's report on the use of the water-clock (Obizzi 1615: 71 f., 81 ff., 86).

What did Sanctorius say in his defense? What was his reaction to the grave allegations? The answer is: very little. Only in 1615, ten years after Obizzi first cast doubt on the originality of the *De statica medicina*, did Sanctorius comment on his possible debt to Cusanus. In the *Commentary on Avicenna*, he stated:

> … he [Ippolito Obizzi] suggested that our static [medicine] was taken from the static experiments of the Cardinal Cusanus, from which, as everyone can see, not a word is taken. For Cusanus never discusses that weighing of the insensible perspiration of the human body with which all of our aphorisms deal (Sanctorius 1625: 81).[28]

Thus, Sanctorius did not deny his knowledge of Cusanus's *De staticis experimentis*, nor did he explain in any detail how his work differed from that of the cardinal, except for the focus on insensible perspiration. Instead, in the next sentence, he directed the reader, first, to his earlier diatribe against Ippolito, which especially concerned the latter's inclination to astrology, and, secondly, to his defense of his own *De statica medicina*, which Sanctorius added as an eighth chapter to the revised edition, under the title *Ad Staticomasticem* (To the Scourge of Statics). This piece of the seventeen aphorisms comprising this defense not one made mention of Cusanus or of Ippolito's allegations of plagiarism. Sanctorius evidently regarded his examination of *perspiratio insensibilis* as unique and original work and accordingly saw no further need to distinguish his *De statica medicina* from Cusanus's treatise (Sanctorius 1625: 81; 1634: 69r–71v).

Sanctorius's meager reference to Cusanus makes it difficult to assess the relation between the *De staticis experimentis* and the *De statica medicina* and, more generally, Sanctorius's quantitative approach to physiology. Since the *De staticis experimentis* appeared in several editions in the sixteenth century, among them a popular edition of Vitruvius's *De architectura* (On Architecture, ca. 30–15 BCE), and since Sanctorius in his *Commentary on Avicenna* did not deny knowledge of Cusanus's treatise,it is likely that Sanctorius had read the work. What is more, Cusanus's

[28] "… protulit nostram staticam à staticis experimentis Cardinalis Cusani fuisse desumptam, à quibus, ut omnes videre possunt, nec verbulum desumptum est: nunquam enim Cusanus aegit de ponderatione insensibilis perspirationis humani corporis, de qua sunt omnes nostri aphorismi." See: Sanctorius 1625: 81. It is interesting to note that Sanctorius never mentioned Ippolito Obizzi by name, but referred to him for example as *Belluni*, or *Astrologus Magnus* (ibid.).

mathematical thoughts were known to a considerable number of Renaissance scholars, among them Girolamo Cardano, an author whom Sanctorius mentioned frequently in his commentaries. Still, these are not certain proofs of a simple and direct connection between Cusanus and Sanctorius. Indeed, besides the many similarities outlined above, there are also many differences between the two authors and their treatises (Nagel 1984: 108; Rudolph 1996: 124).

Differences Between Cusanus and Sanctorius First of all, in the *De staticis experimentis* there is no suggestion that the proposed experiments were actually performed. Contrary to the *De statica medicina*, no measuring results are given and the dialogue ends with the orator's promise to seek to realize the aforementioned weighing procedures. Hence, Cusanus most probably presented thought experiments without any direct practical application. Whether the measuring instruments were actually ever used must be asked also with regard to Sanctorius, although his written work does contain much stronger indications that they were. Not only did Sanctorius present some of his findings in the form of numerical values, but also his terminology implies that he actually performed experiments in something like the modern sense (Sect. 6.2.5). On the assumption that Sanctorius did use his instruments, it will be shown below that the path is long, from the intellectual conception use of an instrument and its operation to its actual application in research and practice (Sect. 7.5). Accordingly, the question of plagiarism concerns here only the mental processes, the ideas behind the quantitative undertakings, and not their practical and material dimensions. In this respect it must be noted also that Sanctorius put forward a much wider range of measuring instruments than Cusanus did, the latter having limited his static experiments to the use of the balance and the water-clock. Sanctorius, by contrast, drew on very recent technologies when developing his measuring instruments, and this in itself does often raise the question of Sanctorius's role in their invention, asin the case of the *pulsilogium* or the thermoscope, for example (Sects. 7.2 and 7.3) (Hoff 1964: 113 f.).

