JOAN BAPTISTA VAN HELMONT AND THE QUESTION OF EXPERIMENTAL MODERNISM

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ABSTRACT — In this paper, I take up the question to what extent and in which sense we can conceive of Joan Baptista Van Helmont's (1579-1644) style of experimenting as "modern." Connected to this question, I shall reflect upon what Van Helmont's precise contribution to experimental practice has been. I will argue – after having analysed some of Van Helmont's experiments such as his tree experiment, ice experiment, and thermoscope experiment – that Van Helmont had a strong preference to locate experimental designs in places wherein variables can be more easily controlled (and, ultimately, in relatively closed physical systems such as, paradigmatically, the vessel, globe, or sphere [*vas, globus, sphera*]). After having reviewed some alternative options, I shall argue that Van Helmont's usage of relatively isolated physical systems and a moderate degree of quantification is the feature that best characterizes his contributions to "modern" experimentation.

1. Introduction: Van Helmont's Reception

The following facts about Joan Baptista Van Helmont (1579-1644)[1] are unanimously accepted by scholars: he was born in Brussels and also died

* The author is indebted, first of all, to Hiro Hirai, Lawrence Principe, and Soraya Sadek for their comments on earlier versions of this paper; secondly, to the participants of a seminar (entitled *Chimie et Mécanisme* and organised by Bernard Joly at the University of Lille on 13 march 2006) for their feedback; thirdly, the Research Foundation (Flanders) for financially supporting this research; and finally, the anonymous referees for their comments. Contact: Dr. Steffen Ducheyne, Research Assistant of the Research Fund (Flanders), Centre for Logic and Philosophy of Science and Centre for History of Science, Ghent University, Blandijnberg 2, B-9000 Ghent, Belgium; E-mail: Steffen.Ducheyne@UGent.be.

[1] For the main biographical facts, see Pagel, 1930, pp. 134-141; Pagel, 1970; and, especially,

there; he studied at the University of Louvain, from which he initially refused to accept his degree (however, in 1599 he obtained his doctorate there); he travelled extensively across Europe (visiting France, England, Switzerland, and Italy); he was strongly influenced by Paracelsian ideas, which led him to conceive of the universe as "an organism in which matter was configured by a series of forces"[2] – however, he rejected Paracelsus's *tria prima* (mercury, salt, and sulphur); he believed that water[3] is the universal element[4] that constitutes all things natural; between 1609-1616 he retired to Vilvoorde to dedicate himself to an intense study of *pyrotechnia*; and, lastly, he coined the term *gas*[5] (the

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NÈVE DE MÉVERGNIES, 1935, pp. 110-148. Still relevant for Van Helmont's civil state is G. Des Marez's study (DES MAREZ, 1907), and for Van Helmont's genealogy Louis Stroobant's article (STROOBANT, 1933-1934). For Van Helmont's collision with the Church, see especially ROMMELAERE, 1868, pp. 27-39. For a portrait of the scientific milieu in which Van Helmont lived, see HALLEUX, 1983. His *magnum opus*, *Ortus Medicinae* (1648), was published posthumously by his son Franciscus Mercurius Van Helmont (1614-1698) (see COUDERT, 1999, for a recent study). It was based on, but not restricted to, the material of *Dageraad ofte Nieuwe Opkomst der Geneeskunst*, which was published originally in Low German (*Nederduits*) in 1644. The content and the title of *Ortus* were carefully chosen by Van Helmont senior.

[2] LÓPEZ-PIÑERO, 2000, p. 291; see also PAGEL, 1930, pp. 33-36. Van Helmont distinguished between *fermentum* (the causal force in material processes), *semen* (the working principle responsible for particular forms), and *archeus* (the vital principle that directs organisms: *werckmeester ter wesentheydt*). The *archeus* is the spiritual gas, the internal efficient cause. Van Helmont referred to this vital principle as *levende lucht* (living air), *d'uytwerkende oorsaecke* (the executing cause), *de smit* (the smith) (VAN HELMONT, 1644, p. 43), or *causa efficiens interna* (VAN HELMONT, 1682, p. 38). The *semen* springs from the *archeus*: it is the substance wherein the *archeus* is present. The *fermentum* is the dispositive means – it is neither substance nor accident – by which the *archeus* generates the *semen*. On this matter see PAGEL, 1930, p. 21. Van Helmont believed that in order to obtain knowledge about the *semina*, i.e., the potential qualities of things, their material substrate must be destroyed (cf. *per ignem philosophus*). See VAN HELMONT, 1944, pp. 43, 200; HIRAI, 2005, pp. 439-462. Van Helmont wrote in his *Eisagoge in artem medicam a Paracelso restitutam* (1607): "Semen est vitale principium in se continens spiritus mechanicus et universas tincturas speciei (cui suum sibi fabricat corpus) magnitudines, figures, colores, sapores, ac caliditates tanquam signaturas proprietatum consentanearum officiis, et destinationibus architectorum spirituum et rei producendae" (VAN HELMONT, 1854, p. 57). This early work was a commentary to Petrus Severinus's *Idea medicinae philosophicae* (1571). Concerning the influence of Severinus's concept of *spiritus mechanicus* on Van Helmont's concept of *archeus*, see HIRAI, 2005, pp. 257-259, pp. 457-459, and CLERICUZIO, 1993, pp. 307-308.

[3] Van Helmont noted: "Itaqua aqua, dum subit leges seminis, etiam sui ponderis, condensationis, & condentiae, dimensionum praeceptis, obligatur" (VAN HELMONT, 1682, p. 68). Van Helmont embraced the concept of mass balance in chemical reactions (NEWMAN-PRINCIPE, 2002, p. 68 ff). See NEWMAN, 2000, pp. 39-46, for the centrality of the mass balance in the history of alchemy.

[4] Van Helmont utilized his famous tree experiment, which we will discuss in what follows, to prove this proposition. Herbert M. Howe has pointed out that the experiment had already been suggested by Nicholas of Cusa in his *Idiota de staticis experimentis* (1450), and also by the author of the pseudo-Clementine *Recognitiones* (1504). See HOFF, 1964, and also HOWE, 1965.

[5] See Walter Pagel's commentary in VAN HELMONT, 1971, pp. III-IV. On the making of gas (*gas-*

spiritus sylvestris that was produced when burning charcoal), which he most likely derived from the Greek *chaos*. What Van Helmont's precise role in the so-called "Scientific Revolution" was and in which way he might have contributed to scientific methodology (and, especially, to experimental designs) is far less from clear.[6]

Past and contemporary appreciation of Van Helmont has always been ambivalent: on the one hand, Van Helmont is praised for various discoveries and for his insistence on empirical observation and experimentation in general;[7] on the other hand, Van Helmont is often portrayed as an irrational mystic and alchemist, who criticised human reason (*mens rationalis*), mathematics, and syllogistic reasoning.[8] He

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maeckinge), named after the Greek chaos, see VAN HELMONT, 1944, p. 92 ff. That was not his sole accomplishment, of course. Walter Pagel also mentions: the examination of the specific gravity of urine for diagnostic purposes, the use of the pendulum for time measurement (*ibid.*, p. 14), the invention of an instrument for thermometry, the discovery of acid digestion in the stomach, the appreciation for bile in the process of digestion in the gut, insight in the indestructibility of matter, the distinction between copper and iron vitriol, the demonstration of the presence of carbon dioxide in the waters of a Spa, the description of the rhythmic movement of muscular viscera, the recognition of the role of acid in inflammation and pus production, the association of the kidneys with ascites and oedema, the denial of "innate heat" and "radical humour," the recognition of exogenous agents causing disease, the description of a variety of causes of bronchial asthma, the introduction of aetiological therapy and numerous chemicals, the attempt at a classification of diseases (*divisio morborum*), and finally, the refutation of putrefaction and decay of humours as causes of diseases and fever (PAGEL, 1948, p. 347n). According to Van Helmont, the humours in medicine are on par with dreamlike entities such as *epicycli* and *eccentrici* in astronomy (VAN HELMONT, 1944, p. 318).

