



Atoms, Mixture, and Temperament in Early Modern Medicine: The Alchemical and Mechanical Views of Sennert and Beeckman

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Recent research on early theories of matter has shown the emergence of atomistic interpretations from the late Middle Ages to the eighteenth century.¹ The Renaissance was a turning point where atomistic theories flourished as transitional accounts which combined ancient atomism, Aristotelian physics, and alchemy. Such an atomist “revival” was prompted by the rediscovery of Diogenes Laërtius’ doxography of Leucippus, Democritus, and Epicurus, and by the first edition of Lucretius’ poem *De rerum natura*. The Aristotelian natural philosophy also played an important role in this current by continuing the scholastic debates on matter, the elements, and their substance. In addition, alchemy was crucial in the atomistic recrudescence as it considered the essential principles of matter, while praising Democritus as an ancient alchemical figure. Collectively,

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these philosophical movements contributed to the emergence of “neo-atomism” in the sixteenth and seventeenth centuries.

So far investigated in natural philosophy and alchemy, early modern neo-atomism has remained largely unexplored regarding medicine. Among the various medical disciplines that participated in the atomist revival, this chapter considers physiology. A branch of theoretical medicine, physiology studies the structure and functioning of the healthy body. In the historiography of the “scientific revolution”, this medical field has long been disparaged as an archaic discipline because of its obedience to Galenism. However, the last decades have witnessed a renewal of interest in early modern physiology. Historians of science have emphasized the importance of this medical field for the explanation of humours, vital functions, and the relationship between body and soul.² Along with these themes, the minute structure of the living body was also a key topic in physiology. The body was indeed considered as composed of four elements, whose four qualities determined the state of health or “temperament”. Defined as a balance of qualities, the temperament came from the union or “mixture” of the elements as the first components of the body.

Established by Aristotle and Galen, the notion of temperament as a mixture of elements roused numerous discussions on the status of matter and the substantial form in scholastic medicine. These debates, in turn, stimulated corpuscular and atomistic explanations in the early modern period. In this regard, the Italian physician Santorio Santori (1561–1636) proposed an interesting interpretation of elements and mixture in his medical works. According to Fabrizio Bigotti, Santorio suggested a pre-atomistic conception of bodies as porous compounds of elements that were characterized by size, shape, and motion in his *Methodus* (1603) and *Commentaria in Artem medicinalem Galeni* (1612).³ However, the originality of Santorio’s theory of matter deserves further appraisal in light of alternative approaches to temperament that were proposed in his own time. This chapter explores this question through the cases of two neo-atomist physicians: the German alchemist Daniel Sennert (1572–1637) and the Dutch engineer Isaac Beeckman (1588–1637).

Sennert and Beeckman were remarkable for providing two different perspectives on atomistic physiology: one based on alchemy and the other on mechanicism. A professor of medicine at the University of Wittenberg, Sennert was emblematic of the early seventeenth-century German

physicians highly trained in the Aristotelian and Galenic philosophy, who attempted to establish Paracelsian medicine in the academic sphere.⁴ Influential in the work of Boyle and Leibniz, his treatises on natural philosophy, medicine, and alchemy were widely read in the seventeenth century. On the other hand, Isaac Beeckman dedicated his life to technical activities in water systems in Zeeland, before occupying teaching positions at the Latin school of Utrecht, Rotterdam, and Dordrecht. Trained in theology at the University of Leiden and in mathematics at the Academy of Saumur (France), Beeckman obtained a medical degree at the University of Caen (France) in 1618, but never practised medicine.⁵ Instead, he developed a medical theory throughout his notebook, where he expounded his atomistic views in a mechanical philosophy that was inspired by his professional activities in hydraulics. Although he did not publish any treatise during his lifetime, his notebook circulated among his circle of scholarly friends, such as the French philosophers René Descartes, Marin Mersenne, and Pierre Gassendi.⁶

Whereas Sennert and Beeckman developed an atomistic account of temperament and mixture, both attached their interpretation to the medical tradition, despite Galen's rejection of atomism. By presenting their medical sources, this chapter aims to place Sennert's and Beeckman's atomistic explanations of temperament in the broader context of Renaissance Galenism. As it explores the role of the Galenic tradition in the emergence of early modern neo-atomism, this study also addresses the intellectual context of Santorio's endeavours in this direction. I will first consider the interpretation of elements and mixture that was applied to the notion of temperament in Sennert's *Institutionum medicinae libri quinque* (1620 [e.p. 1611]) and his *De chymicorum cum Aristotelicis et Galenicis consensu ac dissensu liber* (1629).⁷ Then, I will go on with the conception of temperament in Beeckman's notebook between 1616 and 1620. The final section examines Santorio's theory of mixture in *Methodi vitandorum errorum omnium qui in arte medica contingunt libri XV* (1603) in comparison with Sennert's and Beeckman's respective accounts of elements, matter, and the substantial form.

I SENNERT ON MINIMAL PARTICLES AND THE SUPERIOR FORM

In the history of early modern science, Sennert is an important figure for his project to merge Aristotelian physics, Galenic medicine, and Paracelsian alchemy into a consistent medical philosophy. In 1611, he attempted to systematize his medical thought in the *Institutiones medicinae*, a treatise divided into five books on physiology, pathology, semiology, hygiene, and therapeutics.⁸ Its general structure was comparable to eponymous works by the German physician and botanist Leonhart Fuchs (1501–1566) and the Dutch physician Johan Van Heurne or Heurnius (1543–1601), whom Sennert at times quoted in his treatise.⁹ Undoubtedly, he sought to emulate both medical glories of the reformed Germanic world by publishing his own *Institutiones* in Wittenberg, where he deployed his skills in Aristotelian natural philosophy and expressed openness to alchemical pharmacology.

The first book on physiology (*De φυσιολογία*) adopted the framework of the genre promoted by the *Physiologia* (1567) of the French physician Jean Fernel (1497–1558). The book began by defining medicine, health, and temperament, before ending with the vital functions, such as nutrition and reproduction.¹⁰ In the second edition of his *Institutiones* (1620), Sennert updated some of its parts according to the Paracelsian philosophy that he expounded in the first edition of his alchemical treatise *De chymicorum ... liber* (1619). Nevertheless, his views on temperament were quite similar to those presented in 1611, as they were anchored to the Aristotelian “pluralist” reasoning that he adopted until the second edition of *De chymicorum ... liber* in 1629. From that moment, Sennert developed an alternative interpretation of mixture, which is explored in the second part of this section.¹¹ Before tackling his later resort to atoms in *De chymicorum ... liber*, I shall now consider Sennert’s early interpretation of mixture and temperament in the *Institutiones*.

1.1 *Elements as Minima*

In the medical tradition, the notion of temperament was based on the concept of mixture developed in Galenic medicine and Aristotelian natural philosophy. As stated by Galen in *De elementis secundum Hippocratem*, the temperament resulted from the mixture of the elements, namely their physical union through the balance of their qualities.¹² Such a

conception drew on Aristotle's account of mixture in *De generatione et corruptione*. As Aristotle claimed, the elements mingled by action and passion of their contrary qualities, while their substances remained in potentiality in the compound, so that the resulting body was qualitatively moderate and substantially homogenous.¹³ In medieval and early modern medicine, this description raised abundant debates concerning the status of elements during mixture, in particular their substantial form and qualities.¹⁴ As Fabrizio Bigotti has shown, Santorio addressed this very question between 1603 and 1625 by discussing the medical interpretations of Galen, Avicenna, and Fernel. In order to delineate these various stances, I will now look at Sennert's appraisal of the notion of temperament.

