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### Swedenborg's mentor Christopher Polhem

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# DAEDALUS OF THE NORTH: SWEDENBORG'S MENTOR CHRISTOPHER POLHEM

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David Dunér

## Swedenborg—assistant to Polhem

The Swedish scientist and inventor Christopher Polhem (1661–1751) had a great and decisive impact on Swedenborg. Traces of Polhem's ideas can be found in Swedenborg's natural philosophy, in his mathematics, technology, matter theory, and cosmology. Swedenborg was an assistant to Polhem during the years 1716–1719, a period of intense collaboration. Here, I will show how fundamentally Polhem reshaped Swedenborg's thinking. In order to fully understand Swedenborg's development as a natural philosopher it is necessary to closely investigate his most important mentor.

In Polhem, the famous inventor and director of Stjärnsund manufacturing works in Dalarna, Swedenborg found a community of thought. "If it so be that my foreign journey must needs stand over till the Spring [of 1711], then I am quite content to be with him for some time," wrote Swedenborg to his brother-in-law, the university librarian Eric Benzelius the younger in spring 1710.<sup>1</sup> Benzelius and Bishop Jesper

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<sup>1</sup> David Dunér, born 1970 in Lidingö, Sweden. Received a PhD in History of Science and Ideas at Lund University, Sweden, in 2004. The title of the dissertation is *Världsmaskinen. Emanuel Swedenborgs naturfilosofi* [The World Machine. Emanuel Swedenborg's Natural Philosophy], and concerns Swedenborg's early mechanistic natural philosophy up to 1734. In Spring 2002 he was visiting scholar in History of Science, Medicine, and Technology at Johns Hopkins University, Baltimore, Maryland; and in Fall 2002 visiting scholar in History of Science at Princeton University, New Jersey. Published the article "Swedenborg's Spiral" in *Studia Swedenborgiana*, no. 4, 2002. Currently he has a position as associate professor in History of Science and Ideas at Lund University. He is also secretary of The Scandinavian Swedenborg Society.

Earlier contributions to this journal by Dr. Dunér include "The World Machine—Emanuel Swedenborg's Natural Philosophy," his address to the SSA's Annual Meeting in April 2005 (July–December 2005, 225–231), and "On the Decimal: The First Russian Translation of Swedenborg" (July–December 2009, 933–944).

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<sup>1</sup> Swedenborg to Benzelius, Brunsbo, 6 March 1710. Emanuel Swedenborg, *Opera quaedam aut inedita aut obsoleta de rebus naturalibus I*, ed. A. H. Stroh, Stockholm 1907, 203, cf. 202; *The Letters and Memorials of Emanuel Swedenborg I*, ed. A. Acton, Bryn Athyn PA 1948, 7.

Swedberg tried to prevail upon Polhem to take on his young admirer as an apprentice in mechanics. He declined at first, but after financial negotiations, brokered by the rector of Husby, Jacob Troilius, Polhem said that he could not undertake this trouble “for less than four Rixdalers a week.”<sup>2</sup> Polhem was always anxious to be properly paid. In July, however, he confessed, in letters to Benzelius, that he regarded Swedenborg as “capable of helping me in my current work in mechanics and its experiments.”<sup>3</sup> But there was not to be any study sojourn at Stjärnsund this time. Instead Swedenborg headed off, out into Europe.

During a few days in the winter of 1716 Swedenborg was visiting Polhem in Stjärnsund. He had finally been invited and his plans could be realized. During his visit he seems to have made an impression on Polhem, who wrote to Benzelius: “Some time ago Mr Swedberg was here with me, when I became aware of his intelligence and good qualities and therefore was all the more willing to pass on to him my small knowledge in order to instil light, for which he is inclined and capable through his prior learning and knowledge of mathematical matters.”<sup>4</sup> Three years of close collaboration would follow between them, which meant a great deal for Swedenborg’s continued development as a natural scientist. Polhem brought him along on technical assignments to Karlskrona, Vänersborg, and Bohuslän. Swedenborg read, fair-copied, edited, and published Polhem’s essays on various mechanical and experimental topics in *Dædalus Hyperboreus*; The Daedalus of the North—that is Polhem. In the journal, Swedenborg also called Polhem “our Swedish Archimedes.”<sup>5</sup> But the secretarial task that Swedenborg had undertaken was not all that easy to bear. Polhem writes to him: “. . . as long as I live, I hope material for printing shall not be wanting, so long as Min Herr is pleased to take the trouble to calculate, draw, write up, and prepare all that pertains thereto;

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<sup>2</sup> Troilius to Benzelius, Husby, 3 June 1710. Linköping Diocesan Library (LiSB), S III, no. 93.

<sup>3</sup> Polhem to Benzelius, Stjärnsund, 16 July 1710. *Christopher Polhems brev*, ed. Axel Liljencrantz, Uppsala 1941–46, 6.

<sup>4</sup> Polhem to Benzelius, Stjärnsund, 6 March 1716. *Christopher Polhems brev*, 117; cf. *Opera* I, 239.

<sup>5</sup> *Dædalus Hyperboreus: eller några nya mathematiska och physicaliska försök och anmärkningar: som wälborne herr assessor Polhammar och andre sinrike i Swerige hafwa giordt och nu tijd efter annan til almen nytta lemna* I, introduction, cf. II, 25; VI, 1.

for such work wearies me.”<sup>6</sup> On Polhem’s recommendation, Charles XII appointed Swedenborg as extraordinary assessor in the Royal Board of Mines on 10 December 1716, with the special task of assisting Polhem in his role as head of division.



Figure 1. Christopher Polhem (1661–1751), “Daedalus of the North.” Oil painting by Johan Henrik Scheffel 1730.

