7 Combining Atomism with Galenic Medicine

The Physiological Theory of Isaac Beeckman (1616-1627)

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Abstract
Although he obtained a medical degree at the University of Caen in 1618, Isaac Beeckman never practised medicine. Instead, he developed an atomistic conception of Galenic physiology by discussing, throughout his notebook, the constituents and functioning of the living body. Interestingly, Beeckman applied his atomistic interpretation to the notion of temperament as the balanced proportion of elemental qualities, which defined the state of health. In this chapter, it is shown how his atomistic views on health and temperament amalgamated the Galenic theory of elements, mixture, and digestion. In appraising related interpretations of the body by late Renaissance *novatores*, Beeckman proposed an original theory of the organism, which put forward a mechanistic conception of metabolism as characterized by the rarefaction and condensation of atomic matter.

Keywords: Isaac Beeckman, matter theories, Renaissance, digestion, corpuscular philosophy, mechanism

In the last 30 years, historians of science have shown an increased interest in Isaac Beeckman's physical-mathematical approach to mechanism in the context of the 'Scientific Revolution'.[1] What we know about Beeckman

1 See: Klaas van Berkel, *Isaac Beeckman on Matter and Motion: Mechanical Philosophy in the Making* (Baltimore: Johns Hopkins University Press, 2013); Eio Honma, 'Beeckman's Natural Philosophy', *Historia Scientiarum* 5 (1996), pp. 225-247; Frédéric de Buzon, 'Beeckman, Descartes and Physico-mathematics', in: Daniel Garber and Sophie Roux, eds., *The Mechanization of*

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comes from his notebook that reports his thoughts about experiments, tools, and scientific theories, which he discussed with his circle of friends including Descartes, Gassendi, and Mersenne, among others.[2] However, Beeckman was not only a learned engineer, he was also trained in medicine, and obtained a medical degree from the University of Caen in Normandy in September 1618.[3] He began to study medicine in 1616 in preparation for the dissertation defence at Caen, mostly by reading medical treatises at his hometown, Middelburg.[4] At that time, Beeckman likely had access to these books through the library of his friend Philippus Lansbergen (1561-1632), a Dutch astronomer and Calvinist minister who lived in Middelburg from 1613.[5] Among Beeckman's early medical sources, one can find – aside from Galen – a significant number of Dutch and French authors. In fact, Beeckman's first mention of a medical treatise points to the *Universa medicina* of the French physician Jean Fernel in 1613-1614, which he continued to study until at least 1621.

Beeckman's first inclination for French medical literature – as evidenced by the references to Fernel, Joseph du Chesne, Jean Tagault, Jean Riolan the Elder, and Guy de Chauliac – might have prompted his choice to obtain a medical degree in France. For geographical, confessional, and financial reasons, he was likely compelled to choose the University of Caen as an accessible, religiously tolerant, and affordable institution. Besides, Beeckman was disposed to travel to north-west France, where he previously studied theology, mathematics, and philosophy at the Huguenot Academy of Saumur in the spring of 1612.[6] Beyond these assumptions about Beeckman's motive for graduating from Caen, the references in his notebook and the auction catalogue of his library show his undeniable interest in ancient, medieval,

Natural Philosophy (Dordrecht: Springer, 2013), pp. 143-158; Floris Cohen, *Quantifying Music: The Science of Music at the First Stage of the Scientific Revolution, 1580-1650* (Dordrecht: Reidel, 1984), pp. 116-161; Fokko J. Dijksterhuis, 'Understandings of Colors: Varieties of Theories in the Color Worlds of the Early Seventeenth Century', *Early Science and Medicine* 20 (2015), pp. 515-535.

2 On the nature of Beeckman's notebook, see the chapter 'Framing Beeckman: Cornelis de Waard as Editor of the Beeckman Papers' by Klaas van Berkel in this volume.

3 On Beeckman's medical theory, see: Elisabeth Moreau, 'Le Substrat galénique des idées médicales d'Isaac Beeckman (1616-1627)', *Studium* 3 (2011), pp. 137-151; Mart J. van Lieburg, 'Isaac Beeckman and His Diary-Notes on William Harvey's Theory on Blood Circulation (1633-1634)', *Janus* 69 (1982), pp. 161-163.

4 I am grateful to Klaas van Berkel for making me aware of the essentially bookish nature of Beeckman's medical training, and the need for further investigating the provenance of his medical sources.

5 Van Berkel, *Isaac Beeckman on Matter and Motion*, pp. 85, 130-131.

6 Van Berkel, *Isaac Beeckman on Matter and Motion*, p. 16.

and Renaissance medicine from the formative period of 1616-1618 until his last years.[7] Even as late as in the 1630s, Beeckman proved his up-to-date knowledge of medical debates among his contemporaries such as Santorio Santori, William Harvey, and Daniel Sennert.

Although Beeckman could not be called a 'doctor' to the extent that he never practised medicine, he was certainly a 'physician' in the sense that he applied natural philosophy to the study of medicine. The area of theoretical medicine Beeckman was interested in, corresponded to the field of physiology. As part of the university training in medicine, physiology was centred on the healthy body's structure and functioning, in particular its mere components (elements, humours) and their role in vital functions (generation, growth and nutrition).[8] For his medical education, Beeckman sought to explain how basic constituents such as elements could mingle and result in an organic living body. In this regard, digestion, because it implied the decomposition of food matter and its rearrangement to replenish the body, took an important part of the medical reflections in his notebook.

Interestingly, it was in the physiological moments of his notebook that Beeckman developed most of his atomistic theory of matter.[9] While his interpretation of atomism could be seen as an extension of the corpuscular theory he applied to physics and mathematics, it was also nourished by Lucretius's poem *On the Nature of Things* and by medical works related to the composition of bodies. Between 1616 and 1627, Beeckman read Galen

7 *Journal tenu par Isaac Beeckman de 1604 à 1634*, publié avec une introduction et des notes par C. de Waard, 4 vols. (The Hague: Martinus Nijhoff, 1939-1953) [henceforth *JIB*], IV, pp. 293-304; *Catalogus* [...] *librorum* [...] *Isaaci Beeckmanni* (Dordrecht: Isaac Andreas, 1637). See: Eugenio Canone, 'Il *Catalogus librorum* di Isaac Beeckman', *Nouvelles de la République des Lettres* (1991), pp. 131-159, esp. pp. 131-138; Van Berkel, *Isaac Beeckman on Matter and Motion*, pp. 73-74.

8 On Beeckman's corpuscular and atomistic theory of matter, see: Henk Kubbinga, 'Les Premières théories "moléculaires": Isaac Beeckman (1620) et Sébastien Basson (1621). Le Concept d'individu substantiel et d'espèce substantielle', *Revue d'histoire des sciences* 37 (1984), pp. 215-233; Henk Kubbinga, *L'Histoire du concept de 'molécule'* (Paris: Springer, 2002), I, pp. 203-225; Benedino Gemelli, *Isaac Beeckman. Atomista e lettore critico di Lucrezio* (Florence: Olschki, 2002); Norma E. Emerton, *The Scientific Reinterpretation of Form* (Ithaca: Cornell University Press, 1984), pp. 109-116.

