Newton and the Netherlands

How Isaac Newton was Fashioned in the Dutch Republic

EDITED BY ERIC JORINK AND AD MAAS

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Introduction

ERIC JORINK AND AD MAAS

The Dutch Republic is known as an early adopter of Isaac Newton's natural philosophy. In fact, Newton's success on the Continent was largely effected by Dutch scholars who supported his work at an early stage. This volume, *Newton and the Netherlands,* is largely devoted to the perception of Newton's ideas in the Dutch Republic, as well as the fashioning of the man himself, from the publication of his magnum opus *Philosophiae naturalis principia mathematica* in 1687, until the end of the eighteenth century.

Despite the importance of the Dutch Republic in the history of Newtonianism, surprisingly little research has been done in this field. For most historians the sudden popularity of Newtonianism in the Dutch Republic has been a historical fact requiring no explanation. The introduction of Newtonianism to the Netherlands in 1715 is usually considered the logical next step towards modern science: from Aristotelianism, via Cartesianism towards Newtonianism. Seen from this perspective, the appearance of Newtonian physics in the academic curriculum in 1715–1717 was inevitable, as was the increasing popularity of the man himself. The eighteenth century in the Dutch Republic was, as in England, the age of Newton. Eulogies of 'this miracle of our age' are found not only in scientific texts, but also in sermons and poetry.

In this volume, which is the result of an international conference held in Museum Boerhaave, Leiden, 20–22 April 2010,[1] we would like to draw attention to certain conceptual and contextual problems, and to highlight a number of protagonists and underlying patterns relevant to Newton's success. Drawing on the recent trend in the history of science for concepts such as the 'circulation of knowledge', and the focus on the processes of reception, adaptation and dissemination, we will argue that 'Newtonianism' in the Dutch context was not a stable, coherent system, originating in Britain and waiting to be implemented on the Continent, but a philosophical construction, adapted to local problems and circumstances. The dissemination of Newton was a many-sided and complex process, in which natural philosophy, religious and cultural factors, propaganda and practical concerns, and personal benefits, fears and preferences interacted in a fascinating manner.

As this book shows, the 'Newtonianism' constructed by Dutch natural philosophers appears to be anything but a fixed and clearly defined set of scientific concepts. Many scholars who have been labeled straightforwardly as 'Newtonians', in practice did not embrace Newton's natural philosophy completely. Actually, the Dutch 'Newtonians' mostly used Newton's ideas in a selective or even defective manner, and were far from dogmatic in their adherence to his work. Moreover, what was understood by 'Newtonianism' changed in the course of time. Studying Newtonianism, therefore, is like looking at Dutch fog: it is omnipresent, but intangible as well, it often conceals more than it reveals and at short distances it seems to disappear altogether. It is no surprise that many of the authors in this book are intrigued by the 'foggy', intangible character of Dutch Newtonianism.

In the first chapter Eric Jorink and Huib Zuidervaart present an overview of the colorful rise of Dutch 'Newtonianism', and the way the man himself was put on the map, as well as on the market. As they show, Dutch 'Newtonianism' was a label, an intellectual construction, to a large extent molded by an already existing tradition of empirical research and by a Protestant natural theology which gave the study of nature a strong religious connotation. Newton's natural philosophy was adopted to solve pressing religious and philosophical concerns of Dutch culture, particularly as an antidote to the 'blasphemous' ideas of Spinoza. In the second half of the eighteenth century an increasing terminological vagueness became apparent. 'Newtonianism' became interchangeable with experimental philosophy, 'physico-theology' and natural theology, all of which roughly described the same set of ideas, values and practices. As their research suggests, the sudden success of Newton in the Dutch Republic after the publication of the second edition of the *Principia* in 1713, and the subsequent pirated Amsterdam edition, could be seen as the result of a conscious strategy of philosophers and publishers.

A particularly penetrating insight into the selective way in which Newton's ideas were adopted is provided by Fokko Jan Dijksterhuis in chapter 6. His study focusses on the *Opticks*, Newton's book about his optical experiments and views (first published in 1704). The reception in the United Provinces of this book, which, unlike the *Principia*, has little to say on worldviews and religion, provides a revealing look into the practical use of Newton's work. The polymath Lambert ten Kate and the instrument maker and lecturer Daniel Fahrenheit, two well-known 'Newtonians' who became familiar with the *Opticks*, largely ignored Newton's central claims and freely picked out the elements they could use. For Fahrenheit the *Opticks* proved useful for his pursuits in telescope making, while Ten Kate even aimed to correct some elements of Newton's optics with his own experiments, because they did not fit his own theories. Both were largely indifferent to Newton's natural philosophical system. How 'Newtonian', then, were these scholars actually? Dijksterhuis ends his article by calling into question the usefulness of the term 'Newtonianism', which he considerers 'too ambiguous, to illuminate historical developments'. 'To put it briefly', he concludes, '"Newtonianism" is not a fruitful category for doing history of science'.

Another chapter that discusses the nature of Dutch 'Newtonianism' is the analysis of its intellectual dimension by Rienk Vermij (chapter 7). While emphasizing the heterogeneous character of the Dutch Newtonians, Vermij identifies a common project, namely 'defining the relation between God and nature in a way which answered both scientific and religious demands'. This 'project' had an important impact on the interpretation and perception of Newton's ideas by Dutch scholars.

While in the seventeenth century nature was increasingly considered in terms and concepts adapted from natural philosophy and geometry, there was some unease about its consequences for traditional religious views. The presumption that the universe was directed by a set of eternal and immutable laws of nature could lead to a deterministic worldview in which God's role was marginalized. What was ultimately at stake, Vermij argues, were not philosophical matters as such, but the authority of the Bible. How could the supernatural events of the Scripture be brought in accordance with new scientific developments? From Newton's natural philosophy a worldview could be derived in which the world depended directly on God's benevolence. Vermij argues that this worldview was instrumental in achieving a broad consensus that arose in the eighteenth-century Dutch Republic: the miracles and mysteries of the Bible remained outside the scope of scientific interpretations and, on the other hand, supernatural events were no longer considered credible in daily life.

Henri Krop establishes (chapter 9) that in the course of the eighteenth century a 'Newtonian' philosophical system was taught at the Dutch universities, which included not only natural philosophy, but also a logic and a metaphysics. The rise of such a comprehensive academic Newtonianism was unique to the Netherlands, and was distinct from the popular 'branch' of Newtonianism, which in particular found expression in physico-theological writings.

Krop focuses mainly on the late eighteenth-century writings of the then influential natural philosopher Jean Henri van Swinden, professor at Franeker and Amsterdam. Van Swinden employed in his metaphysics a Cartesian dualism of the bodily and the immaterial world. The latter should be investigated by mathematics and metaphysics, the former by observations. Thus, Van Swinden insisted on a sound combination of rationalism and empiricism for investigating nature, which according to him had a God-given, all-encompassing, teleological order. According to Van Swinden's interpretation, it was Newton who had managed to combine the deductive and the inductive method in a fruitful manner.