### **Christopher Polhem—a success story**

Christopher Polhem had been most famous as an engineer, inventor and industrial pioneer; a technological genius, sometimes called the father of Swedish mechanics. My argument is that he is even more original as a thinker. He spent a great part of his time on studies and speculations concerning physics, chemistry, mathematics, geology, economics, nutrition, linguistics, philosophy, and education. In the evenings Polhem the inventor sat, after a hard day’s work with factory engines or mining machines, and used to ponder the creation of the world and the inner structure of matter. He was a thinker who formed his own ideas indepen-

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<sup>6</sup> Polhem to Swedenborg, Stjärnsund, September 1716. *Opera* I, 260; *The Letters and Memorials of Emanuel Swedenborg* I, 118.

dently of what others thought or said. He also had an infectious impudence and humor that went beyond all conventional barriers. To think, he said, could be as strenuous as physical exertion: “. . . when you think too much, the brain becomes tender and sore, and when you think a lot about things that you never have thought about before, the whole body becomes weak and powerless.”<sup>7</sup>

My major purpose is to show Polhem’s impact on Swedenborg, though I will also give examples of how ideas in history are formed cognitively. I believe that our cognitive abilities, like using metaphors and categorization, and the theories of cognitive science, such as situated cognition and the theory of embodied mind, offer some necessary clues as to how scientists, engineers, and philosophers construct concepts and ideas. In my dissertation, *Världsmaskinen* (‘The World Machine’, 2004), I showed the significance of metaphors in Swedenborg’s natural philosophy.<sup>8</sup> In science, metaphorical thinking is very important, the metaphors enabling the scientist to create new ideas; and in technology, spatial thinking is a major factor for the representations of the mind.

A reason why Polhem developed an original way of thinking could be that he had a troubled educational background. He was an autodidact, and he never really managed to read Latin efficiently. You could say that he stood between the academic and the popular cultures, never finding his place in society. He may have been dyslexic as well and, in addition, he had smudgy handwriting, but this never prevented him from writing many manuscripts. Over 20,000 pages by his hand have survived.

His life is a classic success story. The pre-conditions were not the best for a successful career as an engineer. He was born into relatively ordinary conditions on the island of Gotland on December 18, 1661. His father was a merchant of Austrian descent and died when Christopher was eight years old. His mother soon married a building contractor who did not want to pay for his stepson’s schooling. Instead, an uncle in Stockholm took care of him, but after just two years his uncle died.

Lonely and thrown out into the world, Polhem was forced to start to earn his own living, first as farm-hand, later as an inspector at different

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<sup>7</sup> Christopher Polhem, “Om Naturens värkan i gemen”, in *Christopher Polhems brev*, 36, cf. 22, 100, 236.

<sup>8</sup> David Dunér, *Världsmaskinen. Emanuel Swedenborgs naturfilosofi*, Nora 2004.

manors in Uppland and Södermanland. He did woodwork, including wood-turning, made and repaired tools, and constructed clocks. At the same time he dreamt of studying. The inclination towards mechanical studies, he said later in his life, was so great that he could barely sleep during the nights. But in order to develop his technological skills, he found that he needed theoretical studies, and for this a knowledge of Latin was needed. He therefore made an agreement with a priest. The priest gave him lessons in Latin, and Polhem in return made a clock. Thus the priest saw the potential of this watchmaker and arranged for him to be a student at Uppsala University in 1687. In Uppsala, Polhem studied diligently and seldom slept more than three hours a night; as he himself put it: "too much sleep makes the brain spoilt and useless."<sup>9</sup> During this time he was also given many technical tasks, such as repairing the astronomical clock of Uppsala cathedral. The clock started again and so began his engineering career and fame.

### **Mining machines and manufacturing industry**

Many of Polhem's most famous and important constructions were made for Stora Kopparberg's mine in Falun.<sup>10</sup> He made, in particular, hoisting machines. Usually a horse-driven hoist was used to bring the ore to the surface in baskets or leather sacks. Polhem invented a new sort of machine that was driven by waterpower instead, and avoided the weak link—the hoisting cables made of leather. Instead he let the ore buckets "climb" up from the shaft by the aid of two bars with hooks. On the surface the ore was transported to the furnace where the buckets were emptied and then returned to the mine. It was an automatic machine where only the loading of the ore needed manual work. In 1693 he built a hoisting machine at the mine "Blankstöten." At the same time there was another one of traditional construction. To decide which machine was the

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<sup>9</sup> Cit. in Samuel E. Bring, "Bidrag till Christopher Polhems lefnadsteckning", *Christopher Polhem*, ed. Samuel E. Bring, Stockholm 1911, 14.

<sup>10</sup> Sten Lindroth, *Christopher Polhem och Stora Kopparberget. Ett bidrag till bergsmekanikens historia*, Uppsala 1951.





Figure 3. Polhem's coat of arms. It shows the Pythagorean theorem, a pair of compasses and a lever.

when kings are involved in wars, then it is time to consider one's interests; or, as he put it: "to diligently milk the cow, when two quarrel about it."<sup>11</sup> By order of Charles XII during the last years of his reign, Polhem worked on a canal near Trollhättan and a dock at Karlskrona.