Among the Renaissance physicians who shaped Sennert's view on temperament, Jean Fernel stands as a major figure. His medical philosophy was a Platonic response to the "materialistic" interpretation of Galen, which explained all physiological phenomena by the simple mixture of elements.¹⁵ In *De abditis rerum causis* (1548), Fernel stated that the body's vital principle, as well as poisons and pestilential diseases, had a celestial nature and some "occult" properties, which came from their substantial form.¹⁶ As Hiro Hirai has shown, his account applied the Platonic philosophy of Marsilio Ficino in a medical context by enhancing the divine origin of the form and the role of the world-soul.¹⁷ In his *Physiologia*, first published in 1542 as *De naturali parte medicinae*, Fernel supported the same idea in asserting that the living body had a twofold constitution, one related to the elements (material) and the other related to the vital principle (formal).¹⁸ The material constitution of the body corresponded to the temperament which resulted from the mixture of elements. These elements were arranged in a "juxtaposition" of minute parts whose forms remained intact, that is, in actuality. By contrast, the formal constitution of the body was related to its substantial form, which had a celestial nature and achieved the mixture of elements.

In many respects, Sennert adopted Fernel's approach to temperament, in the first place, by differentiating the body's formal and material constitutions. Following Aristotle and Galen, he considered the structure of the body into organic or "anhomeomerous" parts, such as the organs and limbs. These organic parts were composed of similar or "homeomerous" parts, for instance, the veins, arteries, muscles, tendons, tissues, and bones. As Sennert explained, the homeomerous parts were homogeneous

compounds or “mixts” resulting from the mixture of elements. They constituted the particles (*particulae*) and nearest principles (*proxima principia*) of the body, whose superior form determined their formal or “essential” constitution.¹⁹ Related to the soul, the superior form assumed the vital functions and the specific properties of the body parts, while achieving their elemental or “natural” constitution, in other words, their temperament.

Following Fernel’s interpretation, Sennert considered temperament as the moderate state or “concord” stemming from the “battle” of primary qualities through their mutual action and passion.²⁰ In his view, this qualitative moderation was distinct from the substantial form of the body. It was indeed the diversely balanced constitution of the body which caused its various states of health. In contrast, the formal nature of the living body was an essential constitution which was inalterable for its connection with the soul.²¹ To prove his point, Sennert appraised additional interpretations of temperament by Galenist physicians.

Whereas Sennert claimed the exclusive relationship between the form and the body’s life, he acknowledged that many physicians, such as Leonhart Fuchs, identified the temperament with the substance of the compound.²² However, Sennert objected, this stance contradicted the rules of physics, because it identified the substantial form of a compound with the mixture of its qualities, which had an accidental status. For this reason, Sennert rather followed the views of the Spanish physician Luis Mercado (1525–1611), archiatre of Philip II.²³ According to this stance, the temperament resulted from the alteration of the compound through its qualities. As was claimed by Mercado, this process consisted in the mixture of the elements through the action and passion of their qualities, as well as the “crushing” of the elements into their smallest parts or minima (*comminutio ad minima*).²⁴

Sennert further affiliated Mercado’s view to Avicenna’s definition of temperament or *complexio*. In his view, Avicenna deemed the *complexio* as the quality coming from the mutual action and passion of elements during mixture. As for the substances of the elements, they were reduced to contiguous minima (*partes ad minimas redactae*).²⁵ From Mercado’s and Avicenna’s interpretations of mixture, Sennert suggested that the formation of temperament involved the breakup into elemental minima, whose primary qualities torn up and merged into a single moderate quality.²⁶

Having associated the natural temperament to the primary qualities of the compound, Sennert turned to the definition expounded in Fernel’s

Physiologia. Whereas their respective interpretations were very similar, Sennert questioned Fernel's stance regarding the status of the elements within the compound. Because Fernel described the qualities as "extreme" and the forms as "intact" at the end of mixture, Sennert compared his model to a mere assemblage of grains and peas.²⁷ One must note that in his *Physiologia*, Fernel actually dismissed the interpretation of mixture as an assemblage of elements, in the same way as he rejected atomism. Still, he eventually proposed the ambiguous formula of a "continuous juxtaposition" of intact forms, along with the "concert" of intact qualities.²⁸ In contrast, Sennert asserted the breakup of the qualities and the status *in potentia* of the elemental forms within the compound.

In appraising the stances of Fuchs, Mercado, and Fernel regarding mixture, Sennert gave insight into his own interpretation of temperament. His insistence on the breakup of elements and qualities during mixture reflected his Aristotelian "pluralist" interpretation, which was inspired from the Averroistic model of mixture.²⁹ Following this approach, not only the qualities but also the substantial forms of elements were torn up in small parts within the compound. They united into a plurality of subordinate forms, which constituted a new median form, namely the form of the compound or "mixture". In the Renaissance, this interpretation was developed by Aristotelian philosophers at the University of Padua, such as Giacomo Zabarella (1533–1589). In *De rebus naturalibus libri XXX* (1590), Zabarella claimed the reduction of the elements into small parts of different degrees, which penetrated each other to form a homogenous whole.³⁰ As Emily Michael and William Newman have shown, Sennert developed this model of mixture as early as in his *Epitome naturalis scientiae* (1600). This approach to mixture underpinned his early criticism of Fernel's concept of temperament in the *Institutiones*. However, Sennert changed his interpretation in the second edition of *De chymicorum ... liber* (1629).³¹ The next section moves on to discuss his theory of mixture and temperament in this treatise.

1.2 From Minimal Particles to Atoms

From the first edition of his *De chymicorum ... liber* in 1619, Sennert expounded his medical views on matter by insisting on the benefits of Paracelsian alchemy for the development of pharmacy. As he explained, the separation of the alchemical principles or *tria prima* (Salt, Sulphur, and Mercury) allowed the "fixation" of a powerful "volatile" substance

into a moderate one. Consequently, even violent poisons and toxic metals, such as antimony, mercury, and arsenic, could be transformed into harmless and yet efficient remedies thanks to the alchemical art.³² With this aim in mind, Sennert proposed a conciliation of Paracelsian alchemy with Galenic medicine and Aristotelian natural philosophy. In the same way as other figures of a “chemical compromise”, he believed that the Paracelsian system was profitable for the improvement of drug making, but required the adjustment of its most obscure concepts.³³ To this purpose, Sennert anchored the Paracelsian concepts of principles and “separation” to the Aristotelian notion of mixture and the Galenic account of temperament. For this reason, the theory of temperament expounded in *De chymicorum ... liber* continued that of the *Institutiones*, but further discussed the structure of matter in connection with alchemy.

