Newton and the Netherlands

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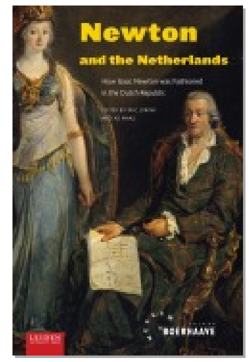

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How Newtonian Was Herman Boerhaave?

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Among historians of science and medicine it is well known that the Dutch medical teacher Herman Boerhaave (1668–1738) was one of the first supporters of Newton in the Dutch Republic. They have described Boerhaave as an 'experimental Newtonian', while Gerrit Arie Lindeboom, Boerhaave's best-know biographer, stated:

> Undoubtedly the appearance of the *Principia* of Newton in 1687, while Boerhaave was a student, must have had a very strong influence on his way of thought, and, in fact, after the death of his teacher, Professor De Volder, Boerhaave was for many years [at least until 1717 when 's Gravesande became professor] the sole defender of the Newtonian principles on the Continent of Europe.[1]

If you add that Boerhaave was considered the *communis Europae praeceptor*, the teacher of all of Europe, it is but a small step to conclude that Boerhaave's teaching was crucial in the dissemination of Newton's work across Europe.

And yet, we hardly find references to Newton in Boerhaave's works. In the eleven orations Newton is mentioned only seven times and a quick search of the eighty-seven works of Boerhaave which can be consulted online gives only twenty-seven hits.[2] Not even the works of Boerhaave's most ardent followers mention Newton very often. Gerard van Swieten (1700–1772), for instance, never named Newton in his published work. William Cullen (1710–1790), professor of medicine in Edinburgh and student of Boerhaave, referred to Newton's work only twice. Albrecht von Haller (1708–1777) mentioned Newton's chemistry a few times, but he was of the opinion that although it would be possible to fill a large volume on the advantages of Newton's mechanical philosophy, it must primarily be considered a 'pleasing amusement'.[3] Boerhaave's pupil William Burton, in the very first biography of Boerhaave, praised Newton's chemistry and character, but never called Boerhaave a 'follower' of Newton. It seems as if either Boerhaave's alleged Newtonianism was not recognized by his pupils, or Boerhaave's medical teaching was not very Newtonian at all.[4]

This brings us to the question of how Newtonian Boerhaave really was. Although Boerhaave owned the first edition of Newton's *Principia*, he hardly ever mentioned the book in his medical teaching. Boerhaave mainly referred to the *Opticks*, first published in 1704, and he was particularly impressed with the thirty-one speculative queries at the end of the book. So, Boerhaave liked Newton the chemist, but he was far more sceptical of Newton the mechanical philosopher. Even more, Boerhaave became increasingly more critical of the natural philosophy of Newton's followers: While he appeared enthusiastic about the 'Prince of Philosophers' in the beginning of his career, in the end he warned those who, in pursuit of Newton, adopted the general laws of attraction in order to explain all natural phenomena.

In this article I argue that (1) Boerhaave was less Newtonian than historians have made us believe; (2) that, if anything, Boerhaave taught a particular kind of Newtonianism and (3) that paradoxically Boerhaave's alleged 'Newtonianism' eventually led to a decline of Newtonian medicine across Europe.

Boerhaave's change of mind

Crucial to my argument is that Boerhaave, at the beginning of his academic career, changed his mind about his research program and that this change had profound consequences on how Boerhaave valued Newton's work. Boerhaave's change of mind is best visible in the sequence of his seven orations on natural philosophical topics delivered between 1701 and 1731. It is remarkable that Boerhaave delivered so many orations. At Leiden University it was customary to deliver an oration upon accepting and resigning a chair, after resigning the office of rector magnificus (this office is comparable to the office of vice chancellor of a university) and after the funeral of a distinguished

Fig. 1: Boerhaave delivering his 1715 oration 'On the Achievement of Certainty in Physics'.

member of the academic community. These were all solemn occasions which normally would not happen very often in the life of one man. The orations marked important points in Boerhaave's academic career and – as is the case with today's orations at Dutch universities – they can be understood as research statements, in which the orator explained how he planned to set out his research.

Leaving aside the funeral oration for Bernard Albinus and the oration on 'Cicero's Interpretation of Epicurus' Maxim on the Highest Human Good Is Right' (1689), Boerhaave's natural philosophical orations can be divided into three parts, corresponding to three periods in his academic career. The orations 'To Recommend the Study of Hippocrates' (1701) and 'On the Usefulness of the Mechanical Method in Medicine' (1703) show the enthusiastic confidence of a starting academic.[5] In the second period Boerhaave delivered the 'Oration on the Simplicity of Purified Medicine' (1709), the 'Discourse on the Achievement of Certainty in Physics' (1715) and the 'Discourse on Chemistry Purging Itself of Its Own Errors' (1718). In these orations Boerhaave appeared to be more reserved about the endless possibilities of natural philosophy.[6] In Boerhaave's last orations, the 'Academic Discourse, Delivered by Herman Boerhaave When He Officially Resigned his Professorships in Botany and Chemistry, Having Obtained an Honourable Discharge, on 28 April 1729' and the 'Discourse on Servitude as the Physician's Glory' (1731), we meet an aged scholar stepping back from his academic duties and contemplating the aims of his pursuits.[7]