This book maintains that even the three Leiden professors who became the figureheads of Newtonianism throughout Europe – Herman Boerhaave, Willem Jacob 's Gravesande and Petrus van Musschenbroek – cannot simply be regarded as 'dogmatic' Newtonians. Rina Knoeff elaborates in chapter 3 that Herman Boerhaave – the first who openly supported Newton in an academic oration – hardly used Newton's mechanical philosophy at all in his medical work. At the beginning of his career, Boerhaave applied Newton rhetorically to criticize the method of Descartes, as an example of a sound use of mathematics in the study of nature. As he later in his career became increasingly skeptical about the usefulness of the mechanical method for medicine, he no longer referred to the 'mathematical' Newton, but rather to his chemistry, to the experimental approach of the *Opticks*. Knoeff concludes that although Boerhaave was inspired by Newtonian methods, he was at the same time critical about Newton's results. Boerhaave's turn to chemistry, with its emphasis on non-mechanical powers in the body, even caused a decline of Newtonian medicine from the 1740s onwards.

Nor did Willem Jacob 's Gravesande, the most influential disseminator of Newton's ideas in the first decades of the eighteenth century, always follow in the steps of his master. As Ad Maas argues (chapter 4), 's Gravesande decided to spend his life on popularizing Newton's natural philosophy not only because of its supreme intellectual qualities but also because it coincided with 's Gravesande's personal preferences and furthered his career. Maas suggests that by dissociating Newton's natural philosophy from the metaphysical and theological concerns that had worried Newton's early Dutch followers, 's Gravesande paved the way for the introduction of Newton's natural philosophical system into the Dutch academic curriculum.

Kees de Pater suggests in chapter 5 that in the case of Petrus van Musschenbroek, too, there is a marked discrepancy between rhetoric and scientific practice. Although Van Musschenbroek portrays himself as a wholehearted follower of Newton, he deploys in his research a rather individual interpretation of what Newtonianism concerns, focusing especially on its empirical aspect. As De Pater concludes, the limits of this approach became clearly visible in Van Musschenbroek's research, which tended to result in a rather pointless piling up of experimental data. On the other hand, Van Musschenbroek was not always able to abstain from 'feigning hypotheses' when speculating about the nature of matter and forces.

Two of the contributions to this volume reach beyond the borders of the Dutch Republic. The tragic central figure of Jordy Geerling's article (chapter 8), Johann Konrad Franz von Hatzfeld, was a German lackey, who spent some years in England, but also stayed for a while in the Republic, the refuge for a number of European freethinkers. In The Hague, Hatzfeld published his *La découverte de la vérité* (1745), which contained a ferocious attack on Newton's natural philosophy. Hatzfeld was condemned for the opinions he expressed in his book, not for his attack on Newton, but for his radical religious and political views. His books were burnt and Hatzfeld was banished.

Hatzfeld's story is a case study in how personal and social factors could lead to radicalization. By following Hatzfeld's footsteps, Geerlings opens a fascinating panorama of marginal intellectuals who built *perpetua mobilia* and considered fermentation to be the driving force of the universe, and of radical Wolfians, *Aletophilen,* Freemasons and — to be sure — anti-Newtonians.

In Rob Iliffe's article (chapter 2), the somewhat unfathomable figure of Nicolas Fatio de Duiller leads us over the border of the United Provinces. For a while Fatio held a unique position as a close collaborator of both Christiaan Huygens and Isaac Newton, and seemed to be on the brink of joining the ranks of the most prominent mathematicians and natural philosophers. For a brief period of time he seems even to have obtained Newton's assent for taking care of a revised, second edition of the *Principia*, in which Fatio would incorporate his own theory of gravity. However, the close association with Newton and Huygens also made it difficult for him to develop his own reputation in the community of natural philosophers, and after the first years of the 1690s, he gradually faded from view.

In contrast to the other articles in this volume, Iliffe's contribution addresses not the dissemination, but rather the genesis of Newton's ideas. His story describes the intriguing period directly after the publication of the *Principia*, in which its contents were widely discussed and its main conclusions had not yet taken shape as the indisputable laws of mechanics. This was also the period in which the controversy between Newton and Leibniz about differential calculus started. In both developments, Fatio and Huygens played a significant role. Also in contrast to the other contributions in this book, we see in Iliffe's chapter the 'real' Newton in action. It is here that we finally meet a person who can safely be considered as a Newtonian.

Between the English and the Dutch coast lies the North Sea. It is often from this direction that dense fog penetrates the Netherlands. Sometimes, in the patches of fog that move over the country, one can recognize, with a little imagination, the figure of Isaac Newton, chasing the ghost of Spinoza.

Note

1 We would like to thank Pete Langman and Nadine Akkerman, who came up with the idea for this conference.

‘The Miracle of Our Time’

How Isaac Newton was fashioned in the Netherlands

ERIC JORINK AND HUIB ZUIDERVAART

Introduction

It has more or less become a truism that the Dutch Republic played an important, not to say crucial, role in the spread of ‘Newtonianism’ in Europe during the early eighteenth century.[1] As Klaas van Berkel has written:

> It is partly or even mainly thanks to intellectual circles in the Dutch Republic that Newton’s ideas were after all accepted in the rest of Europe; Dutch scientists and Dutch manuals were responsible for the spread of Newtonianism through Europe. For once, the Netherlands was indeed the pivot of intellectual Europe.[2]

It is well known that in 1715 Herman Boerhaave (1668–1738), by far the most famous professor of the Dutch Republic, was the first academic to speak in public strongly in favour of Newton, calling him ‘the miracle of our time’ and ‘the Prince of Geometricians’.[3] In the very same year, the mathematician and burgomaster Bernard Nieuwentijt (1654–1718) published his *Het regt gebruik der wereldbeschouwing* (The Religious Philosopher: Or, the Right Use of Contemplating the Works of the Creator), a work which would become extremely popular, both in the Netherlands and abroad, and which made important references to Newton.[4] *Het regt gebruik* contributed much to the popularity of the experimental natural philosophy, so characteristic of eighteenth-century Dutch culture. Moreover, in 1715 a young journalist and lawyer named Willem Jacob ’s Gravesande (1688–1742), travelled to London as secretary to the Dutch ambassador. Here, he attended John Desaguliers' lectures, made acquaintance with Newton and was elected a Fellow of the Royal Society. Having tasted English 'Newtonianism', in 1717 's Gravesande was appointed professor of mathematics and astronomy at the famous University of Leiden. As such, he was in the right position to preach the gospel of Newton. Three years later, in 1720, 's Gravesande published his well-known *Physices elementa mathematica, experimentis confirmata: sive introductio ad philosophiam Newtonianam*. In this work, 's Gravesande gave a systematic account of 'Newtonian' physics as he saw it. The work was an instant success, going through many editions, translations and reprints. It was through 's Gravesande's handbook that his 'Newtonianism' was exported to Britain. 's Gravesande acquired such a reputation as an apostle of Newton, that an ambitious young Voltaire came to Leiden in 1735 to follow the professor's lectures. Voltaire, already fascinated by Newton and his natural philosophy, was by then working on his own *Élémens de la philosophie de Newton*, to be published in Amsterdam in 1738.

For a long time, the sudden popularity of Newton in the Dutch Republic seemed to need no explanation: 'Newtonianism' was seen as the logical step, from 'Aristotelianism', via 'Cartesianism', towards modern science. From this perspective, the introduction in 1715–1717 of Newtonian physics into the academic curriculum was inevitable.