9 On early modern physiology, see: Vivian Nutton, '*Physiologia* from Galen to Jacob Bording', in: Manfred Horstmanshoff, Helen King, and Claus Zittel, eds., *Blood, Sweat and Tears: The Changing Concepts of Physiology from Antiquity into Early Modern Europe* (Leiden: Brill, 2012), pp. 27-41; Andrew Cunningham, 'The Pen and the Sword: Recovering the Disciplinary Identity of Physiology and Anatomy before 1800, I: Old Physiology – the Pen', *Studies in History and Philosophy of Biological and Biomedical Sciences* 33 (2002), pp. 631-665; Thomas S. Hall, *Ideas of Life and Matter, Vol. 1: Studies in the History of General Physiology, 600 B.C.-1900 A.D.: From Pre-Socratic Times to the Enlightenment* (Chicago: University of Chicago Press, 1969).

as well as late Renaissance physicians such as Jean Fernel (1497-1558), Giovanni Argenterio (1513-1572), and Andreas Libavius (c. 1555-1616). The latter offered original Galenic theories that promoted Platonic philosophy, the revision of traditional pathology, and the promotion of medieval alchemy, respectively. However, the importance of these medical *novatores* has been unexplored in historical studies dedicated to Beeckman, whereas the Galenic tradition is key to contextualizing his atomistic theory. For this reason, this chapter explores Beeckman's medical theory of matter from a broader perspective, including the late Renaissance. Such an approach offers the advantage of clarifying how Beeckman could effortlessly reconcile Galen and the atomistic philosophy despite their presumed incompatibility. Galen, indeed, rejected atoms and corpuscles in *On the Elements According to Hippocrates*, and extensively criticized the corpuscular philosophy of the Greek physician Asclepiades of Bithynia throughout his works.[10] Nevertheless, this did not prevent Beeckman from reinterpreting Galenic physiology from an atomistic and mechanistic viewpoint.

The first part of this chapter examines Beeckman's medical theory of matter and how it integrates the traditional theory of elements and qualities into an atomistic framework. The next part discusses how his atomistic theory of elements applies to fundamental physiological notions, such as temperament and digestion.

1 Atoms, Elements, and Homogeneous Parts

From the beginning of his notebook, Beeckman's matter theory is remarkable for its conciliation of the traditional theory of elements with Lucretian atomism. Beeckman had the opportunity to study the physics of elements during his university training when he read up on the Aristotelian theory of matter-form or 'hylomorphism'.[11] According to Aristotle, all beings of the natural world were composed of four elements (air, water, earth, fire) which

10 Galen, *On the Elements According to Hippocrates*, trans. by Philip de Lacy (Berlin: De Gruyter, 1996). For the Latin edition, see: Galen, *De elementis ex Hippocrate,* in: *Claudii Galeni opera omnia*, ed. Karl Gottlob Kühn (Hildesheim: Georg Olms, 1821-1833), I, pp. 413-508. In this chapter, I will use Kühn's edition of Galen's works.

11 See: Craig Martin, 'Elements and Qualities', in: Thomas Glick, Steven J. Livesey, and Faith Wallis, eds., *Medieval Science, Technology and Medicine: An Encyclopedia* (Abingdon-New York: Routledge, 2005), pp. 157-158; Graig Martin, 'Hylomorphism', in: Glick, Livesey, and Wallis, eds., *Medieval Science*, pp. 234-236.

each were characterized by two of the four primary qualities (hot, cold, dry, moist). The elements were made of two principles: 'matter' which played the role of material substrate, and 'form' which determined their essence. During the generation of natural beings, the elements united through a process of 'mixture' during which they mingled their qualities and obtained a new 'substantial' form.

To this Aristotelian framework, Beeckman applied an atomistic conception of matter based on Lucretius's *On the Nature of Things*. As one of the first sources of the 'atomist revival' in the Renaissance, the poem was first printed in 1473 with numerous re-editions in the sixteenth and seventeenth centuries.[12] Beeckman possessed several copies of *On the Nature of Things*, including Denys Lambin's edition and commentaries, and started discussing Lucretius in his notebook in 1614-1615.[13] In this section I consider how Beeckman developed an atomistic conception of Aristotelian physics, which applied to elements and compounds bodies.

Four Atomic Elements

In his notebook, Beeckman followed the Aristotelian and Galenic tradition by reporting the four elements as basic components of bodies, to which were related the four primary qualities. At the same time, he merged this framework with his atomistic and corpuscular views. This interpretation came early in his notebook, in between 1616 and 1618, when he explained that bodies were composed of atoms surrounded by interstitial vacuum. The latter was described as 'intermediate empty spaces' forming pores of diverse size.[14] The same interstitial void was discussed in Beeckman's correspondence as early as in 1613.[15] In the corollaries of his medical thesis defended in 1618 at Caen, he also stated the existence of *vacuum intermixtum* and even identified to air pressure the concept of *fuga vacui* caused by pump suction.[16] Although the idea of void was contrary to the tradition, Beeckman was familiar with it through his professional experience in hydraulic

12 See: Christoph Lüthy, 'Atomism in the Renaissance', in: Marco Sgarbi, ed., *Encyclopedia of Renaissance Philosophy* (Cham: Springer, 2018); Ada Palmer, *Reading Lucretius in the Renaissance* (Cambridge: Harvard University Press, 2014), pp. 192-232.

13 Gemelli, *Isaac Beeckman*, p. xi.

14 *JIB*, I, p. 132: 'Deus corpora atoma primò movit non minus quàm creavit; motis semel nunquam quiescebant, nisi ab invicem impeditis. Ergo congredientes et cum vacuo misto, convenienter materia et forma extiterunt omnium compositorum coeli et Terrae.'

15 *JIB*, IV, p. 27.

16 *JIB*, IV, p. 44.

engineering. From his apprenticeship in candle making in 1610-1611, he had worked on water pipes and pumps for the construction of breweries and fountains.[17] In addition, Beeckman read of Hero of Alexandria's *Pneumatica* (*Liber spiritalium*) around 1616. In this treatise, Hero supported the particulate structure of matter and the existence of dispersed vacuum following the example of pumps, which prompted Beeckman's commentaries in his notebook.

For Beeckman, the four elements were atoms endowed with four types of shapes which determined their primary qualities.[18] It was their motion, shape (*figura*) and number that caused the 'forces' of bodies, that is their properties.[19] Heat and cold were due to the motion, speed, and size of atoms.[20] Moistness and dryness were related to the round or sharp shape of atoms. The same reasoning applied to sensory qualities such as taste. Following a Lucretian topos, Beeckman explained that pleasant and unpleasant flavours were due to round or sharp atoms, and their resulting accordance with the pores.[21]

Moreover, Beeckman revisited the Aristotelian notion of form related to the elements. In the Aristotelian tradition, form was the active principle that determined the essence of the elements, particularly during their mixture, for which the elemental compound acquired a 'substantial form'. However, for Beeckman, form was nothing but the arrangement of atoms, more precisely their 'situation' (*situs*), an equivalent of the Lucretian notion of 'position' (*positura*), which designated the spatial position of atoms with respect to each other.[22] The form of a compound varied according to the diverse arrangements of atoms at geometrical and spatial levels, for example, in a square or in a cube. As explained in Beeckman's notebook, two compounds

17 Van Berkel, *Isaac Beeckman on Matter and Motion*, pp. 16-19.

18 *JIB*, I, pp. 152-153: 'At calor, frigus, humiditas, siccitas tactu apprehenduntur absque specie figurarum, tametsi intellectu solâ figurarum ratione videantur. Unde verisimiliter concluditur omnes omninò rerum differentias ex figurâ atomorum petendas esse; et quia dictae qualitates solae tactui sunt subjectae, omninòque quatuor tantùm corpora simplicia, in totâ rerum naturâ, terram, aquam, aerem, ignem animadvertimus.'

19 On the Lucretian notion of shape (*figura*), see: Gemelli, *Isaac Beeckman*, pp. 90-96; Lucretius, *De rerum natura*, 1, 685, and 2, 1021.