Historians of medicine have always interpreted the early orations of 1701 and 1703 as the summit of Boerhaave's medicine. In these orations Boerhaave pleaded for the adoption of a mechanical method in medicine. He stated that:

> The human body is composed in such a way that its united parts are able to produce several motions of very different kinds which derive – fully in accordance with the laws of the mechanics – from the mass, the shape and firmness of the parts and from the way in which they are linked together. [...] Therefore man has a body in the sense which the mechanicians give to that term and show all the characteristics which are displayed by this clearly defined category.[8]

As a result Boerhaave continuously urged his listeners to search for the 'true' mechanistic laws and principles upon which medicine should be built. He strongly believed that these natural laws and principles would be revealed to man through sense-perception and experiment. If students would make this their business, so Boerhaave argued, 'we shall eventually have at our disposal a medical science which is more reliable, not subject to phantasy, not continuously changing, but eternal'.[9] In fact, Boerhaave was confident that it would be possible to develop a true medicine in which the laws of nature governing the body would be fully known.

However, it is crucial to realize that Boerhaave delivered these orations right at the beginning of his time at Leiden University, and they are by no means representative for his further career. In the six years between his 1703 oration on the adoption of the mechanical method and his 1709 oration on the simplicity of purified medicine Boerhaave developed a much more cautious attitude towards the possibility of unveiling true knowledge. He disapprovingly pointed at philosophers (i.e. Cartesians) who 'think so highly of their own far-sighted intelligence that they deem it sufficient merely to refer to this intelligence in physical matters'. Instead, Boerhaave argued that 'the first principles of nature are wholly hidden from us', and that the only thing we can perceive through experiment and observation are the properties of hidden first causes.[10]

In particular the 1715 'Oration on the Achievement of Certainty in Physics', reflected Boerhaave's scepticism with respect to the thought of ever achieving certainty. Ironically, this oration has often been read as the epitome of Boerhaave's Newtonian research program. Yet the oration was first and foremost a critique of universally adopting a Cartesian intellectual approach in the study of nature.[11] Right at the beginning of his oration Boerhaave stated:

> They [the Cartesians] almost seem to think themselves able by mere meditation to find in their own thoughts the ways and means by which the whole universe holds together and moves. [...] [I]f we ponder the matter honestly in our mind, however, it will be seen that this cognitive error is a common source of corruption; there is none other whose bad effects constitute a greater hindrance for the progress of medicine.[12]

Boerhaave mentioned Newton as a counter example – as someone who kept away from Cartesian speculation. Boerhaave claimed that *not even* the celebrated Newton was able to understand the nature of gravity (or attraction), even though he had shown that gravity is attached to all visible bodies and always follows the same laws.[13] So rather than reading the 1715 oration as Boerhaave's promotion of Newtonianism in the Netherlands, the oration must be considered a call for 'moderation in the glorification of the universal force of acknowledged principles'. And in the pursuit of this argument Newton was only mentioned as a fine example of how this should be done.

In 1718, upon delivering his chemistry oration, the change in Boerhaave's mind was complete. While fifteen years earlier he strongly believed in the project of uncovering universal mechanical laws governing the human body, Boerhaave now thought it impossible to disclose 'the permanent laws and eternal covenants' of nature. And he argued that it is an arrogant presumption to 'predict with mathematical certainty and prove each individual change that will result when bodies are brought together in collision'.[14]

Boerhaave's last two orations have a more reflective character as Boerhaave pondered the fruits of his pursuits. The fight against Cartesianism was not so much an issue anymore and, as a result, the counter example of Newton's wisdom in studying nature disappeared from the orations.

'Newtonian' medicine?

Even though Boerhaave's orations primarily referred to Newton as a counterexample in the fight against Cartesianism, Boerhaave's admiration for the English 'Prince of Philosophers' was nevertheless enormous and unwavering. This is remarkable because Boerhaave, while changing his mind about the nature and working of the body, also changed his opinions about his fellow natural philosophers. For instance, in the beginning of his career he was very critical about the iatrochemists Paracelsus (1493–1541) and Jan Baptista Van Helmont (1579–1644), while towards the end he almost lovingly referred to 'Father Helmont'. And although Boerhaave was fairly positive about René Descartes (1596–1650) at the beginning of his career, ten years later he despised Cartesianism. Yet Boerhaave's high veneration for Newton remained as before. Even more, Boerhaave's change of mind almost seems to reflect Newton's changing focus from the mathematical approach of the *Principia* towards the experimental method of the *Opticks*.