[6] His role for medicine is perhaps more clear: his therapeutic maxims and new conception of illness contributed to medicinal practice. Illness is a material substance, not a mere quality (VAN HELMONT, 1664, p. 495). Sickness was not caused by disequilibrium in the humours or a *diathesis*, but by a concrete physical substance (PAGEL, 1930, pp. 36-42; see also ROMMELAERE, 1868). Walter Pagel fittingly concludes his study on Van Helmont as follows: "Helmonts zeitlose Bedeutung liegt somit in der *vormorgagnischen* Auffindung und Nutzbarmachung der *lokalen* Angsriffspunkte der Krankheitsursachen and des lokalen Krankheitsgeschehens im biologischen Zentrum der betreffenden Stelle. Dauraus erklärt sich auch die vorzügliche Betrachtung der *Krankheitsursachen* bei Helmont, die bis zur Identifizierung von Krankheit und Krankheitsursache geht. Nicht die *Krankheit als Schädigung von Form und Funktion*, wie bei GALEN, sondern *From und Funktion des Schädigers* stehen bei Helmont vorzüglich in Rede" (PAGEL, 1930, p. 131). For a recent study on Van Helmont's conception of illness, see GIGLIONI, 2000, pp. 97-133.

[7] E.g., PARTINGTON, 1961, II, pp. 209-243. Franz Strunz saw Van Helmont as the founding father of quantitative chemistry and praised his contribution in the area of experimental proof (STRUNZ, 1907, p. 25). W. Rommelaere noted that in Van Helmont we can find the first elements of rational chemistry (ROMMELAERE, 1868, p. 24).

[8] PAGEL, 1948, pp. 349-350. On Van Helmont's critique of syllogistic reasoning, see his chapter *Logica Inutilis* (VAN HELMONT, 1648, pp. 41-45). Of course, for Van Helmont there was no contradiction between the two trends; they were two sides of the same coin (see also HEINECKE, 1995, p. 69). Walter Pagel (1898-1983) was one of the first scholars who took seriously both the "scientific" and "non-scientific" trends in Van Helmont's work (DEBUS, 1998, pp. 68-70). See

claimed, for instance, that we should not have a rational mind but rather an intellectual one.[9] According to Van Helmont, only the soul could provide a deeper understanding of nature.[10] Animal reason (*mens sensitiva*) knows only the external appearance of things: the *signatum*, but not the meaning hidden within it (*de zegelaer*).[11] Insight works by means of forms, figures, and examples (*gedaenten, figueren, en voorbeelden*) rather than by means of deductive reasoning.[12] Dreams were equally important to Van Helmont. In the introduction to *Ortus Medicinae* (1648), Van Helmont testified of a revealing dream he had: he found himself in an empty bubble of which the diameter reached from the centre of the earth to the heavens above. From this dream, Van Helmont understood that in Jesus Christ we live, move, and have our being.[13] Van Helmont also criticised the restrictiveness of mathematics: mathematics studies only the quantitative aspects of things, not their inner qualities. Proper science deals not only with *how much* things are, but also with *how* they are.[14] Mathematics places entities under the *praedicamentum quantitatis*: it does not succeed in penetrating the essence of things (*wesentheyt*).[15] Likewise, the Aristotelians – by neglecting the inner principles, the *semina*, of things[16] – reduced things to the status of an artefact.[17] Nature is not concerned with external signs, but only with causes.[18]

Recently, William R. Newman and Lawrence M. Principe have done an excellent job in gaining more insight into Van Helmont's experimental

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also Debus, 1977, II, pp. 295-380. William R. Newman and Lawrence M. Principe have, on a more general level, shown that "chemistry" and "alchemy" were undifferentiated disciplines before the eighteenth century, and that the separation between the two is an artificial distinction that was not shared by the pre-eighteenth-century adepts (Newman-Principe, 1998; see also their accompanying Principe-Newman, 2001).

[9] Van Helmont, 1682, p. 19.

[10] Van Helmont, 1944, pp. 17-19.

[11] *Ibid.*, p. 12.

[12] *Ibid.*, p. 22. Berthold Heinecke has recently made the interesting claim that Van Helmont's reservations against deductive reasoning pertain only to the *context of discovery* (in other words, in the *context of justification*, deductive reasoning is perfectly legitimate) (Heinecke, 1995, p. 67).

[13] Van Helmont, 1944, p. 22.

[14] *Ibid.*, p. 3. As a consequence of such mathematical thinking, some thinkers have equivocated duration with a mathematical continuum consisting of infinite points (*ibid.*).

[15] Van Helmont, 1944, pp. 3-4.

[16] Van Helmont added that knowledge of the *semina* is a "*naturalis consideratio*" not a "*fantastica superficiei circumductis contemplatio*" (Van Helmont, 1854, p. 104).

[17] Newman - Principe, 2002, p. 62. For Van Helmont's critique of Aristotle, see Browne, 1979.

[18] Van Helmont, 1944, p. 115.

practices – some of which we will discuss in the following section. Van Helmont indeed frequently referred to "experiments" (*experimenta mechanica*) to justify his claims. *Prima facie*, this suggests that one could rightfully claim that there is a modern component to Van Helmont's thinking. Not very surprisingly, Van Helmont's experimental procedures have been labelled as "quantitative" and "controlled."[19] In similar spirit, Robert Halleux once stated that in Van Helmont's mature work we see "the first trends of a method of enquiry, based upon organized and justified experiments."[20] By "modern experimental procedures," I have in mind such procedures as: quantification, control, theory-guided practice, practice-informed theory, replication, and reproducibility.[21] One aspect might be added to that list. Van Helmont defended the idea of the conservation of weight (*pondus*): all substances are made of an indestructible amount of water that has been rarefied or condensed by the *semina*.[22] He emphasised the superiority of quantitative measurements derived from weighing things, as compared to the scholastic determination of essences by means of logic.[23] Correspondingly, chemical reactions do not affect the weight of the substances involved. Van Helmont saw this as a general maxim of nature: everything desires to remain itself as far as possible.[24]

The theme of this essay is connected to this matter. What was Van Helmont's precise contribution to scientific methodology? To what extent can his scientific practice be regarded as "modern"? Why is it that historians of science have granted (and continue to grant) Van Helmont's style of experimenting the label of "modern"? As I see it, the reasons for this ought to be rendered more explicit. Let me first of all point out that we should always be aware that Van Helmont's concept of *experience* (*d'ervarentheyt*)[25] and *experiment* were not yet as sharply delineated as ours are.[26] Contrary to an experience, an experiment presupposes the involvement of a specific question about nature that the

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19 Brock, 1992, pp. 50-51.