20 *JIB*, I, p. 216.

21 *JIB*, I, pp. 149-150: 'Praeterea multa sunt insipida, calida, frigida, humida, sicca; sapida verò sunt onmia quae aliquam corpori nostro compositionem similem adepta sunt, id est cujus cavitates et asperitates cavitatibus et asperitatibus ita respondeant, ut ea suaviter nos afficiant.' See: Gemelli, *Isaac Beeckman*, pp. 59-61; Lucretius, *De rerum natura*, 2, 402-407.

22 On Lucretius's notion of *positura*, see: Gemelli, *Isaac Beeckman*, p. 79 et passim; Lucretius, *De rerum natura*, 1, 685; 2, 1017-1022. For Beeckman, *situs* relates to the position of particles, while *dispositio* refers to the proportionate arrangement of the compound.

of different nature might have the same 'portions' and 'particles' of fire, air, water and earth, but differed in their disposition.[23] Thus, the distance between the pores also defined their specificity ('essential difference'), that is their form.

Minimal Particles and *Homogenea*

In 1620, Beeckman further developed his atomistic theory of matter by positing different structural layers such as *minima*, particles, and homogeneous parts. His explanation drew on the Aristotelian and Galenic philosophy, which defined the body as structured into different levels of 'parts', comprising organic, homeomerous, and elemental parts. Body parts included organic parts (limbs and organs) – also called 'anhomeomerous' – which were made of 'homeomerous' parts such as nerves, flesh, muscles, and other tissues.[24] The 'homeomerous' parts were homogeneous compounds resulting from the achieved union ('mixture') of elements. This sophisticated framework allowed Beeckman to enrich his atomistic theory in order to investigate the specific properties of bodies and living beings.

As Beeckman explained in his notebook, atoms agglomerated into different levels of composition, first, *minima*, and then, 'minimal particles'.[25] The latter operated the actions of an organic body part; when destroyed, they were decomposed into their own *minima*.[26] Beeckman's terminology was common in the medical tradition. A similar definition of elements as 'minimal particles' – in the sense of minute portions – was endorsed in Renaissance medicine according to Galen's definition of the element in *On the Elements According to Hippocrates*. Following this treatise, physicians

23 *JIB*, I, p. 153: 'Fieri enim potest ut duae res aequalibus constent portionibus corporum ignis, aeris, aquae et terrae, suntque tamen dissimilis naturae. Nam hisce sita est ignis particula inter terram et aerem, et etiam inter aerem et aquam, omninòque multae sunt quatuor simplicium figurarum in unâ lineâ dispositarum aut in formâ cubi redactarum, positurae diversitates.'

24 See: Martin, 'Hylomorphism', pp. 234-236.

25 *JIB*, II, p. 96: 'Impraesentiarum autem sciendum est ignem purum non esse atomum (non enim atomus in aere ascenderet, quia ubique corpore plenus est ideòque gravis), sed ignis minima particula composita est ex multis atomis, ita junctis ut multum inter eas sit vacui.'

26 *JIB*, II, p. 117: 'Particula minima dupliciter dicta est sumi. Primò pro eâ minimâ quae primò possit perficere membri actiones, quamquam secundò ea constet ex multis absolutè minimis secundùm membri substantiam, ita ut hac divisâ substantia propria membri pereat, illâ verò divisâ actiones vel omnes vel hae, ita ut intelligantur quaedam actiones majoribus, quaedam minoribus particulis perfici.'

tended to consider the elements as the smallest parts of bodies subject to a union in order to constitute the body parts.[27]

To his conception of bodies as aggregates of particles, *minima* and atoms, Beeckman added that compounds were structured in primary and secondary *minima* as 'homogeneous' parts (*homogenea*).[28] By calling these *minima* 'homogeneous', Beeckman implicitly identified them with the homeomerous parts of bodies. In the same way, the 'minimal particles', which were composed of *minima*, corresponded to the traditional organic parts. Following this reasoning, the *minimum* designated the finite number of atoms that a body part needed to function. It was only to this extent that Beeckman adopted the Aristotelian terminology of 'natural *minimum*' as a body part that could not be indefinitely small in the same way as it could not be indefinitely large.[29] But Beeckman's *homogenea* also referred to other sources which were mentioned in his notebook. Among them, one can find several treatises on alchemy, physics, and logic.

Beeckman's penchant for alchemy overall reflected his deep interest in matter theories such as the one expounded in the *Alchymia* (1606) of the German physician Andreas Libavius (c. 1550-1616).[30] From Libavius's treatise, Beeckman retained the definition of the alchemical art as the 'separation' – the alchemical process of extraction – of homogeneous bodies from a substance.[31] With this definition of *homogenea*, Libavius aimed to continue the medieval alchemical tradition by merging the

27 See: Gweltaz Guyomarc'h and Stéphane Marchand, eds., 'Studies on Galen's *De elementis*', *Aitia* 7:2 (2017).

28 *JIB*, II, pp. 117-118: 'Sic quoque interdum in unâ re diversorum homogeneorum minima conjuncta minimum sunt alicujus virtutis. Hoc verò minimum, conjunctum cum ejusdem generis minimo, aliam virtutem exerit. […] Sit igitur medicis id minimum, quod non minori quàm haec est particulâ opus, et vim optatam exerit. Liceat verò hoc minimum secare in alia, et haec in alia usque ad humores, elementa et atomos.'

29 Aristotle, *Physics*, 1.4, 187b35-188a13. See: John E. Murdoch, 'The Medieval and Renaissance Tradition of *Minima Naturalia*', in: Christoph Lüthy, John E. Murdoch, and William R. Newman, eds., *Late Medieval and Early Modern Corpuscular Matter Theories* (Leiden: Brill, 2001), pp. 91-132.

30 On Libavius, see: Bruce T. Moran, *Andreas Libavius and the Transformation of Alchemy: Separating Chemical Cultures with Polemical Fire* (Sagamore Beach: Watson, 2007); William R. Newman, *Atoms and Alchemy: Chymistry and the Experimental Origins of the Scientific Revolution* (Chicago: University of Chicago Press, 2006), pp. 66-84; Owen Hannaway, *The Chemists and the Word: The Didactic Origins of Chemistry* (Baltimore: Johns Hopkins University Press, 1975).

31 *JIB*, II, p. 127. See: Andreas Libavius, *Syntagmatis selectorum* […] *Alchymiae arcanorum tomus primus*, 5.18 (Frankfurt: Nicolaus Hoffmann/Peter Kopff, 1615), pp. 193-194; Andreas Libavius, *Examen sententiae Parisiensis scholae contra alchymiae latae*, in: Libavius, *Alchymia recognita, emendata, et aucta* (Frankfurt: Johann Saur/Peter Kopff, 1606), pp. 8-9.

Aristotelian physics with the explanation of material change.[32] In turn, Beeckman used Libavius's reasoning with a somewhat different objective: to describe the body parts as homogeneous compounds according to the regular union of their atomic components. Interestingly, Libavius's late works, too, presented these homogeneous bodies as composed of minimal particles and atoms, but this aspect was not commented on in Beeckman's notebook.[33]

Rooted in early medicine and alchemy, Beeckman's notion of homogeneous part was also inspired from natural philosophy and logic, which he studied for his philosophical training at the University of Leiden between 1607 and 1610. Beeckman likely borrowed the term *homogenea* from the works of the German theologian Bartholomew Keckermann (c. 1571-1609), which he commented on in 1618.[34] Two treatises of Keckermann, in particular, showed the physical-logical counterpart of Beeckman's account of *homogenea*. In his *Systema physicum*, Keckermann defined elements as simple homogeneous bodies. By taking the example of heat, which assembled homogeneous parts and disintegrated heterogeneous parts, Keckermann specified that the term 'homogeneous', which was familiar to all logicians, designated things that shared the same nature and denomination. In his *Systema logicae*, Keckermann also presented as *homogenea* the bodies whose parts had the same name as the whole.[35] He anchored the term to the Greek notion of 'homeomerous' body such as water, wine, blood, gold or wood, whose *minima* and particles had the same name as the whole.