A second major difference between the quantitative approaches of Cusanus and Sanctorius is the context in which they appeared. As mentioned earlier, the *De staticis experimentis* is only one among four papers published by Cusanus in his book *Idiota* and one should be careful not to consider it independently of the other papers. Paula Pico Estrada has argued that the *De staticis experimentis* needs to be read as an analysis, from a philosophical viewpoint, of the workings of the human mind with regard to its knowledge of the natural world. The text does not express the belief that reality has a mathematical structure apprehensible to the human mind. Rather, it refers to the mind's action of "measuring" whatever it encounters, which it conceives of as a creative action by which the power of the mind approximates God's own creative power, so Estrada. Without going into the details of Cusanus's philosophical notions underlying this, it is apparent that Sanctorius's *De statica medicina* follows an entirely different goal. While Cusanus examined the human mind and its rapport to truth, Sanctorius reinterpreted the doctrine of the six non-natural things according to his concept and observation of insensible perspiration. Even though Sanctorius, in his commentaries, related his quantitative approach to his wish to attain more certainty in medicine, he thereby pursued different epistemic notions than Cusanus (Sect. 6.2).[29] He composed the *De statica medicina* explicitly as a medical treatise aimed at improving and facilitating the work of the practicing physician. Cusanus, on the contrary, did not focus exclusively on medicine in his *De staticis experimentis*, but dealt more generally with ideas about using quantitative procedures in the investigation of nature. The different orientations of these two works are reflected also in their titles: Cusanus referred to static *experiments* (*De staticis experimentis*) and Sanctorius to static *medicine* (*De statica medicina*) (Pico Estrada 2008: 137, 144).

In conclusion, after weighing up the differences and similarities between Sanctorius and Cusanus, I must say that this is more than just a "genial coincidence." In my opinion, it is significant that Cusanus had already conceptualized many of the quantitative measurements which Sanctorius later claimed to have realized and, moreover, had published them in a work with a title so similar to Sanctorius's *De statica medicina*. While not sharing the same epistemic goals as Cusanus, who, for his part, was no medical practitioner, Sanctorius was able to find in the *De staticis experimentis* much to inspire his own quantitative approach to physiology. Even though Cusanus's work makes no reference to the doctrine of the six non-natural things, it includes common Hippocratic-Galenic notions of the influence on the human body of external factors, such as the climate of the geographic region in which a person lives. What is more, it expresses a desire to put quantitative procedures in the service of medicine, in order to enhance the discipline's certainty. The fact that Sanctorius denied any connection between the *De staticis experimentis* and the *De statica medicina* by highlighting his measurement of insensible perspiration underlines that he considered this the original aspect of his work; and while Sanctorius was certainly right to do so, it is notable that he said nothing about Cusanus's possible influence on his other quantification efforts, not even to challenge Obizzi's remark regarding the similarity of their respective methods to measure the pulse. This is interesting, as *perspiratio insensibilis* played no part in these. It has been shown earlier that insensible perspiration and its quantification were not pivotal to Sanctorius's other publications (Sect. 3.3.7) and, as will be further elaborated below, nor were they pivotal to Sanctorius's other measuring instruments (Sect. 6.1.2). Hence, in this context, Sanctorius's appeal to the weighing of insensible perspiration as a distinguishing criterion is to no effect. In view of the evidence at hand, it is thus highly probable that the *De staticis experimentis* did

[29] A central aspect of Cusanus's epistemology was the idea of the impossibility of attainment of certain or complete knowledge on this earth. According to him, mathematics was the only measure by which the human mind could gradually approach knowledge of nature without ever fully achieving it. For more information, see: Nagel 1984: 1–85, Pico Estrada 2008. Contrary to this, Sanctorius still adhered to Aristotelian logic and conceived of medical knowledge as conjectural due to medicine's standing as an art (*ars*). However, departing from tradition, Sanctorius thought that uncertainty in medicine could be eliminated, or at least reduced by means of his measuring instruments (Sect. 6.2) (Siraisi 1987: 235–8).

indeed serve, in a more general sense, to inspire Sanctorius's quantitative approach to medicine and his development of measuring instruments.