Whereas the first edition of *De chymicorum ... liber* endorsed a pluralist interpretation of mixture, its second edition (1629) expanded on a different model. Sennert, indeed, followed the argument of the Italian physician Julius Caesar Scaliger (1484–1558), whose *Exotericæ exercitationes* (1557) against Gerolamo Cardano’s *De subtilitate* enjoyed great renown in Northern Europe.³⁴ For his theory of mixture, Scaliger was an important figure in the diffusion of the Aristotelian corpuscularianism that was developed at the University of Padua in the Renaissance. Sennert adopted his description of mixture as the motion of the smallest bodies (*motus corporum minimorum*) towards a mutual contact, which resulted in the formation of a single being.³⁵ As Sennert previously stated in the *Institutiones*, these “miscible” elements were reduced to minimal parts, which were subject to a mutual action and passion through their contrary qualities. However, he joined Scaliger in asserting that these forms bound together under the supervision of the superior form of the compound. They remained intact, that is, in actuality, though in an inferior degree to the substantial form of the “mixt”.

By supporting Scaliger’s interpretation, Sennert meant to contend with the Latin pluralist account of mixture, which he affiliated to Zabarella, Averroes, and the Franciscan theologian John Duns Scotus (c.1266–1308).³⁶ Despite his endorsement of this view in his previous works and his constant reference to Zabarella’s account of the superior form, Sennert eventually qualified the tearing (*refractio*) of the forms during mixture as “pure fiction”.³⁷ With this assertion, he joined Scaliger, Avicenna, and Fernel in their claim of the permanence of intact forms within the compound.³⁸ As William Newman has shown, Sennert’s change

of interpretation aimed to provide an account of mixture that was more consistent with the atomistic framework that he adopted in the first edition of *De chymicorum* (1619).³⁹ As he merged the concept of mixture with the alchemical notion of separation, Sennert identified the alchemical principles or *tria prima* to Democritean atoms whose reunion (*synkrisis*) and separation (*diakrisis*) caused the generation of bodies.⁴⁰ In his view, all “fixed” and “volatile” substances involved in alchemical operations resulted from such a process of *diakrisis* and *synkrisis*.⁴¹ In support of this interpretation, Sennert referred to ancient authorities, most notably, Aristotle, Galen, and Avicenna.

To justify his adhesion to the atomistic philosophy of Democritus, Sennert first explained that Presocratic philosophers transmitted correct conceptions of natural change, although their terminology was misunderstood by their adversaries. In his view, it was because the Democritean reunion (*concretio*) of corpuscles was a more convincing explanation than the mixture of elements that the philosophical tradition partly followed atomism in postulating the association and separation of discontinuous components.⁴² As Sennert pointed out, whereas Aristotle rejected Democritus as a leading figure of mathematical atomism in *De generatione et corruptione*, he remained open to physical atomism.⁴³ As was illustrated in the *Meteorologica*, Aristotle, indeed, described bodies as composed of corpuscles and pores, while considering natural phenomena, such as rarefaction and condensation, as a process of *diakrisis* and *synkrisis*.⁴⁴

Sennert took much of these arguments from a major source in his work, the German physician Andreas Libavius (c. 1550–1616).⁴⁵ A ferocious adversary of the Paracelsian system, Libavius sought to show the initial compatibility of medieval alchemy with the authorities of Aristotle and Galen. Sennert partially adopted his concept of separation or *diakrisis* (*separatio*) and reunion or *synkrisis* (*concretio*) in the pharmacological part of his *Institutiones* (1611). Although this treatise did not mention atoms, it supported the reunion and separation of minimal parts (*partes minimae*) following the terminology of the medieval treatise *Summa perfectionis* attributed to the Arab alchemist Geber (Jabir ibn Hayyan). It was in the first edition of *De chymicorum ... liber* (1619) that Sennert defined these minimal parts as Democritean atoms.⁴⁶

Having claimed the compatibility of Aristotle with Democritus, Sennert finally considered Galen’s account of elements as a forerunner of atoms. Whereas Galen castigated Democritus’ atoms in *De elementis secundum Hippocratem*, he described the resolution of the compound into smallest

parts or particles (*minimas particulas*) during mixture.⁴⁷ Not only did Galen define the element as the minimal part of bodies, Sennert claimed, he also stated that the mixture of qualities was facilitated by the division of the compound into smaller parts.⁴⁸ According to Sennert, Avicenna honed this view in his *Canon* by defining *complexio* as the quality that arose from the mixture of elements by contact of their minute parts.⁴⁹ In the same way as he did in the *Institutiones*, Sennert quoted Avicenna to assert the resolution of the compound into contiguous minima and eventually endorsed Avicenna's view on intact elemental forms. From all this, Sennert concluded that authorities like Aristotle, Galen, and Avicenna were in fact reconcilable with his Democritean interpretation of elements.

In claiming his obedience to the medical tradition, Sennert deemed his account of mixture as more adequate to his atomistic explanation of the *tria prima*. Defined as atoms and minimal particles, the alchemical principles corresponded to what Sennert called the “homeomerous” bodies. In the philosophical tradition, such a type of bodies included homogenous compounds of elements, for instance, tissues, bones, blood, wood, and metals. In the *Institutiones*, Sennert defined such homeomerous parts as the “particles” (*particulae*) and nearest principles of bodies, which were endowed with a superior form. In his *De chymicorum ... liber*, he employed the same terms to designate the *tria prima* as homeomerous parts and “first mixts”, which were atomic compounds with a superior form.

As Sennert further stated, the form of homeomerous bodies was superior to that of their constituent elements in degree and in nature. The superior form, indeed, had a celestial nature rooted in the divine creation. As Michael Stolberg and Hiro Hirai have shown, Sennert considered that the forms were transmitted through the seeds that were propagated by God at the Creation.⁵⁰ Such an idea was already present in one of his major sources, Andreas Libavius. The latter suggested that homeomerous bodies like body parts and the alchemical principles had a celestial essence. For instance, in his *Novus de medicina veterum ... tractatus* (1599), Libavius identified the *tria prima* as elemental compounds (*elementata*) and “first mixts” in the hierarchy of beings, in the same way as the homeomerous parts. Such compounds enclosed a powerful essence—in the sense of superior form and quintessence—which was responsible for their alchemical and physiological properties. For Libavius, this essence was infused by God during the Creation and then remained immanent in the homeomerous parts of bodies.⁵¹

In enhancing the celestial powers of the substantial form, Sennert took up Libavius' strategy of counteracting the Paracelsian emphasis on the *tria prima* by showing their elemental composition. This interpretation was anchored in medieval alchemical treatises such as John of Rupescissa's *De consideratione quintae essentiae* about the divine essence enclosed in elemental compounds. It also referred to the *Rosarium philosophorum* in distinguishing the four elements from the first compounds that contained a quintessence.⁵² In consequence, Sennert's interpretation of the *tria prima* continued medical and alchemical explanations of homeomerous bodies as homogenous mixtures of elements. Their alchemical and sensory properties, he claimed, came from their superior form, which arranged the atoms with the instrument of the body heat.⁵³ As for the atoms, they were directed by the superior form and provided the elemental matter of homeomerous bodies.