In 1700 Polhem started a mechanical manufacturing industry in the southern parts of Dalecarlia, in the village of Stjärnsund. Polhem was critical of how the state managed its finances. Sweden was a producer of raw materials, such as iron and copper, that were exported cheaply. In England and other countries, more complicated products were made of these, adding value, and they then were imported back into Sweden for a greater amount of money. Polhem grieved at this and said: ". . . foreigners regard us Swedes as idiots of the worst sort, that are good for nothing else than to put food into the mouths of their craftsmen."<sup>12</sup>

A greater profit would be yielded if Sweden by itself processed its raw materials. In Stjärnsund, Polhem therefore started a large scale production

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<sup>11</sup> Christopher Polhem, "Instruction för alle våre consuler, comisshafvare och factorer på dhe orther, hvarest dhe vistas" (1716), in *Christopher Polhems efterlämnade skrifter* II, ed. Gösta Lindeberg, Uppsala 1951, 66; Swedenborg's manuscript, in Eric Benzelius the younger, *Collectanea physica-mathematica, såsom ock åtskilligt rörande Sveriges natural historia, hvaraf gjordes bruk vid Societatis litterariae inrättande i Upsala*. LiSB, N 14a, no. 17, fol. 31–36; Emanuel Swedenborg, *Em. Svedenborgii autographa ed:photolith* I, ed. R. L. Tafel, Stockholm 1869, 17.

<sup>12</sup> Cit. in Bring 1911, 102.

of different kinds of household utensils, such as mugs, bowls, and plates of iron, coated with a thin layer of tin. Polhem's tinned plates were the subject of a little piece written by Swedenborg, which can be viewed as a kind of advertising brochure, *Underrättelse, om thet förtenta Stjärnesunds arbete, thess bruk, och förtening* ("Information about tinned Stjärnsund work, its use, and tin-plating," 1717). It concludes with the words: "N.B. It has been noted that if children who are plagued by worms eat food that has stood on untinned iron vessels overnight, exceedingly sour, then the worms are consumed hereby, which is left to others to investigate further."<sup>13</sup> Among other things Polhem produced clocks, padlocks, farming tools, and tools for carpenters, metalworkers, and smiths. One of Polhem's most odd inventions was his artful tap—a lock that prevented servants stealing wine and spirits from the housewife's store.

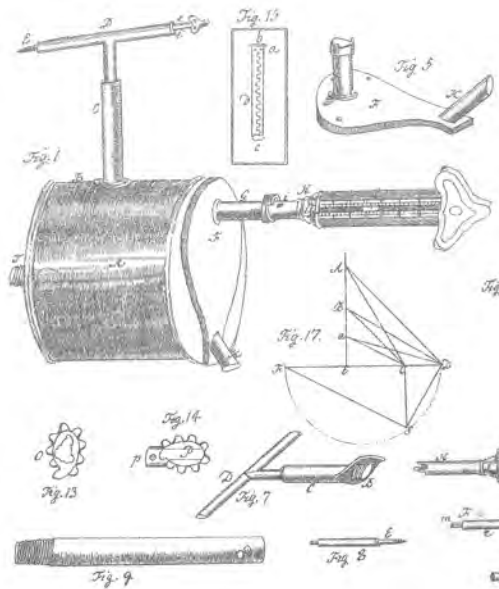


Figure 4. Polhem's artful tap—a lock that prevented servants stealing wine and spirits from the housewife's store. Published in Swedenborg's *Dædalus Hyperboreus* V (1717).

<sup>13</sup> Emanuel Swedenborg, *Underrättelse, om thet förtenta Stjärnesunds arbete, thess bruk, och förtening*, Stockholm 1717, [4]; Carl Sahlin, *Vår järnindustris äldsta reklamtryck*, Örebro 1923; advertisement in *Stockholmiske kundgiörelser* 1717:15.

Stjärnsund was a manufacturing industry, or better, a proto-industrial mechanical workshop. His idea was that the machines should be driven as far as possible automatically. Instead of human muscle power, the machines should be driven by waterpower. A visiting French traveller was so impressed by the workshops that he said this was not at all a manufacture, but an "aquafacture."<sup>14</sup> The advantage of water-driven machines, Polhem pointed out, was that they needed neither payment nor hay.

### Mechanics of the world

Polhem had an original visual or spatial way of thinking concerning technology. The machines were formed in his mind, in his inner vision. In his "Laboratorium mechanicum" which he founded in 1697, he wanted to develop mechanics, both theoretically and practically, especially with the help of models and parameter variations.<sup>15</sup> Polhem's most famous experimental machine was his hydrodynamic machine from 1702 that tested different kinds of waterwheels and the declination of the water channel.

This project exemplified one of Polhem's primary thoughts: that there is a connection between theory and practice. Theory without practical knowledge, and practical skills without theoretical insight, could not lead to anything of greater use. In the dialogue between Lady Theoria and master builder Practicus, Practicus explains his feelings for Theoria.<sup>16</sup> The young lady then explains for Practicus how mathematical knowledge could be applied to the construction of watermills. Polhem's conclusion is that there would be remarkably beautiful children if they joined each other and were married.

An important part of Polhem's technological education was his "mechanical alphabet" which consisted of a number of simple, pedagogic

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<sup>14</sup> Aubry de La Motraye, *A. de Motraye's Travels through Europe, Asia, and into Part of Africa*; . . . London 1723.

<sup>15</sup> Svante Lindqvist, *Technology on Trial. The Introduction of Steam Power Technology into Sweden, 1715–1736*, Uppsala 1984, 67–74.

<sup>16</sup> Christopher Polhem, "Samtahl emällan fröken Theoria och byggmästar Practicus om sitt förehafvande", in *Christopher Polhems efterlämnade skrifter* I, ed. Henrik Sandblad, Uppsala 1947, 277 ff.