5.4 Three Instances of Quantitative Physiological Reasoning

Another form in which quantification pervaded Galenic medicine was its use as a mode of argumentation in the discussion of physiological problems. Owsei Temkin and Jerome Bylebyl have drawn attention to instances of quantitative physiological reasoning in Galen's work as well as in the work of Renaissance scholars. In the next paragraphs, I will briefly describe these efforts and analyze their possible relation to Sanctorius (Temkin 1961; Bylebyl 1977).

5.4.1 Galen and the Quantification of Urine

In one and the same passage of his work *De naturalibus facultatibus* (On the Natural Faculties), Galen both mentioned Erasistratus's approach to insensible perspiration (Sect. 5.3.1) and tried to confute the view that the kidneys produced urine merely as a residue of their own nutrition. Galen believed rather, that the kidneys had a special faculty to attract for their nourishment only the thin and watery parts of the venous blood, generated during the process of digestion, and wouldexcrete the rest as urine. This was confirmed, so Galen, by the observation that the daily amount of urine corresponded to the daily amount of ingested drinks (Sect. 5.3.1) and could therefore be quite copious. If the urinary output was merely residue of the kidneys' nutritional matter, the absurd consequence, as Galen explained, would be that all the other body parts would produce similarly large amounts of residual fluid, proportionate to their size. And thus, he wrote:

> Now it is agreed that all parts which are undergoing nutrition produce a certain amount of residue, but it is neither agreed nor is it likely, that the kidneys alone, small bodies as they are, could hold four whole *congii*, and sometimes even more, of residual matter.[30] For this surplus must necessarily be greater in quantity in each of the larger viscera; thus, for example, that of the lung, if it corresponds in amount to the size of the viscus, will obviously be many times more than that in the kidneys, and thus the whole of the thorax will become filled, and the animal will be at once suffocated. But if it be said that the residual matter is equal in amount in each of the other parts, where are the *bladders*, one may ask, through which it is excreted? For, if the kidneys produce in drinkers three and sometimes four *congii* of superfluous matter, that of each of the other viscera will be much more, and thus an

[30] *Congius* was a Roman measure for liquids and corresponds to about six English pints, or 3.48 liters. The amount of urine that Galen specified, four *congii*, is thus about twenty-four English pints, or 13.92 liters. This is nearly five times as much as the average daily urinary output and could only be excreted if a very large amount of wine was drunk. See: Smith 1848a, Galen and Brock 1916: 111, fn. 2.

> enormous barrel will be needed to contain the waste products of them all. Yet one often urinates practically the same quantity as one has drunk, which would show that the whole of what one drinks goes to the kidneys (Galen and Brock 1916: 111 ff.).

Hence, Galen pointed here to two difficulties: firstly, that the lungs were not able to eliminate residual fluid, which would consequently simply accumulate in the thorax and cause suffocation; and secondly, that there apparently was no surplus to supply the much larger amounts, which should be eliminated by the other parts, as the kidneys alone quickly eliminated a quantity of fluid nearly equal to that ingested. Without going into the details of Galen's argumentation, or discussing its conclusiveness, what is of interest here is that Galen put forward a numerical value for the urinary output to support his notion of the attractive faculty of the kidneys.[31] Remarkably, just as Sanctorius would do, more than a millennium later, in his measurement of insensible perspiration, Galen quantified a physiological process, the production of urine by the kidneys, by referring to the equilibrium between ingestion and excretion (Temkin 1961: 472–4; Bylebyl 1977: 374 f.).

Galen's argumentation suggests that he measured the amount of urine excreted by people who drank large amounts of wine (*drinkers*), and whose urinary output was therefore much larger than normal. It is of course questionable whether he really collected the urine of others, who might well have relieved themselves more than once while drinking large amounts of wine. Yet, the fact that Galen indicated the quantity of urine in *congius*, a measure which was often used for wine, gives cause to assume that he was directly comparing the consumption of wine with the excretion of urine. But regardless of whether or not Galen actually measured urine, the possibility and importance of quantifying excretions was conceptually formulated in his work. What is more, when comparing the intake of fluids to the output of urine in human bodies, Galen also already paid heed to the loss possibly caused by other excretions—feces, sweat, and insensible perspiration, for example—and therefore tried to reduce these to a minimum; which is why he proposed conducting his measurements in the wintertime, on people who rested and drank a lot in a short period of time (Sect. 5.3.1).[32] Thus, Sanctorius could draw on earlier works regarding not only the practice of quantifying food and drink, but also the quantification of excretions.