Boerhaave's changing views on secretion illustrate how he adopted the different Newtons in his early as well as in his late medicine. At the time, secretion was a matter of great urgency. It can even be stated that all Dutch anatomical experiments were to some extend directed at showing how the fluids proceeded and are produced through the intricate structure of the tubes and vessels.[15] Shortly after becoming a lector of medicine at Leiden University, Boerhaave presented a theory of secretion based on (Newtonian) mathematics. It was based on the Galenic assumption that the body consisted of a netlike organization of interconnected tubes and vessels and that this structure determined the nature and motions of the humours. 'Is it not obvious', so Boerhaave asked, 'that the effects [of the arteries on the blood] have to be deduced and explained from this structure'.[16] In his view, blood consisted of particles which upon being moved around in the body broke up into smaller particles according to the shapes and sizes of the vessels. The large particles of blood fitted the arteries, while the small particles of lymph fitted the lymphatic vessels. He believed that not only the bloods, but also the other fluids of the body, such as milk and semen, were produced in the same way through their movements in the small tubes of the glands. Although Boerhaave thought that the solid particles of the fluids were distinguished from one another through their specific elasticity, gravity, consistency, adhesiveness, the speed and direction of movement, he refused to explain the working of the body in terms of individual qualities of each particle. Instead he emphasized the common nature of fluids as explained by the mechanicians – life, health and even the working of remedies depended upon the mechanical motion of the fluids in the solids.

In short, Boerhaave argued that the solid parts of the body worked like '*mechanical instruments*, which through their form, firmness, and through the way in which they are joined, are able to sustain other parts, or to produce certain movements'.[17] Above all, Boerhaave argued that only the mechanicians, and Newton above all, were entitled to claim that they were dealing with proper knowledge about the solid parts and that physicians should listen only to them – 'only their pronouncements should be taken into account, only their principles should be appealed to, only their methods should be applied'.[18]

Boerhaave's early iatromechanics was far from experimental. His ideal student would hastily proceed from the data perceived through the senses towards a logical deduction of the 'nearest causes of each effect'.[19] That is not to say that Boerhaave was necessarily Cartesian in his approach – although he undoubtedly must have been influenced by the Cartesian climate in which he worked. Boerhaave considered the Cartesian method haphazard and its conclusions speculative, having no bearing on real things. Instead, Boerhaave referred to Newton (among others) as an example of how one should rightly apply the mathematical method to whatever can be observed. And undoubtedly the Newton Boerhaave referred to was the 'mathematical' Newton of the *Principia*.[20]

In the 1710s, however, shortly after Newton's publication of the *Opticks*, Boerhaave, who owned a copy of the first English edition of 1704 as well as a copy of the 1706 Latin edition, moved away from a strict mechanism and started praising the merits of chemistry. He no longer believed it possible to logically deduce knowledge about causes, and he started emphasizing that the only thing a natural philosopher could ever know were the effects of unknown causes. He furthermore devoted much more attention to the (what he called) individual 'latent peculiar powers' of particular bodies and he argued that 'chemistry is best adapted for discovering these [...] powers', which also made chemistry 'the best and fittest means of improving natural knowledge'.[21] In Boerhaave's words,

> chemistry surpasses other disciplines in usefulness [...] in physics we can be of good cheer with this guide, in medicine all possible good may be expected from it. It teaches most faithfully how the deepest secrets may be revealed, intricacies be disentangled, how hidden forces of bodies may be discovered, imitated, directed, changed, applied and perfected.[22]

As a result, Boerhaave no longer praised the merits of a 'mathematical' Newton, but he referred to Newton the chemist. Upon accepting the chair of chemistry in 1718 he stated: 'When he [Newton] explains the laws, actions and forces of bodies – basing himself upon the careful study of their effects – he appeals to chemistry and to nothing else'. Boerhaave was particularly pleased with Newton's promotion of chemical methods in order to uncover the workings of the powers of nature. He continued his speech explaining that when Newton

> again relates the forces so found to other phenomena that are still to be explained he calls upon purely chemical methods, and through his illustrious example he demonstrates that if chemistry did not exist it would be impossible for even the most perspicacious of mortals to gain insight into the proper nature and forces of single bodies.[23]

Boerhaave was so impressed by the *Opticks* that he stated: 'I never saw a book where [there] were stronger arguments drawn from experiments: it is the best pattern in the world and deserves the highest honour'.[24]

