# Helmont's Mechanical Experiments

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In this essay, I will discuss four significant experiments from Van Helmont's work in full detail: (1) the thermoscope experiment, (2) the transmutation experiment, (3) the ice-experiment, and (4) the willow experiment. I will draw the main material from both *Ortus Medicinae* and *Dageraad*. 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 edition – I refer to the latter in footnotes.[1] I will focus on and discuss what Van Helmont calls *mechanical experiments*. It should be stressed, as Newman and Principe have noticed before me, that the term "mechanical" is somewhat misleading here. 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 which were deliberately manipulated at the hand of the investigator of nature and is not directly connected to simple machines*. 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 in the following section.

Let us first of all look at Van Helmont's thermoscope experiment.[2] According to Van Helmont, the demonstration was essentially based on mathematics (he calls it a "*demonstratio mathematica*"[3]). 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 which was coloured red by the steeping of roses. It is essential that the two spheres are perfectly closed "*perfec-*

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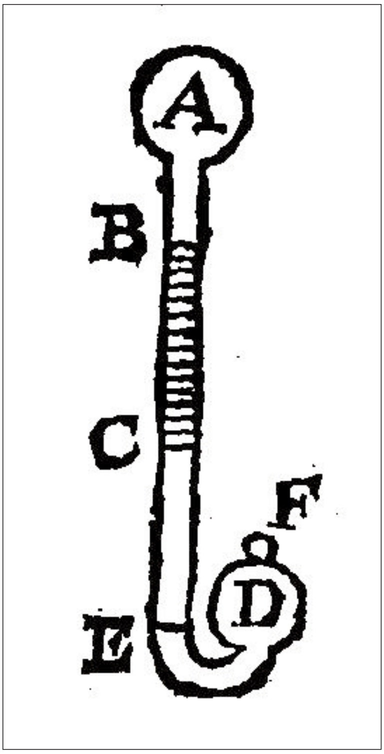


**Figure 1.** ***Van Helmont's thermoscope experiment.*** **From Van Helmont, *Works*, 60.**

*tissime clausa*".[4] 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 Figure 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 straightning, according to the qualities of the heat and cold, and because the just extension of quantity is not had in the air, unless when it is temperate.[5]

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*"[6]). The amount of fluid remains the same, contrary to the opinion of Van Helmont's opponent, Henricus van Heers, a physician of Liège, according to whom the compressing of air by heath produces water ("*quod aer compressus, conversatur in aquam*"[7]). Van Helmont stressed that van Heers faulty interpretation was due to his ignorance of mathematics:

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.[8]

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.[9] Since no extra water was produced when heating the air contained in A, the thesis that air can be transformed into water is untenable, according to Van Helmont. 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:

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

2. 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.
3. By using the sphere we establish a relatively isolated physical system.

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.[10] 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 which has an *identical* weight to that of the original material. When this salt is mixed with a corrosive it turns into "vivid water".[11] 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*, precisely lies in his reference to the conservation of matter. Van Helmont's reasoning process[12] goes as follows:

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))*
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 mentioning of the creation of the four elements.[13]

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.[14]

One thing we should keep in mind, as T.S. Patterson has argued, 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*.[15] Newman & Principe stress that Van Helmont had no distinct terminology for absolute and specific weight. We notice that Van Helmont used the sphere as a means to isolate the volume of water and air. No water or air can escape, nor 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 is changed into water (this would result in a change in the absolute weight of the water). The changes in specific weight can thus only be explained by the expansion of the water when freezing. This converges with what Van Helmont wrote in his letter to Père Marin Mersenne on the 30th of January, 1631: "*glaciari ipsum est actus effectivus et primarius aquae*".[16] According to Van Helmont, this is a "mechanical" demonstration: *probatur per mechanicam*.