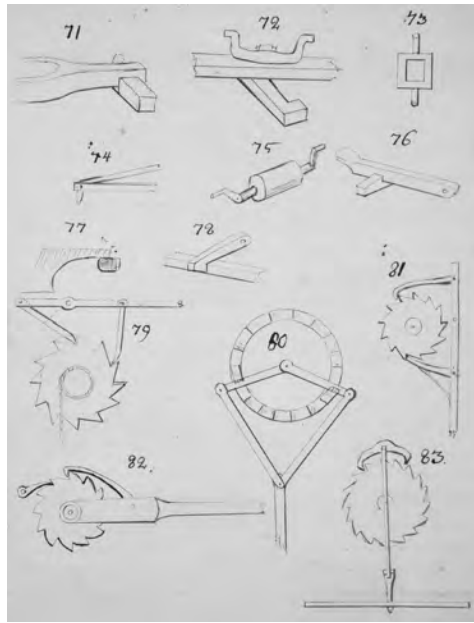


Figure 5. The mechanical alphabet. Drawings from 1729 by Polhem’s disciple Carl Johan Cronstedt of Polhem’s pedagogic wooden models that showed the basic mechanical laws. Photo: The National Museum of Science and Technology, Stockholm.

wooden models that showed the basic mechanical laws.<sup>17</sup> The models represented the basic components of all engineering, like springs, cog-wheels, and other mechanical movements. Each of them represented a “letter” in the mechanical alphabet. If he knew these mechanical letters a mechanic could build any machine he liked. Like a poet who could write the most beautiful poetry with the help of the ordinary alphabet, a technician could construct “sentences” with the mechanical letters; in other words, make complicated machines that could do useful work. To Polhem it was as important for a mechanic to know all the cogs, levers, and hooks of a machine as it was important to a scholar to know the letters of the alphabet.

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<sup>17</sup> David Dunér, “Språket i universum. Polhem och alfabetkonsten, *Lychnos* 2007, 154–157.

Turning to his more theoretical achievements, Polhem was a Cartesian. Mechanics could explain a range of natural phenomena. That was in line with Swedenborg's own conception. One popular metaphor for God in the 17th and 18th centuries was the "Great Clockmaker." Almost all scientists followed the mechanistic worldview. As a mechanic Polhem had no problem explaining the mechanical movements of the world machine and its small mechanical parts. Thus Polhem—who actually was a real clockmaker—took apart the Great Clockmaker's clock.

In many ways Swedenborg's theory of matter is closest to that of Polhem. For Polhem everything is mechanical, everything can be explained with matter and motion. He often made comparisons between the human artificial mechanics on one hand and the natural mechanics on the other. To Polhem, the mechanical structure of subtle nature is not unlike an inventor or carpenter's machine constructions. He speculated a great deal concerning the inner matter of nature. The particles of matter must be spherical. The sphere is not just the most perfect form; it is also the most convenient form for motion like all the bodies of the sky that are spheri-



Figure 6. The spherical particles of matter in Polhem's *De gravitate et compressione aeris* (no date). Photo: The Royal Swedish Academy of Sciences, Stockholm.

cal.<sup>18</sup> The sphere is the body that has the greatest possible volume in relation to surface area.

In a characteristic way, Polhem compares the particles with peas, linseed, and seeds of rye, barley, and wheat. In concrete reality he finds models; from the visible and known, he drew conclusions on the abstract, invisible, and unknown. This is what I call metaphorical thinking. The mechanical laws are the same. The mechanics of peas differ from the mechanics of particles only in magnitude.

He also compares the smallest particles of nature with cogwheels. If you have four cogwheels in a square, all the wheels will turn easily; but if you have three in a triangle they will get stuck. This explains the mobility of liquid substances and the immobility of solid substances. The geometric structures therefore explain mobility and rest, heat and cold, life and death. Geometry also causes taste and feeling. Particles with acute angles have a strong and bitter taste, and those with more blunt angles have a more sweet and pleasant taste.

But no matter how fine matter is, it leaves a vacuum, Polhem states in opposition to René Descartes. Without a vacuum, motion would be impossible and all matter just a single, bulky, unmoveable mass. Empty space could also explain transparency. The particles of ether, the messengers of light, can then pass between the round particles, like pouring water into a barrel of round bullets; at least a quarter of nature is without matter.

Polhem was still a Cartesian, not an admirer of Isaac Newton, even though he took vacuum into account. He said that Newton was in fact a great mathematician, but slightly naive, when for the sake of his honour he made everything complicated. The same sickness had struck the mathematician John Wallis Polhem said to the astronomer Pehr Elvius the older in 1712. "But for those who with industry want to sharpen their brains, then they are both good grindstones; namely, Wallis to sharpen first, Newton afterwards." And he said finally: "I can explain everything in an easier way."<sup>19</sup> The simple explanation is the pressure of ether; you do not need any occult antipathies and sympathies, just pure mechanics.

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<sup>18</sup> Christopher Polhem, "Discurs om dhe 4 elementerna eld väder vatt[en] och jordh" (before 1711), in *Christopher Polhems efterlämnade skrifter* III, ed. Axel Liljencrantz, Uppsala 1952–53, 74.

<sup>19</sup> Polhem to Elvius, Stjärnsund, 31 May 1712. *Christopher Polhems brev*, 88.

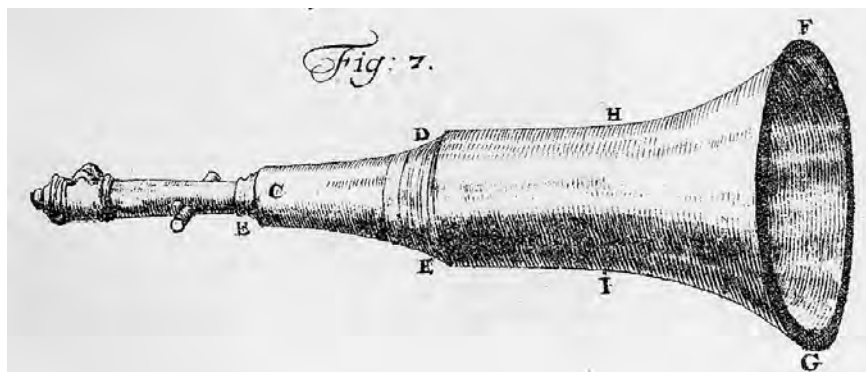


Figure 7. Polhem's thunder tube. Published in Swedenborg's *Dædalus Hyperboreus* I (1716).