Boerhaave's turn towards chemistry – a turn which he saw paradigmatically expounded in Newton's work – had profound consequences for the way Boerhaave explained secretion in the human body. In his mechanical system he proposed that the nature and motion of the humours resulted from the structure of the tubes and vessels. In his chemical textbook of 1732, however, Boerhaave devoted much more attention to the powers of the humourous particles themselves. Boerhaave, in other words, changed from researching the solid parts of the *vasa minora* and the *vasa majora* to investigating the fluids circulating within the solids. After years of experience Boerhaave had become convinced that the round and neutral particles contained in the fluids could change into another nature and so harm the body. He furthermore pointed at the chemical reactions between particles and the effects of heat in order to explain the circulation of fluids in the body. With respect to secretion, Boerhaave no longer solely believed that all the fluids of the body were contained in the blood and were filtered through the different vessels. Instead, he argued that 'in each part of an animal we find humours of a peculiar kind, which always appear specifically different from another'. It follows that Boerhaave no longer believed that all the tubes and vessels of the body were necessarily connected but rather that some fluids were (chemically) changed, mixed and perfected in the enclosed spaces of the vessels themselves. For instance Boerhaave considered the glands as separate and independent membranous follicles, rather than as parts of an interconnected structure of vessels. This point of view brought him into conflict with his good friend Frederik Ruysch (1638–1731), whose famous injection preparations were meant to show just how the tubes and vessels of the body mechanically interconnect.[25]

While examining the forces contained in the fluids Boerhaave not only considered the mechanical forces of attraction, but he also included non-mechanical entities, such as *effluvia*, seminal principles, *spiritus rector* and pure fire.[26] He argued that in particular processes of secretion and mixing of fluids (which he extensively discussed in the chapter on *menstrua* in his *Elementa chemiae* of 1732) must be exam-

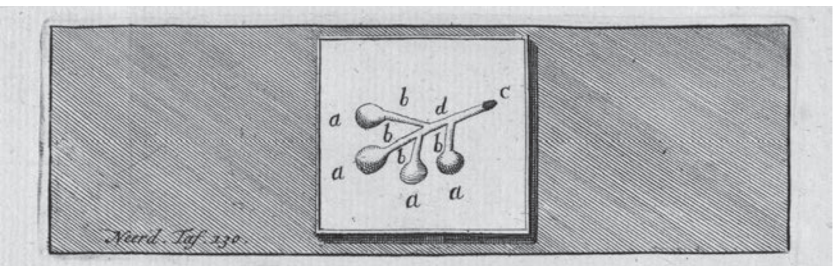

Fig. 2: Boerhaave's image of a gland represented as a closed-off vessel. Note that the extremities of the gland look like chemical retorts.

ined chemically. Since mixtures of particles caused reactions between particles, they showed that individual powers determined the particular nature of the bodily fluid. So Boerhaave considered chemistry – and not mechanics – much better suited to investigate the processes of the body. Boerhaave argued:

> I have learnt from experience that different parts, of different properties, are mix'd in with all such bodies; whilst these parts [of bodies] have respectively their own peculiar powers of attracting, repelling, and changing themselves in many other ways. We must not, therefore, attribute more to mechanical power, than the author of nature has given to natural bodies: nor extend this power beyond its proper bounds, in accounting for chemical operations. This declaration is forc'd from me, by the regard I bear to truth: and may clear me from the imputations of pretending to explain chemical operations upon mechanical principles.[27]

The Boerhaavian decline of Newtonian medicine

Paradoxically, Boerhaave's turn towards chemistry for medicine – which was inspired by Newton's chemistry in the *Opticks* – unwittingly led to a separation of medicine and Newtonian natural philosophy in the latter half of the eighteenth century. Historian Theodore Brown has already pointed at Boerhaave's promotion of a Newtonian experimental (as in the *Opticks*) rather than a mathematical (as in the *Principia*) approach in medicine as an explanation for the decline of British Newtonianism in the 1740s.[28] Yet I would rather point at Boerhaave's focus on the many latent peculiar powers of bodily substances as explanation for the decline of the Newtonian mechanical philosophy in medicine.

As soon as Boerhaave started doing chemical experiments he discovered a world filled with occult powers peculiar to every combination of particles.[29] Among them he counted the seminal powers or *threads of the warp*, the powers of fire, water and earth, the powers of *effluvia, spiritus rector* and *impetum faciens* and many more powers yet to be discovered. More importantly, Boerhaave believed these powers to be innate properties of bodily substances. So, where Newton needed the concept of the aether in order to explain how immaterial forces materialized, Boerhaave's chemistry for medicine was built on the idea that all the powers of nature were inseparable parts of matter. I suggest that it was precisely the huge diversity of non-mechanical vital powers which distinguished Boerhaave's system from Newton's and, moreover, that Boerhaave's teaching aim of researching these powers ultimately led to a decline of Newtonianism in medicine.