From references in his books, it is clear that Sanctorius was familiar with Galen's work *De naturalibus facultatibus* (e.g., Sanctorius 1625: 162; 1629a: 51, 514; 1629b: 137). While he did not discuss Galen's quantitative argumentation regarding urinary output, in the *Commentary on Galen* Sanctorius related the *De statica*

[31] According to Owsei Temkin and Rudolph Siegel, Galen's theory of urine formation is somewhat ambiguous and contradictory (Temkin 1961: 474, fn. 27, Siegel 1968: 131). For more information on this theory and on Galen's doctrine of kidney function, see: ibid.: 126–34.

[32] I assume that Galen proposed to compare the amount of ingested drink with the amount of excreted urine in winter because he thought that sweat and insensible perspiration were less profuse during this season (e.g., Galen and Johnston 2018: 363). However, Sanctorius held that in robust bodies insensible perspiration was greater in winter than in summer and claimed that this was also confirmed by Galen (Sect. 3.3.1) (Sanctorius 1629a: 382 f.).

medicina explicitly to Galen's statement, quoted above, that the whole amount of consumed drink became urine, except for that which was excreted as feces, sweat, or insensible perspiration (Sect. 5.3.1). In the context of a discussion on reduced urinary output as a sign of imminent disease, Sanctorius explained:

> But regarding the way in which insensible and free perspiration diminishes urine, as we explained so exactly in our book *De statica medicina*, nobody truly understands it without appeal to the principles of the *statica*. But that urine is often dissolved by means of sweat, or by means of invisible perspiration, Galen easily explains in the first book of *On the Natural Faculties*, … (Sanctorius 1612a: 756).[33]

Thus, there is a direct link between Galen's quantitative reasoning and Sanctorius's measurement of insensible perspiration. Although Sanctorius did not refer in the *De statica medicina* to Galen's calculation of urinal output, but instead arrived at his own results, it seems that he accepted Galen's argumentation overall, as he was convinced of the kidneys' selective attraction of mattter. Due to the fact that Sanctorius on other occasions explicitly connected his weighing procedures to Hippocrates's work *De flatibus* (Breaths) and to various books by Galen, in particular his *De tuenda sanitate* (Hygiene) and *Methodus medendi* (Method of Healing), it is difficult to assess the relation between the quantitative reasoning in Galen's *De naturalibus facultatibus* and Sanctorius's static medicine. What is more, despite the striking parallels between the two quantitative approaches, there are also important differences (Sanctorius 1614: 13v; 1625: 21–4, 556, 569; 1629a: 23 f., 70 f.; 1902).

Galen used a quantitative argument, the high amount of urinary output, to defend his physiological theory, according to which the kidneys possessed a faculty to attract the matter they required to function. Sanctorius used a quantitative argument, the high amount of insensible perspiration, to show that this physiological phenomenon strongly influenced the state of health and that it was therefore necessary to systematically observe its occurrence. Hence, in the case of Galen, it was not important for the physician to personally observe for himself the quantity of urine, while in the case of Sanctorius there was a direct relation to medical practice. According to him, the monitoring of the *perspiratio insensibilis* by means of systematic weighing was fundamental to the preservation of health. Right at the beginning of the *De statica medicina*, he stated:

> If the physician, who is responsible for the health of others, takes care only of the sensible additions and evacuations and does not know their daily amount of insensible perspiration, he deceives them [his patients] and will not cure them (Sanctorius 1614: 1v).[34]

[33] "… quomodo verò insensibilis, & libera perspiratio minuat urinam: nos in lib.de statica medicina adeò exactè declaravimus, ut nemo sanè percipiet, nisi ad statica principia confugiat. Quod verò urina saepè resolvatur per sudorem, vel per invisibilem perspirationem Galenus facilè declarat I. de facul. naturalibus, …" See: Sanctorius 1612a: 756.

[34] "Si medicus, qui praeest aliorum sanitati, sit solum capax additionis, vel evacuationis sensibilis, & nesciat quanta quotidie illorum sit perspiratio insensibilis, illos decipit, & non medetur." See: Sanctorius 1614: 1v.