With his explanation of homogeneous parts made of particles and *minima*, Beeckman aimed to propose a theory of matter that worked at logical and physical levels. In his view, the *homogenea* were structured in 'primary' and 'secondary' levels, corresponding to minimal particles and *minima*,

32 See: Moran, *Andreas Libavius*, pp. 40-43; Elisabeth Moreau, 'Reforming the *Prisca Medicina*: Libavius' Axioms of Elements and Mixture', in: Pietro D. Omodeo and Volkhard Wels, eds., *Natural Knowledge and Aristotelianism at Early Modern Protestant Universities* (Wiesbaden: Harrassowitz Verlag, 2019), pp. 255-270.

33 See: Newman, *Atoms and Alchemy*, pp. 66-84.

34 On Keckermann, see: Joseph S. Freedman, 'The Career and Writings of Bartholomew Keckermann (d. 1609)', *Proceedings of the American Philosophical Society* 141 (1997), pp. 305-364; Cees H. Leijenhorst, 'Place, Space and Matter in Calvinist Physics: Petrus Ramus, Clemens Timpler, Bartholomæus Keckermann and Johann Heinrich Alsted', *The Monist* 84 (2001), pp. 520-541.

35 See: Bartholomew Keckermann, *Systema physicum septem libris adornatum* (Hanover: Wilhelm Antonius, 1612), pp. 128 and 133; Keckermann, *Systema logicae tribus libri adornatum* (Hanover: Wilhelm Antonius, 1611), p. 190.

respectively.[36] In other words, the first 'union' or 'conjunction' of elements resulted in a *minimum*. Then, the first level of *minima* formed the first or 'primary' homogeneous part. In turn, the primary *homogenea* constituted the *minima* of the 'secondary' homogeneous parts. In case of division, the secondary *homogenea* lost their particular force and fell back to the level of the primary *homogenea*. If further divided, the primary *homogenea* regressed to the elemental level of which they consisted. Conversely, atoms and minimal particles mingled to form complex and various *homogenea*. If Beeckman could not determine the exact number of *minima* which composed primary *homogenea*, he assumed that they existed in a finite number sufficient to produce a great diversity of things. They did so in the same way as the letters of the alphabet were able to produce an infinite number of words.[37]

So far, it has been shown that, whereas Beeckman adopted the traditional terminology of elements, qualities, and form, his theory of matter had little to do with the Aristotelian notion of matter-form or 'hylomorphism'. In fact, Beeckman eliminated the traditional distinction between substance and accident, and between primary and secondary qualities, since all these notions derived from the arrangement and motion of atoms. This reflected the corpuscular and mechanistic framework that Beeckman early proposed in his notebook, which has been much explored by historians of science. On the other hand, his conception of elements as particles and portions paid tribute to the Galenic definition of elements as the 'smallest' or 'minimal' particles of bodies. Beeckman, indeed, conceptualized a structural layering of atomic elements, which was strongly indebted to the Galenic approach to the body's composition in elements, homeomerous, and organic parts. Having explored Beeckman's account of atomic elements, *minima* and *homogenea*, I shall now turn to the application of this theory to physiology.

36 *JIB*, II, pp. 118-119: 'Nam prima elementorum conjunctio efficit hujus compositi aliquod minimum, quae multa simul sumpta, statuunt unum et primum homogeneum. Hujus primi homogenei minimum, conjunctum cum alterius primi homogenei minimo (quod ex aliâ mixtione elementorum existit) efficit minimum secundi homogenei, quo primò omnium et propriè continet suam vim; tum si tenuiùs secetur, etiam vim primi homogenei; ac tertiò, adhuc tenuiùs sectum, profert vim elementi.'

37 *JIB*, II, p. 122: 'Non autem existimandum est multa esse homogenea tam exiguorum minimorum. Cùm enim ea proximè constent ex elementis, necesse est pauca duntaxat esse homogenea, aptè mixta, à se invicem differentia. Haec verò homogenea pauca, inter se mixta ita ut res magnae inde fiant, constituunt multas res à se mutuò differentes. [...] Quot autem primum homogeneum minimis elementorum constet, nobis est ignotum.'

2 Temperament as a Geometric Proportion of Particles

Throughout the *Journal*, Beeckman's medical questioning is centred on the structure and functioning of the living body. In Galenic medicine, this theme corresponded to physiology as a theoretical branch of medicine rooted in natural philosophy. Developed in late medieval Latin-Arabic medicine, physiology was based on the Galenic and Aristotelian account of 'natural things'.[38] It examined the body's first components – elements, humours – and their balance, which determined the body's state of health or 'temperament'. These notions were fundamental to understanding vital functions such as generation, growth, and nutrition. Beeckman followed this physiological framework by studying 'temperament' as a way to investigate the living body at the level of its smallest constituents.

In the Galenic tradition, temperament – also named 'complexion' – resulted from the balance of the elements and their primary qualities into a moderate state. This notion also relied on the Aristotelian concept of 'mixture', that is the homogeneous union of elements into a new compound. The compound or 'mixt' was considered as acquiring a new 'substantial' form, while its constitutive elements remained in potentiality. This definition of mixture raised many debates on the status of elements, particularly their form (essence) and qualities, during and after mixture. In late Renaissance medicine, a successful interpretation of mixture and temperament was that of the French physician Jean Fernel, whose *Universa medicina* (1567) was several times re-edited in the early modern period.[39] Fernel stated that elements equalled to minute particles which juxtaposed during mixture and acquired a form of divine origin.[40] While the prominent place given to the celestial nature of the form pointed to a Platonic inclination, Fernel's account also drew on a longer tradition rooted in Avicennian medicine.[41]

38 See: Nutton, '*Physiologia*'; Nancy Siraisi, *Medieval and Early Renaissance Medicine* (Chicago: University of Chicago Press, 1990), pp. 78-80, 101-109.

39 On Fernel, see: José Kany-Turpin, ed., 'Jean Fernel', *Corpus. Revue de Philosophie* 41 (2002), pp. 5-197; John Henry and John M. Forrester, 'Introduction: Tradition and Reform: Jean Fernel's *Physiologia* (1567)', in: *The* Physiologia *of Jean Fernel*, trans. by John Forrester (Philadelphia: American Philosophical Society, 2003), pp. 1-13; John Henry and John M. Forrester, 'Jean Fernel and the Importance of His *De abditis rerum causis*', in: *Jean Fernel's* On the Hidden Causes of Things*: Forms, Souls, and Occult Diseases in Renaissance Medicine* (Leiden-Boston: Brill, 2005), pp. 3-65.

40 'The *Physiologia* of Jean Fernel (1567), ed. and trans. by John M. Forrester', *Transactions of the American Philosophical Society* 93 (2003), pp. 210-212.