Boerhaave's keen interest in the infinitely many latent peculiar powers of bodies was in contrast with Newton's insistence on reducing all the forces of nature to two or three general principles (or forces) of motion. Although it can be said that Newton's thirty-first query in the *Opticks* ('Have not the small particles of bodies certain powers, virtues or forces, by which they act at a distance [...] but also upon one another for producing a great part of the phaenomena of nature?') opened the door for a materialism of subtle fluids bearing quantities of inherent properties, Newton also argued that

> To tell us that every species of things is endow'd with an occult specific quality by which it acts and produces many effects, is to tell us nothing: but to derive two or three general principles of motion from phaenomena, and afterwards to tell us how the properties and actions of all corporeal things follow from those manifest principles, would be a great step in philosophy.[30]

Ultimately Newton's forces of attraction (gravity, magnetism and electricity) were mechanical in nature. Newton believed that the main project of natural philosophy was to 'learn what are the laws and properties of attraction' and that ultimately the natural philosopher must deduce causes from effects until he comes to the very first cause (which is not mechanical). In the process, the Newtonian natural philosopher had to eliminate as many causes as possible so that 'every true step made in this philosophy brings us not immediately to the knowledge of the first cause, yet it brings us nearer to it'.[31]

Boerhaave, on the other hand, argued that it is impossible to ever come near to knowing the first cause. Unlike Newton's project, Boerhaave's research and teaching was not directed at reducing all the different forces of nature to only few natural laws which would lead him to a glimpse of the divine. Instead of directing his gaze upwards, Boerhaave focused on down-to-earth nature and his research was primarily directed at seeing God's steering hand in the creation. Boerhaave would not dream of limiting God's omnipotence to only a few natural laws. In his eyes this would be the same as to capture the greatness of God into the limited capacity of the human mind. Unlike Newton, Boerhaave, through emphasizing the endless number of essentially unknowable and occult powers, pointed at the fact that man can never fully know how God steers His creation. In his view, natural philosophers could only perceive traces of God's providential hand in nature, in much the same way as we are able to see tracks in the snow, where the cart itself has disappeared. For instance, Boerhaave discussed 'the seeds of things' as first principles which in his view form the foundation and support of every single body. Yet he argued that

> no man can by any power of observation detect the power that brings the scattered elements together in the structure of the seed; still less can he discern the way in which this power disposes and orders them. The seminal principle of even the most simple thing cannot be copied by any imitative method.[32]

On many occasions Boerhaave warned his students to restrict themselves to the observation of the effects of the many essentially unknown powers and he pointed at chemical experiments as the best way to do so. This would give them a clear idea of the working of nature while at the same time it would prevent them from strolling into the domain of the divine.

In his lectures Boerhaave told his students over and over again that the working of nature cannot be reduced to only a few natural laws. With respect to Newton he praised the experimental approach of the *Opticks*, but he was very critical about the universal application of its results. In line with his insistence on the working of uncountable powers in nature, Boerhaave appreciated Newton's premise that nature is always more complicated than it seems. For instance, Boerhaave admired Newton for proving that although everyone believed that a ray of light is perfectly simple, it can be divided into seven colours. Yet at the same time Boerhaave was exceedingly careful in universally applying Newtonian mechanical laws. More than once, Boerhaave mentioned Newtonian natural philosophers as examples of how not to do natural philosophy. He ridiculed the fact that they tried to explain everything in terms of mechanical laws of attraction – impossible in his view, because there were as many distinct kinds of attraction as there were bodies. Boerhaave was particularly critical of the Newtonian physiology of the British Newtonian physiologist James Keill (1673–1719), who in his view attached far too much value to the forces of attraction.[33] In short, Boerhaave's seemingly contradictory view of Newton's philosophy indicates that he accepted and was perhaps inspired by Newtonian methods, while at the same time he was critical of Newtonian conclusions.

At Leiden University Boerhaave was not alone in his selective praise of Newton. We find exactly the same attitude in the work of Boerhaave's great friend Bernard Siegfried Albinus (1697–1770), well-known author of an anatomical atlas on the bones and muscles, the *Tabulae sceleti et musculorum corporis humani*, first published in 1747. Like Boerhaave, Albinus believed that life 'does not only consist in the (mechanical) circulation of the fluids, (although it is essential), but in the ultimate solid particle that is constantly moving'.[34] And just like Boerhaave, Albinus began by mentioning Newtonian forces, but he immediately played down their importance through mentioning them only as part of the many different individual powers moving the human body. For instance, Albinus mentioned the Newtoninan force of cohesion in order to explain muscle contraction, but he valued the individual powers of the *stimulus*, the irritation and the will much more.[35] Moreover, Albinus argued that although he was of the opinion that most things in the body take place because of mechanical laws, there was something very subtle in the parts of the body, a force resembling the Hippocratic *enormoun*, which did not act mechanically, but was of crucial importance for the life and motions of the body.[36] One might argue that this force resembled the Newtonian suggestion of the aether, but Albinus, although clearly aware of Newton's work, never made this link. On the contrary, he identified this force in a Boerhaavian manner as surfacing 'latent peculiar powers of bodies' like *vis vegetans*, *aura seminalis, vis agitans* and *vis ciens*.