In this article, we will argue that 'Newtonianism' is a rather problematic term in the Dutch context. The success of Newton's conception of nature was not predetermined, nor was it self-evident. The philosophical concept named after the great Englishman was an elaboration of an already existing tradition of empirical research, founded in Leiden in the early seventeenth century: Newton, as he was fashioned by the Dutch, fitted nicely into this tradition. In 1715, in the context of the Protestant Dutch Republic, Newton was modelled into a useful icon, to combat the clergy's growing fear of extreme rationalism. The emergence of Dutch 'Newtonianism', and the popularity of Newton himself, can only be understood in the light of the philosophical and theological developments of the late seventeenth century. For that reason we will present an outline of these developments. 'Newtonianism' in the Dutch context was not an imported coherent system, waiting to be implemented, but a philosophical — and to a certain extent social — construction, created for and adapted to specific local problems and circumstances.

Scientific culture in the Dutch Republic

In the mid-seventeenth century the young Dutch Republic had become one of the most flourishing countries of early modern Europe, not only in terms of commerce but also in terms of art, learning, science and technology.[5] During the Dutch Revolt many Protestants had fled the Catholic South and started a new life in the North. This had far-reaching consequences: while intellectual life in the sixteenth century had been concentrated in the Southern Netherlands, especially in Antwerp and Louvain, the emphasis now shifted to the North.[6] The Amsterdam region became a particular hub of trade, traffic and technology, drawing not only Protestant refugees from the Spanish Netherlands, but also many Scandinavians and Germans who escaped the Thirty Years' War, as well as Sephardic Jews and (later in the seventeenth century) French Huguenots. This mixture of persons, ideas and goods provided a fertile soil for the exchange and creation of knowledge. In a recent volume, Sven Dupré and Christoph Lüthy state:

> the 'circulation of knowledge' was perhaps nowhere as intense as in the early modern Low Countries, and this had to do as much with the circulation of scholars which was, in the *Carrefour de la République des Lettres*, particularly lively, as with the extraordinary nodal points that cities like [first] Antwerp and [later] Amsterdam represented in the international exchange of goods, news, and skills.[7]

Lacking an older scholastic tradition, the newly founded Protestant universities of the North, especially those of Leiden (established in 1575) and Utrecht (established in 1636) could be more innovative than most of the older universities. They attracted many students, professors and visitors from abroad. To give a few examples: the Leiden medical faculty improved upon the new approach introduced by the Italian universities in the sixteenth century. A *theatrum anatomicum* was established in 1590, as well as a *hortus botanicus* in 1594, both supported by huge collections of curiosities. In 1634 the university founded an astronomical observatory (the first of its kind in Europe) and clinical teaching started two years later, becoming famous throughout Europe during the professorship of the iatro-chemist Francis de le Boë Sylvius (1614–1672). Up to the era of Boerhaave (1668–1738), Leiden's medical faculty was considered the best in Europe, attracting many students from all over the Continent.[8] An empirical approach towards the investigation of nature thus lay deeply rooted in the academic curriculum.

An important factor was the religious context of scientific discourse and practice. The Northern Netherlands was a striking example of religious pluriformity. The most powerful denomination was the Reformed (*Gereformeerde* or *Contra-remonstrant*) Church, which was, however, not the largest in terms of membership; it contained several currents, ranging from the Puritan-like orthodoxy of the influential Utrecht professor of theology Gisbertus Voetius (1589–1676), to the more liberal followers of his Leiden colleague Johannes Cocceius (1603–1669). Although the Reformed Church was never to acquire the status of a state religion in the young Republic, and was in fact just one of the many denominations in the religious landscape, it was privileged, and those who held public office (including university professors) were required to subscribe to its doctrines. Besides the Reformed Church there existed a stunning variety of denominations, such as the Remonstrants, Mennonites, Huguenots, Lutherans, Jews, and all kinds of sects, such as Collegiants, Millenarians, Quakers, Labadists and Borelists. Moreover, there was a large Catholic minority. Two things are of importance here: first, that the religious pluriformity of the North stimulated theological, philosophical and scientific debates; and, second, that the largely Protestant culture of the North had a strong undercurrent of natural theology which, in turn, encouraged an open eye towards God's creation. The notion of the Book of Nature, that is to say, the idea that Creation was the second revelation of God next to the Bible, was of great influence. Important in this respect is the so-called 'Belgic Confession' of 1561, a document that formed the basis of the orthodox Reformed Church in the Dutch Republic. Article II, in the edition of 1619, runs:

> We know him [God] by two means. First, by the creation, preservation, and government of the universe, since that universe is before our eyes like a beautiful book in which all creatures, great and small, are as letters *to make us ponder the invisible things of God: his eternal power and his divinity*, as the Apostle Paul says in Romans 1:20. All these things are enough to convict men and to leave them without excuse. Second, he makes himself known to us more openly by his holy and

divine word, as much as we need in this life, for his glory and for the salvation of his own.[9]

Since nature was God's creation, the study of nature was an enterprise with strong religious connotations. The order of nature as a whole, as well as the existence of each and every individual creature, was seen as the manifestation of God, the almighty Architect. This principle was invoked by those who advocated empiricism.

Of similar importance in this respect was René Descartes (1596–1650), who lived in the Dutch Republic from 1628 to 1649. His revolutionary new philosophy, as outlined in the *Discours de la méthode* (published in Leiden in 1637), was embraced from the start by some university professors from Utrecht and Leiden.[10] To Dutch professors of the (higher) faculty of medicine and the (lower, propaedeutic) faculty of philosophy, Descartes' rationalism and his geometrical, mechanistic approach towards nature, seemed an all-encompassing alternative to the increasingly problematic philosophy of Aristotle. It was within a Cartesian context that new hypotheses, such as Nicolaus Copernicus' heliocentric theory (*De revolutionibus orbium coelestium*, 1543) and William Harvey's theory of the circulation of the blood (*De motu cordis*, 1628) were debated and – after fierce opposition by orthodox theologians – gradually accepted.[11] The work of Christiaan Huygens (1629–1695), by far the greatest mathematician and natural philosopher of the Dutch Golden Age, is unthinkable without Descartes (although he developed an increasingly sceptical attitude towards the Frenchman's work).[12]

However, in the eyes of orthodox theologians and philosophers, Descartes' philosophy threatened to destroy old certainties. Descartes not only offered a new natural philosophy, but a new epistemology and metaphysics as well. Cartesian doubt seemed to open the gate to scepticism and even to atheism. Cartesian physics seemed to presuppose God as a distant engineer and, probably worst of all, Cartesian rationalism implied that *all* of God's creation could be explained and understood. In 1642, the orthodox party, led by Voetius, started a long and bitter campaign against the New Philosophy. Although Cartesianism was twice officially banned from the Universities of Leiden and Utrecht, it was never threatened seriously. The universities' curators tried to effect a peaceful coexistence between the two sides, alternately appointing Cartesians and Aristotelians to the chairs of medicine, philosophy and even theology. Nevertheless, the relations remained strained.

The orthodox Voetians saw their worst nightmare come true, when in 1670 Benedictus Spinoza (1632–1676) anonymously published his *Tractatus theologico-politicus*. Spinoza, amongst other things, drew the Cartesian notion of the immutable laws of nature to its logical conclusion: God was bound by his own laws and the Biblical miracles could thus never have happened. The Bible was not God's revelation to man, nor the key to nature's secrets, but only the history of a certain tribe in the Middle East. In the *Ethica* (published posthumously in 1678), Spinoza advocated at length the absolute certainties offered by the geometrical method. By now, to the orthodox clergy, rationalism and mathematics seemed the source of atheism and hence of all evil in the world. The problem was not only that Spinoza was seen as irreligious, since he postulated that God and Nature were identical (the notorious *Deus sive Natura*), but that he claimed his atheistic ideas to be based on absolute mathematical certainty.