2 ISAAC BEECKMAN ON ATOMIC ELEMENTS AND GEOMETRICAL PROPORTION

In comparison with Sennert, Beekman's medical atomism was less inspired by alchemical concerns than by professional activities in hydraulic engineering and the study of physics, astronomy, and mathematics. His interest in these fields resulted in a mechanical approach to natural phenomena. For this reason, Beekman is also an interesting point of comparison with Santorio, who adopted a mechanical view on medicine and its instruments and whose works were partly quoted in Beekman's notebook. In his first notes between 1604 and 1608, the young Beekman briefly investigated questions of astronomy and mathematics, which he gathered from ancient and contemporary texts, such as the works of Euclid, Ptolemy, Copernicus, Tycho Brahe, and Simon Stevin. Most of these authors were recommended to Beekman by the Dutch mathematician Rudolph Snel or Snellius (1546–1613) during his studies at Leiden in 1607–1610. Snellius also trained Beekman in Ramist philosophy, whose focus on logic partly shaped Beekman's medical theory of matter.

In about 1616, Beekman was studying treatises of medicine in view of obtaining a medical degree at Caen (Northwest France). As he was occupied in reading these works, he sought to answer a series of medical questions. These issues were often problematized in mechanical terms, as evidenced by the numerous schemata, geometric modelling, and

measurements in his notebook. In the corollaries of his medical thesis (1618), Beeckman applied the knowledge he acquired during his studies in Leiden, his mathematical training in Saumur, and his work on fountains and waterpipes.⁵⁴ Most notably, he stated the existence of interstitial void (*vacuum intermixtum*) and ascribed the traditional *fuga vacui* of pump suction to air pressure.⁵⁵ Although the notion of void was much debated in Aristotelian philosophy, it was diffused, in the early modern period, through ancient treatises on mathematics and engineering, such as the *Pneumatica* of Heron of Alexandria, also known as *Spirituum liber*. Abundantly commented upon by Beeckman in 1616, Heron's *Pneumatica* described the discrete structure of matter and the dispersed vacuum in water pumps.

Despite his primary concern with mathematics and engineering, Beeckman's medical thinking was far from being purely mechanical. As will be shown in this section, it integrated an atomistic theory in a medical context grounded in Galen. Beeckman's atomistic sources were overall based on Lucretius' *De rerum natura*.⁵⁶ In this section, I examine his early physiological theory between 1616 and 1620 as the result of his eclectic synthesis of Galenism, mechanicism, and atomism.⁵⁷

2.1 Elements and Pores

In the same way as Sennert, Beeckman did not consider atomism as incompatible with the traditional physics of elements and qualities, in spite of Aristotle's and Galen's numerous objections to Democritus. As he explained, bodies were composed of atoms (*atomi*) which were separated by interstitial void. The latter formed "intermediate empty spaces", that is, pores of diverse size between each atom.⁵⁸ As will be examined in the last section of this chapter, Beeckman shared a similar conception of the *primordia*—elements or atoms—to that of Santorio. In his view, the motion (*motus*), shape (*figura*), and number (*quantitas*) of atoms brought about the "forces" of bodies, namely their physical qualities. Following this reasoning, Beeckman deemed the four elements as atoms endowed with four types of shapes which were associated with the primary qualities.⁵⁹ Hot and cold qualities were due to the atomic motion, speed, and size.⁶⁰ Moist and dry qualities depended on the round or sharp atomic shape. Secondary qualities, such as taste, were caused by the shape of atoms and their ability to fit the pores. For instance, a round shape caused pleasant flavours, while

a sharp or hooked shape brought disagreeable flavours, following the account of Lucretius.⁶¹

By defining the four elements as four types of atoms, Beeckman reinterpreted the notion of substantial form related to the elements. As seen in the previous section, late Renaissance philosophers such as Fernel and Sennert claimed the supra-elemental status of the substantial form as a superior entity of celestial origin, which achieved elemental bodies and caused their vital properties. In contrast, Beeckman viewed the form as the mere arrangement of atomic elements, in particular their *situs*. This term corresponded to Lucretius' notion of "position" (*positura*), namely, the spatiality of atoms.⁶² Consequently, the form varied according to the geometrical arrangements of atoms, for instance, in a square or a cube. As Beeckman explained, two distinct bodies with the same elemental portions and particles had a distinct atomic disposition.⁶³ In consequence, the interval between the pores also determined the "essential difference" of bodies, that is, their form. Thus, in deriving the distinction between substance and physical qualities from the arrangement of atoms, Beeckman challenged the Aristotelian theory of matter-form, despite his traditional terminology of elements, qualities, and form.

Beyond this apparently materialistic interpretation, Beeckman expounded teleological views on the origin and organization of atoms. On the one hand, he adopted Galen's conception of finality in *De usu partium*.⁶⁴ Following Galen, he deemed the body matter as created by a demiurge, as was shown by the adequate structure and functioning of the organism. Interestingly, this teleological conception of physiology overlapped Beeckman's Calvinist faith regarding predestination.⁶⁵ He indeed stated that the concourse of atoms, which were "skillfully" designed by God, did not occur by chance.⁶⁶ Moreover, Beeckman integrated Lucretius' philosophy into his account of divine providence. As he explained, the divinely achieved atoms caused the harmonious functioning of nature by gathering in suitable circumstances depending on particular settings.⁶⁷ Their many arrangements resulted in a highly diverse nature, in the same way as the letters of the alphabet could formulate an infinity of words.⁶⁸

2.2 *The Minima and "Homogenea" of Bodies*

In 1620, Beeckman integrated key notions in the Galenic approach to elements, namely minima and "particles", into his atomistic theory. In his

view, atoms agglomerated into different levels, including minima and minimal particles (*minima particula*).⁶⁹ Rooted in Galen's *De elementis*, these minimal particles were part of a complex material structure. According to Beeckman, they operated the actions of a body part and broke up into their constituent minima in case of destruction.⁷⁰ Such a description echoed the traditional subdivision of the body parts into organic or "anhomeomerous" parts, such as the limbs and the organs, and similar or "homeomerous" parts, such as nerves, flesh, muscles, and tissues. Interestingly, Beeckman juxtaposed this explanation with the Aristotelian natural minima, though in the sense of the limited number of atoms that were required to operate a physiological function.⁷¹

According to Beeckman, the compounds were arranged into primary and secondary minima, which were also called "homogenous" parts (*homogenea*).⁷² In Beeckman's interpretation, the notions of *homogenea* and *minima* drew on the Galenic conception of body parts. This term referred to the traditional homeomerous parts, namely the homogenous compounds resulting from the "perfect" mixture of elements. As Benedino Gemelli has pointed out, the notion of minimum in Beeckman's thinking stood as a type of particle which was less theoretical than the atom and more convenient in a physical or chemical context.⁷³ Overall, Beeckman's concept of *homogenea* sought to explain the different physiological and medicinal properties which resulted from the gradual formation of complex bodies.

Among the possible sources for Beeckman's terminology of *homogenea*, alchemy and natural philosophy also had a prominent place. On the one hand, the alchemical works of Andreas Libavius were part of the references cited in his notebook. In particular, Beeckman noted Libavius' approach to alchemical substances as entities made of homogenous bodies.⁷⁴ On the other hand, Beeckman's terminology of *homogenea* likely referred to the works of German Calvinist theologian Bartholomaeus Keckermann (c.1571–1609). A professor of philosophy at the University of Dantzic (now Gdansk), Keckermann attempted to conciliate the Ramist logic with the Aristotelian philosophy of Zabarella.⁷⁵ While Beeckman mentioned Keckermann's *Systema logicae* (1600) in his correspondence of 1613, he also commented on his *Systema physicum* (1600) in 1618 in his notebook. From Keckermann, he kept the definition of elements as simple homogenous bodies which shared the same nature and denomination, in reference to the traditional homeomerous bodies, such as water, wine, blood, gold, and wood. As Keckermann pointed out, their minima and particles had

the same nature as the whole body which they constituted.⁷⁶ In consequence, Keckermann's account pointed to the multiple acceptations of *homogenea* as elements, particles, and minima, while emphasizing their status as homeomerous bodies.