Many of Boerhaave's students, who often also attended the lectures and dissections of Albinus, adopted Boerhaave's double view on Newton. Upon returning home they introduced a kind of Boerhaavian (critical) Newtonianism in many medical centres across Europe. This Newtonianism was inspired by the experimental approach of the *Opticks*, but contrary to Newton it emphasized the working of non-mechanical and essentially unknown powers in the body.

Historians of medicine have already noticed that soon after Newton's death in 1727, physicians in England started moving away from a strict application of Newtonian (mathematical) ideas in medicine.[37] This was not only caused by the fact that Newton himself had passed away and was no longer breathing down their necks, but also by the fact that most of them had studied with Boerhaave. For instance, the work of Henry Pemberton (1694–1771) shows an important Boerhaavian nuancing of Newtonian physiology.[38] Pemberton not only was a pupil of Boerhaave in the 1710s, he was also employed by Newton to superintend the third edition of the *Principia* in 1726. In his lectures Pemberton often praised Newton for drawing attention to the active powers of the smallest parts of bodies and the importance of chemistry in discovering them.[39] At the same time, however – and it is almost as if we hear Boerhaave speak – he was cautious in adopting the term 'attraction' for all kinds of powers.[40] Moreover, Pemberton thought it impossible to account for all bodily actions in a thoroughly mechanistic manner. In his republication of William Cowper's *Myotomia reformata* (1724), which was a highly mathematical essay on muscle contraction, Pemberton claimed in the introduction – as Albinus had done in Leiden – that it was impossible to account for muscle contraction solely in mechanistic terms. Pemberton claimed that 'the functioning animal may manifest phenomena for which the physiologist could currently find no explanation in physical terms'.[41] In a truly Boerhaavian manner he argued that the human mind was simply not up to fully understanding the divine wisdom evident in the structure and working of the body. In this situation it would be better, so he argued, to exercise restraint by observing, collecting, and cataloguing the phenomena, than to formulate universally valid mechanical laws.

Not only in London, but also elsewhere, we meet a similar Boerhaavian Newtonianism and we find it in particular in discussions on the nervous system. As a result of Boerhaave's insistence on the powers of the smallest particles of matter increasingly more attention was paid to whatever was going on in the infinitely small vessels of the nervous system (which, by the way, was also hinted at by Newton in the twenty-fourth query of the *Opticks*). From the 1730s until his death Boerhaave devoted most of his time lecturing and researching nervous diseases.[42] So important did Boerhaave consider this topic and so often did he advertise its crucial importance for medicine that many of his pupils took up his interest in the working of the nervous system. The above-mentioned Henry Pemberton, for instance, speculated a lot on the characteristics of the nervous fluids.

An exemplary follower of Boerhaave in this respect was the influential Scottish medical teacher William Cullen, another student of Boerhaave. In his lectures on physiology he discussed the nervous system directly after discussing the nature of the solids and even before treating the (mechanical) circulation of the blood. Cullen did so because he considered that 'the nervous system, as the organ of sense and motion is connected with so many functions of the animal oeconomy, that the study of it must be of the utmost importance, and a fundamental part of the study of the whole oeconomy'.[43] He argued that the fundamental part of the nervous system consisted of vital solids and that these vital solids contained many peculiar powers. Moreover, Cullen, being a disciple of Boerhaave, argued that these so-called vital solids showed up in chemical experiments. Cullen clearly adopted the Newtonian chemical approach – which emphasized the importance of chemical methods to disclose the latent peculiar powers of bodies – so successfully advocated by Boerhaave in Leiden. Yet Cullen hardly ever mentioned Newton or Newtonian mechanical laws in the bodily oeconomy. Paradoxically, Newton was there, but at the same time his name had disappeared from medical teaching.

This also goes for the work of Albrecht von Haller. I suggest that his well-known and controversial research on irritability and sensibility was dually inspired by Boerhaave as well as by Newton's speculations on the presence of a vibrating motion in the aetherial medium of the nerves. Hubert Steinke has recently argued that it is problematic to call Von Haller's physiology Newtonian. In particular, the working of irritability (which Von Haller explained as a complex innate property of the muscular fibres) could not be subjected to the common Newtonian laws of movement. This was even more the case since Von Haller's ideas on forces and matter differed from Newton's; 'whereas for Newton forces had no material existence and were closely linked with space, for Von Haller they were properties of a substance'.[44] So, although Von Haller, in his lectures on physiology, mentioned Newton as the first author who suggested (in the twenty-fourth query of the *Opticks*) that the powers of bodies were increased by the nervous juice which moves from the brain towards the extremities of the nerves, Von Haller refused to explain the working of the nervous system in mechanical terms only. Instead, in a Boerhaavian manner, he directed his investigations at discovering the vital powers moving the body.[45] And this, of course, is reminiscent of Boerhaave's idea of latent peculiar powers inherent in the particles of the body.