This was what rationalism would inevitably lead to: an attack on the authority of Scripture. Spinoza's philosophy was abhorred by nearly all of his contemporaries, who were convinced that rationalism and the geometrical method would inevitably lead to atheism. In the eyes of many Dutchmen, Spinoza reaped the harvest that Descartes had sown. The Leiden Reformed consistory noted with disgust that the *Opera posthuma* 'perhaps since the beginning of the World until the present day [...] surpasses all others in godlessness and endeavours to do away with all religion and set godlessness on the throne'.[13] The Leiden city council and the governing body of the university decided that, since the *Opera* paved the way for 'an absolute *atheism*', the book was to be banned immediately, all copies sold were to be confiscated and burned, and the owners fined.[14] After ample deliberations, the book was banned by the States of Holland for containing 'very many profane, blasphemous, and atheistic propositions'.[15]

Besides the contents of Spinoza's philosophy, there was also a force at work that can be called the personal factor. While earlier philosophers such as Aristotle, Francis Bacon (1551–1621) and even Descartes were only vaguely associated with real persons, the memory of the 'most horrible of atheists', the 'apostate Jew', the 'destroyer of Christianity' remained much alive during the eighteenth century. Pierre Bayle (1647–1706), '*le philosophe de Rotterdam*', included an entry on

Spinoza in his famous *Dictionaire historique et critique* (first edition 1697; in later editions this entry was expanded), which was immediately issued as a separate treatise in Dutch, *Het leeven van B. De Spinoza, met eenige aanteekeningen over zyn bedrijf, schriften, en gevoelens* (1698).[16] On the basis of thorough research, the Lutheran minister Johannes Colerus (1647–1707) published his short biography of Spinoza in 1705.[17] Although both writers vehemently rejected Spinoza's system, they had to admit that the philosopher had lived like a saint: modest, peaceful, abstemious. This image was endorsed by Spinoza's correspondence, first published in the banned *Opera posthuma* (1678), and available to a wide audience through the translation published in *De boekzaal van Europe* in 1705. Spinoza really presented the most pressing intellectual problem of the later seventeenth and early eighteenth century.[18]

Newton enters the stage

It was against this background that Newton entered the Dutch intellectual sphere. The first serious attention given to Newton in the Netherlands followed the publication of 'An Accompt of a New Catadioptrical Telescope' in the *Philosophical Transactions* of March 1672. Very few Dutchmen were able to read English at that time, but the invention was also discussed in the *Journal des sçavans*, an edition of which was published in Amsterdam in 1673. It was Christiaan Huygens who had been personally responsible for the French analysis. Already in January 1672 Huygens was informed of Newton's invention, in a letter by Henry Oldenburg (c. 1618–1677), the secretary of the Royal Society. Huygens immediately informed Jean Gallois, the editor of the *Journal des sçavans*, of this remarkable new kind of telescope.[19] Shortly afterwards, in March 1672, Oldenburg sent Huygens Newton's 'New Theory about Light and Colours', which was published in the current issue of the *Philosophical Transactions*.[20] Again Huygens gave a positive response. In July 1672 Huygens wrote to Oldenburg that he appreciated the 'colour hypothesis of Mr. Newton', and although the 'Experimentum crucis' was a bit obscure in its presentation, he understood that it underscored Newton's new optical theory.[21] Newton's invention and his new theory of light prompted Huygens, a skilled lens-grinder who had constructed telescopes and discovered the rings of Saturn, to follow Newton's work intensely; it had the same effect on lesser minds.[22]

Dutch reactions to the first edition of Newton's *Principia* (1687)

The publication of Newton's *Principia* in 1687 aroused great attention in the Netherlands, but only among a small minority. It is well known that Huygens received a copy from the author, studied the book intensively, and discussed its contents with Nicolas Fatio de Duillier (1664–1753). 'I wish to be in Oxford', Huygens wrote to his brother, 'just to meet Mr. Newton, for I greatly admire the beautiful inventions that I find in the book he sent me'.[23] Huygens was much impressed by the book, although he did not subscribe to its main idea: the theory of universal gravitation. To Huygens, still working within what might be called a Cartesian framework, the concept seemed to bring back qualities such as occult powers and hidden properties. Newton's theory just seemed 'absurd'.[24] Nevertheless, Huygens appreciated the mathematical ingenuity of the *Principia*, and he recommended the book to the influential Amsterdam burgomaster Johannes Hudde (1628–1704), one of the very few other Dutchmen able to follow Newton's calculations.[25] As Rob Iliffe describes in this volume, Huygens remained for some years in close contact with Newton, using Fatio de Duillier as a go-between.

A third important Dutch intellectual to be acquainted with the *Principia* at a very early stage was the Leiden professor of philosophy Burchardus de Volder (1643–1709).[26] De Volder, a close friend of Huygens and Hudde, personally met Newton as early as 1674, when he visited England. He was much impressed by Boyle's and Hooke's experiments performed at the Royal Society. Back home in Leiden, and with the approval as well as the financial support of the Leiden curators, he started a *theatrum physicum* in which he used a Boylian air-pump to illustrate his lectures. Leiden University was the first in Europe to provide such facilities for experimental philosophy. Cambridge (where Newton had lectured from 1669 to 1701) followed in 1707, while Paris had to wait until 1751. But as pioneering as it was, De Volder's initiative fitted neatly into the long-standing empirical tradition in Leiden that had begun with the *hortus botanicus* and the *theatrum anatomicum*. Tellingly, the curators approved De Volder's request in the hope that 'many students from other universities and academies will be lured hither' by his often spectacular demonstrations.[27] By way of these demonstrative experiments, De Volder (and his lesser-known colleague, Wolferd Senguerd, 1646–1724) created a fertile ground for the blossoming of eighteenth-century experimental physics.

Although De Volder also had the privilege of receiving an author's copy of Newton's *Principia*, he never became an advocate for the work's theories. De Volder's experimental method was evidently inspired by Boyle, not by Newton. Much like his friend Huygens, De Volder admired the mathematical side of Newton's work, but he only mentioned Newton in passing during his academic career.[28]

This was not the case in the lectures of the Scotsman Archibald Pitcairn (1654–1713), a friend and early follower of Newton, who in 1692 was appointed professor of medicine in Leiden. However, he left this post within a year. Although it is suggested that Pitcairn had an impact on a number of Scottish students who had followed his Leiden lectures, there is no hard evidence that he gained any Dutch followers.[29]

There are other indications that the Leiden academic community had little interest in Newton's book. In 1687 the influential Leiden bookseller Pieter van der Aa (1659–1733) received twelve copies of the *Principia* in commission from Newton's publisher in London, with the explicit intention of selling them on the Dutch market and at the Frankfurt book fair. But after two years of prudence Van der Aa returned the seven copies that still remained in stock.[30] Through the purchase of the famous library of Isaac Vossius (1618–1689), Leiden University acquired a copy of the *Principia* as early as 1690, but it took twelve years before the collection could be consulted.[31] Even in 1711 the Leiden professor in chemistry, Jacobus le Mort (1650–1718), ridiculed Newton's concept of universal attraction.[32] So before 1715, in academic circles, Newton was admired as a mathematician, but not as a physicist.