20 Halleux, 1988, p. 98.

21 Cf. Newman-Principe, 2002, p. 13.

22 *Ibid.*, pp. 70-71, pp. 83, 90; Van Helmont, 1664, pp. 31, 143; Van Helmont, 1944, p. 69.

23 Newman-Principe, 2002, p. 68.

24 Van Helmont, 1664, p. 76.

25 E.g., Van Helmont, 1944, p. 99.

26 Halleux, 1988, p. 95.

experimental outcome is designed to answer.[27] Experiments always describe specific events and attempt to provide answers to specific questions. In Van Helmont's usage of these terms there was no sharp distinction between the two. According to Halleux, three expressions frequently occur in Van Helmont's experimental procedures:[28]

1) *experimentum*: technical or medical procedures that are not fully justified rationally and for which there is no other evidence of their validity except for the success they produce;

2) *mechanica probatio* ("hands-on demonstration"): proofs taken from the laboratory; and,

3) *quaerere per ignem* ("questioning by fire"): Paracelsian methods of chemical fire analysis.[29]

In their recent study, Newman and Principe have particularly focussed on (3).[30] Van Helmont used different expressions to refer to this practice: "by the art of fire,"[31] "artificial fire,"[32] "by an artificial diligent search,"[33] and "artificial skill."[34] I will consider Halleux's trichotomy as a valuable working hypothesis, but my essay does not need to presuppose its validity. I will take up this issue near the end of this essay. In this paper, it is my aim to supplement Halleux and also Newman and Principe from a methodological perspective. By carefully analysing some of Van Helmont's paradigmatic experiments (see section 2), I will be able to point to the *underlying epistemological unity* they exhibited: Van Helmont's style of experimenting displayed a strong preference to situate experimental designs in *loci* wherein variables can be more easily controlled (and, ultimately, in relatively closed physical systems).

One *caveat* should be made from the outset: I do not endorse an *essentialist* idea of science, i.e., I do not commit myself to the view that there is an "essence" of science – if there could be such a thing – that

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27 DEAR, 1995, pp. 21-25.

28 HALLEUX, 1998, p. 96.

29 The translations of the terms are by Newman and Principe. They prefer the first term over Halleux's translation "mechanical demonstration" (*handtdadelijcke mechanijcke bewesen*), since Van Helmont did not necessarily refer to machines. The second term is preferred over Halleux's "searching by fire," since Van Helmont wished to contrast his method with the Scholastic *quaestio*. See NEWMAN-PRINCIPE, 2002, p. 71n.

30 *Ibid.*, pp. 76-89.

31 VAN HELMONT, 1664, p. 50.

32 *Ibid.*, p. 52.

33 *Ibid.*, p. 65.

34 *Ibid.*, p. 412.

remains fixed throughout its history. Scientific knowledge and its relevant inferential procedures change over time; both vary at different places and at different moments in time. Correspondingly, it is not my aim to demonstrate that Van Helmont anticipated our modern conception of science in general or, more specifically, of experimentation. There is no teleology in the development of science. Rather, my aim is to compare some features of experimentation that have become *crucial to our contemporary understanding of experiments* with some features of what might *prima facie* be considered "experimental knowledge" that were *important to Van Helmont*.[35] In doing so, it will be possible to carefully ascertain Van Helmont's contribution to experimental methodology.[36]

2. Van Helmont's Paradigmatic Experiments

In this section, I will in full detail discuss four significant experiments from Van Helmont's work: (1) the thermoscope experiment (2) the transmutation experiment (3) the ice experiment, and (4) the willow-tree experiment. I will draw the main material from both *Ortus Medicinae* (1648) and *Dageraad* (1644). These experiments have been selected on the basis of their being methodologically relevant and sufficiently detailed. For the English translation of *Ortus Medicinae*, I have relied on the English version of 1664, *Oratrike or Physick Refined* (which is, by the way, not an excellent translation), and compared it to the Latin

35 As a possible response to the lurking issue of anachronism, Abdelhamid I. Sabra fittingly puts it as follows: "*Science* and *scientific* are our own terms and they express *our* own concepts (which, by the way, does not mean that they are sharply defined or unproblematic); and, therefore, the study of any past intellectual activity can be relevant to what we call 'history of science' only to the extent that such an activity can be shown to help us understand the modes of thought and expression and behavior, that *we* have come to associate with the word *science*. This is not anachronism, presentism, whiggism, or any of the objectionable isms, but a consequence of the fact that we who are writing the history also have a location of our own that defines our perspective and, hence, the questions we pose from our vantage point and the terms in which these are framed. Nor should this admission to a definite point of view discourage or detract from investigating past modes of thought and expression behavior under other categories deemed suitable for elucidating these modes 'in their own terms,' as the phrase goes" (Sabra, 1996, p. 656).

36 Robert E. Kohler recently pointed to the necessity of a general history of science, i.e., a history of science for all historians of science without losing the advantages of case study. He suggests that one way of structuring the rich material provided by micro-studies is "to structure case studies around the activities or issues that are common to knowledge production generally" (Kohler, 2005, p. 224; cf. p. 226). I am very sympathetic towards such an approach. In this paper, the methodologically relevant (and hence unifying) issue is scientific experimentation.

edition – I refer to the latter in footnotes.[37] I will focus on and discuss what Van Helmont calls *mechanical experiments*. It should be stressed, as Newman and Principe have previously observed, that the term "mechanical" is somewhat misleading here.[38] The Low German equivalent "*handtdadelijcke mechanijcke bewesen*," i.e., "hand-on" or "handicraft," better illustrates Van Helmont's notion of a mechanical experiment: *generally, it referred to natural processes that were deliberately manipulated at the hand of the investigator of nature, and it is not directly connected to simple machines*. In the following section I will use my analysis of these experiments as a basis for a general discussion of the characteristics of experimentation in Van Helmont's work.

(1) Let us first of all look at Van Helmont's thermoscope experiment.[39] According to Van Helmont, the demonstration was essentially based on mathematics (he calls it a "*demonstratio mathematica*").[40] It sets out to falsify the thesis according to which water and air can be transformed into one another: Van Helmont rejected both that air can be transformed into water by heating, and that water can be transformed into air by heating. (Van Helmont accepted that water can be produced by the condensation of air, and hence, by cold.) Now for the experiment itself. Two spheres, A and D, are connected to each other by BCE. Both spheres are filled with air. The pipe BC is filled with vitriol that has been coloured red by the steeping of roses. It is essential that the two spheres be perfectly closed, "*perfectissime clausa.*"[41] Van Helmont established by observation that without the opening in F, the liquor in BC cannot be moved from its place by heating the air in A (see Fig. 1). Van Helmont points to the great practical difficulty of the experiment:

The preparation of the demonstration. It is very great, because the air suffers enlarging, and the heaping together or straightening, according to the qualities of

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[37] Van Helmont's works were also translated into French by Jean Le Conte: *Les Oeuvres de Jean Baptiste Van Helmont traittant des principes de médicine et physique* (Lyon, 1670), and into German by Christian Knorr von Rosenroth (who was assisted by Van Helmont junior): *Aufgang der Artzney-Kunst* (Sulzbach, 1683). For a thorough study of the dissemination of Van Helmont's work in the seventeenth century, see CLERICUZIO, 1993.