Following this scheme, Beeckman established two levels of homogenous parts, which corresponded to the subdivision of bodies into minimal particles and minima. As he explained, the elements first united (*conjunctio*) into some minima, which formed the "primary" homogenous part, as well as the minima of the "secondary" homogenous parts.⁷⁷ When these secondary *homogenea* were divided, they lost their specific properties and broke up into primary *homogenea*. Similarly, the primary *homogenea* were decomposed into their constituent elements, atoms, and minimal particles. Although Beeckman was unable to specify how many minima entered in the composition of primary *homogenea*, he insisted that their finite number was able to build an abundance of natural beings.⁷⁸

2.3 The Spatial Arrangement of "Particles"

As he began to study Galenic medicine, Beeckman noted the discontinuous interpretation of elements and mixture in Renaissance physiology. In 1618, he reported in his notebook that Fernel's *Physiologia* asserted the intact status of the elements that were united in the compound during mixture.⁷⁹ From Fernel's explanation of temperament, Beeckman retained the definition of mixture as a juxtaposition of elemental minute parts. Following this view, he considered the healthy temperament as a correct arrangement of particles, namely elemental atoms. Therefore, the substantial form of the body was nothing but the "disposition" (*dispositio*) and "binding" (*connectio*) of its material components.⁸⁰

Interestingly, Beeckman drew his interpretation of temperament as a disposition of atomic elements on anatomy and logic. One major reference was *De morbis* (1548) by the Italian physician Giovanni Argenterio (1513–1572). From this treatise, Beeckman borrowed the definition of health and illness as a correct or incorrect *connectio* and *dispositio* of the anatomical parts.⁸¹ However, he applied it to his matter theory so that the binding and disposition related to the elemental particles of the body.⁸² As will be seen in the last section of this chapter, this reasoning offered similarities with Santorio's account of mixture in *Methodus vitandorum*. Moreover, the notions of *connectio* and *dispositio* reflected Beeckman's sources in logic and dialectics. Among them, Melanchthon's

Erotemata dialectices (1547) took a logical approach to the notion of form as the *dispositio* and *connexio* of the constituents of discourse. Keckermann, who likely inspired Beeckman's concept of *homogenea*, also took up this definition in his logical works.⁸³ Similarly, Beeckman viewed the healthy temperament as the correct binding and disposition of its minimal parts.

One year later, Beeckman related his interpretation of temperament as the binding of minimal parts to the Galenic conception of *eukraton*, namely the well-tempered body. In the medical tradition, this notion designated the most appropriate temperament (*temperatura*).⁸⁴ Its constitution was different for each species following the idea of a "latitude" of temperament.⁸⁵ This entailed that a fish, a lion, or a human being had a distinct *eukraton*, which was characterized by a moderate state (*medium*) coming from the mixture of their elements. For Beeckman, the ideal temperament of the human being was equal in weight (*ad pondus*) to the extent that its qualities were equally distributed from a quantitative point of view.⁸⁶ Whereas Galen stated the theoretical nature of the temperament equal in weight, which could not be found in nature, Beeckman believed that the ideal temperament consisted in such a quantitative balance of elements in relation to a middle state.

Beeckman honed his interpretation of temperament as an arithmetic proportion of elements from an atomistic perspective. As he stated in 1620, the ideal constitution (*eukraton*) was a proportionate union and a quantitative disposition of elemental particles and minima. If this conception corresponded to the Galenic definition of temperament equal in weight (*ad pondus*), Beeckman considered this terminology of little importance because the mathematical proportion alone was insufficient to define temperament. As he explained, the position and shape of the minima also needed to be taken into account.⁸⁷ Because of their geometrical proportion and their position (*situs*), the particles of the human body consisted in regular polyhedra. The shape of its minima was composed of twenty triangles, which formed "suitably connected" icosahedra.⁸⁸ In Beeckman's interpretation, this geometrically ordered shape was implicitly equivalent to a homogenous part. The regular shape of their minima defined the substantial form with its specific properties. Thus, for Beeckman, it was the diverse arrangements of icosahedra which defined the temperament and particular features of each human being.⁸⁹ This reasoning also implied that all living beings were provided with a particular atomic disposition, which was defined by its regular shape. However, the exact configuration of each species was unknown to Beeckman.

A remaining question is the source of Beeckman's interpretation of the primordia as polyhedral figures. This idea was first developed in Plato's *Timaeus*, where the four elements were presented as polyhedra made up of triangular units designed by God.⁹⁰ The Platonic solids were also discussed in Euclid's *Elementa* from a mathematical perspective. But Beeckman's discussion on the polyhedral constitution of the living realm was overall reminiscent of Kepler's *Strena sive De nive sexangula* (1611).⁹¹ In investigating the geometrical structure of snow crystals, Kepler postulated that living beings might be composed of pentagonal figures which formed regular polyhedra, namely dodecahedra or icosahedra.⁹² According to this theory, their regular figure was related to an internal formative principle, which was responsible for the reproduction and functioning of living beings.⁹³

Whereas Beeckman adopted a similar geometric and corpuscular reasoning, his primary objective was to propose a mathematical definition of temperament on the basis of a determinate number of components.⁹⁴ Hence his mathematical approach was distinct from the Renaissance Platonic approach to polyhedra as geometrical instantiations of living beings. In commenting upon Kepler's *Strena* in around 1628, Beeckman actually considered the notion of "formative nature" as "ridiculous and unworthy of a philosopher".⁹⁵ In his view, the qualities and faculties of bodies were not related to an incorporeal entity depending on the substantial form of beings, which early physicians and alchemists had associated to the "total substance" and the quintessence. For Beeckman, all these notions corresponded to the atomic composition and shape of homogenous bodies.⁹⁶

3 SANTORIO'S THEORY OF MIXTURE IN LIGHT OF SENNERT AND BEECKMAN

Having explored Sennert's and Beeckman's interpretations of temperament, I will close this investigation by comparing their theories of mixture and elements with Santorio Santori's early theory of mixture in *Methodus* (1603).⁹⁷ In the eighth book of this treatise, Santorio harshly criticized the notion of hidden or "occult" (*reconditae*) qualities related to the substance by targeting Fernel's exposition of the total substance (*tota substantia*) in *De abditis rerum causis*.⁹⁸ This concept was developed by Galen about powerful qualities, such as magnetic, physiological, pharmacological, and

toxic powers, which were known by experience but impossible to explain rationally. Fernel sought to elucidate their origin by associating the body's total substance to its superior form. Since the forms had a celestial origin and were diffused by the world-spirit through the seeds, the total substance did not result from the mixture of elements but had a divine nature causing its strong powers. With this reasoning, Fernel attempted to provide a consistent explanation of the hidden causes of poisons, violent diseases, and epidemics like plague and syphilis in a fashionable Platonic framework.⁹⁹