Polhem tackled a wide range of topics; for example, he also studied sound and proposed some experiments concerning sound that should be executed in the mountains of northern Sweden. He made earphones and a thunder tube, presented in Swedenborg's *Dædalus Hyperboreus*. If you put a funnel on a cannon, then it will sound like a whole army of cannons and the enemies will run away in horror.

### Causes of things

Both Polhem's and Swedenborg's theories of matter proceed from the round figure, the sphere. Sometimes their thinking is so similar that several manuscripts have been confused.<sup>20</sup> As Polhem's secretary, Swedenborg made transcripts of his manuscripts. One example of a work written in Swedenborg's hand, but composed by Polhem, is the dialogue between the kinswomen Chymia and Mechanica on the essence of nature,

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<sup>20</sup> Christopher Polhem, *Copia af en instruction och fullmacht som igenom sådant tilfelle är inhemptat som förtalet vtwijsar* (1716). LiSB, N 14a, no. 17, fol. 31–36; *Photolith.* I, 7–18; *Christopher Polhems efterlämnade skrifter* II, 61–67; Christopher Polhem, *Om sättet för handels och manufakturernas uphjelpande* (c. 1716). LiSB N 14a, no. 37, fol. 102–104; *Photolith.* I, 68–73; *Christopher Polhems efterlämnade skrifter* II, 72–74; *De causis rerum; Discours emellan Mechaniquen och Chymien.*

*Discours emellan Mechaniquen och Chymien om Naturens wäsende* (1718).<sup>21</sup> These personifications of chemistry and mechanics discuss, among other things, the roundness and smoothness of particles, and the angular figures of salt. Chymia asks Mechanica how stones have become round; it is an effect of the water rubbing the stones against each other as it flows and washes with a strong and steady movement, Mechanica answers. In a notebook, Swedenborg had also written twenty cryptic lines of excerpts from Polhem, probably from the years 1716–1718.<sup>22</sup> These unnoticed lines in Latin contain physical experiments and notes on topics such as the way spheres move in water and in pendulums. Towards the spring of 1720 Swedenborg also had a collection of Polhem's books in his home: "Councilor of Commerce Polhem's books must be somewhere among my papers; as soon as they are found, they should be sent back", he wrote to Benzelius.<sup>23</sup> He may be referring to bound collections of Polhem's manuscripts.

A manuscript that was long attributed to Swedenborg, but which has been shown to have been composed by Polhem, is *De causis rerum*.<sup>24</sup> The manuscript also exists in two additional versions, one complete in a transcript by Jacob Troilius from 1711, and a fragmentary copy in Polhem's hand. Evidence suggests that it was part of plans by the Collegium Curiosorum for the publication of Polhem's essays. In letters to Benzelius in the autumn of 1710 Polhem tells of his ideas about the compression of air, the equilibrium of the planets, the rise and fall of the barometer, the difference between liquid and solid matter, the floating and sinking of fish bladders—all topics that recur in *De causis rerum*.<sup>25</sup> Polhem had also made additions to Troilius's transcript, which can be interpreted as a sign that it was authorized and approved by him. *De causis rerum* in Swedenborg's

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<sup>21</sup> Christopher Polhem, "Discours emellan Mechaniquen och Chymien om Naturens wäsende" (1718), *Opera quædam aut inedita aut obsoleta de rebus naturalibus* III, ed. A. H. Stroh, Stockholm 1911, 248 f; *Christopher Polhems efterlämnade skrifter* III, 161 f, 165 f.

<sup>22</sup> Emanuel Swedenborg, *Ex Polhemio*. Royal Academy of Sciences, Stockholm (KVA), cod. 86, 277.

<sup>23</sup> Swedenborg to Benzelius, 29 February 1720. *Opera* I, 300; *The Letters and Memorials of Emanuel Swedenborg* I, 231.

<sup>24</sup> Christopher Polhem, *De causis rerum* (before 1711). Royal Library, Stockholm (KB), X 517:1, fol. 176–197; Troilius's transcript (1711). KB, X 521, 1–29; Swedenborg's transcript (1716). LiSB, N 14a, no. 30, fol. 54–55; *Photolith.* I, 24–27; *Opera* III, 231–233.

<sup>25</sup> Polhem to Benzelius, 10 September 1710. *Christopher Polhems brev*, 7 f, cf. 11 f; *Opera* III, 231 f.

hand is in part a summary and in part a pure transcript, probably of Troilius's version, but also of another transcript by Troilius, Polhem's *Tanckar om Barometrens stigande och fallande* (Thoughts about the rise and fall of the barometer).<sup>26</sup> Swedenborg's version of *De causis rerum* was presumably written in 1716 as a digest of Polhem's thoughts about the causes of things, probably intended for the second issue of *Dædalus Hyperboreus*. There is no obvious reason to assume that it was written in 1717, as was previously believed. Several letters from the spring of 1716 discuss the experiment in *De causis rerum* about the oscillation of a sphere under water.<sup>27</sup> At the last moment, however, Polhem wanted it to be dropped. His reason is not stated; perhaps he no longer agreed with himself.