This shows that Sanctorius's quantification of insensible perspiration had an immediate bearing on therapy—a cure was only possible if the amount of insensible perspiration in patients was known for certain. Accordingly, while Galen's quantitative physiological reasoning was purely conceptional, as a means to confirm a theory, Sanctorius's quantification of insensible perspiration was directly related to medical practice. As has been demonstrated in Chap. 3, the Galenic concepts of the internal physiological processes that led to the formation of insensible perspiration were not called into question by Sanctorius. His interest lay in insensible perspiration *per se* and in its systematic quantification by means of firsthand observation. It is, however, unclear whether Sanctorius really envisaged that his colleagues and readers might imitate his weighing chair and conduct weighing procedures themselves, or whether he considered it enough that they follow the rules he had laid down in the *De statica medicina*, based on his own measurements.[35]

Another difference between Galen and Sanctorius is their measuring methods. Urine could be measured directly, just like any other liquid.[36] Contrary to this, insensible perspiration could be quantified only indirectly, by inference, namely by comparing the quantities of substances ingested respectively of the substances excreted—be these sweat, urine, or feces.[37] Accordingly, Galen expressed the quantity of urine in a measure for liquids that was common in his time, while Sanctorius referred to insensible perspiration by weight, as it was a steelyard which enabled him, in the first place, to determine its amount. While Galen could simply use a prefabricated vessel to measure both, the volume of wine ingested and the volume of urine excreted, to determine the quantity of insensible perspiration Sanctorius had to develop, as will be shown below, a method and an instrument of his own.

All in all, the similarities between Galen's quantitative reasoning and Sanctorius's static medicine as well as Sanctorius's reference to Galen's work *De naturalibus facultatibus* imply that there was a relation between Galen's quantification of urine and Sanctorius's measurement of insensible perspiration. However, as has been mentioned, also other works of Galen may well have inspired Sanctorius's novel approach to physiology; and it was still a big step from Galen's observation of drinkers' urinary output in to Sanctorius's weighing procedures to indirectly quantify an invisible phenomenon. Moreover, Sanctorius related his static aphorisms

[35] In the *De statica medicina*, Sanctorius alternated between different perspectives. Often, he used an impersonal, objective style, e.g., "one discovers that …" (*deprehendatur*), or "it is demonstrated that …" (*patet*). But sometimes he directly addressed the reader by writing, for example, "if you then observe from the weighing that …" ("*si ex ponderatione videris, …*"), or "if you have transpired at night more than usual …" ("*si magis solito noctu paerspiraveris, …*"). Thus, occasionally it seems as if Sanctorius was inviting his readers to perform the weighing procedures themselves (ibid.: 3v, 10r, 12r, 14r–14v).

[36] Galen does not seem to have considered the different densities of wine and urine.

[37] In the *De statica medicina*, Sanctorius also referred to sweat, in certain cases, but only in more general terms, without stating exact quantities. This implies that he did not differentiate between sweat and insensible perspiration in his weighing procedures (Sect. 7.5.1) (Sanctorius 1614: e.g., 4r, 5v, 10r,14r–14v).

directly to medical practice, whereas in Galen's clinical practice there was no desire to quantify—an aspect that will be examined more closely below.

5.4.2 Leonardo Botallo and the Production of Blood

However, one does not have to go as far back as antiquity to encounter instances of quantitative physiological reasoning. In fact, such efforts can be found also in the Renaissance, chronologically close to Sanctorius. In the sixteenth century, the Italian physician Leonardo Botallo tried to determine the amount of blood generated daily in the human body. This endeavor was driven by practical medical considerations, as Botallo promoted a more liberal use of phlebotomy (drawing blood) than hitherto usual.