41 Hiro Hirai, *Medical Humanism and Natural Philosophy: Renaissance Debates on Matter, Life and the Soul* (Leiden-Boston: Brill, 2011), pp. 46-79; Elisabeth Moreau, 'Elements, Mixture and

This medieval and Renaissance Galenic tradition formed the broader context of Beeckman's medical theory of matter and the conceptual foundation for his atomistic interpretation of the living body. From the beginning of his study on Galenic physiology, Beeckman had been aware of the Renaissance debates on mixture and temperament. The first physiological work he started to read for his medical studies in 1616 was Fernel's *Physiologia*, which was included in the *Universa medicina*. As Beeckman later noted in 1618, Fernel stated that the elements remained intact after their mixture in the compound, which brought about the body's temperament.[42] From this account, Beeckman took the idea of a juxtaposition of elemental particles, which he combined with his own atomistic matter theory. As a result, his account of temperament kept the traditional terminology of matter, form, and elements, though in a different sense. His reflections on this theme were developed between 1616 and 1627 and edited in the first and second volumes of the *Journal*. Afterwards, his physiological investigation became centred on digestion, which will be examined in the last section of this chapter.

Well-Connected and Arranged Particles

In addition to reinterpreting the Aristotelian account of elements and matter-form from an atomistic viewpoint, Beeckman revisited the Galenic concept of temperament. While the medical tradition defined it as the healthy constitution resulting from the balanced mixture of elements, Beeckman considered it as a correct arrangement of particles. In his view, the body's form (essence) was nothing but the 'disposition' (*dispositio*) and 'binding' (*connectio*) of its material parts.[43] As discussed in the previous section, these material parts were described as atomic elements arranged in different levels of *minima* and particles. For Beeckman, this implied that the form of the healthy body was the correct 'disposition' or 'binding' of its parts.[44] Such a disposition referred to the proper union of the elements,

Temperament: The Body's Composition in Renaissance Physiology', in: Chiara Beneduce and Denise Vincenti, eds., *Oeconomia Corporis: The Body's Normal and Pathological Constitution at the Intersection of Philosophy and Medicine* (Pisa: Edizioni ETS, 2018), pp. 51-58.

42 *JIB*, I, pp. 168-169. See: 'The *Physiologia* of Jean Fernel', 2.6 and 2.8, 200-204, and 210-211.

43 *JIB*, I, p. 203: 'Sanitatis quaedam dispositiones sunt visus, quaedam auditus. Materiaque visûs nihil est aliud quàm dispositiones quaedam ejusmodi quae visum constituunt, forma verò visûs istarum dispositionum apta compositio. […] Sic sanus habet pro materiâ proximâ corpus animalis, pro formâ ejus partium aptam dispositionem; sic morbi materia sunt dispositiones quaedam corporis, forma verò mala earum connectio.'

44 *JIB*, I, p. 203: 'Materiaque visûs nihil est aliud quàm dispositiones quaedam ejusmodi quae visum constituunt, forma verò visûs istarum dispositionum apta compositio. […] Sic sanus habet

and no longer to their mixture in the Aristotelian sense of the term. In consequence, the notions of matter and form took a different meaning adapted to Beeckman's atomistic theory. The form of the compound equalled to the ad hoc arrangement of its atoms, while its matter consisted of the elemental matter of which it was made.

For this interpretation of health as the correct arrangement of parts, Beeckman referred to the Italian physician Giovanni Argenterio, who was famous for his criticism of Galen regarding the notions of disease, cause, and symptom.[45] From Argenterio's treatise *De morbis* (1548), Beeckman borrowed the definition of health and illness as a correct or incorrect binding and disposition of the main body parts (limbs).[46] However, he applied this approach to his matter theory in such a way that the 'binding' and 'disposition' were related to the elemental particles that constituted body parts. Consequently, health was determined by the correct arrangement of the body from an atomic – rather than anatomic – viewpoint.

Interestingly, Beeckman's insistence on the *connectio* and *dispositio* of material units also pointed to his training in logic and dialectics. Among his sources, the German theologian Philip Melanchthon (1497-1560) gave a logical definition of form as the order, disposition, and binding (*connectio*) of the parts of an argumentation in the *Erotemata dialectices* (1547).[47] Keckermann, from whom Beeckman's partly derived the notion of *homogenea*, also used this formulation in his treatises on logic. In the same way, Beeckman considered the healthy constitution as a correct binding and disposition of its minimal parts.

Regular Polyhedra

In 1618, when discussing the nature of a healthy constitution, Beeckman provided his own interpretation of a classical question in Galenic medicine: how to define the most appropriate temperament (*temperatura*)?[48] For his

pro materiâ proximâ corpus animalis, pro formâ ejus partium aptam dispositionem; sic morbi materia sunt dispositiones quaedam corporis, forma verò mala earum connectio.'

45 Nancy Siraisi, 'Giovanni Argenterio and Sixteenth-Century Medical Innovation: Between Princely Patronage and Academic Controversy', *Osiris* 6 (1990), pp. 161-180.

46 Giovanni Argenterio, *De morbis libri XIIII* (Lyon: Sébastien Honoré, 1558 [1548]), pp. 652-654.

47 Philipp Melanchthon, *Erotemata dialectices* (Wittenberg: Johan Crato, 1556 [1547]), p. 142; Bartholomew Keckermann, *Systema logicae minus* (Hanover: Wilhelm Antonius, 1606), pp. 247-248.

48 *JIB*, I, p. 347: 'Dico igitur id in unoquoque genere eucraton esse, cujus omnes actiones etc. omnium individuorum optimae sunt. Sic homo aliquis est temperatissimus; qui verò homines ab hujus temperaturâ deficiunt, contrarijs juvantur. Leo quis est temperatissimus, multò quidem

medical training, he was familiar with the traditional account of temperament as a proportionate state resulting from the balance of primary qualities. Such a proportion was defined according to an ideal model, the Galenic notion of *eukratos*, from the Greek 'well-mixed'. Beeckman adopted this framework by stating that the balanced constitution varied from one species to another according to the traditional notion of 'latitude of temperament'.[49] For instance, the ideal temperament was different for a fish, a lion or a man. Each species had a particular moderate status (*medium*) achieved by the mixture of elements.

As he continued his discussion on the ideal temperament, Beeckman added that it was structured *ad pondus*, that is, as an arithmetically equal distribution of primary qualities.[50] This statement tended to go against the Galenic tradition, which established that the constitution *ad pondus* was purely theoretical and could not be found in the physical world. Instead, it was held that the ideal temperament of each species was a proportionate qualitative state (*in justitiam*). By contrast, Beeckman believed that temperament precisely consisted in a quantitative balance of elements and qualities related to a medium point. Thus, the notion of ideal constitution designated a proportionate union and a quantitative disposition of elemental particles and *minima*. In 1620, Beeckman refined this definition of temperament *ad pondus* by specifying that it was also determined by the situation and shape of its *minima*. The particles of the compound had a geometrical proportion and a particular situation (*situs*) resulting in the formation of regular polyhedra.[51] For instance, the human being was formed of polyhedral *minima*, whose shape was ordered in 20 triangles which formed 'suitably connected' icosahedra. If Beeckman also posited that dogs were formed of octahedral *minima*, he did not clarify how the five types

calidior homine […]. Sic piscis aliquod genus temperatissimum est multòque homine frigidius, ideòque et multò frigidioribus quàm homo recreatur.'

49 On the latitude of temperament, see: Per-Gunnar Ottosson, *Scholastic Medicine and Philosophy: A Study of Commentaries on Galen's Tegni* (*ca. 1300-1450*) (Naples: Bibliopolis, 1984), pp. 167 et passim.

50 *JIB*, I, pp. 296-297: 'Sic uniuscujusque speciei est aliquis status temperatissimus: is in leone est calidior, in piscibus frigidior, in homine temperatus ad pondus. […] Sic uniuscujusque hominis est temperamentum aliquod medium peculiare, ad quod ubi perveniat, optimè habet.'