*De causis rerum* gives good insight into the foundations for Polhem's natural philosophy of the causes of things. Its contents were thus undoubtedly known to Swedenborg, besides all the other manuscripts he must have read and all that was said during their conversations. Polhem begins with "On the first beginnings and creation of the world", where he attempts to understand and explain what Moses really meant by his account of the creation. He cannot get it to make complete sense and tries to find explanations in natural philosophy. What kind of water was above and under the firmament? Moses must have meant that both the heaven and the sea consisted of water,

chiefly because he says of the flood that *the windows of heaven were opened* and poured out water: but thus and much besides seems to be a metaphorical manner of speaking, as is otherwise stated, e.g. that it rained as if the skies were open. Or it did not rain but gushed down, it poured down, etc.<sup>28</sup>

The earth and the sea were held together like a round ball or sphere and hovered freely in the air, "like the egg yoke within the white." It is not until the second chapter about the equilibrium of the planets that Swedenborg begins his excerpts from Polhem.

<sup>26</sup> Christopher Polhem, *Tanckar om barometrens stigande och fallande*. KB, X 521, 34–37.

<sup>27</sup> *Opera* I, 244, 247, 250, 259; *The Letters and Memorials of Emanuel Swedenborg* I, 84, 89.

<sup>28</sup> KB, X 521, 6.

The core of Polhem's theory of matter can be found in *De causis rerum*. His theory combined a corpuscular natural philosophy with Cartesian mechanics and a micro-macrocosmic world-view, where Plato's regular polygons and the classical idea of the perfect sphere are the models for the subtle geometry of microparticles. Here he is still on Descartes' side regarding the non-existence of the vacuum. There is no space or extension that does not contain matter. Universal matter therefore cannot be of a form that prevents movement, such as cubic and tetrahedral forms, but must be round "as all heavenly bodies, stars, sun, moon, earth, and planets are round."<sup>29</sup> Particles, in other words, are imagined by analogy with the heavenly bodies. And perhaps the spaces between these are also filled with even smaller spheres. These spheres fill infinity, and each sphere is filled with other particles of ether, air, water, and these in turn of even smaller, and so on to infinity, to both minimum and maximum. Universal matter becomes infinite, or rather indefinite in smallest and the largest, "and thus no particle of matter be envisaged as being so small that it cannot be infinitely smaller."<sup>30</sup> It is like an infinite regression, where one can never come to the end, any more than to the diagonal in a square or quadrature of the circle. In a fragment of *De causis rerum* Polhem postulates three things: 1. That we humans cannot imagine a thing being so small or so large that nature cannot make it even smaller or larger to infinity. 2. Nothing in nature can be grasped that does not have a certain figure, round or square, however small or large it may be. 3. Particles which are further apart occupy more space than those of equal number which are more closely packed.

This central idea of Polhem's about the particles of matter being round was taken over and elaborated by Swedenborg. In *Prodromus principiorum rerum naturalium* (1721) Swedenborg applies geometry to matter in a way that is very similar to Polhem's stacks of cannonballs. He places bubbles in different formations with specific numerical proportions between matter and intervening space. But unlike Polhem's basic system of two different ball formations, Swedenborg identifies eight different formations in which

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<sup>29</sup> KB, X 517:1, fol. 196v; cf. *Christopher Polhems efterlämnade skrifter* III, 74, 313.

<sup>30</sup> KB, X 517:1, fol. 178v.

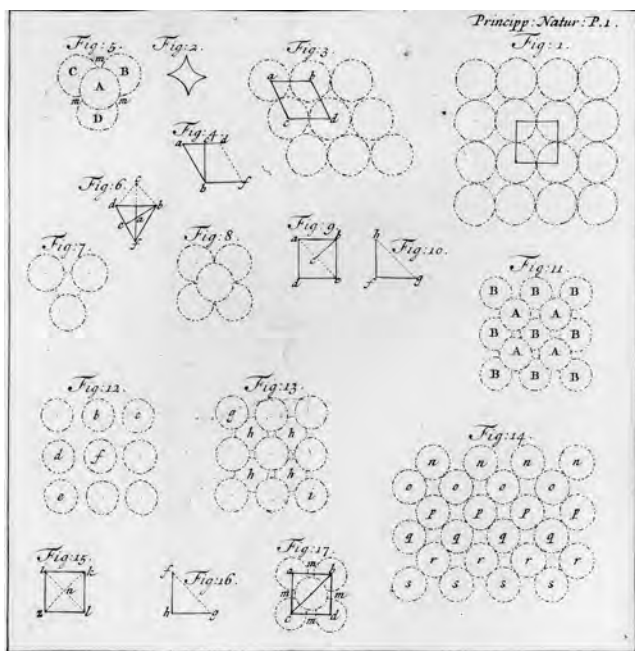


Figure 8. Swedenborg's formations of round particles. The vertical position (1), with cubic particles in the intervening spaces (2). The triangular position (3). The fixed triangular pyramidal position (5). The fluid triangular pyramidal position (7). The fixed quadrilateral pyramidal position (8). The fluid quadrilateral pyramidal or the natural position (11–13). Swedenborg, *Prodromus principiorum rerum naturalium* (1721).

round particles can be arranged.<sup>31</sup> Closely akin to Polhem's theory of spheres, he tried in *Miscellanea observata* (1722) to construct a particle system based on the simplest figure, the sphere, and the angular particles lying between spheres. In a manuscript about the principles of natural things, *Principia rerum naturalium ab experimentis et geometria sive ex posteriori et priori educta* (c. 1729–1731), entitled *The Minor Principia*, he has distanced himself some way from his original particle physics in *Prodromus principiorum*. Instead of a rather stiff, Polhem-inspired theory of matter as

<sup>31</sup> Emanuel Swedenborg, *Prodromus principiorum rerum naturalium sive novorum tentaminum chymiam et physicam experimentalem geometricè explicandi*, Amsterdam 1721; *Opera* III, 8–13; translation C. E. Strutt, *Some Specimens of a Work on the Principles of Chemistry, with Other Treatises*, new ed., Bryn Athyn PA 1976, 8–15.

stacks of balls, bubbles, and angular intervening particles, he has developed a more dynamic theory in which the motion of the point has a central role.