In contrast to Fernel's account of the whole substance, Santorio believed that the attribution of "occult" qualities to the body's form and substance was philosophically dubious as all qualities were supposed to derive from matter. At first, he seemed to claim that such operative powers derived from the harmony and proportion of qualities, namely their temperament. Following the Galenic tradition, which Fernel, Sennert, and Beeckman adopted, Santorio described temperament in relation to mixture as a union of minute parts and particles. But his theory took an original turn as he attributed to these parts some shape (*figura*), position (*situs*), and interstices (*meatus*) in compliance with Galen's definition of the body's disposition.¹⁰⁰ It should be noted, however, that Galen's terminology designated the shape and position of anatomical parts, while Santorio pointed to their smallest components, namely the elements.¹⁰¹

To counter any accusation of Democritean atomism, Santorio asserted that the substantial form underpinned the qualities of a compound. Each of them emerged from matter thanks to the "working" (*opificio*) of its arrangement.¹⁰² In order to produce an infinite number of forms, matter was disposed in eight "positions" from which came various properties, first rarity and density, then primary qualities such as heat and cold, finally secondary qualities such as sharpness and softness. By "position", Santorio meant eight types of *situs*: inside and outside, forwards and backwards, left and right, upwards and downwards.¹⁰³ He further compared this model to the structure and functioning of a clock, due to a "more divine handicraft" (*diviniori artificio*).¹⁰⁴ Still, Santorio did not provide any further details on the union of particles within the body, nor did he elaborate his matter theory in relation to physiological phenomena in *Methodus vitandorum*. According to Fabrizio Bigotti, Santorio later offered additional explanations of his matter theory in his *Commentaria* on Galen's *Ars medica* (1612) and in the *marginalia* of his *Commentaria* on Avicenna's *Canon*

(1625).¹⁰⁵ These accounts also give insight into his physiology of digestion and perspiration in *Medicina statica* (1614).

For his criticism of the supra-elemental character of the substantial form and the Platonic philosophy of Fernel, Santorio's interpretation contrasted with Sennert's medical theory of matter. Both physicians viewed temperament as a union of the minimal particles of bodies, in the sense of discrete units of matter which juxtaposed during mixture. Such an interpretation of the elements was stimulated as much by the Galenic debates on mixture as by the Renaissance approach to natural minima in the Aristotelian school of Padua. Whereas Santorio preserved the terminology of matter-form, elements, and qualities in his account of mixture, he nonetheless reduced the substantial form to the shape, position, and motion of elements as discrete units of matter. Thus, in suggesting the emergence of substances and their qualities from matter, Santorio diverged from Sennert's interpretation of the substantial form.¹⁰⁶ Sennert indeed adopted Fernel's conception of the form as a supra-elemental entity which supervised elemental compounds and conferred them some "occult", that is, physiological and alchemical, powers.

On the other hand, Santorio's interpretation of mixture offered similarities with Beekman's account of temperament. While it is difficult to establish whether Beekman read Santorio's *Methodus vitandorum*, he provided comparable statements in his notebook between 1616 and 1620. As shown in the previous section, Beekman claimed that the substantial form of bodies resulted from the spatial arrangement and the various dispositions of minimal particles, which were initially designed by God. In addition, both Santorio and Beekman applied the anatomical views of Galen about the disposition of the body parts at the level of their smallest components. However, Santorio's and Beekman's sources for the geometrical arrangement of elements, in analogy with that of anatomical parts, drew on distinct sources. Beekman's conception of atomic *dispositio* was anchored in Argenterio's account of anatomical disposition, in addition to Lucretian atomism and Ramist logic. In contrast, Santorio's account of material shape, position, and number was inspired from the matter theory of the Venetian theologian Paolo Sarpi (1552–1623). Moreover, Santorio did not mention atoms or atomist philosophers in his medical account of elements and mixture.¹⁰⁷

Like Santorio, Beekman applied a mechanical analogy to the functioning of the human body, but in relation to pumps and waterpipes rather than clocks. He integrated this scheme in Lucretian atomism and Galenic

physiology, which he comprehensively applied to his explanation of health and nutrition. For instance, Beeckman provided a hydraulic interpretation of digestion as a process of dilation and contraction of the digestive organs, where body heat and pressure transformed the atomic arrangement of food by rarefaction and condensation.¹⁰⁸ In the same way, the concoction of the four humours in blood was described as a reconfiguration of chyle into four *homogenea*.¹⁰⁹

Although it is unlikely that Beeckman's atomistic reasoning was rooted in *Methodus vitandorum*, he was acquainted with some of Santorio's works that were subsequent to this treatise. These works include *Ars de statica medicina* (1614), *Commentaria in primam Fen primi libri Canonis Avicennae* (1625), and *De remediorum inventione* (1630), as attested by Beeckman's notebook and *Catalogus librorum*.¹¹⁰ Between 1628 and 1631, Beeckman discussed Santorio's *Commentaria* on Avicenna in his notebook, mostly about mechanical problems and the *pulsilogium*, but did not relate these themes to his own medical theory of matter.¹¹¹ In addition, he expressed a deep interest in Santorio's medical instruments in his correspondence of 1631–1633.¹¹² Therefore, if Beeckman's physiological theory drew on the works of Santorio, it would be overall on his *Medicina statica* regarding nutrition as a process of perspiration, evacuation, and repletion of the digestive organs.

4 CONCLUSION

Sennert's and Beeckman's medical accounts of elements, mixture, and temperament proposed two contrasting atomistic conceptions of the body. On the one hand, Sennert adopted a Democritean view on elements and mixture as a consequence of his theoretical obedience to Paduan Aristotelianism and his practical concerns in alchemical pharmacy. His medical theory of matter was rooted in the medieval and Renaissance interpretations of elements as contiguous particles that mingled during the formation of temperament. Whereas this view took an atomistic dimension, it was only to emphasize the reunion of discontinuous material units. Overall, his theory of matter remained imbued with Aristotelian hylomorphism as it insisted on the role of the superior form in the formation of bodies. On the other hand, Beeckman considered Lucretian atomism as the most adapted framework to apply his theoretical and practical concerns in geometry, hydraulics, and engineering. Unlike Sennert, he comprehensively applied the traditional characteristics of atoms, such as

size, shape, and position, as well as the notion of interstitial vacuum, to his account of temperament and mixture.

In identifying bodies as homogenous compounds of elemental “particles”, both Sennert and Beeckman reinterpreted in atomistic terms the traditional discussions on the role of elements, qualities, and the substantial form in the constitution of bodies. This framework was centred on the Galenic account of temperament as a proportion of the elemental qualities, and the Aristotelian definition of mixture as the homogenous union of the elements through their matter and form. Both early modern physicians defined elements as minimal particles which aggregated into homogenous body parts. However, in contrast with Sennert, Beeckman shaved away the Aristotelian model of mixture as a battle of elemental qualities, from which emerged the substantial form, while the elements remained in potentiality in the compound. Instead, he understood the substantial form as the proportional arrangement of atoms from a geometrical and spatial point of view. It was their regular positioning which ensured the homogeneity of the body.