[38] Cf. note 29.

[39] A careful reading of the 1648 edition is advisable here. See also VAN HELMONT, 1971, pp. 98-100. This experiment is absent in *Dageraad*. Strunz is one of the few authors who briefly discusses the thermoscope experiment (STRUNZ, 1907, pp. 40-42).

[40] VAN HELMONT, 1648, p. 60.

[41] ID., 1682, p. 62.

the heat and cold, and because the just extension of quantity is not had in the air, unless when it is temperate.[42]

When heating the air in A, no extra water was produced. Van Helmont explained this by assuming that the air in the upper part of the vessel thickened as it tried to expand ("*Aër* [...] *accrescit per augmentum dimensionum, & ideo occupat plus loci, quam antea*").[43] The amount of fluid remains the same, contrary to the opinion of Van Helmont's opponent, Henricus van Heers, a medic from Liège, according to whom the compressing of air by heath produces water ("*quod aer compressus, conversatur in aquam*").[44] Van Helmont stressed that van Heers's faulty interpretation was due to his ignorance of mathematics:

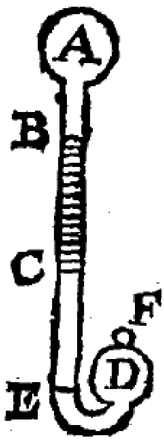

Fig. 1 – Van Helmont's thermoscope experiment.

> But Heer boasted amongst *Idiots*, that he had sometimes been a Professour (*sic*) of the *Mathematicks* at *Padua*. Wherefore I would demonstrate in paper, his every way ignorance of Mathematics.[45]

Next, Van Helmont proceeded to show that the water cannot dry up ("*exsiccare*") or be exhaled ("*exhalare*") by heating, if A and D are kept carefully shut.[46] Since no extra water was produced when heating the air contained in A, the thesis that air can be transformed into water is, according to Van Helmont, untenable. Similarly, since no water disappeared when heating the vessel, the thesis that water can be transformed into air ("*quod liquor sit mutatus in aëris*") is untenable. The above experiment further exhibits the following features:

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[42] VAN HELMONT, 1664, p. 61. Translation of: "Praeparatio demonstrationis. Est maxima, quod aer patiatur dilationem, & constructionem juxta qualitates caloris, & frigoris, & quod justa extensio quantitatis in aëre non habeantur, nisi cum est temperatus" (VAN HELMONT, 1682, p. 62).

[43] VAN HELMONT, 1682, p. 62.

[44] *Ibid.*, p. 65.

[45] VAN HELMONT, 1664, p. 60. Translation of: "Heer autem apud Idiotas ostentabat, se quandoque Patavii suisse Matheseos Professorem. Quare volui in charta demonstrare, ipsius omnimodam ignorantiam Matheseos" (VAN HELMONT, 1648, p. 64).

[46] VAN HELMONT, 1664, p. 60. Translation of: "Itaque juxta hypothesin Heer (quod aer compressus, conversatur in aquam) liquor nunquam defuisset in vase. [...] Non potest autem siccitatem admittere, in vitro exquisite clauso nisi sua hypothesis destruatur (nimimur quod aer compressus, mutetur in aquam) nec iterum ista hypothesis subsistere potest, nisi admiserit continuationem liquoris" (VAN HELMONT, 1648, p. 65).

(a) The potential movement of the water is visualised by colouration – note that there are only four figures in *Ortus* (they are absent in *Dageraad*).

(b) By using a sphere (*sphera* or *globus*), all disturbing factors (e.g., extra air or fluid) are screened off. The amount of air and water is kept fixed.

(c) By using the sphere, we establish a relatively isolated physical system (see section 3).

(2) Van Helmont claimed to have rebutted Aristotle's doctrine of the four elements and to have proven by "*handtdadelijcke mechanijcke bewesen*" and "*mathese*" that all matter originates from water.[47] I refer to this experiment as the transmutation experiment. These proofs consisted in showing that all material can be reduced "by art" to a salt that has an *identical* weight to that of the original material. When this salt is mixed with a corrosive, it turns into "vivid water."[48] Once the corrosive is again separated from the "vivid water," an *identical* amount of corrosive is separated from an amount of clear water. Hence, Van Helmont is able to conclude that the original material should consist of water in the first place (reference to the constancy of matter is crucial in his argumentation). As I would interpret it, Van Helmont's reference to *mathese*, lies precisely in his reference to the conservation of matter. Van Helmont's reasoning process goes as follows:[49]

(1) all material $=>_{\text{(by fire)}}$ salt [*where the initial matter weighs as much as the obtained salt*];
(2) salt + corrosive $=>_{\text{(mixing)}}$ vivid water;
(3) vivid water $=>_{\text{(filtering)}}$ corrosive + clear water [*where the corrosive weighs as much as the corrosive used in* (2)];

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47 VAN HELMONT, 1944, pp. 61, 64, cf. p. 114. Van Helmont argued that fat and oils can be transformed again into water by distilling the soap he obtained from mixing fat with alkalis (*ibid.*, p. 109; NEWMAN-PRINCIPE, 2002, p. 79).

48 Van Helmont noted that: "Voorts bewijst oock onze ervarentheyt dat alle vast lichaam, des hout, gewas, visch, vleesch, alle sout, swavel, keye, marchasite, aerde, sandt, steen, metael en bergwerck, wordt by konst [i.e., by "*vuer-konst*," (by art)] verkeert tot een daedelijck sout, *bestaende in het selve zijn voorigh gewichte*, en dat van dit sout, wordende daer nae dickwils geprobeert met het *specificum corrosivum* van Paracelsus, verandert gansch en geheel in een vluchtig water 't welck ten lesten soet wordt als regen-waeter, mits dat het voorsegde corrosijf daer van wordt gescheyden *sonder verlies van het gewichte* [...]" (VAN HELMONT, 1944, p. 51; my emphasis).

49 The mercurial alum example Newman and Principe discuss can be cast in similar terms (NEWMAN-PRINCIPE, 2002, pp. 80-83).

(4) all material =>$_{\text{(by fire, mixing and filtering)}}$ water [by steps (1)-(3) and the conditions in (1) and (3)].

Bear in mind that by steps (2) and (3) Van Helmont is able to show that:

salt + corrosive =>$_{\text{(mixing and filtering)}}$ corrosive + clear water.

Since the corrosive is identical, we have:

salt =>$_{\text{(mixing and filtering)}}$ clear water.