### Earth—6000 years old?

Polhem's mechanical mind also led him into other more controversial questions. How God really created the world puzzled him. Did God really make all this in only six days? Is earth just a couple of thousand years old? And what did Moses really mean when he wrote about the first six days of creation? Thus, Polhem examined the statements of Moses. There was something that was not right, he suspected. Many times his scientific speculations came into conflict with Christian doctrines concerning creation. Polhem thought in his own way; he did not care so much about what others had to say about it, or what was considered appropriate.

According to Genesis it says that: "In the beginning God created the heaven and the earth. And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters." Polhem formulated it in another way. In a collection of fragments bearing the label "Attempts at a new and brief art of writing", Polhem tries to translate the first verses of Genesis into a universal language.<sup>32</sup> He had an idea about an artificial language: a perfect language that could be understood by everyone, no matter from where they came or what natural language they spoke. As the greatest and the most perfect of spirits, God must be called—according to Polhem's universal language—"Spav", and if we say that he "created", it must be "ila." "Heavens" is "f" and "earth" is "k." And "earth was" is "ika", and "formless and void", is "v." God's spirit must be called "Sve." Thus, the two first verses of the Bible are, according to Polhem's universal language: "Spavilafk ikav Sve."

Applying one's universal language to a religious text was common in the history of artificial languages. That was also the case in comparisons between natural languages. George Dalgarno, for example, translated Genesis in this way: "Dan semu, Sava samesa Nam thn Nom. Thn nom

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<sup>32</sup> Christopher Polhem, *Försök till en ny och kort skrifkonst*. KB, N 60, fol. 13 f.

avesa sof-shana thn draga, thn gromu avesa ben mem shf bafu: thn uv shf Sava damesa ben mem shf nimmi.”<sup>33</sup> Later on also Swedenborg tried to construct a universal language in the manuscript, *Philosophia universalium characteristica et mathematica* (1740).<sup>34</sup>

That was, in fact, an unusual example from the works of Polhem. In fact he rarely mentions God or biblical texts. Polhem never uses arguments based on God, the Bible or theological doctrines. That was rather unusual in the science of those days. God and the creation were for most scientists like axioms: starting points for all science. The omnipotent God guaranteed the laws of nature. Polhem did not fit into this pattern.

Concerning the age of the world, there is something wrong with Moses' description of creation, Polhem said. He suspected that the age of universe must be much greater than the 6000 years that theologians said could be proved by the Bible. In the year 1710, Polhem wrote to Benzelius in Uppsala, and said that the world must be much older than Moses states.<sup>35</sup> That such a great “building like the infinite space, with all its content, could not be older than about 6000 years, perhaps more, seems not to be likely.” And he continues: “If I dared to state my opinion, it would not be unlikely that earth was first a sun, and then after many hundred thousand years turned into what it now is.” Polhem knew that these opinions could not be spread to ordinary people. “Forgive my free speech”, he ends the letter. But all this he dared to say to Benzelius—he who later on became archbishop of Sweden. Polhem was not afraid to say what he thought.

In another letter he even explains an experiment concerning the age of the world. “If you compare the size of the sun with a fat, dry tree root which burns easily, and take the time it takes for it to burn low, then you get the number of years for the sun, which consists of 28 digits, a length not

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<sup>33</sup> George Dalgarno, *Ars signorum, vulgo character universalis et lingua philosophica*, London 1661, 118; *George Dalgarno on Universal Language. The Art of Signs (1661), The Deaf and Dumb Man's Tutor (1680), and the Unpublished Papers*, ed. David Cram & Jaap Maat, Oxford 2001, 276.

<sup>34</sup> Emanuel Swedenborg, *Em. Svedenborgii autographa ed:photolith VI*, ed. R. L. Tafel, Stockholm 1869, 265–269; translation C. Olds, *Scientific and Philosophical Treatises (1716–1740)*, ed. W. R. Woofenden, Bryn Athyn PA 1992, 165–171.

<sup>35</sup> Polhem to Benzelius, 19 November 1710. *Christopher Polhems brev*, 42–44.

far from eternity.”<sup>36</sup> This is probably the highest estimate in the history of science concerning the total lifespan of the sun. It will survive at least one billion billion billion years. The French naturalist Georges Louis Leclerc de Buffon, who had the honour of being named the discoverer of long-range geological time, succeeded a couple of decades later in a similar experiment concerning the age of the earth, reaching, however, the comparably modest estimate of only 74,832 years.

The idea of the retarding motion of the earth, with a spiral path proceeding from the sun, was something that Swedenborg had read and transcribed several times from Polhem. In Polhem’s dialogue between chemistry and mechanics, of which there also exists a transcript by Swedenborg, there is another analogy between the sphere in a vortical motion of water and the earth in a vortical motion of ether. Our globe is held in equilibrium in the ether by the lighter fire in its interior. His allegorical figure “Miss Mechanica” compares this with the way a hollow lead ball under water can be kept floating. If the earth were heavier than this equilibrium with the ether, it would travel out in a spiral, further and further from the sun, and if it were lighter it would be drawn in towards the sun and destroyed.<sup>37</sup> Swedenborg—while he was assistant to Polhem—puts forward in the manuscript *En ny theorie om jordens afstannande* (“A new theory about the retardation of the earth,” 1717) a number of reasons for the opinion that the earth has been moving increasingly slowly since the beginning.<sup>38</sup> Around 1718–1719 he also wrote two versions about the motion and position of the earth.<sup>39</sup>

Polhem had other controversial thoughts. He believed in a Cartesian, actually an originally Galenic, idea of “spiritus animales”; that there is a

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<sup>36</sup> Christopher Polhem, “Om Elementernas jemvicht [1.]” (1722), in *Christopher Polhems brev*, 154.