"Bloodletting"—as the evacuation of blood for a cure or prevention was known—was frequently recommended by physicians in order to mitigate the harmful effects of an abnormally large volume of blood in the body. In the words of Sanctorius, an "excess or plethora of blood" (*polyaemia*) might, for example, fill the veins to such an extent that neither spirits nor blood could pass, which would led to a sudden corruption of blood and then death (Sanctorius 1629b: 96 f.). Specific quantities of how much blood should be let had been already defined by Galen, who regarded three cotyles as a moderate evacuation. This implies that Galen measured the amount of blood that he removed from his patients—hence, a further form of quantification already practiced in ancient medicine, yet which shall be mentioned here only as a side note (Brain 1986: 133).[38]

In 1577, Botallo published his work *De curatione per sanguinis missionem* (On Healing by Phlebotomy), in which he put forward his concept of the human body as a siphon. On the basis of the Galenic physiology of nutrition, he argued that the body constantly lost substance through insensible perspiration and steadily compensated this loss by taking up fresh blood from the veins (Sect. 3.2.5). In order to determine the amount of blood to be extracted in phlebotomy, Botallo attempted to estimate the quantity of the liver's daily output of fresh blood to the veins. He admitted that no certain measure could be given, as the rate would differ greatly from one individual to another as well as from day to day, influenced as it was also by a person's activities, amount of nutrition ingested, and overall state of health. Still, he suggested that in a healthy, well-nourished body of moderate size, around ten to eight ounces of fresh blood were generated per day. In a later edition of his work, published in 1583, Botallo even increased this estimate to one pound (Botallo 1577: 11, 163 f.; 1583: 174).

Medical experience, rather than mathematical calculations, was the basis of Botallo's quantification of blood production. As a military surgeon, he had often

[38] For further passages in which Galen referred to specific quantities regarding venesection, see: Brain 1986: 31, 87, 89, 92.

treated patients who almost bled to death, but whose bodies were sufficiently replenished with fresh blood within three to four days. Probably, it was observations like these that made him conclude that the healthy body contained about twelve to fifteen pounds of blood in total. Botallo knew people who regularly had from eight to twelve ounces of blood let twice per month for many years without suffering from a blood deficiency. In his view, this confirmed that any blood lost was quickly replaced, since these people would otherwise be bled dry within one year. Another experience to which Botallo referred was the large loss of blood by patients with hemorrhoids or other forms of chronic bleeding, which could amount to fourteen or more pounds per month. In order to sustain such chronic losses, Botallo argued, the liver must produce at least eight to ten ounces of blood per day (Botallo 1577: 159–64).

But what happened in a body that was not subject to unusual losses of blood? How could it be capable of holding such large amounts of blood? Insensible perspiration was the solution. It has already been mentioned that Botallo thought that blood production was proportional to the excretion of insensible perspiration. By emphasizing the persistence and abundance of this invisible loss, he tried to show that the body was able to remove large quantities of blood in the course of normal, daily nutrition. Interestingly, in this context, he proposed to perform a weighing procedure, either in thought or in deed: weigh a piece of moist clay, then put it aside, and measure its weight again the next day to find out how much moisture it has lost. From this experience, it could be inferred, so Botallo, that even the healthy human body could daily dispose of eight to ten ounces of blood, if one considered its great size and the fact that it was subject to internal and external heat. It is unclear, however, whether Botallo himself carried out the weighing procedure he suggested, since he did not specify any quantitative outcome (Botallo 1577: 164–7).

Jerome Bylebyl already pointed out the striking similarities to Sanctorius's work. Both physicians emphasized the importance of insensible perspiration and posited its considerable occurrence on the basis of weighing procedures. Admittedly, Botallo's observation of the weight of moist clay can be hardly compared to Sanctorius's systematic weighing of human bodies and yet, the basic approach to quantifying invisible losses indirectly by means of a pair of scales was formulated already in Botallo's work. However, contrary to Sanctorius, Botallo was interested in quantifying insensible perspiration only insofar as this might support his view of the daily copious production of blood. His ultimate goal was to promote a liberal use of phlebotomy, and not the observation and quantification of invisible losses. In a way, this was the exact opposite of what Sanctorius did in the *De statica medicina*. According to him, insensible perspiration, as the main determinant of health and disease, could be regulated by dietetics with no need for phlebotomy. Thus, Botallo and Sanctorius advocated different forms of therapy, bloodletting and dietetics, but simultaneously shared a common concern for medical practice. Both based their quantitative reasoning on experience and observation. However, Botallo specified numerical values only for blood production and not for insensible perspiration. For the latter, he simply relied on the knowledge he had gained during his medical practice and, too, able to draw on the long tradition of phlebotomy, which had included a quantitative dimension—the measurement of blood removed from the patient—at the least since Galen's day. Sanctorius, on the contrary, had to break new ground for the measurement of insensible perspiration in the human body.