Amsterdam mathematical enthusiasts

As Rienk Vermij has shown, the earliest Dutch admirers of Newton were not to be found among university professors, but among an informal group of Amsterdam mathematicians in the 1690s.[33] In the Dutch Republic, a lively intellectual culture existed, including many informal clubs where philosophical, religious and scientific ideas were debated. In the mid-seventeenth century most Dutch cities had a *theatrum anatomicum*, which not only served for a medical education, but were also used as cultural convergence points: places where a library was formed, natural history specimens were collected and intellectual discussion was possible.[34] And there were other forms of intellectual life too. To name a few examples: a group of early followers of Spinoza held weekly meetings in the 1660s; in the same period the research-oriented Collegium Privatum Amstelodamense was founded, which focussed on comparative anatomy and included John Locke (1632–1704) during his stay in Amsterdam. In the 1690s the Haarlem-based Collegium Physicum discussed problems from the post-Cartesian textbook by Jacques Rohault (1618–1672), performing experiments and arguing with congenial enthusiasts from elsewhere, such as the Amsterdam Mennonite merchant Lambert ten Kate Hermansz (1674–1731) and the Rotterdam Quaker Benjamin Furly (1636–1714).[35]

The group of Amsterdam mathematicians seemed to have included a broker named Jacob Makreel, a Mennonite merchant named Adriaan Verwer (c. 1655–1717), and the physician, mathematician and regent Bernard Nieuwentijt, who lived in nearby Purmerend.[36] The group was interested not only in mathematics, but in philosophical and religious themes as well. They had many foreign contacts, including George Cheyne (1671–1743) and David Gregory (1659–1708), who kept them informed on British affairs. For example, Nieuwentijt, who was working on infinite series, learned from Gregory that Newton had already published on this topic (apparently this concerned the pieces included in John Wallis' *Algebra* of 1685). In 1694 and 1695 Nieuwentijt published two mathematical tracts on the brand new calculus, the *Considerationes* and the *Analysis infinitorum*, in which he rejected Leibniz's approach to the subject, but praised Newton, referring several times to lemmas from the book of 'this illustrious author', identified later on as the *Principia*.[37] So the Amsterdam group apparently discussed Newton's *Principia* at an early stage, and one wonders if its members were among the buyers of the five copies that Van der Aa had sold. Nieuwentijt considered Newton to be the greatest living mathematician, while Verwer embraced the universal law of gravitation. However, this support for Newton was strongly stimulated by ulterior motives.

The pious Verwer, an active member of the Amsterdam Mennonite congregation Het Lam en de Toren (The Lamb and the Tower), was typical of the many Dutchmen who sought God outside the boundaries defined by the orthodoxy of the Reformed Church.[38] Although Verwer as far as we know had no academic training, he knew Latin, was a skilled mathematician and maritime expert, and studied history, religion, philosophy and linguistics. He vehemently rejected the Spinozist conception of God and Nature. Already in 1683, he had published a refutation of Spinoza's *Ethics*, namely *'t Mom-aensicht der atheistery afgerukt* (Atheism Unmasked). Throughout his life, he continued to seek proof of non-natural and non-material forces in Creation, which he evidently found in the work of Newton.[39] Verwer's copy of the *Principia*, now in Utrecht University Library, contains his manuscript notes.[40] In his *Inleiding tot de christelyke gods-geleertheid* (Introduction to Christian Theology, 1698), Verwer explicitly referred to the *Principia* to prove that the elliptical shape of a planet's orbit would be impossible 'without the interception of a Governor, who exists outside these things'.[41] Elsewhere in his book, Verwer used Newton's formula for the inverse square law to give the mathematical proof that 'eternal happiness is proportional to good works, and inversely proportional to divine grace'.[42]

Anti-Spinozism was also to become a life-long concern for Nieuwentijt, who in 1715 and (posthumously) in 1720 would publish two books explicitly directed against the 'ungodly philosopher', namely *Het regt gebruik der wereldbeschouwingen, ter overtuiginge van ongodisten en ongelovigen* (translated into English by John Chamberlayne as *The Religious Philosopher: Or, the Right Use of Contemplating the Works of the Creator* in 1718) and *Gronden van zekerheid [...] ter wederlegging van Spinoza's denkbeeldig samenstel* (Grounds of Certainty [...] Intended to Refute Spinoza's Imaginary System).

The main objections of Verwer and Nieuwentijt to Spinoza were that he did not believe in God as the Almighty Creator, but only in blind fate and chance and, moreover, that he undermined Christian faith by claiming absolute mathematical certainty. Both Verwer and Nieuwentijt sought to do the opposite, i.e. to strengthen Christianity on the basis of mathematical arguments. And it was here that Newton was put to use. The Englishman was seen as a brilliant mathematician of unimpeachable conduct. But more importantly, Newton made a clear distinction between pure and applied mathematics. Mathematics was essential for the study of nature, but only when mathematical reasoning was tested by experience could one say that mathematics had anything to do with reality.[43] This was crucial for Verwer and Nieuwentijt. In his *Gronden van zekerheid* the latter used this distinction to tackle Spinoza's claim to mathematical truth. Moreover, Newton was very clear about the place of God as the ultimate ruler of the universe. The metaphysical nature of gravity underscored this picture of Newton as a real Christian mathematician. Newton's work seemed to provide an uncontested basis for a truly Christian natural philosophy. Newton saved, so to speak, the mechanical way of reasoning, from the atheistic spell of Descartes and Spinoza.[44] Thus, in the wake of the publication of the first edition of the *Principia*, a small group in the Netherlands created an image of Newton which presented him not just as a pious mathematician, but as a philosopher whose message was relevant to the whole of Christianity. It was these aspects that set the stage for Newton's later success in the Dutch Republic.[45] Without this aura, he would never have been so influential.

Jean Le Clerc

This pious fashioning of Newton would have been impossible if his anti-Trinitarian tract, *An Historical Account of Two Notable Corruptions of Scripture,* which he had sent to Locke in the early 1690s, had been printed by the Amsterdam publisher Jean Le Clerc (1657–1736). This Swiss Huguenot had to flee from his native Geneva because of his unorthodox ideas and subsequently earned a living in Amsterdam as a journalist and professor of theology at the Remonstrant seminary. For a few months, Newton favoured the idea of allowing Le Clerc to publish a Latin or French translation of his *Historical Account*, but then he withdrew it.[46]

As is now well known, Newton spent much of his time on biblical criticism, millenarian prophecies and alchemy. Only a small circle knew of Newton's heterodox ideas. But in the wake of the *Principia*, he seriously considered publishing some of his religious works. In the *Historical Account*, Newton argued that the dogma of the holy Trinity had no foundation in Scripture, and that the biblical passages 1 John 5.7 (the 'Johannine comma') and 1 Timothy 3.16 were corrupt. Le Clerc's copy, written in Locke's hand, went missing. The work was finally published in 1754.[47] Had Le Clerc published it in the 1690s, Newton would have had a lifelong reputation among the Dutch for propagating unorthodox, if not heretical, ideas, putting him firmly in the camp of freethinkers and atheists, with Isaac la Peyrère (1596–1676), Isaac Vossius and Spinoza.[48]

Le Clerc, who was a personal friend of Verwer, would serve the 'Newtonian case' in other ways.[49] He edited the *Bibliothèque universelle*, which was the only Dutch-issued journal to publish a review of Newton's *Principia*. The review was printed anonymously in 1688, but was in fact written by Locke, who lived in the Dutch Republic from

1684 to 1688, and would have a notable impact on the intellectual life of the Netherlands.[50] Other Dutch journals, such as Pierre Bayle's *Nouvelles de la République des Lettres*, completely ignored the *Principia*.