Note that, next to these "mechanical" proofs, Van Helmont also stressed a biblical reason not to accept Aristotle's doctrine: in *Genesis* there is no mention of the creation of the four elements.[50]

(3) The next experiment I shall discuss is the ice experiment. The aim of the experiment is (again) to show that air cannot be turned into water. It proceeds as follows:

> Fill a glassen and great Bottle, with pieces of Ice, but let the neck be shut with a Hermes Seal, by the melting of the glasse in the same place. Then let this Bottle be put in a balance, the weight thereof being laid in the contrary Scale; and thou shalt see that the water, after the Ice is melted, shall be weightier by almost an eight part than it self being Ice. Which thing, since it may be a thousand times done by the same water reserving always the same weight, it cannot be said, that any part thereof has been turned into air.[51]

One thing we should keep in mind, as T.S. Patterson has argued, is that Van Helmont refers to an increase of the *specific weight* of the water, i.e., the weight per fixed unit of volume, obviously not of its *absolute weight*.[52] Newman and Principe further stress that Van Helmont had no distinct terminology for absolute and specific weight.[53] We notice that Van Helmont used the sphere as a means of isolating the volume of water and air. No water or air can escape or enter the vessel. Since the absolute weight of the water remains identical, the variations in its specific weight cannot be attributed to the fact that some amount of air

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[50] VAN HELMONT, 1944, p. 64.

[51] VAN HELMONT, 1664, p. 75. Translation of: "Probatur per mechanicam. Imple lagenam vitream & magnam, fructis glaciei, collum vero claudatur sigillo Hermetis, id est, per vitri ibidem liquationem. Ponatur haec tum lagena, in bilance, adjecto pondere, in oppositum, & videbis quod propemodum octava sui parte, aqua, post resolutam glaciem, erit ponderosior seipsa glacie. Quod cum millesies ex eadem aqua fieri potest, reservante semper idem pondus, dici non potest, quod ejus pars aliqua in aerem sit versa" (VAN HELMONT, 1948, p. 79).

[52] PATTERSON, 1936, pp. 463-464; Patterson's interpretation is also followed in NEWMAN-PRINCIPE, 2002, pp. 72-74.

[53] *Ibidem.*

is changed into water (this would result in a change in the absolute weight of the water). The changes in specific weight can thus be explained only by the expansion of the water when freezing. This corresponds with what Van Helmont wrote in his letter to Père Marin Mersenne on 30 January 1631: "*glaciari ipsum est actus effectivus et primarius aquae.*"[54] According to Van Helmont, this is a "mechanical" demonstration: *probatur per mechanicam*.[55]

(4) Hereafter follows a description of Van Helmont's famous tree experiment,[56] which Van Helmont also considered to be a mechanical demonstration ("*ostendi in mechanica*"):[57]

But I have learned by this handicraft-operation, that all Vegetables do immediately, and materially proceed out of the Element of Water only. For I took an Earthen Vessel [*vas*], in which I put 200 pounds of Earth that had been dried in a Furnace, weighing five pounds; and at length, five years being finished, the Tree sprung from thence, did weigh 169 pounds, and about three ounces: But I moystened the Earthen Vessel with Rain-water, or distilled water (always when there was need) and it was large, and implanted into the Earth and least the dust that flew about should be co-mingled with the Earth, I covered the lip of the mouth of the Vessel, with an Iron-plate with Tin, and easily passable with many wholes. At length, I again dried the Earth of the Vessel, and there were found the same 200 pounds, wanting about two ounces. Therefore 164 pounds of Wood, Barks, and Roots, arose out of water onely.[58]

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[54] MERSENNE, 1936-1988, III, p. 61.

[55] VAN HELMONT, 1648, p. 79.

[56] As is widely known, Robert Boyle (1627-1691) accepted the experiment's validity and noted that Van Helmont is "an Author more considerable for his experiments than many Learned men are pleas'd to think him" (BOYLE, 1661, pp. 111-115). Boyle was not alone in his praise for Van Helmont: Antoine Laurent Lavoisier (1743-1794) also praised Van Helmont (NEWMAN-PRINCIPE, 2002, pp. 297-303).

[57] *Ibid.*, p. 108.

[58] VAN HELMONT, 1664, p. 109. Translation of: "Omnia verro vegetabilia immediatè, & materialiter, ex solo aquae elemento prodire hac mechanica didici. Caepi enim vas terreum in quo posui terrae in clibano arefactae ℔ 200, quam madefeci aqua pluvia, illique implantavi truncum salicis, ponderantem ℔ 5. ac tandem exacto quinquennio, arbor inde prognata pendebat ℔ 169, & circiter unas tres. Vas autem terreum, sola aqua pluvia, vel distillata, semper (ubi opus erat) maduit, eratque amplum, & terrae implantatum, & ne pulvis obvolitans terrae commisceretur, lamina ferrae, stanno obducta, multoque foramina pervia, labrum vas tegebat. Non computavi pondus soliorum quaterno autumno deciduorum. Tandem iterum siccavi terram vasis, & repertae sunt eaedem librae 200 duabus circiter uniciis minus. Librae ergo 164 ligni, corticum, & radicum, ex sola aqua surrexerant" (VAN HELMONT, 1648, pp. 108-109).

Newman and Principe note that this experiment "gives a clear example of his quantitative technique."[59] The *explanandum* here is the weight and growth of the tree. First of all, the weight of the earth is measured. That the earth has been dried on a fire and is isolated from the external world by means of a plate is significant here, since these conditions guarantee that no other elements than earth could reside in the pot. That the water is distilled (or is rainwater) equally guarantees that no other elements than water reside in the pot. This assumption was later challenged by James Woodward in 1700. In contemporary parlance, we would say that these variables (earth and water) are controlled.[60] Then, the gained weight of the tree is measured (*ca.* 164 pounds). Note however that after five years Van Helmont weighed the "Wood, Barks, and Roots." Apparently, Van Helmont did not include the weight of the leaves, for whatever reason. Notice further that Van Helmont is not worried at all by the difference of two ounces. Given that in the pot there did not reside any other elements than earth and water, and that the earth did not diminish significantly, Van Helmont (wrongly) concluded that the water *alone produces* the growth of the tree.

One remark should be added here. Van Helmont sometimes used the term "mechanical experiment" in a very loose sense. A mechanical experiment does not always refer to an experiment made at the hand of the natural philosopher. For instance, from the fact that flowers follow the motion of the Sun (even when the Sun does not shine), Van Helmont concluded that flowers have some kind of *instinctum*.[61] In this case, no direct intervention or isolation of variables is presupposed. This example shows that Van Helmont's idea of mechanical experiment was not limited to experiments as "*experimenta*," that is, purposely performed tests of naturalistic theses, but it also contained a broader spectrum of rather loose evidence. As I have stressed in the introduction, Van Helmont did not have the same notion of experiment as we do. Van

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[59] NEWMAN-PRINCIPE, 2002, p. 79; see also HERSHEY, 2003, for a good account of the successfulness of Van Helmont's tree experiment.

[60] Note, however, that in Nicholas of Cusa's presentation of the "experiment," in his *Idiota de staticis experimentis*, such screening-off procedures are accentuated less (HOPKINS, 1996, p. 614; HOWE, 1965, p. 408).

[61] VAN HELMONT, 1664, p. 1114; VAN HELMONT, 1944, p. 333. I have run through Van Helmont's collected work in search of relevant fragments containing reference to mechanical experiments. The example with the flowers was one of the few examples I found.