It is interesting, in this regard, to note that Sanctorius's static observations suggested that the body's normal rate of turnover of substance was much higher than had been previously assumed. While Botallo considered his estimate of the daily blood production, eight to ten ounces, already as immensely large, Sanctorius determined that the daily amount of insensible perspiration was far greater. In the *De statica medicina*, he stated that around five pounds of insensible perspiration were excreted per day. One can only imagine the astonishment of the readers, confronted with Sanctorius's claim that such large bodily losses occur daily yet go unnoticed (Sanctorius 1614: 2v).[39]

Perusal of Sanctorius's commentaries reveals that he was acquainted with the work of Botallo, as he mentioned him in the discussion of the production of the vital spirits. Moreover, Botallo's book, *De curatione per sanguinis missionem*, was published in several editions during Sanctorius's lifetime (1577, 1580, 1583). This, together with the fact that Botallo was of Italian origin and maintained relations with the famous Medici family, enjoying the favor of Catherine de' Medici (1519–1589), implies that Sanctorius knew Botallo's treatise on phlebotomy.[40] However, Sanctorius nowhere referred to Botallo's estimate of blood production nor to the work *De curatione per sanguinis missionem*. Therefore, the discussion of a possible relation between Botallo's quantitative reasoning and Sanctorius's measurement of insensible perspiration remains pure speculation. What is beyond all speculation, however, is that Sanctorius was familiar with Galen's treatises on phlebotomy and at times specifically quoted Galen with regard to the amounts of blood that should be evacuated in phlebotomy (Sanctorius 1612a: 260; 1625: 746; 1629a: 468, 517 f.; 1629b: 161).

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[39] Writing in France in the sixteenth century, it can be assumed that Botallo used the Roman *libra* (pound) as a unit of measurement. It was equal to 327 g and divided into twelve *unciae* (ounces: one ounce = 27.25 g) (Cardarelli 2003: 73 f.). In Venice, the *oncia grossa* (39.5 g) and the *oncia sottile* (25 g) were in use. It is not known to which *oncia* Sanctorius was referring in the aphorisms of the *De statica medicina*. In the introduction to his edition of the *De statica medicina*, Giuseppe Ongaro referred to the *oncia sottile* without explaining the choice (Sanctorius and Ongaro 2001: 46). Given the precision of Sanctorius's quantitative statements and his aim to quantify the *perspiratio insensibilis*, this choice seems reasonable. Hence, Botallo's and Sanctorius's quantitative values cannot be compared directly. On the assumption that they used the units of measurement just mentioned, the five pounds to which Sanctorius referred are equal to 1500 g and Botallo's eight to ten ounces corresponds to 218–72.5 g.

[40] For bio-bibliographical information on Leonardo Botallo, see: Taccari 1971.

5.4.3 Cesare Cremonini and the Quantity of Arterial Blood

The last instance of quantitative physiological reasoning that shall be considered here is Cesare Cremonini's dispute of the view that arterial blood was excluded from nutrition.[41] According to Galenic medicine, the venous and arterial systems were completely distinct. While the veins carried blood and provided nutrition, the arteries contained a mixture of spirits and blood and served the dissemination of vital spirits (Sects. 3.2.5 and 3.2.6). This opinion was opposed by Aristotelians, who held that the heart was the main source of nutriment and that both, veins and arteries were involved in the process of nutrition. As one of the leading Aristotelian philosophers of the late sixteenth and the early seventeenth century in Italy, Cremonini wrote:

> Galen wants the venous blood to be, of its own substance, suitable for nutrition, so that from it all the members are nourished. I wish that Galen would tell me what becomes of the arterial blood? For it is continually generated, and once generated is diffused in great quantity to the entire body through the arteries. What then becomes of it, if it is always generated but is not consumed as nutriment? It would grow to infinity, because he says that an immense amount is always generated, but none of it is consumed" (Cremonini 1627: 338).[42]