Hereafter, follows a description of Van Helmont's famous tree-experiment,[17] which Van Helmont also considered to be a mechanical demonstration ("*ostendi in mechanica*"):

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.[18]

Newman & Principe note that this experiment "gives a clear example of his quantitative technique".[19] 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.[20] 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 difference of two ounces. Given that there did not reside any other elements than earth and water in the pot, and that the earth did not diminish significantly, Van Helmont (wrongly) concluded that *only* the water *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*.[21] In this case, no direct intervention or isolation of variables is presupposed. This example shows that Van Helmont's idea of mechanical experiment is not limited to experiments as "*experimenta*", that is purposely performed tests of naturalistic theses, but 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 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*) 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.[22]

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,[23] it would be clearly wrong to call Van Helmont's experimental procedures equally quantified as 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).[24] The importance of mathematical arguments in Van Helmont's work is mainly restricted to determination of weights and density-ratios. However, it should be granted that Van Helmont's ordering of the density-ratio's of tin (which he used as his standard unit), iron, copper, silver, lead, mercury, and gold differs from the modern ones by only an average of less than 2 percent.[25] It should be kept in mind that these were *proportions* between the specific weights of these materials, not absolute values. The exact values are mostly presented roughly and full details are in most cases not treated (at least in the published versions). The prominence of the mathematics involved in weighing procedures derived from Van Helmont's thesis that the quantity of matter remains constant during chemical reactions.

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 *only* be explained by referring to the variations in *A*. A "relatively closed system" (see *infra*) precisely serves as a *locus* in which the keeping fixed of factors 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".[26] A closed physical system is hermetically isolated and independent from its environment: there are no interactions between 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,[27] which allows screening-off 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 of 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.[28]

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 interfere with the internal processes. 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".[29] Creating relatively closed systems is a way of controlling variables – of course, Van Helmont did not himself use terminology like this. However, his practice is embodied by 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*.

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, the putative increase of water *could*, assuming this set-up, only be produced be the air contained in the vessel. Now we are a position to properly test whether the heating of the air (our active intervention $a_0$) in A produces the fluid in BC to move or creates an increase in the amount of fluid. This turns out not to be the cause. 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 which we have weighed on 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 in the idea that knowledge of nature is produced by isolating certain natural processes or creating – or at least, trying to create as good as possible – relatively closed physical systems. The sphere is paradigmatic for this practice.

## Notes

[1] Van Helmont's works were also translated in French by Jean Le Conte: *Les Oeuvres de Jean Baptiste Van Helmont traittant des principes de médicine et physique* (Lyon: 1670) and in 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 A. Clericuzio, "From Van Helmont to Boyle. A Study of the Transmission of Helmontian Chemical and Medical Theories in Seventeenth Century England," *BJHS* 26(3) (1993): 303-334.

[2] In contrast to a thermometer, a thermoscope does not have a scale. A careful reading of the 1648 edition is advisable here. This experiment is absent in *Dageraad*. Strunz is one of the few authors who briefly discusses the thermoscope experiment (F. Strunz, *Johann Baptist Van Helmont (1577-1644)* (Leipzig/Vienna, Franz Deuticke: 1907), 40-42).

[3] J. B. Van Helmont, *Ortus Medicinae, id est initia physicae inaudita. Progressus medicinae novus, in morborum ultionem ad vitam longam* (Amsterdam, Elzevir: 1648), 60.

[4] Van Helmont, *Ortus Medicinae*, 62.

[5] J. B. Van Helmont, *WORKS, Containing his most Excellent Philosophy, Chirgury, Physick, Anatomy. Wherein The Philosophy of Schools is Examined, their Errors Refuted and the Whole Body of Physick REFORMED and RECTIFIED. Being a new rise and progresse for PHILOSOPHY and MEDICINE, for the Cure of Diseases and the Lengthening of Life*, transl. by J. Chandler (London: 1664), 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, *Ortus Medicinae,* 62).

[6] Van Helmont, *Ortus Medicinae,* 62.

[7] Van Helmont, *Ortus Medicinae,* 65.