Helmont's loose usage of the term "mechanical experiment" shows that Halleux's reduction of it to "proofs taken from the laboratory" is too narrow: for Van Helmont it referred to more than that. In addition to that, Van Helmont allowed for anecdotes (*een geschiedenis*)[62] and loose observations. For instance, the constant dripping of saltpetre in caves is an indication (*een teken*) that stone is transformed again into its primary principle: water.[63]

3. Modern Strata in Van Helmont's Experimental Procedures

Now that we have carefully acquainted ourselves with Van Helmont's style of experimentation, it is time to address his way of experimenting more generally. In this section, I will discuss what *prima facie* might appear as appropriate modern concepts to describe Van Helmont's most original contribution to experimental designs. The options are: (1) the idea of an operative science; (2) quantification; (3) replication and reproduction; and, finally (4) the importance attributed to isolating certain factors of a physical system by keeping variables fixed (ultimately, this entails the creation of a relatively closed physical system, where almost all external variables are screened off, and only the relevant internal properties are manipulated). I will discuss these features separately in the following subsections. I shall try to argue that the second and the fourth option – in the sense that will be specified below – best highlight Van Helmont's contributions to experimental reasoning.

Scientia Operativa: From Aristotle to Van Helmont

The first option to describe Van Helmont's contribution to experimental methodology was his adherence to the idea of a *scientia operativa*. One might try to make a similar move, as Antonio Pérez-Ramos has done in the case of Francis Bacon, and argue that Van Helmont was one of the earliest defenders of the idea of an operative science. Van Helmont indeed considered medicine a handcraft (*handt-werck*) on a par with carpentry and ironwork.[64] Healing is a "work" that

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[62] E.g., Van Helmont, 1944, pp. 41-43.
[63] Van Helmont, 1944, p. 202.
[64] *Ibid.*, p. 3.

is completed by the art of fire.[65] His scientific practice comprised a strong insistence on intervening and manipulating natural processes. Van Helmont explicitly spoke of "handicraft-operations" ("*handtdadelijcke mechanijcke bewesen*" or "*handdadige Mechanica*"):[66] operations made at the hand of the inquirer.[67] The standard Latin expression for this type of experiment is "*per mechanicam.*"[68]

In the literature on the emergence of the idea of science as an operative science (*scientia operativa*), Francis Bacon is usually given special credit for this transformation.[69] Accordingly, Bacon reacted against the Aristotelian dichotomy[70] between products of nature (*naturalia*) and human arts (*artificialia*) by showing that there is no ontological difference between the spontaneous workings of nature and the workings that are directed or manipulated by man's purposive action.[71] Nature always maintains the same *modus operandi*. Recently, scholars have tempered the usual focus on Bacon with respect to the emergence of *scientia operativa*. In her broad study, Pamela H. Smith concludes that the idea of *scientia operativa* had a broad sociological adherence between the fifteenth and seventeenth centuries among artists, natural philosophers, medics, craftsmen, etc.:

> The idea of an "active science," however, goes back not to Bacon, but to the writings and works of art of Dürer, Leonardo, Palissy, to the makers of the works of art that filled art and curiosity cabinets, and to the writings and persona of Paracelsus. These artisans and practitioners appealed to nature as the basis of their science.[72]

These artisans and practitioners endorsed an artisanal epistemology, which consists of the following elements: (1) nature is seen as primary,

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65 *Ibid.*, p. 195.

66 *Ibid.*, p. 238.

67 At the beginning of *Vierde Pael*, Van Helmont wrote: "De kennis der natueren wordt alleen genomen uyt 't gene dat in der daet is, en niet uyt verdichte beschouwingen" (Van Helmont, 1944, p. 37).

68 Van Helmont, 1648, p. 79.

69 See especially Pérez-Ramos, 1988, and Pérez-Ramos, 1996. For Bacon, a knower is essentially a maker. True knowledge refers to knowledge that is made or can be made (reproduced, modelled, fabricated, etc.); cf. Pérez-Ramos, 1996, p. 110. In order to know a phenomenon, we should be able to (re)produce it (*ibid.*, p. 115). Put more precisely: "The capacity of (re)producing Nature's 'effects' was perceived as the epistemological guarantee of man's knowledge of natural processes in the external world" (Pérez-Ramos, 1988, p. 59).

70 See also Dear, 1995, p. 155.

71 Pérez-Ramos, 1996, pp. 110-116.

72 Smith, 2004, p. 239.

and knowledge resides in nature; (2) matter is active, and one must struggle bodily with it to arrive at knowledge of it; (3) this struggle is called experience (and is learnt by replication); and (4) imitating nature produces an effect that displays the artisan's knowledge of nature.[73] In his recent *Promethean Ambitions*, William R. Newman further nuances the views of Pérez-Ramos, Dear, and indirectly Smith.[74] Newman points to the "non-interventionist fallacy," which consists in the erroneous belief that "the Stagirite and his followers[75] were fundamentally non-experimental or even actively opposed to experiment, because experimentation involved intervention in natural processes."[76] In Newman's view, Pérez-Ramos, Dear, and indirectly Smith have assumed that the neglect of experimentation was derived from the Aristotelian dichotomy between *naturalia* and *artificialia*. In any case, Van Helmont did not perceive a relevant difference between *naturalia* and *artificialia*.[77] Many alchemists and scholastics did not perceive a strict dichotomy between art and nature, nor were their scientific inquiries devoid of experimentation.[78] There was a rich experimental literature in medieval and early modern alchemy.[79] Aristotle also performed and utilized experiments in the interventionist sense. Newman refers, for instance, to Aristotle's *Meteorology*, where his explanation of the rainbow was based on a manufactured analogue.[80] Ancients, scholastics, and alchemists were deeply immersed in interventionist-type experimentations.[81] According to Newman, the "maker's tradition of knowledge" goes back to Aristotle. Neglecting for a moment the tenability of Newman's thesis,[82] there is

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73 *Ibid.*, p. 149.

74 NEWMAN, 2004.

75 This refers to medieval scholastics, such as Themo Judaei and Nicole Oresme (see *ibid.*, pp. 242-243), but also to medieval and early modern alchemists such as Avicenna, Petrus Bonus, "Geber," and Daniel Sennert (see NEWMAN, 1997, pp. 309-312; see also NEWMAN, 2001).

76 *Ibid.*, p. 238.

77 This can be seen from the following quote: "Natura siquidem, sua opera metitur distillando, irrigando, siccando, calcinando, resolvendo, iisdem planè mediis, quibus vitra, ejusmodi operationes absolvunt. Adeoque Artifex, naturae operationes mutando, ejusdem proprietates, & scientiam nanciscitur" (VAN HELMONT, 1982, p. 48, cf. p. 100). See also HEINECKE, 1995, pp. 71, 73.

78 E.g., NEWMAN, 1997, p. 312.

79 *Ibid.*, p. 316.

80 *Ibid.*, p. 242.

81 NEWMAN, 2004, esp. pp. 238-289.

82 Newman's interpretation is hampered by the superiority of *theoretical knowledge* for Aristotle. It should be stressed that for Aristotle *practical knowledge* remained inferior to

sufficient reason not to see the idea of an operative science as an original contribution of Van Helmont's to experimental design: the idea of *scientia operativa* had already been put into practice during the Middle Ages (and possibly during Antiquity).