Hence, Cremonini developed a quantitative argument, the danger of an impossibly large aggregation of blood in the arteries, in order to support his position that the arterial blood was consumed by the body as a major source of nutriment. Notwithstanding that Cremonini's quantification remained here on a rather general level and was purely conceptual—he did not mention any specific figures, nor did his reasoning include any form of measurement—it is still interesting for the following reasons. Cremonini was professor of natural philosophy at the University of Padua and the passage just quoted is from a transcript of his academic lectures, which he published in 1627 under the title *Apologia dictorum Aristotelis de origine, et principatu membrorum adversus Galenum* (Apology of Aristotle's opinions about the origin and the primacy of the members against Galen). As one of the three first ordinary professors of the arts and medicine faculty, he had many medical students in his audience. What is more, he was a direct colleague of Sanctorius during his tenure as first ordinary professor of theoretical medicine (Chap. 2). Sanctorius did not mention in his books the passage by Cremonini quoted here, but he did discuss the philosopher's opinion with regard to innate heat, mostly dismissively, in the

[41] In his article, *Nutrition, Quantification and Circulation*, Jerome Bylebyl pointed out two further examples of quantitative physiological reasoning that are contemporary to Sanctorius. These are the quantitative arguments of the Venetian physician Emelio Parigiano (1567–1643) and of Caspar Hofmann, a German professor of theoretical medicine (Sect. 2.5, fn. 46). As I could not find any reference to them in Sanctorius's works, I do not consider their quantitative reasonings here. For more information, see: Bylebyl 1977: 378–85.

[42] "Desiderarem, ut Galenus mihi diceret, quid fiat ex sanguine arteriali; nam continuè generatur, & generatum in multa quantitate diffunditur per totum corpus per arterias. Quidnam fit ab ipso, si semper generatur, & non absumitur in nutrimentum? Crescet in infinitum, quia semper generari nihil absumi dicit immensum." See: Cremonini 1627: 338. The English translation is taken from: Bylebyl 1977: 381.

Commentary on Hippocrates.[43] Here, too, it is unclear whether Sanctorius was aware of his colleague's quantitative argument regarding the nutritive process, so its influence should not be overestimated. Nonetheless, Cremonini's quantitative physiological reasoning, however basic it may be, attests that such notions were alive and kicking in medical circles at the University of Padua, and were used to refute rival theories. Even in the absence of specific figures, its existence alone proves that quantification was not unknown in the field of physiology, but was indeed put forward in arguments in the very milieu in which Sanctorius lived and worked (Sanctorius 1629a: 307 f., 329, 338 f.; Siraisi 1987: 222).

5.4.4 Quantification—A Growing Trend

To sum up, the picture painted by these last pages reveals that quantitative elements increasingly came to pervade Galenic medicine, both in theory and in practice. Certain forms of quantification can be identified in Galen's own work as well as that of Renaissance scholars. As has been shown, physicians, pharmacists, dieticians, and also laymen recognized the importance of measuring nutrition, excretions, and remedies and, in some cases, put this into practice. Cusanus proposed that the physician use a balance for quantification, in order to more accurately determine his patient's state of health. Galen and, much later, Botallo each pointed out the relevance of the amount of insensible perspiration. Like Botallo, the Alexandrian physician Erasistratus had put forward the idea of indirectly measuring invisible losses by means of a balance. In their discussion of physiological problems, Galen and Cremonini both used quantification as a mode of argument to defend one theory and refute another. In retrospect, Sanctorius's quantitative approach to physiology thus seems like a plausible evolution of these forms of quantification. However, Sanctorius placed himself explicitly in the tradition of Hippocrates and Galen, yet remained silent on, or—as with regard to Cusanus—altogether refutedany contemporary scholars' influence on his work. And nonetheless, the sometimes striking similarities between Sanctorius's endeavors and those of his contemporaries make it likely that their undertakings were to some extent related, even though the sources currently available here do not permit more than speculation. Hence, it is time now to finally consider Sanctorius's own quantification efforts and his development and use of measuring instruments in order to further uncover the path that led to his innovative approach to physiology.

[43] As Cremonini published his work *Apologia dictorum Aristotelis de origine, et principatu membrorum adversus Galenum* only in 1627, it is hardly surprising that Sanctorius did not refer to it in his works *Methodi vitandorum errorum*, *Commentary on Galen*, *De statica medicina*, and *Commentary on Avicenna*, which had all been published earlier. The *Commentary on Hippocrates* and the *De remediorum inventione* are the only works that Sanctorius published after 1627. It is of course possible that Sanctorius heard about Cremonini's quantitative argument while they both were teaching at the University of Padua.

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