These are only few examples of how during the eighteenth century, as a result of Boerhaave's insistence on explaining the working of 'latent peculiar powers', Newtonian mechanical physiology declined. Although Boerhaave was inspired by Newton's experimental approach, his chemistry for medicine was no 'sublimer mechanics' as some early-eighteenth-century Newtonians would have it.[46] Since it was directed at discovering the vital powers of bodies rather than universal mechanical laws 'acting at a distance', Boerhaave's chemistry was essentially different from the chemistry advocated by Newton in the *Opticks*. Boerhaave's ideas were adopted by many of his pupils and brought to medical centres across Europe. And it was not only Boerhaave's promotion of an experimental approach, as Theodore Brown has argued, but also and more importantly Boerhaave's insistence on the existence of infinitely many powers of nature, which was taken up by his followers. Ultimately, it can be argued that Boerhaave's teaching opened the way for the vitalistic physiologies of the second half of the eighteenth century. It is ironic that Newton's own suggestions of non-mechanical powers together with his insistence on chemical experiment – which were both adopted by Boerhaave, the teacher of Europe – resulted in the collapse of Newtonian mechanics in medicine.

Notes

1 G.A. Lindeboom, *Herman Boerhaave: the man and his work* (Leiden 1968), p. 7. For Boerhaave as experimental Newtonian, see: I.B. Cohen, *Franklin and Newton: an inquiry into speculative Newtonian experimental sciences and Franklin's work in electricity as an example thereof* (Cambridge, MA 1956), pp. 214ff.; H. Metzger, *Newton, Stahl, Boerhaave et la doctrine chimique* (Paris 1930). For a more critical attitude towards Boerhaave's Newtonianism, see: R.E. Schofield, *Mechanism and materialism: British natural philosophy in an Age of Reason* (Princeton 1970); A.E. Shapiro, *Fits, passion and paroxysms: physics, method, and Newton's chemistry of coloured bodies and fits of easy reflection* (Cambridge 1993).

2 See the digitalised sources on ECCO (Eighteenth Century Collections Online).

3 A. von Haller, *Dr. Albert Haller's physiology; being a course of lectures upon the visceral anatomy and vital oeconomy of human bodies*, 2 vols (London 1754), vol. 1, pp. i, lix.

4 For a discussion of Boerhaave's Newtonianism among historians, see also R. Knoeff, *Herman Boerhaave (1668–1738): Calvinist chemist and physician* (Amsterdam 2002), p. 120.

5 H. Boerhaave, *Oratio de commendando studio Hippocratico* (1701); H. Boerhaave, *Oratio de usu ratiocinii mechanici in medicina* (Leiden 1703).

6 H. Boerhaave, *Oratio qua repurgatae medicinae facilis asseritur simplicitas* (Leiden 1709); H. Boerhaave, *Sermo academicus de comparando certo in physicis* (Leiden 1715); H. Boerhaave, *Sermo Academicus de chemia suos errores expurgante* (Leiden 1718).

7 H. Boerhaave, *Sermo academicus quem habuit quum honesta missione impetrata botanicam et chemicam professionem publice poneret xxviii Aprilis 1729* (Leiden 1729), and H. Boerhaave, *Sermo Academicus de honore medici, servitute* (Leiden 1731).

8 H. Boerhaave, 'On the usefulness of the mechanical method in medicine', translated in E. Kegel-Brinkgreve and A.M. Luyendijk-Elshout (eds), *Boerhaave's orations* (Leiden 1983), pp. 85–120, on 119.

9 Ibidem, p. 112.

10 H. Boerhaave, 'Discourse on the achievement of certainty in physics', translated in Kegel-Brinkgreve and Luyendijk-Elshout (eds), *Boerhaave's orations* (note 8), pp. 145–179, on 155.

11 It must be remarked that in the same oration Boerhaave also praised Descartes' mathematical writings, wondering 'that such diverse products could originate from the same man'. So although the oration is directed against the Cartesian method, it is not directed against Cartesian mathematics.

12 Boerhaave, 'Achievement of certainty in physics' (note 10), p. 155.

13 Ibidem, pp. 161–162.

14 H. Boerhaave, 'Discourse on chemistry purging itself of its own errors', in Kegel-Brinkgreve and Luyendijk-Elshout (eds), *Boerhaave's orations* (note 8), pp. 180–213, on 162.

15 See, for instance, the experiments of Reinier de Graaf, Jan Swammerdam and Frederik Ruysch.

16 Boerhaave, 'Usefulness of the mechanical method' (note 8), pp. 85–120, on 99.

17 Ibidem, p. 102, my italics. See also Newton's second book of the *Principia* (prop. 32, theorem 26, 327), where Newton argued that when the particles of a fluid are similar and have the same given ratio of density to each other and the same motion, these particles 'will continue to move among themselves with like motions and in proportional times'.