Moreover, both Sennert and Beeckman dismissed the impious dimension of atomism by emphasizing their creation by God, from which originated the harmony and functionality of nature as a sign of the divine providence. If Sennert sought to highlight the celestial origin of the superior form to explain the physiological and alchemical properties of bodies, Beeckman focused on the creation of atoms, minima, and particles as the fundamental units of matter, which were subject to an infinite number of arrangements. By “atomizing” the notion of form, which traditionally emphasized the superior and even divine nature of the body’s substance, Beeckman took an original position towards the medical tradition.

In sum, Sennert’s and Beeckman’s medical theories of matter offer an interesting point of comparison to understand the various intellectual strategies that late Renaissance physicians developed to support atomism in a Galenic context. Most remarkably, the questions at stake, including the conception of elements as minimal particles, the nature of the substantial form, and the notion of “occult” qualities, formed the subtext of Santorio’s theory of matter. Although he did not explicitly refer to atoms or atomist philosophers, Santorio developed an original conception of elements that were subject to a clockwork process of mixture. For his reinterpretation of temperament from a mechanical perspective, Santorio’s account is better understood if placed in the context of Sennert’s reception of Paduan Aristotelianism and Beeckman’s atomistic conception of

the substance. Together, the three physicians provide striking illustrations of the complex relationship between Galenic medicine and the emergence of atomistic explanations of temperament in the early seventeenth century.

NOTES

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2. See Manfred Horstmanshoff, Helen King and Claus Zittel (ed.), *Blood, Sweat and Tears: The Changing Concepts of Physiology from Antiquity into Early Modern Europe* (Leiden: Brill, 2012); Andrew Cunningham "The Pen and the Sword: Recovering the Disciplinary Identity of Physiology and Anatomy before 1800. Part 1: Old Physiology: the Pen," *Studies in History and Philosophy of Science*, 33 (2002): 631–65.
3. See Fabrizio Bigotti's chapter, "Gears of an Inner Clock: Santorio's Theory of Matter and its Applications," in this volume.
4. On Sennert, see Emily Michael, "Sennert's Sea Change: Atoms and Causes," in Lüthy, Murdoch and Newman, eds., *Late Medieval*, 331–362; ead., "Daniel Sennert on Matter and Form: At the Juncture of the Old and the New," *Early Science and Medicine*, 2 (1997): 272–99; Newman, *Atoms*, 85–156; Clericuzio, *Elements*, 9–34; Hiro Hirai, *Medical Humanism and Natural Philosophy: Renaissance Debates on Matter, Life and the Soul* (Leiden: Brill, 2011), 151–72; Michael Stolberg, "Particles of the Soul: The Medical and Lutheran Context of Daniel Sennert's Atomism," *Medicina nei secoli*, 15 (2003): 177–203.
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6. Isaac Beeckman, *Journal tenu par Isaac Beeckman de 1604 à 1634*, edited by Cornelis de Waard, 4 vols (The Hague: Martinus Nijhoff, 1939–53).
7. Daniel Sennert, *Institutionum medicinae libri V* (Wittenberg: Z. Schürer, 1620); id., *De chymicorum cum Aristotelicis et Galenicis consensu ac dissensu* (Wittenberg: Z. Schürer Sr, 1629).
8. On Sennert's approach to physiology, see Elizabeth Moreau, "Vegetal Analogy in Early Modern Medicine: Generation as Plant Cutting in Sennert's Early Treatises (1611–1619)" in *Vegetative Powers: The Roots of Life in Ancient, Medieval and Early Modern Natural Philosophy*, edited by Andreas Blank and Fabrizio Baldassarri, 221–240 (Cham: Springer, 2021).
9. Leonarth Fuchs, *Institutionum medicinae, ad Hippocratis, Galeni, aliorumque veterum scripta ... Libri quinque* (Lyon: T. Guerin, 1555); Johannes Heurnius, *Institutiones medicinae* (Lyon: Officina Plantiniana, 1592).
10. See Jean Fernel, "The Physiologia of Jean Fernel (1567). Tr. John M. Forrester", *Transactions of the American Philosophical Society*, 93 (2003): i–636.
11. On the evolution of Sennert's philosophy, see Michael, "Sennert's Sea Change"; Christoph Lüthy "Daniel Sennert's Slow Conversion from Hylemorphism to Atomism," *Graduate Faculty Philosophy Journal*, 26 (2005): 99–121.
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- id., “Humanisme, néoplatonisme et *prisca theologia* dans le concept de semence de Jean Fernel,” in *Jean Fernel. Corpus*, edited by José Kany-Turpin, *Revue de philosophie*, 41 (2002): 43–70.
18. Fernel, “Physiologia”, 3, 214–55. See Elizabeth Moreau, “Elements, Mixture and Temperament: The Body’s Composition in Renaissance Physiology,” in *Oeconomia corporis: The Body’s Normal and Pathological Constitution at the Intersection of Philosophy and Medicine*, edited by Chiara Beneduce and Denise Vincenti, 51–8 (Pisa: Edizioni ETS, 2018).
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 20. *Ibid.*, 1.4, 16b.
 21. *Ibid.*, 1.3, 8a.
 22. *Ibid.*, 1.4, 14a. See Fuchs, *Institutionum*, 1.3.1, 45.
 23. On Luis Mercado, see Michele L. Clouse, *Medicine, Government and Public Health in Philip II’s Spain* (Farnham: Ashgate, 2011), 43–74.
 24. Sennert, *Institutionum*, 1.4, 14b.
 25. *Ibid.*, 1.4, 15a. See Avicenna, *Avicennae Arabum medicorum principis [Canon medicinae]* (Venice: Giunta, 1595), 1.1.3.1, vol. 1, 11ab.
 26. Sennert, *Institutionum*, 1.4, 15b–16a.
 27. *Ibid.*, 1.4, 16ab.
 28. Fernel, “Physiologia”, 2.8, 208–13.
 29. Emily Michael, “Averroes and the Plurality of Forms,” *Franciscan Studies*, 52 (1992): 155–82.
 30. Jacopo Zabarella, *De misti generatione et interitu libri tres*, in *De rebus naturalibus libri XXX* (Venice: P. Meietus, 1590), 407–78.
 31. Michael, “Daniel Sennert”; *ead.*, “Sennert’s Sea Change”; Newman, *Atoms*, 85–156.
 32. Sennert, *De chymicorum* (1629), 12, 213b–14a.
 33. On the “chemical compromise” in the seventeenth century, see Allen G. Debus, *Science, Medicine and Society* (New York: Science History Publications, 1972), 151–65.
 34. Julius Caesar Scaliger *Exotericarum exercitationum liber quintus decimus De subtilitate ad Hieronymum Cardanum* (Paris: M. Vascosan, 1557), f. 143 v. On Scaliger’s concept of mixture, see Kuni Sakamoto, *Julius Caesar Scaliger, Renaissance Reformer of Aristotelianism: A Study of His Exotericae Exercitationes* (Leiden: Brill, 2016); Christoph Lüthy “An Aristotelian Watchdog as Avant-Garde Physicist: Julius Caesar Scaliger,” *The Monist*, 84 (2001): 542–61.
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39. Newman, *Atoms*, 85–153.
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41. Ibid., 12, 213b–14a.
42. Ibid., 12, 211b.
43. Ibid., 12, 211b–12a. See Aristotle, *On Generation and Corruption*, 1.2, 315b7–10.
44. Aristotle, *Meteorology*, 1.9, 346b23–25, and 2.9, 369b35–36. See William R. Newman, “Corpuscular Alchemy and the Tradition of Aristotle’s Meteorology, with Special Reference to Daniel Sennert,” *International Studies in the Philosophy of Science* 15 (2001): 145–53.
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46. Sennert, *Institutionum*, 5.2, 1046; Id., *De chymicorum* (1619), 18, 358. See Newman, *Atoms*, 89–91.
47. Sennert, *De chymicorum* (1629), 12, 212a.
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50. Hirai, *Medical Humanism*, 151–72; Stolberg, “Particles”.
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55. Beeckman, *Journal*, vol. IV, 44 (1618). See Edward Grant, *Much Ado about Nothing: Theories of Space and Vacuum from the Middle Ages to the Scientific Revolution* (Cambridge: Cambridge University Press, 1982).
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 59. *Ibid.*, 152–3.
 60. *Ibid.*, 216.
 61. *Ibid.*, 149–50. See Gemelli, *Isaac Beeckman*, 59–61; Lucretius, *De rerum natura*, 2, 402–7.
 62. See Gemelli, *Isaac Beeckman*, 79 et passim; Lucretius, *De rerum natura*, 1, 685 and 2, 1017–22.
 63. Beeckman, *Journal*, vol. I, 153.
 64. *Ibid.*, vol. I, 163–4.
 65. van Berkel, *Isaac Beeckman*, 140–7.
 66. Beeckman, *Journal*, vol. II, 62–3.
 67. *Ibid.*, 43, 57.
 68. See Gemelli, *Isaac Beeckman*, 53–8, 97–102; Lucretius, *De rerum natura*, 2, 688–99, 1013–22.
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 71. Aristotle, *Physics*, 1.4, 187b35–188a13. See John E. Murdoch “The Medieval and Renaissance Tradition of *Minima Naturalia*,” in Lüthy, Murdoch and Newman, eds., *Late Medieval*, 91–132.
 72. Beeckman, *Journal*, vol. II, 117–18.
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 74. Gemelli, *Isaac Beeckman*, 127. In this passage, Beeckman quoted Andreas Libavius, *Syntagmatis selectorum ... Alchymiae Arcanorum tomus primus*, 5.18 (Frankfurt: N. Hoffmann and P. Kopff, 1615), 193–4.
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79. Beeckman, *Journal*, vol. I, 168–9.
80. *Ibid.*, 203.
81. Giovanni Argenterio, *De morbis libri XIII* (Lyon: S. Honoré, 1558), 2.23, 652–4. See Nancy G. Siraisi, “Giovanni Argenterio and Sixteenth-Century Medical Innovation: Between Princely Patronage and Academic Controversy,” *Osiris* 6, (1990): 161–80.
82. Beeckman, *Journal*, vol. I, 221–2.
83. Philipp Melanchthon, *Erotemata dialectices* (Wittenberg: J. Crato, 1556), 3, 142; Bartholomaeus Keckermann, *Systema logicae minus* (Hanover: W. Antonius, 1606), 247–8.
84. Beeckman, *Journal*, vol. I, 347.
85. On the latitude of temperament in scholastic medicine, see Per-Gunnar Ottosson, *Scholastic Medicine and Philosophy: A Study on Commentaries on Galen’s Tegni* (ca. 1300–1450) (Naples: Bibliopolis, 1984), 166–94; Roger K. French, *Canonical Medicine: Gentile Da Foligno and Scholasticism* (Leiden: Brill, 2001), 106–7.
86. Beeckman, *Journal*, vol. I, 296–7.
87. Beeckman, *Journal*, vol. II, 70.
88. *Ibid.*, 124–5.
89. *Ibid.*, 125.
90. Plato, *Timaeus*, 55a–56c. On the geometrical approach to the form, see Emerton, *Scientific Reinterpretation*, 126–53.
91. Johannes Kepler, *The Six-Cornered Snowflake*, trans. Colin Hardie (Oxford: Oxford University Press, 2014).
92. Johannes Kepler, *Strena seu De nive sexangula* (Frankfurt: G. Tampach, 1611), 12.
93. Lancelot L. Law Whyte, “Kepler’s Unsolved Problem and the *Facultas Formatrix*,” in Johannes Kepler *The Six-Cornered Snowflake* (Oxford: Oxford University Press, 2014), 57–63.
94. Kepler took this interpretation from Giordano Bruno, *De triplici minimo* (1591). However, Beeckman did not mention this work in his diary and commented on Bruno only from 1632. On Bruno’s atomistic interpretation of the minimum, see Hilary Gatti (2001) “Giordano Bruno’s Soul-Powered Atoms: From Ancient Sources towards Modern Science,” in Lüthy, Murdoch and Newman, eds., *Late Medieval*, 163–80.
95. Beeckman, *Journal*, vol. III, 33–4.
96. Beeckman, *Journal*, vol. II, 83, 85–6, 118, 127–9.
97. On Santorio, see Fabrizio Bigotti “A Previously Unknown Path to Corpuscularism in the Seventeenth Century: Santorio’s *Marginalia* to the *Commentaria in Primam Fen Primi Libri Canonis Avicennae* (1625),” *Ambix*, 64 (2017): 29–42; Nancy G. Siraisi, *Avicenna in*