Quantification

Van Helmont's critique of mathematics should not be interpreted as a rejection of mathematics *in toto*, but only as a prudent awareness of the limits of mathematics.[83] The *archeus* compelled nature to obey mathematics.[84] Already in 1607, Van Helmont considered mathematical demonstrations (*geometricae demonstrationes*) essential for appraising nature ("*quas sola natura metiri potes*").[85] Van Helmont distinguished between *scientia memorativa* (collecting and preserving observations) and *scientia applicationis rerum ad mensuram* (applied mathematical knowledge).[86]

Although modern quantitative-like aspects play a role in Van Helmont's experimental procedures, and although he often stressed the mathematical component in his arguments,[87] it would clearly be wrong to consider Van Helmont's experimental procedures equally quantified with respect to our contemporary ones, in which both the level of accuracy has become more important (since our means of measurement have expanded drastically) and the mathematics involved has become more complex (e.g., the usage of statistics and formulae).[88] The importance of mathematical arguments in Van Helmont's work is mainly

theoretical knowledge (see e.g., *Metaphysica*, A, I, 981^{a}-981^{b}). For Aristotle, proper knowledge was equivalent to theoretical knowledge of first principles and causes. This seems to suggest that in Aristotle's work there was perhaps a moderate interventionist component, but that it had to obtain full autonomy. As Peter Dear has recently noted, the content of Aristotelian natural philosophy was "essentially and solely speculative because it was about understanding things, not doing things" (DEAR, 2005, p. 394).

83 NEWMAN-PRINCIPE, 2002, p. 67.

84 VAN HELMONT, 1944, p. 41.

85 ID., 1854, p. 25.

86 ID., 1682, p. 9.

87 See for instance, VAN HELMONT, 1662, pp. 60, 82, 326. Van Helmont criticised his adversaries for not paying attention to the mathematical details of experiments: "*Quare volui in charta demonstrare, ipsius omnimodam ignorantiam Matheseos*" (VAN HELMONT, 1648, p. 64).

88 Newman and Principe conclude their study by claiming that "Van Helmont used no less mathematics than most modern-day chemists" (NEWMANN-PRINCIPE, 2002, p. 319).

restricted to the determination of weights and density ratios. However, it should be granted that Van Helmont's ordering of the density ratios of tin (which he used as his standard unit), iron, copper, silver, lead, mercury, and gold differs from the modern ones only by an average of less than 2 percent.[89] It should be kept in mind that these were *proportions* between the specific weights of these materials, not absolute values. The exact values are for the most part presented roughly, and full details are in most cases not treated (at least not in the published versions). The prominence of the mathematics involved in the weighing procedures derived from Van Helmont's thesis that the quantity of matter remains constant during chemical reactions.[90]

In the previous section, I have shown how crucial the constancy of weight (or quantity of matter) was for the establishment of Van Helmont's thermoscope experiment, transmutation experiment, and ice experiment. In his famous willow experiment, the weights of the earth and of the tree are determined roughly, and that is all. Notice, by the way, that the difference between the initial weight of the earth and the final weight of the earth (two ounces) is not that problematical for Van Helmont. It is simply explained by the *ad hoc* hypothesis that a certain amount of earth in a pot disappears over time (it is either blown away by the wind or carried away by the water). In 1700, John Woodward noticed that not even "the clearest water is very far from being *pure* and wholly *defecate*:"[91] it contained "vegetable terrestrial matter" and minerals.[92] Woodward limited the role of water to the distribution of matter in plants. Johann Joachim Becher (1635-1682)[93] also argued that the growth of the tree results from the earth being brought into the tree by means of the water.[94] A thorough argument of Van Helmont's conclusion would need to refer to more precise measurements (presupposing more fine-tuned instruments).[95] In the case of the ice

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89 *Ibid.*, pp. 74-75.

90 Cf. LASSWITZ, 1926, p. 249.

91 WOODWARD, 1699, p. 195.

92 *Ibid.*, p. 196. Van Helmont himself surprisingly observed that all clear water contains a certain salt (*onsmaeckelijck sout*), since all standing water ultimately becomes unclear (VAN HELMONT, 1944, p. 59).

93 See SMITH, 1994, for a recent study on Becher.

94 BECHER, 1733, p. 38; MORAN, 2005, pp. 148-149.

95 Obviously, Van Helmont had no instrumental means to discover and detect the role of minerals in the growth process of plants.

experiment, an exact quantity of the water's specific gravity is not provided. This seems to have been not that important to Van Helmont. The quantitative aspects in Van Helmont's work are restricted to weighing matter[96] in order to guarantee that it is kept constant. Van Helmont's aspirations in the area of exactitude remained fairly modest, *however, not unimportant*. *Quam proxime* was good enough for Van Helmont.

Replication and Reproducibility

What about replication (which refers to the fact that we are able to obtain the same results with the same experimental setup) and reproducibility (which refers to the fact that we are able to obtain the same results with a different investigator)?[97] Replicating and reproducing experimental designs are indeed the pillars of modern science.[98] Procedures of social (or better: epistemological) control, such as having experiments witnessed and attested by qualified observers, i.e., fellow gentlemen *virtuosi*, were crucial to the establishment of modern science.[99] Van Helmont did not seem to stress these conditions much.[100] Van Helmont's work did not incorporate (as Boyle's work did) an explicit *social technology*, i.e., certain conventions experimental philosophers should use in dealing with each other and in considering knowledge claims.[101] Van Helmont did not engage in public experimentation. In addition to that, a detailed *literary technology* is also

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96 For a study of the corpuscular components in Van Helmont's work, see NEWMAN, 1993. For some critical comments on Newman's corpuscular interpretation of Van Helmont, see CLERICUZIO, 2000, pp. 56-61.

97 Boyle emphazised the importance of Van Helmont's willow experiment being confirmed by more than one witness, especially since "the Extravagancies and Untruths to be met with in Helmonts Treatise of the Magnetick Cure of Wounds [which caused Van Helmont's collision with the Church] have made his Testimonies suspected in his other Writings" (BOYLE, 1661, p. 113).

98 See, for instance, GIERE, 2004.

99 See SHAPIN-SCHAFFER, 1985, pp. 55-60; see also SHAPIN, 1988, for a portrayal of England during the seventeenth century.

100 The following event might be considered exemplary for Van Helmont's neglect of replication. Boyle and Starkey never succeeded in duplicating Van Helmont's universal solvent that could reduce all substances to their prime matter: the *alkahest.* On the *alkahest*, see Pagel's commentary in VAN HELMONT, 1971, p. VII. The problem of duplicating the *alkahest* increased the difficulty of accepting Van Helmont's larger claims about the material foundations of matter. See MORAN, 2005, p. 140.

101 SHAPIN-SCHAFFER, 1985, p. 25.

absent in Van Helmont's work. The contrast between Boyle's detailed written accounts of experiments and of his air-pumps is striking in this respect.[102] He did mention replication and reproducibility rather sporadically and did not insist much on them as a criterion of valuable scientific knowledge.[103] For instance, Van Helmont did not give specific information that allows one to redo certain experiments. An experiment, for Van Helmont, was thus a personal testimony, which is not directly supposed to be redone by different agents in order to qualify as scientifically valuable. In the thermoscope experiment, Van Helmont's only comment on its preparation was that it is "very great" (see the quote in section 2). In the ice experiment, he stresses that the absolute weight of the water stays the same "since it might be a thousand times done by the same water." His tree experiment is apparently based on Van Helmont's observation of only one tree. As far as we know from Van Helmont's published account, the experiment was not replicated. These "modern" trends remained fairly underdeveloped in Van Helmont's work.