51 *JIB*, II, pp. 124-125: 'Si igitur primordia nostra forent tales pyramides ordinatae, et ad constitutionem speciei virtutes activas exerentes, requiretur compositum ordinatum, circulo inscribendum. […] Constituant igitur icosahedra, aptè sibi invicem conjuncta, hominem vel hominis semen; octahedra verò canem. […]. Videmus enim canum diversa genera esse infinita et indies inter se commutari, quod indicat canum omnium minimum naturale idem quidem esse, sed positionis diversitatem esse variam.'

of regular polyhedra were distributed among the different animal species. Nonetheless, he considered that the connection of triangular units produced a geometrically ordered shape, whose diverse arrangements defined the particular features of each individual.

Among the possible sources for Beeckman's notion of polyhedral units of matter, one can find a range of ancient and early modern treatises. At first, Plato, in his *Timaeus* 55a-56c, described the four elements as polyhedra made up of triangular units, whose proportion in number, motion, and qualities had been harmoniously arranged by God. In a mathematical context, Euclid developed a demonstration of the Platonic solids in his *Elementa*. Moreover, the concept of a polyhedral configuration of the natural world was tackled by the *Six-Cornered Snowflake* (*Strena seu de nive sexangula*) (1611) of the German astronomer Johannes Kepler.[52] In this inquiry on the hexagonal structure of snow crystals, Kepler envisaged, among other possible explanations, that living beings might be composed of regular solid figures in a pentagonal proportion (dodecahedron or icosahedron).[53] According to this theory, the geometrical figure was related to an internal organizing principle responsible for the propagation of living beings: a 'seminary' or 'formative' faculty emanating from the earth's 'vapour'.

Although Beeckman shared Kepler's geometric and corpuscular reasoning, his primary objective was to show the mathematical possibility of defining temperament with a finite number of constituents.[54] For his strictly mathematical concern, he thus deviated from Kepler's supposition of a 'formative nature'. In a commentary on the *Six-Cornered Snowflake* around 1628, Beeckman even noted that this concept was 'ridiculous and unworthy of a philosopher'.[55] In the same way, Beeckman broke with the Renaissance Platonic tradition by explaining that the particular virtues of compounds were not due to an incorporeal entity of celestial origin, which was related to the seed or to the substantial form. In his view, all these notions pertained to the atomic composition of bodies and to the shape of their homogeneous parts. Consequently all living beings were provided with a particular atomic composition, a proportionate shape, and a correct disposition, although the exact configuration of each species was

52 Johannes Kepler, *The Six-Cornered Snowflake*, trans. by Colin Hardie (Oxford: Oxford University Press, 2014 [1966]); Johannes Kepler, *L'Étrenne ou la neige sexangulaire*, trans. by Robert Halleux (Paris: Vrin, 1975).

53 Johannes Kepler, *Strena seu de nive sexangula* (Frankfurt: Gottfried Tampach, 1611), p. 12.

54 On Beeckman and Kepler, see the chapter 'Optics, Astronomy, and Natural Philosophy: Beeckman, Descartes, Kepler, and the Dutch Connection' by Édouard Mehl in this volume.

55 *JIB*, III, pp. 33-34.

unknown to Beeckman. Following his previous statements about health and temperament, this entailed that the polyhedral *minima* corresponded to homogeneous parts. On the other hand, their form – in the Aristotelian sense of the term – equalled the regular shape of their *minima*, which gave specific characteristics to each species.

While it would be tempting to consider Beeckman's theory as materialistic, his explanations of the body's composition did take the intervention of divine providence into account. At first, Beeckman followed Galen's teleology expounded in *On the Usefulness of the Parts of the Body*. According to this treatise, the physiological processes were not associated to any divine intervention but presupposed a demiurge having created matter.[56] Nonetheless, the divine providence was evidenced by the determined functioning and usefulness of each body part, and, more broadly, by the body's organism whose structure was perfectly adequate to its function. As Klaas van Berkel has pointed out, Galenic teleology was particularly suited to the Calvinist dogma of predestination in which Beeckman believed.[57] As Beeckman explained in his notebook, God 'skilfully' created atoms so that their concourse was not accidental.[58] The divine creation ordained particular atoms, *minima*, and corpuscles which determined the organization and functioning of nature.[59] The achieved atoms combined in a favourable situation according to specific conditions inscribed in all constituents of nature. Consequently, a limited number of principles was able to produce the whole diversity of nature, just like an infinite number of words could be created from the letters of the alphabet.[60] This teleological reasoning formed the background of Beeckman's approach to physiology.

56 Galen, *De usu partium*, 11.14, ed. Kühn III, pp. 899-911; *JIB*, I, pp. 163-164: 'Cùm Gal. [...] probet hominem certâ prudentiâ, non fortuitò constructum esse, ita ut nulla pars magis illi conveniret quàm quas habet. [...] Sic numerus et ordo creata sunt corporum, extra quae nihil fit; apta tamen facta sunt ut concursu suo non infinita, sed finita non determinata producant. [...] Cùm enim opifex sit omnipotens, quidni posset, quod nos non intelligimus? id enim tantummodo intelligimus fieri posse, quod Deus intelligi posse voluit.'

57 Van Berkel, *Isaac Beeckman on Matter and Motion*, pp. 140-147.

58 On the necessity of an ordained universe in Lucretius, see: Gemelli, *Isaac Beeckman*, pp. 53-59; Lucretius, *De rerum natura*, 1, 159-204, and 2, 700-710, 720-729, 1067-1069.

59 *JIB*, II, p. 43: 'Adhaec mirari potiùs convenit Dei sapientiam qui naturae primordia, minimaque corpuscula ex nihilo creata, talem figuram dederit ut ex ijs non quidvis possit nasci, sed ea duntaxat quae convenientia toti universitati futura erant. Atomorum igitur, ut ait Lucretius, figurae sunt finitae idque ex finitis formis et speciebus rerum rectè probat; at nos harum figurarum in atomis causam Dei providentiae attribuimus.'

60 *JIB*, II, p. 57: 'Quantò igitur satiùs est dicens omnia haec a naturâ et constitutione loci esse nata, Deum verò ejusmodi principia creasse in principio, quae sibi mutuò juncta, non possint non hoc facere. Si enim conveniant haec primordia fit avis, si illa, canis, si alia, piscis. Non verò

3 Digestion as Rarefaction and Condensation of Food Matter

Besides supporting a general explanation of health, Beeckman's atomistic conception of elements and body parts shaped his understanding of physiological functions. Among them, digestion had a prominent place as an organic process relying on the transformation of matter.

In the latest phase of his notebook, Beeckman's medical account mostly explored digestion, which was a central question in Galenic physiology. As a vital function, digestion was considered as responsible for maintaining life by assimilating the nutritive properties of food during their conversion into humours. What raised Beeckman's attention was the decomposition of food into its smallest ingredients, its circulation through the digestive organs, and the very process of digestion as a transformation of matter by the body heat. Most notably, Beeckman reinterpreted in an atomistic way some major concepts introduced by Galen in *On the Natural Faculties*: heat, natural faculties, and food 'concoction' in the digestive organs.[61]

By developing the role of natural faculties during digestion, Galen centred the discussion on the 'attracting' faculty. Attraction was considered as ensuring the passage of ingested food into the digestive organs where food was subject to concoction. Galen considered two causes of attraction: a magnetic force related to the specific properties of the body's substance or 'total substance', and *fuga vacui*, that is the natural motion of beings in order to avoid vacuum. In addition to expounding his own interpretation of physiological attraction, Galen debunked Erasistratus's mechanistic interpretation of digestion as a process of contraction and dilation. In the same way, he rejected Asclepiades' corpuscular theory of digestion as a phenomenon of rarefaction and condensation.[62] Nonetheless, Galen conceded that the attraction of humours by *fuga vacui* during digestion was caused by the contraction and dilation of the organs. Following this reasoning, the body's vessels were comparable to water pipes of different

concursus hic in infinitum magis variat quàm ex 24 litteris infinita vocabula possunt fieri trisillaba aut decem syllabarum etc.' The analogy between the arrangements of principles and that of letters is borrowed from Lucretius, *De rerum natura*, 2, 688-689, 1013-1022.