- Renaissance Italy: The Canon and Medical Teaching in Italian Universities after 1500* (Princeton NJ: Princeton University Press, 1987), 206–352.
98. Jean Fernel, *Jean Fernel's On the Hidden Causes of Things: Forms, Souls and Occult Diseases in Renaissance Medicine*, trans. John M. Forrester (Leiden: Brill, 2005). See John M. Forrester, "Jean Fernel and the Importance of his *De abditis rerum causis*," in Fernel *On the Hidden Causes*, 3–66; Hirai, *Medical Humanism*, 46–79; Brian P. Copenhaver, *Magic in Western Culture, from the Antiquity to the Enlightenment* (Cambridge: Cambridge University Press, 2015), 301–13.
 99. Richardson, "Generation".
 100. Santorio Santori, *Methodi vitandorum errorum omnium ... libri XV* (Venice: F. Bariletto, 1603), 8.5, f. 155 v.
 101. See Galen, *On the Usefulness of the Parts*, trans. M. Tallmadge May (Ithaca: Cornell University Press, 1968); id., *On Anatomical Procedures*, trans. Charles Singer (Oxford: Oxford University Press, 1956).
 102. Santorio, *Methodi*, VIII.8, f. 158 v.
 103. Ibid., VIII.7, f. 157 v.
 104. Ibid., VIII.10, f. 160 r.
 105. Bigotti, "Gears of an Inner Clock."
 106. On Sennert's reception of Santorio in his posthumous *Paralipomena* (1643), see William Newman's chapter in this volume.
 107. Bigotti, "Previously Unknown Path", 36–7.
 108. On Beeckman's approach to digestion, see Moreau, "Combining Atomism."
 109. Beeckman, *Journal*, vol. II, 103–4.
 110. Ibid., vol. IV, 302; S.n., *Catalogus variorum et insignium librorum clarissimi doctissimique viri D. Isaaci Beeckmanni* (Dordrecht: I. Andreae, 1637).
 111. Ibid., vol. III, 41, 174, 177, 183.
 112. Ibid., vol. IV, 207, 216.