18 Boerhaave, 'Usefulness of the mechanical method' (note 8), p. 102.

19 Ibidem, p. 117.

20 Ibidem, p. 104. The oration was delivered in 1703, before the publication of the *Opticks*. For an example, see Knoeff, *Herman Boerhaave* (note 4), p. 172.

21 H. Boerhaave, *A new method of chemistry,* trans. P. Shaw, 2nd ed. (London 1741), vol. 1, p. 173. I use this translation of Boerhaave's *Elementa chemiae* (Leiden, 1732) as I consider it a better translation than the 1735 translation of Timothy Dallowe.

22 Boerhaave, 'On chemistry' (note 14), p. 211.

23 Ibidem, p. 212.

24 H. Boerhaave, *A method of studying physick,* trans. Mr. Samber (London 1719), p. 98.

25 I have argued this more extensively in R. Knoeff, 'Chemistry, mechanics and the making of anatomical knowledge: Boerhaave vs. Ruysch on the nature of the glands', *Ambix* 53 (2006), pp. 201–220.

26 For Boerhaave the difference between mechanics and chemistry was that the former was concerned with the formulation of general laws common to all bodies, while the latter investigated the latent properties peculiar to every single body. This meant that although it could in general be argued that, for instance, *effluvia* or pure fire could be seen as very small particles fitting a mechanistic framework, it was nevertheless possible for Boerhaave to understand them in a chemical way as particles endowed with non-mechanical, even occult, powers.

27 Boerhaave, *A new method* (note 21), vol. 1, p. 511.

28 See T.M. Brown, 'From mechanism to vitalism in eighteenth-century English physiology', *Journal of the history of biology* 7 (1974), pp. 179–216.

29 Note that Boerhaave hardly ever spoke about forces (which have a mechanical connotation), but always referred to powers (which can be explained chemically).

30 I. Newton, *Opticks, or a treatise of the reflections, refractions, inflections & colours of light* (New York 1979; based on Newton's fourth edition, 1730), pp. 401–402.

31 Ibidem, p. 369. Note that Newton was always very cautious about hypotheses and he often despised the Cartesians for posing too many hypotheses. Newton never considered his 'causes' hypothetical.

32 Boerhaave, 'Achievement of certainly in physics' (note 12), p. 165.

33 For Keill see A. Guerrini, 'James Keill, George Cheyne, and Newtonian physiology, 1690–1740', *Journal of the history of biology* 18 (1985), pp. 247–266, and A. Guerrini, 'The Tory Newtonians: Gregory, Pitcairne, and their circle', *Journal of British studies* 25 (1986), pp. 288–311.

34 H. Punt, *Bernard Siegfried Albinus (1697–1770) on 'human nature': anatomical and physiological ideas in eighteenth-century Leiden* (Leiden 1983), p. 141.

35 Ibidem, p. 139.

36 The term *enourmoun* cannot be found in the *Corpus Hippocraticum*, but is attributed to Hippocrates by Galen. See J.K. van der Korst, *Een dokter van formaat. Gerard van Swieten, lijfarts van keizerin Maria Theresia* (Amsterdam 2003), pp. 34–35.

37 See the before mentioned articles by Brown and Guerrini (notes 28 and 33).

38 Pemberton's critical Newtonianism has also been discussed by Theodore Brown in his article 'From mechanism to vitalism' (note 28).

39 H. Pemberton, *Course on chemistry* (London 1731), pp. 13–14.

40 H. Pemberton, *A view of Sir Isaac Newton's philosophy* (London 1728), p. 144.

41 Pemberton in Brown, 'From mechanism to vitalism' (note 28), p. 189.

42 Boerhaave's lectures on the nervous diseases have been translated and edited by B.P.M. Schulte in his *Herman Boerhaave praelectiones de morbis nervorum 1730–1735* (Leiden 1959).

43 W. Cullen, *Institutions of medicines, part I, physiology. For the use of students in the University of Edinburgh* (Edinburgh 1777), p. 24. Boerhaave, as far as I know, never used the word 'oeconomy' in relation to human physiology.

44 H. Steinke, *Irritating experiments: Haller's concept and the European controversy on irritability and sensibility, 1750–90* (Amsterdam 2005), p. 115. For Haller as a Newtonian, see S. A. Roe, '*Anatomia animata*: the Newtonian physiology of Albrecht von Haller' in: E. Mendelsohn (ed.), *Transformation and tradition in the sciences: essays in honor of I. Bernard Cohen* (Cambridge, 1984), pp. 273–300.

45 A. von Haller, *Dr. Albert Haller's physiology* (London 1754), p. 316.

46 See, for instance, the work of Peter Shaw. In the footnotes to his translation of Boerhaave's chemical textbook, he tried his hardest to change Boerhaave's chemistry into a branch of Newtonian mechanics. Chemistry, he argued, is 'sublimer mechanics', for mechanics, being the doctrine of motion, is a key to understanding chemical effects. Shaw in Boerhaave, *A new method* (note 21) vol. 1, p. 155.