61 Galen, *De naturalibus facultatibus*, ed. Kühn II, pp. 1-214.

62 On Asclepiades of Bithynia, see: J.T. Vallance, *The Lost Theory of Asclepiades of Bithynia* (Oxford-New York: Clarendon Press-Oxford University Press, 1990); David Leith, 'The Qualitative Status of the *Onkoi* in Asclepiades' Theory of Matter', *Oxford Studies in Ancient Philosophy* 36 (2009), pp. 283-320; David Leith, 'Pores and Void in Asclepiades' Physical Theory', *Phronesis* 57 (2012), pp. 164-191.

size in a garden.[63] Such an explanation undoubtedly struck Beeckman's attention and buttressed his hydraulic understanding of the digestive system.

What Beeckman proposed, in turn, was a synthesis of Galen's account of digestion which, interestingly, included the views attributed to Erasistratus and Asclepiades.[64] Whereas his conception of digestion relied on a Galenic framework and terminology, it supported the body's atomic structure and porosity. A major theme in his interpretation was the role of heat and *fuga vacui* in the phenomenon of attraction. In reconsidering Galen's account in *On the Natural Faculties*, Beeckman stated that heat 'compressed' the body, hence causing the attraction of humours by dilating the pores.[65] This process also caused the rarefaction of humours, which were transformed into vapours while penetrating the pores.[66] Thus, for Beeckman, it was the body heat that operated physiological functions by creating a movement of attraction by *fuga vacui*.[67]

Beeckman further applied this reasoning to the transformation of food in the digestive system. He understood the Galenic notion of cooking or 'concoction' of food stuff by the body heat as a phenomenon of *fuga vacui* caused by the dilation and rarefaction of heat. According to Beeckman, the liver was subject to a process of dilation due to the formation of vapours. By way of suction movement, it attracted the food 'concocted' in the mesenteric

63 Galen, *De naturalibus facultatibus*, 3.15, ed. Kühn II, pp. 206-214.

64 *JIB*, I, pp. 159-160: 'Cùm Gal., Lib. 1 Περι φυσικῶν <δυνάμεων>, multa contra Epicurum et Asclepiadem disputat. Concludit in fine Libri, et in principio secundi, viscera et partes omnes trahere sibi familiaria. Sed τὸ συστέλλειν hoc pacto exornari poterit: omnia terrestria undique premuntur ab incumbente aere, […] ergo multò magis ea, quae sunt in corpore, accedente coincidentiâ circumjacentium corporum.'

65 *JIB*, I, p. 145: 'Calor attrahit etiam hac ratione. Dilatantur calore pori alicujus partis. Cùm autem totum corpus perpetuò contenta premat continuendo, non est absonum humorem, pressum in locum patentiorem, vijs amplioribus factis, detrudi, etiamsi concederemus partem calefactam non minus solito premere.'

66 *JIB*, I, p. 149: 'Moderatus calor in corpore humores, ut decet, attenuat perque poros transmittit. Major verò calor plus attenuat quàm transmittit, ideòque partem distendit. Minor autem calor non sufficienter attenuat, ita ut vapor spiracula non possit penetrare, atque idcirco etiam distendit. At minimus calor non magis distendit quàm lagenam vitream, aquâ plenam, ignis paucus disrumpit.'

67 *JIB*, II, p. 123: 'Non mirum est putrescentibus humoribus ad cor rapi. Trahit enim cor fluvidam materiam ratione caloris. Est etiam viscus omnium calidissimum in corpore nostro, ideòque calor trahit per fugam vacui, ut ignis magnus minorem ignem et aerem ad se trahit.'

veins.[68] In the corollary of his medical thesis, Beeckman considered that suction movement was due to *fuga vacui*, which he assimilated to air pressure. As he integrated this statement into his medical theory, he broke with the Galenic interpretation of attraction – either as a magnetic force or as *fuga vacui* – since it was pressure, in his view, which was responsible for the attraction of food in the digestive organs.[69] He further explained that the digested food was filtered through the wall of the digestive organs, which were pierced with pores of various shapes, just as if it passed through a sieve.[70]

Following his reinterpretation of heat, attraction, and concoction, Beeckman formulated in atomistic terms the Galenic natural faculties. While maintaining the Galenic terminology and accent on the primary qualities, he emphasized the dilation and rarefaction of matter, as well as the shape of its particles.[71] He began by reporting the four natural faculties as 'attracting', 'concocting', 'retaining', and 'expelling', respectively.[72] The attracting faculty caused the dilation of pores by the body heat so that food matter could be received in the digestive organs. The concocting faculty, which was stimulated by moistness, achieved food transformation. The retaining faculty, which was stimulated by cold and dryness, prevented digestive matter from slipping by grasping it with the 'hooks' of digestive wall particles. By tightening the digestive wall, the retaining faculty facilitated the expulsion of the remaining nutriment by the expelling faculty. Nonetheless, Beeckman expressed his doubts on the notion of natural faculty later in his notebook. To explain the passage of food from the stomach to the liver

68 *JIB*, I, p. 102: 'Iecur sugit alimentum per venas meseraicas, quia ab alimenti spiritibus corpus jecoris dilatatur calore; sedato calore id, quod suxerat, in venas dimittit coincidendo, per quas illud simili coincidentiâ partium undique aequaliter distribuitur.'

69 Even when Beeckman maintained the Galenic view of attraction as a magnetic force during digestion, he explained it as a phenomenon of pressure on food particles, see: *JIB*, I, p. 309.

70 *JIB*, I, pp. 159-160: 'Cùm ullum viscus, praeter proprium, possit unumquodque penetrare, quia pori visceris uniuscujusque respondent corporis uniuscujusque formis; non aliter quàm si cribrum diversis foraminibus perforatum sit rotundis, triangulatis, lunaribus etc. [...] Immisso cibo ventriculus et intestina etiam supra generalem dictam pressionem se contrahunt, quodque hepar potest penetrare, expellitur; quod verò hepatis poris non respondet, alio vergit. Idem etiam fit in venis post hepar.'