[8] Van Helmont, *WORKS,* 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, *Ortus Medicinae,* 64).

[9] Van Helmont, *WORKS,* 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, *Ortus Medicinae,* 65).

[10] J. B. Van Helmont, *Dageraad ofte Nieuwe Opkomst der Geneeskunst, in verborgen grond-regulen der Nature* (Oud Hollandsch van Gelder en Zonen: 1944 [1644]), 61, 64, cf. 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 (Van Helmont, *Dageraad*, 109; W. R. Newman and L. M. Principe, *Alchemy Tried in The Fire, Starkey, Boyle and the Fate of Helmontian Chymistry* (Chicago/London, Chicago University Press: 2002), 79).

[11] 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, *Dageraad*, 51 [emphasis added]).

[12] The mercurial alum example Newman & Principe discuss can be cast in similar terms (Newman and Principe, *Alchemy Tried in The Fire*, 80-83).

[13] Van Helmont, *WORKS,* 64.

[14] Van Helmont, *WORKS,* 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, *Ortus Medicinae*, 79).

[15] T. S. Patterson, "Van Helmont's Ice and Water Experiments," *Annals of Science* 1 (1936): 463-464; Patterson's interpretation is also followed in Newman and Principe, *Alchemy Tried in The Fire*, 72-74.

[16] M. Mersenne, *Correspondance du P. Marin Mersenne Religieux Minime* (17 vol.), P. Tannery, C. de Waard & R. Pintard (eds.) (Paris, Presses Universitaire de France: 1932-1988), vol. 3, 61.

[17] 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)" (R. Boyle, *The Sceptical Chymist or Chymico-Physical Doubts and Paradoxes, Touching the Spagyrist's Principles Commonly called Hypostatical* (London, F. Cadwell for F. Crooke: 1661), 111-115). Boyle was not alone in his praise for Van Helmont: Antoine Laurent Lavoisier (1743-1794) also praised Van Helmont (Newman and Principe, *Alchemy Tried in The Fire*, 297-303).

[18] Van Helmont, *WORKS,* 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 pluvial, 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, *Ortus Medicinae*, 108-109).

[19] Newman and Principe, *Alchemy Tried in The Fire*, 79; see D. Hershey, "Misconceptions about Helmont's Willow Experiment," *Plant Science Bulletin* (49)3 (2003): 78-84 for an good account of the successfulness of Van Helmont's tree-experiment.

[20] Note, however, that in Nicholas of Cusa's presentation of the "experiment" in his *Idiota de staticis experimentis* (Co*dex Cusanus Latinus* 218, folia 132$^{r}$-137$^{v}$) such screening-off procedures are accentuated less (H. M. Howe, "A Root of van Helmont's Tree", *Isis* 56(4) (1965): 408-419, 408).
[21] Van Helmont, *Dageraad*, 333). I have run through Van Helmont's collected work in search for relevant fragments containing reference to mechanical experiments. The example with the flowers was one of the few examples I found.
[22] Van Helmont, *Dageraad*, p. 202.
[23] See for instance, Van Helmont, *Works*, 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, *Ortus Medicinea*, 64).
[24] Newman & Principe conclude their study by claiming that "Van Helmont used no less mathematics than most modern-day chemists" (Newman and Principe, *Alchemy Tried in The Fire*, 319).
[25] Newman and Principe, *Alchemy Tried in The Fire*, 74-75)
[26] See A. Pickering, "The Hunting of the Quark," *Isis* 72(2) (1981): 216-236 and H. Radder, *The Material Realization of Science, A philosophical View on the Experimental Natural Sciences, Developed in Discussion with Habermas* (Assen/Maastricht, Van Gorcum: 1988).
[27] G.H. Von Wright, *Explanation and Understanding* (London, Routledge and Kegan Paul: 1971).
[28] Radder, *The Material Realization of Science,* 63-64 [subscripts and italics added]).
[29] Pickering, "The Hunting of the Quark," 218.