The Vessel as a Closed Physical System

In Van Helmont's work we clearly see an *interventionist approach* towards scientific inquiry. According to such an approach, causal relations can be discovered by actively manipulating natural processes. *Generally*, if we wish to establish whether *A* causes *B*, we will need to establish whether deliberate and purposive variations in *A* result in variations in *B* – *while keeping fixed all other factors*. If *A* produces the expected changes in *B*, the causal relation is established. That other factors are kept fixed is essential here: it allows us to reason that the variations in *B* can be explained *only* by referring to the variations in *A*. A "relatively closed system" (see *infra*) serves precisely as a *locus* in which keeping factors fixed is facilitated. I will begin by clarifying my terminology; then I will show how it is embodied in Van Helmont's experimental practice.

Let me first of all clarify what I mean by the term "closed physical system."[104] A closed physical system is hermetically isolated and independent from its environment: there are no interactions between

[102] On these see *ibid.*, pp. 26-30; PRINCIPE, 1995, p. 395.

[103] VAN HELMONT, 1648, p. 54.

[104] See PICKERING, 1981; RADDER, 1988.

components of the system and the surrounding environment. Such a system has a constant number of particles, energy, or volume, etc. Such a system is literally "cut loose" from its environment. A closed system is especially useful to isolate the relevant properties we are interested in. Such a system guarantees us that no other influences are active (and hence, that no external influences need to be adduced for the effects we observe in the system under consideration). In explaining G. H. Von Wright's intuition of closed systems,[105] which allows the screening-off of causal influences from outside the system, Hans Radder supposes the following definition of physical "closedness:"

> Suppose we have a system *S* localized in space and time with initial and final states *a* and *b*. We now examine the role of state a_0, which immediately precedes *a* and is therefore outside *S* [note that a_0 is produced only by active and intentional interference]. If system *S* is to be closed in the above sense, then firstly a_0 must not be sufficient for *a*, and secondly, not sufficient for all next stages of *S* up to and including final state *b*. Thus for closedness a first condition is that the system will not "by itself" move from state a_0 to *a*. Furthermore a_0 must not "influence" *S* through one of the intermediate states or the final state, i.e. a_0 must not be sufficient for one or more of these states.[106]

The idea is that by purposive intervention we produce the required initial state in a closed system where – by definition – no other causal variables are active or can interfere with the internal processes (see Fig. 2): The causal influence of a_0 is strictly restricted to producing *a*, and it has no effect on what happens further in the closed system. Of course, in practice we do not have closed physical systems at our disposal. The best we can do is to try to create "relatively closed physical systems."[107] Creating relatively closed systems is a way of controlling variables – of

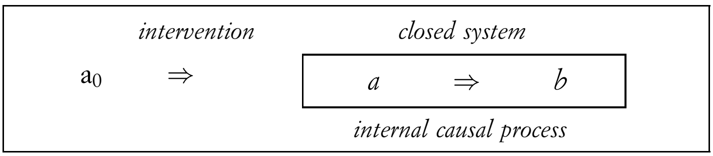

Fig. 2 – Intervention in a closed physical system.

[105] See Von Wright, 1971.
[106] Radder, 1988, pp. 63-64 (subscripts and italics added).
[107] Pickering, 1981, p. 218.

course, Van Helmont did not himself use terminology like this. However, his practice is embodied this procedure. Van Helmont frequently used the sphere as a relatively closed physical system. This interventionist approach, which is especially striking in the works of Van Helmont, is a particularization of *scientia operativa*.

Let us return to some of the experiments discussed in section 2. In the thermoscope experiment we discussed, the vessel is used to keep the amount of air and fluid fixed. Hence we are able to screen off the external addition of air or water as being causally relevant for the observed process. In other words, assuming this setup, the putative increase of water *could* only be produced by the air contained in the vessel. Now we are in a position to properly test whether the heating of the air (our active intervention a_0) in A causes the fluid in BC to move or creates an increase in the amount of fluid. This turns out not to be the case. The ice experiment takes place in an isolated vessel, wherein the total amount of water is kept fixed. Our intervention is to freeze the amount of water that we have weighed beforehand and then to let it melt again. Van Helmont established that the variations in the specific weight of the water cannot be caused by the fact that some amount of air is transformed into water (since the absolute weight of the water remains the same). The variations of the specific weight of water are caused by the expansion of the water itself. Studying the behaviour of a growing tree is not possible in a closed system – for the obvious practical reason that the tree would simply cease to exist without water and oxygen. What we can do is try to control as many variables as possible. This is what is attempted in Van Helmont's tree experiment: the earth is kept constant and the water is purified. According to Van Helmont, only the addition of the water can explain the growth of the plant. In many of Van Helmont's experiments, procedures of keeping variables fixed – as well as reference to relatively closed physical systems, in which all external variables are screened off – frequently occur. Van Helmont had a particular and profound insight into the idea that knowledge of nature is produced by isolating certain natural processes or creating – or at least trying to create as well as possible – relatively closed physical systems. The sphere is paradigmatic for this practice.

4. Afterthought

Concerning Halleux's trichotomy, I wish to point out the following. A full confirmation of the falsification of Halleux's classification can only be based on a thorough study of Van Helmont's complete work. This clearly exceeds the content of this essay. Besides a careful philological comparison of Van Helmont's usage of words such as "*experimentum*," "*observatio*," etc., a careful study of Van Helmont's implicit methodological considerations is also a *desideratum* if we seek to understand Van Helmont's idea of "experiment." I hope to have demonstrated the importance of such a methodological outlook.

In this paper, I have *not* argued that Van Helmont anticipated our modern conception of experimentation. Rather, I have analysed to what extent the characteristics of Van Helmont's concept of experimentation correspond to characteristics of our modern conception of experimentation. Of the four components discussed in the previous section, the frequent reference to closed or controlled systems and a moderate level of quantification (in the sense specified in section 3) seem to have been Van Helmont's most significant contributions to experimental methodology. Van Helmont was not only a "philosopher of fire" ("*philosophus per ignem*"), but also a "philosopher of the sphere" ("*philosophus spherae*") – see Fig. 3. The sphere or vessel refers to processes of inquiry such as isolating, manipulating, and controlling natural processes. The vessel was perhaps Van Helmont's primary tool of investigation and it symbolized the *epistemological ideal* according to which we gain knowledge about nature by isolating natural phenomena and by screening off some factors while keeping others fixed. Although Van Helmont's procedures of screening-off frequently turned out to be insufficiently fine-tuned, learning from Van Helmont's failure undoubtedly paved the way for the development of more complex strategies of controlled experimentation.

In line with the above interpretation, Woodward's refutation of Van Helmont's willow experiment included both more exactness and more variables being fixed. Woodward weighed plants and the composition of water in more detail. He put different plants of the same kind near the same window (hence: species, warmth, and amount of air and light are kept fixed).[108] He further compared water of different origin (rainwater, Thames water, etc.) and constructed an artefact that guaranteed that the water could only be exhaled by the plants.[109]

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108 WOODWARD, 1700, p. 199.

109 *Ibid.*, pp. 201-202.

Fig. 3 – Engraving of Van Helmont holding a vessel by Johann Alexander Baener (1647-1720). Frontispiece of VAN HELMONT, 1683.

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