71 On Beeckman's corpuscular explanation of natural faculties between 1616 and 1618, see: *JIB*, I, p. 165.

72 *JIB*, II, p. 116: 'Hîc sitae sunt quatuor facultates universales. Attractrix non est aliud quàm pororum in particulâ conveniens apertio, ut materia legitima possit, aliunde in eam commodè expressa, a particulis recipi. [...] Coctrix facultas fit particulâ humidiore existente. [...] Retentrix facultas requirit siccitatem, ne ob fluxibilitatem humidam contenta excidant, sed firmiter velut duris uncis comprehendatur. [...] Expultrix verò amat frigus.'

during digestion, he eventually substituted the compression of the stomach to the attracting faculty, which he judged 'incomprehensible'. In his view, it should rather be understood as a phenomenon of rarefaction as the stomach evacuated digested food after discharging the liver.[73]

For his atomistic account of digestion, Beeckman might have found a source of inspiration in the medical philosophy of Asclepiades – through the lenses of Galen in *On the Natural Faculties* – especially to describe the formation of the humours. Asclepiades founded his physiological theory on the movement of corpuscles through invisible pores of varying size and shape, which played a key role in the rarefaction of the humours. According to Galen, his conception of corpuscles and pores was comparable to Epicurus's notions of atoms and empty spaces.[74] Similarly to Asclepiades, Beeckman explained that particles united to form natural *minima* and homogeneous bodies as a result of the dilation of the pores under the action of heat.[75] These homogeneous bodies constituted the four humours that were contained in the blood mass, namely blood, bile, melancholy, and phlegm.[76] To maintain the functioning of the body parts, these humours were constantly produced from the minimal particles of ingested food.[77]

Following this reasoning, Beeckman described digestion as a process of rarefaction that consisted in a 'separation' of food matter by the body heat.[78] The concoction of chyle was ensured by the liver through the rarefaction of food matter, whose useless residue was transformed into vapours evacuated

73 *JIB*, II, p. 133: 'Sed procul dubio voluit significare ventrem potiùs sese comprimendo alimentum visceribus tradere, quàm id ab ijs trahi vi attractrice, tam incomprehensibili. Exonerato igitur hepate et rarefacto, occasio datur ventri sese in hepar recepturum et vacuum exonerandi.'

74 Leith, 'Pores and Void', pp. 164-191. Leith has noted that Lucretius counted nutrition as a proof of the existence of vacuum: Lucretius, *De rerum natura*, 1, 350.

75 *JIB*, II, pp. 103-104.

76 *JIB*, II, p. 104: 'Enimverò haec minima filamenti constant ex quibusdam homogeneis, videlicet ex sanguine, bile, melancholiâ et phlegmate, aut saltem horum similibus; haec demum si placet, immediatè ex elementis. Haec homogenea primò ab elementis mutantur. Si igitur calor diutiùs membro adsit, ita ut non solùm poros majores, verùm etiam exiguos inter minima occupet, vel ibi mutat nutrimentum […], vel à poris ijs pergit ad ipsa minima naturalia eaque penetrat.'

77 *JIB*, II, p. 117: 'Ac jam sciendum est calorem et humorem aut potiùs ignem, aerem, aquam, terram, aut potiùs bilem, sanguinem, pituitam et melancholiam, indesinenter à minimâ constrictae in ipsis minimis haerent, non exerunt vires; imò si nihil perpetuò deflueret, particulâ separari et in poris minimis versari. […] Hinc necessaria per nutrimentum restauratio particularum, quae jam totae hoc defluxu consumptae sunt, et sua munera jam defuncta evanuerunt.'

78 *JIB*, II, 108: 'Ideò nullo negotio à cibo separatur, cujus omnes particulae inter se sunt connexae, aqueae videlicet cum terreis, adeò ut calor nequeat particulas cibi frangere, sed eas duntaxat ita separat, ut chylus, et chymus legitimus inde existat, unde partes corporis possint nutriri.'

by the pores. As Beeckman explained, this process started with the separation of particles and homogeneous bodies from food by the vital heat.[79] These particles, in turn, bound to the fire particles of the body heat in order to be transformed into 'wind', 'vapour', and other forms of exhalation. From that moment, they passed through the pores of the digestive organs' membrane and were processed into chyle. Thus, for Beeckman, digestive concoction was a process of rarefaction associated with the dilation and contraction of digestive organs. This reasoning was integrated into Beeckman's framework of 'natural *minima*' and pores. Such an approach led him to define nutrition as the renewal of 'useful' food particles, which filled the empty pores of digestive organs.[80]

4 Conclusion

Beeckman's medical theory was the result of a diligent reading of Galen between late 1616 and early 1618 in preparation for his medical degree at the University of Caen in September 1618. It was in this medical context that he developed an atomistic theory of matter in his *Journal*. Beeckman's medical atomism relied on the Galenic framework of elements, qualities, and temperament, but challenged the Aristotelian physics of matter-form. In his theory of matter, he put forward atomic elements with interstitial vacuum, which were each characterized by a particular shape at the origin of their qualities. This atomistic interpretation led Beeckman to abandon the Aristotelian notion of a substantial form in the formation of the body. Nonetheless, he sought to solve the problem of the materialistic tone of his theory by Galenic teleology, which he merged with his Calvinist faith. In his view, it was divine creation that ensured the creation of atoms and determined their organic functioning in nature, including the human body, through their multiple permutations following a regular structure.

79 On homogeneous and heterogeneous humours in Beeckman's conception of pathology, see the chapter 'Physician, Patient, Experimenter, and Observer: Isaac Beeckman's Accounts of Illness and Death' by Dániel Moerman in this volume.

80 *JIB*, II, p. 103: 'Haec minima sunt homogenea respectu ipsorum filamentorum. Omnes enim ejus partes sunt tales, et nutrimentum debet fieri talis pars, antequam possit dici pars corporis nostri. Id autem nutrimentum est ea materia, quae in his exiguis poris continetur fitque talis particula non exeuns è loco suo recipiendo à lateribus suis, id est à minimis his naturalibus, quibus comprehenditur calor, humores, quod in ijs est praecipuum, atque ita antiquum minimum perit, inutili excusso aut exhalante.'

Beeckman integrated his atomistic conception into his Galenic approach to physiology around 1620. Most remarkably, he developed a physiological account of the body as structured into elements, particles, *minima*, and homogeneous bodies. For his account of health and temperament, Beeckman took up the Galenic conception of mixture as a homogeneous union of elemental particles. However, he argued that these particles functioned as atoms that obeyed an accidental concourse and aggregated to form various layers of *minima*. To define the latter, Beeckman proposed an eclectic terminology, of which the notion of homogeneous (*homogenea*) was the most striking example. Drawing on Aristotle's physics, Galenic medicine, Libavius's alchemy, and Keckermann's logic, the notion of *homogenea* designated homogeneous parts whose atomic arrangement was regular and well-disposed. Following this interpretation, the *homogenea* took the meaning of 'homeomerous' parts which were composed of atomic elements and constituted the body's tissues with determined properties.

Beeckman also applied his atomistic account to the physiological phenomenon of digestion. He considered it as a process of contraction and dilation due to the pressure applied to food matter within the digestive organs. The ingested food was concocted and broken down by a vital heat of strictly elemental nature, consisting of fire. Beeckman's interpretation of digestion was nurtured by his expertise in hydraulic engineering, which he combined with Galenic medicine, Lucretian atomism and, presumably, the corpuscular views of Asclepiades and Erasistratus transmitted by Galen. This allowed him to maintain the traditional notions of humours, vital heat, and natural faculties which intervened during food 'concoction'. Nonetheless, it was the atomic arrangement of the bodily substances and the vacuum within their pores that prevailed in Beeckman's explanation of digestion.

In sum, Beeckman's medical theory of matter illustrates how apparently antithetic Galenism and atomism could be combined in the early modern period, as well as the intellectual roots of such a stance in the Renaissance medical tradition. His physiological thinking was part of a classical set of questions on the composition of living bodies in Galenic philosophy, which prompted a corpuscular reinterpretation of elements in the Renaissance. In this context, Beeckman stands as an interesting figure whose views on atoms and physiology were distinct from those of atomist physicians such as Girolamo Fracastoro, Sébastien Basson, and Daniel Sennert. In the early seventeenth century, atomist physicians commonly referred to ancient philosophers in postulating the discrete structure of elements that juxtaposed to form bodies. But Beeckman was remarkable in positing the notions of atomic shape and vacuum within a mechanical framework.

Further studies need to be conducted in order to explore the possible influence of Beeckman's medical atomism on his scholarly network.

About the Author

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