Given Locke's review, Le Clerc must have had a basic idea of the *Principia*. But like Verwer, he was rather eclectic. When in 1696 he wrote a textbook on physics, he just repeated the views of several authors on various subjects, including a brief account of Newton's theory of gravity, which he used to repudiate the Cartesian vortices, although he still interpreted gravity in a corpuscular way.[51] Evidently Le Clerc accepted Newton's way of mathematical reasoning, without giving it credit as an accurate picture of reality.

The Amsterdam scholar would again pay attention to Newton's work after the 1706 Latin edition of Newton's *Opticks*, a work whose somewhat neglected reception in the Netherlands is addressed by Rina Knoeff and Fokko Jan Dijksterhuis in this volume. Le Clerc was one of the few in the Republic to review the *Opticks*. It is tempting to see a connection between the enthusiasm for Newton among the Amsterdam amateurs and the 'Newtonian' edition of Rohault's famous textbook on physics, issued in 1708 by the Amsterdam publisher Johannes Wolters.[52] At first sight Rohault's work was a manual on Cartesian physics, but in 1696 – and again in 1702 – the English Newtonian Samuel Clarke had produced an edition with very extensive notes, adding many references to the *Principia*. In fact, before 1713 this annotated Rohault edition was for many scholars the first introduction to Newton's way of physical reasoning.[53]

During these years Le Clerc's enthusiasm for Newton increased. In 1690, he called Newton 'this great mathematician' and in 1706 'one of the greatest mathematicians that ever lived'. But he really became a Newtonian after reading the second edition of the *Principia*, published in Cambridge in 1713. In a review in his new journal *Bibliothèque ancienne et moderne* he called Newton without reservations '*the* greatest mathematician the world has ever seen'.[54] According to Le Clerc, it was Newton who gave the *coup de grâce* to materialistic and atheistic speculations. As Vermij has noted, 'upon reading the second edition of the *Principia* Le Clerc apparently came to realize the full impact of Newton's ideas'.[55] In his review he focused mainly on Roger Cotes' preface and on the new 'Scholium', the two additions which were so successful in giving the highly abstract book a more philosophical twist. Le Clerc was a sworn enemy of Descartes' materialism and of Spinoza's conception of nature, and now he realized that Newton stipulated that the universe was governed by a force – gravitation – which could not be explained in any mechanical way. This anti-materialistic approach was exactly what he needed. The law of universal gravitation described with mathematical precision what happened in the heavens, but its nature was evidently metaphysical. It therefore provided the ultimate proof of God's existence. In 1715, in the introduction to a series of reviews of works by other British scholars, like George Cheyne, John Ray and William Derham, Le Clerc added that Newton's principles:

> show that it is impossible that the world has been made, and remains in its present state, by purely mechanical forces and movements. This leads us to recognise that there is a fully immaterial God, who is the creator of the world. [...] This is quite different from the principles of Descartes, who believed that it sufficed for God to have given motion to matter just once to see everything in the world, or at least everything material, come forth from it.[56]

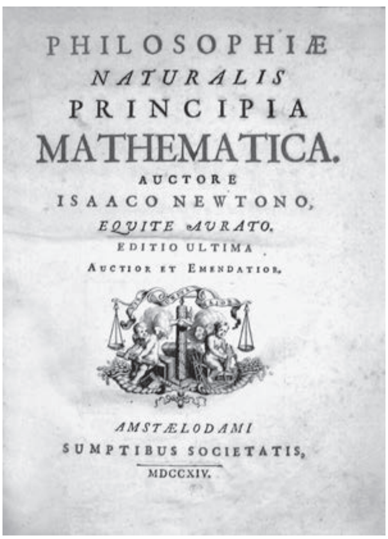
For the Dutch scholars Newton had published the second edition of his book at the right time. He entered the stage at a moment when the discontent with Cartesian physics and Spinozist rationalism was mounting. In other words, Newton became so successful not because he was right, but because he was useful. In the Dutch context, his work was increasingly considered as much more than a physical theory, but as the incontestable basis of a Christian philosophy of nature. Inspired by Cotes' foreword to the *Principia* and the remarks in the *Scholium*, the book was no longer seen as a rather abstruse hypothetical description of the world system, but as a major achievement in natural philosophy. Dutch culture at this time showed a preoccupation with mathematicians and the problem of certainty, as well as with atheism, and 'Newtonianism' was now presented as the answer to all these problems.

The pirated Amsterdam edition of the 1713 Cambridge version of the *Principia*

As is well known, the real triumph of Newton on the Continent started with the second edition of the *Principia*.[57] The Cambridge edition was published in May 1713, and according to a list personally made by Isaac Newton, probably some seventy copies were distributed as presentation copies, among which were four for the university libraries in Leiden, Utrecht, Franeker and Groningen.[58]

Bearing in mind that, among the group of scientific enthusiasts in Amsterdam, Newton was seen as an anti-atheistic and trustworthy guide to a new handling and study of nature, we can now understand better why within a few months after the second Cambridge edition of the *Principia*, a pirated version was printed, with a new typeface and re-engraved plates, in the city. In the Newtonian scholarship little attention is given to this Amsterdam edition, which appeared first in 1714, and was reprinted in 1723 in a slightly expanded version (fig. 1).[59] A closer look at these two pirated editions reveals some intriguing facts, relevant to a better understanding of the reception of Newton in the Republic.

The Amsterdam edition was announced in July/August 1713 in a new Dutch-issued journal in French, the *Journal littéraire de La Haye*. The anonymous journalist wrote that this reprint was to be published by a company of booksellers ('*une compagnie des libraires*') and would be based on the second edition of the *Principia* which had just been



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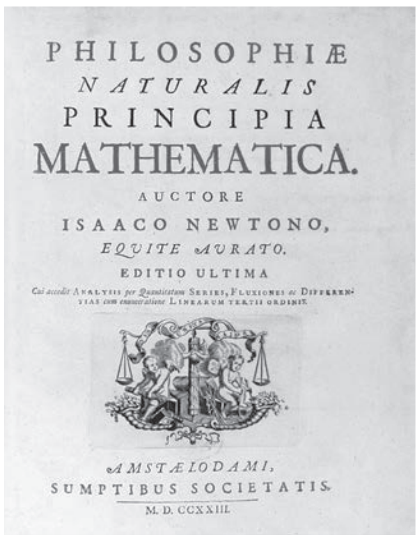

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Cui accedit ANALYSIS per Quantitatum SERIES, FLUXIONES ac DIFFERENTIAS cum enumeratione LINEARUM TERTII ORDINIS.
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SUMPTIBUS SOCIETATIS.
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Fig. 1 & 2: The two Amsterdam reprints of Newton's *Principia*, issued by an 'anonymous' Amsterdam publisher, using the device *Vis unita major* (The united force is greater).

published in England ('*qui vient de paroître en Angleterre*').[60] Obviously, the editors of the *Journal* were very well informed about events both in England and in Amsterdam. It soon turned out that the pirated edition was issued as a joint venture of at least ten Amsterdam booksellers and printers, using the device *Vis unita major* (The united force is greater). This company was founded in 1711 in response to an agreement between 54 book publishers from Amsterdam, Leiden, The Hague, Rotterdam and Utrecht, in an attempt to regulate the book trade. The pirating of foreign books was also discussed in this compact, which in some cases would be an enterprise only to be tolerated if it was a concerted action, with a shared profit.[61]