<sup>37</sup> *Opera* III, 250; *Christopher Polhems efterlämnade skrifter* III, 164; cf. *Christopher Polhems brev*, 23.

<sup>38</sup> *Opera* III, 269–282; LiSB, N 14a, no. 34; *Photolith*. I, 28–65; translation H. Lj. Odhner, ‘A New Theory about the Retardation of the Earth’, *The new philosophy*, April 1950.

<sup>39</sup> Emanuel Swedenborg, ‘En ny mening om jordens och planeternas gång och stånd eller några bewis at jorden löper alt sachtare och sachtare: at winter och summer, dagar och dygn til tiden blifwa lengre och lengre in til werldsens sista tid’, *Opera* III, 283–298; Emanuel Swedenborg, *Om jordenes och planeternas gång och stånd: thet är några bewisliga skiäl at jorden aftager i sitt lopp och nu går langsammare än tillföre; giörande winter och sommar, dagar och nätter lengre i anseende til tiden nu än förr*, Skara 1719; *Opera* III, 299–320.

fluid in the nerves that explains communication through the nerves, from the extremities to the brain, and back. This idea Swedenborg also discusses in mechanical terms in his works on tremulation from 1718–1720.<sup>40</sup> But what is the soul? It too consists of matter, Polhem answered. Concerning the soul, Polhem has a really radical opinion, which is hard to understand as anything other than a materialistic standpoint. He says that something material is alive as long as it contains salt and sulphur, “but after death turns the body into pumice-stone, and the soul into mercury and air.”<sup>41</sup>

As a mechanic, as a self-taught man, as an independent freethinker, Polhem seems to be an early example of a radical materialist, decades before the French Enlightenment and the materialist Julien Offray de La Mettrie's *L'Homme machine* (1748). He was a discoverer of time (the duration of geological processes) before Buffon. Polhem the clockmaker questioned the Great Clockmaker. Something was not right, he suspected.

### The material soul

The tight collaboration between Polhem and Swedenborg seems to have been ended in April 1719. Polhem writes to Benzelius in a state of anxiety and wonders what was wrong. He had received three unopened letters in return, but he still hoped to get an answer from Swedenborg, since “we love him like our own beloved son.”<sup>42</sup> Swedenborg must have been furious—or in despair. The reason why Swedenborg had this strong reaction must be found not in scientific disputes but in emotional experiences. A story goes that Swedenborg fell in love with Polhem's youngest daughter, Emerentia. She was then just 13–14 years old. A contract was signed between Polhem and Swedenborg which said that she will be his in the future. But Emerentia became so grieved that her brother Gabriel felt sorry for her and stole the contract from Swedenborg, who had no other

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<sup>40</sup> Emanuel Swedenborg, “Bewis at vårt lefwande wesende består merendels i små Darringar thet är Tremulationer” (1718), *Dædalus Hyperboreus* VI, 10–14; Emanuel Swedenborg, “Anatomi af vår aldrafinaste natur, wisande att vårt rörande och lefwande wäsende består af contremiscentier” (1720); facsimile, *Photolith*. I; ed. David Dunér, *Om darringar*, Lund 2007; translation C. T. Odhner, *On Tremulation*, 2nd ed., Bryn Athyn PA 1976.

<sup>41</sup> KB, X 521, 24 f.

<sup>42</sup> Polhem to Benzelius, Karls grav, 18 April 1719. *Christopher Polhems brev*, 141.

satisfaction in his love than reading it every day. Swedenborg then saw her sorrow and gave it up. He left the house and promised that he never will think about women anymore, less still to marry someone.<sup>43</sup>

To conclude: many of Polhem's mechanical constructions were actually not invented by him. I would rather say that his importance as an engineer has more to do with his experimental inclination and his more scientific approach to mechanical problems, and also his interest in the education of engineers. As a scientist and thinker he used his cognitive abilities, not least the human mind's way of using metaphors. Polhem had a great impact on Swedenborg's natural philosophy. He was praised during his time, but also made enemies and was infamous for his fussy behaviour and meanness. He was, however, elected as one of the very first members of the Royal Academy of Sciences in 1739. In last years he lived in a house on Södermalm, not far from his last major engineering project, the locks of Stockholm. A few months before he died, he was carried in a chair to the locks and saw the first ship sailing from lake Mälaren out into the sea.

He died nearly ninety years old, in August 1751. Here the story could have ended, but it does not. His former disciple, Swedenborg, later gave an account of a meeting with Polhem in the spiritual world where he faced a cruel destiny. The problem with Polhem was that he could not think about anything else than material things; he was only interested in mechanics and physics, and was unsympathetic to spiritual things. Swedenborg saw him sitting in the spiritual world constructing mechanical birds, cats, and infants, and when Polhem invented an apparatus for communicating with evil spirits, he was thrown down to the darkest corners of hell and deprived of his inventiveness.<sup>44</sup> To Swedenborg, Polhem embodied the delusions of an atheistic mechanism. But Polhem himself was to a high degree conscious of his genius. It will, he claimed, take many centuries for someone equal to me to be found. He may have been right. □

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<sup>43</sup> "Tillägg ur Exegetiska och Philantropiska Sällskapets Handlingar," in Carl Robsahm, *Anteckningar om Swedenborg* (1782), Sollentuna 1989, 75 f.

<sup>44</sup> Emanuel Swedenborg, *Diarium spirituale* I–VII (1745–65), ed. Immanuel Tafel, Tübingen & London 1843–46; translation G. Bush, J. H. Smithson & J. F. Buss, *The Spiritual Diary of Emanuel Swedenborg* I–V, London 1883–1902, n. 4722, 6049, 6071.