In regard to the *Principia* the obvious question is: why would such a large group of booksellers expect a profit from the illegal issue of a just-reprinted difficult book, the sales of whose first edition of 250–400 copies had been notoriously poor? Why did they expect to profit from this investment? And who took the initiative for this costly enterprise – with an estimated print run of 750 copies – and for what reasons?[62]

As we will outline below, the 1714 Amsterdam reprint coincided with a Newtonian offensive not only by Le Clerc, but also by Boerhaave, Nieuwentijt, 's Gravesande and the versatile scholar Lambert ten Kate. As Meindert Evers has already remarked in a survey of Newton's reception in one of Le Clerc's journals, it seemed that this was a *konzertierte Aktion*: a coordinated action to put Newton firmly on the map, as well as on the market.[63] The truth of this claim remains a matter of speculation, but it cannot be disputed that within three years of the launch of the second edition, many Dutch professors and non-academics, both in Latin and in the vernacular, strongly spoke out in favour of Newton and his method. So let us examine the Amsterdam reprint in greater detail. Who might have been involved in it?

Let us start with the announcement in the *Journal littéraire* of July/August 1713. This journal had been started just a few months before by Thomas Johnson, a Scottish bookseller whose shop in The Hague was a centre for British citizens residing in Holland. It was probably Johnson who organized a steady correspondent for the *Journal littéraire* in London, in the person of Pierre des Maizeaux (c. 1666–1745), a Huguenot and an acquaintance of Le Clerc.[64] In 1720 Des Maizeaux would also edit the Amsterdam edition of the famous Leibniz-Clarke correspondence on the priority dispute with Newton in regard to the invention of differential calculus.[65] Since 1708 Johnson had maintained close contacts with the Amsterdam publisher Jean-Louis de Lorme (one of Le Clerc's main publishers), who (until his departure to France in 1711) provided him — as the only bookseller in The Hague — with a copy of all the '*livres étrangers*' published in Amsterdam.[66] After 1711 De Lorme's role as Le Clerc's publisher and probably also as Johnson's provider of foreign books was taken over by the brothers Rudolf and Gerard Wetstein.[67] This publishing company participated in the *Vis unita major* book company that would publish the *Principia*. So it is evident that information, both from the English edition of the *Principia* and from the Amsterdam initiative, came together in The Hague.

Then there was the editorial board of the *Journal littéraire*. At its very start in 1713 the journal was run by two Dutch Huguenots, Albert Henri de Sallengre (1694–1723) and Thémiseul de Saint Hyacinthe (1684–1746), together with two genuine Dutchmen, Justus van Effen (1684–1734) and Willem Jacob 's Gravesande. As Ad Maas describes in his contribution to this volume, in later years 's Gravesande would become the most influential figure in spreading the fame of Newton and systematizing a natural philosophy he called 'Newtonianism'. But in 1713 's Gravesande was still working as a lawyer in The Hague, having finished his education at Leiden University in 1707, where he had matriculated in the faculty of law three years before. However, 's Gravesande had been interested in mathematics, physics, ethics and philosophy for a long time and during his student years he even wrote a work, *Essai de perspective*, which was published in The Hague in 1711. There he became one of the founders of the *Journal littéraire* (1713). Most likely, it was 's Gravesande who was the editor responsible for the many articles devoted to physics and mathematics.[68] Generally, the *Journal* took a leading role in propagating books on natural theology, such as Derham's *Physico-theology*, with the explicit aim of refuting atheism.[69]

We know for certain that 's Gravesande was acquainted with Bernard Nieuwentijt, who was directly related to the Amsterdam mathematicians. Contacts between Nieuwentijt and 's Gravesande date back to 1712, when the latter made a calculation on the ratio of the number of newborn boys and girls, a piece which Nieuwentijt would include in his aforementioned book, *Het regt gebruik*.[70] This bestseller was published in 1715 by the widow of Johannes Wolters, together with her son from an earlier marriage, Joannes Pauli. They too were participants in the Amsterdam *Vis unita major* company that brought the *Principia*

Fig. 3: Jean Le Clerc, together with Willem Jacob 's Gravesande, the main constructor of Dutch 'Newtonianism'.

into print. As a matter of fact, in *Het regt gebruik* some vignettes are exactly identical to those used in the pirated edition of the *Principia*.[71]

When we combine these facts with a statement made in 1722 in a letter by Nicolaas Struyck (1687–1769), an Amsterdam mathematician with close connections to the Amsterdam *Vis unita major* publishing consortium, the identities of the actors responsible for the Amsterdam Newton editions becomes more clear.[72] To one of his correspondents Struyck remarked that he had found some printing errors in his own 1714 Amsterdam copy of Newton's *Principia*, which faults he would report to 'Professor 's Gravesande, *who is here supervising a third edition*'.[73] Obviously this was *not* a statement concerning the genuine third *London* edition, issued by Cotes in 1726, but rather the second Amsterdam printing of the *Principia*. This edition with a new typeface was issued in 1723. Moreover, this second Amsterdam printing would become the only version in which Newton's wish to include four small mathematical tracts was fulfilled. Who else than a person with close contacts to Newton could be aware of this wish of the great 'Master'?[74] With this knowledge in mind, it seems plausible that a collective effort of Le Clerc, 's Gravesande and, perhaps, Nieuwentijt, was the driving force behind the Amsterdam printing of 1714. 's Gravesande probably played the same role at the second extended print run of 1723.

Putting Sir Isaac on the shield: The construction of an anti-atheistic Dutch 'Newtonianism'

In early 1715 Jean Le Clerc contributed to the 'new' Newtonian offensive by including in his *Bibliothèque ancienne et moderne* a French translation of large parts of a book by the British 'Newtonian' George Cheyne, entitled *Philosophical Principles of Natural Religion* (London 1705). In this publication Le Clerc again pointed to 'the most sublime and very important truths' that Newton had discovered.[75] Based on Le Clerc's lengthy summary in the *Bibliothèque*, the aforementioned Lambert ten Kate soon made a loose Dutch translation, to which he added extensive personal remarks.[76] Like his close friend Verwer, Ten Kate had a Mennonite background. As a well-to-do citizen, he could spend most of his time as a *virtuoso*, studying history, the arts, linguistics, philosophy and the natural sciences. Ten Kate certainly used Newton's thoughts on religion to promote scientific interest among the Dutch. The long title of his adaptation of Cheyne, published in 1716, leaves little doubt as to Ten Kate's interests: *Den Schepper en Zyn bestier te kennen in Zyne schepselen* (To Know the Creator from His Creatures, According to the Light of Reason and Mathematics, [written] to Cultivate a Respectful Religion; to Destroy the Basis of Atheism; and for an Orthodox Use of Philosophy).[77] According to Ten Kate, all scientific research should be subservient to a better understanding of divine Revelation. In the introduction of his book, Ten Kate underlined the fact that Descartes' mechanical philosophy led to Spinoza's system. However, both philosophers had neglected experience and experiments, and had abused mathematics, 'but some distinguished men in England, who disliked the uncertainties of hypotheses, have based themselves only on a *Philosophia Experimentalis*, by means of mathematics'.[78] The success of this approach was demonstrated by 'the most famous mathematician *Newton*' who had discovered the law of gravitation, thereby eliminating the dangers of philosophy and putting mathematics at the basis of religion: 'Sir Newton gave such a mathematical account of Nature, that man cannot but see God's hand in the appearances (as Professor Cotes justly states in the second edition of Newton's work)'.[79]

Le Clerc was very pleased with Ten Kate's work. It was the only book in Dutch ever to be reviewed in the *Bibliothèque ancienne et moderne.* In their approval of Newton's method, Le Clerc and Ten Kate were followed by Herman Boerhaave. The Leiden professor, without any doubt the most famous Dutch scholar of his time, was the first academic to speak publicly in Newton's favour.[80] The occasion on which Boerhaave delivered his *Sermo academicus de comparando certo in physicis* was highly symbolic and without doubt deliberately chosen. It was on 8 February 1715, the 140th anniversary of Leiden University, and the day Boerhaave resigned as Rector Magnificus. Instead of addressing a medical subject, Boerhaave raised his eloquent voice to make a bold statement that concerned the members of all faculties. Since physics was essentially the study of God's creation, the method followed was of relevance to Christian society as a whole. In plain language, Boerhaave rejected the speculations by Descartes and the dangerous pretensions by some ungodly mathematicians, i.e. the Spinozists. Instead, he advocated the method of Newton, 'the miracle of our time', 'he who deserves everywhere to be honoured as the leading figure', 'the Prince of Geometricians'.[81] It was only through Newton's method that certainty was to be achieved: 'Everything that has been discovered in physics by geometricians through deduction from observation stands with such unshaken truth that not a single mortal has any doubt on these points – whereas fictions soon collapse and show their true nature'.[82] Although some orthodox Cartesians, such as the Franeker professor of philosophy Ruardus Andala (1665–1727), protested vehemently, it was clear that the intellectual climate was changing.[83] As Rina Knoeff notes in her contribution to this volume, Boerhaave himself, after his programmatic and highly political oration, never introduced Newton's ideas into his courses, nor paid much attention to the Englishman. This only reinforces the impression that Boerhaave's outburst in favour of Newton was part of a coordinated action.

To be sure, only a few months later, Bernard Nieuwentijt published his *Het regt gebruik der wereldbeschouwingen*, which was an explicit attack on Spinoza. In this book Nieuwentijt pointed out how sound scientific principles demonstrate the wisdom and power of the Creator. Science was here mainly understood as experimental physics and

Nieuwentijt often referred to Newton's *Principia* (both the first and second editions). However, Nieuwentijt, who maintained a literal reading of the Bible, was somewhat cautious in praising Newton's system too much, since this implied that he had to speak out in favour of the heliocentric system. Nevertheless, according to Nieuwentijt, Newton was to be counted among the greatest philosophers of his age, whose work demolished the system of Spinoza. Nieuwentijt's work immediately became a bestseller. The book went through eight editions and would inspire many Dutchmen to write and publish books with a similar approach.[84]

's Gravesande's career switch

Thus, within two years, an academic audience as well as a more general public was instructed on how the dangers of Spinozism could be counteracted by the work of Newton. His Dutch admirers started to develop a systematized interpretation, adapted to local circumstances and local needs. In subsequent years 's Gravesande would become by far the most influential figure in this process. As we have seen, he took a strong interest in natural philosophy and scientific culture when he was a lawyer and an editor of the *Journal littéraire de La Haye*. In 1715 his career took a rather unexpected turn when he was asked to become the secretary of a Dutch diplomatic mission to England.[85] According to the biography of 's Gravesande by his student Jean Allamand (1713–1787), it was on this trip that he became converted to Newtonianism. But as we hope to have demonstrated, there are good reasons to believe that 's Gravesande was already very much aware of the significance of Newton's work and its potential for the Dutch intellectual climate before his journey to England.

Be this as it may, shortly after his return, in May 1717, 's Gravesande received the surprising invitation to become professor of mathematics and astronomy at Leiden University, more or less as the successor to De Volder, who had died in 1709.[86] 's Gravesande's inaugural address, *De matheseos in omnibus scientiis praecipue in physicis usu* (1717), touched upon the same theme as Boerhaave's oration of 1715: the thorny problem of certitude in science. Once more, Newton was introduced as the antidote to the poisonous Spinoza. 's Gravesande's ambitions went much further than to deliver a methodological *oratio pro domo*. During his entire career he wanted to be a philosopher of the commonwealth, concerned with the well-being of society at large. Later in life 's Gravesande would formulate what has been aptly described as his 'surviving-axiom': the conviction that truth is essentially an idea that is not in contradiction with the values of society (i.e. Christianity) as such. Morality and science constituted two sides of the same coin.

The newly-appointed professor started his oration by saying that many people distrust mathematicians, and even consider them atheists. Indeed, there had been mathematicians who denied the existence of God – an obvious reference to Spinoza – but that did not mean that mathematics was bad in itself. On the contrary, by means of this discipline we could understand something of the immutable laws God imposed on nature:

> These laws, which depend on the will of the Creator alone, must be drawn out, so to speak, from the phenomena themselves, since they are not revealed to us by any divine revelation. Men who construct hypotheses and use these as the basis of a system are running gladly into error and shutting themselves out from the gate of true physics.[87]

The only way to grasp the truth is to follow Newton's method of describing nature in mathematical terms, and trying to confirm the 'laws' thus formulated by observation and experiment. By proposing this combined mathematical-experimental method Newton was 'the king of the mathematicians and innovator of the true philosophy'. 's Gravesande was very explicit about the Englishman and described him as 'a man beyond all praise'.[88]

In the following decades, 's Gravesande was very successful at promoting Newton. He agreed with Newton that mathematical reasoning was important in natural philosophy, but in line with the Dutch empirical tradition, he made a firm distinction between pure and applied mathematics. Thus, although 's Gravesande remained critical towards his hero – the method was more important than the man – it was 's Gravesande who adapted Newton's work in such a way that it could be digested by its readers and taught at universities. His two-volume handbook *Physices elementa mathematica, experimentis confirmata,* with the significant subtitle *Introductio ad philosophiam Newtonianam* (1720–1721) not only became the most influential textbook on this subject in the eighteenth century, both in the Netherlands and abroad, but its title also suggested that there was such thing as a coherent Newtonian philosophy. That this Newtonian philosophy was for a large part 's Gravesande's own interpretation of Newton was not stated in so many words. He only admitted that 'Whoever would compare various philosophers' writings on "physics", could hardly doubt that this word designates many diverse branches of knowledge, even though all of them promise to convey the true cause of natural phenomena'.[89]

In his book 's Gravesande described the many experiments he had performed himself, and which could be copied by his readers and students. He elaborated upon De Volder's and Senguerd's teaching of experimental physics, putting the emphasis not on demonstrative, but on heuristic value. 's Gravesande was an ingenious inventor of instruments and had all his devices (including an apparatus to compare the velocity of falling bodies, and another demonstrating that the path of a thrown body is a parabola) built by the famous Leiden instrument workshop of Jan van Musschenbroek (1687–1748). The latter was the brother of Petrus van Musschenbroek (1692–1761) who, as Kees de Pater describes in this volume, would become 's Gravesande's colleague in 1736.[90] Thanks to 's Gravesande and the Van Musschenbroeks, Leiden University turned into Europe's most famous university in the field of natural philosophy. 's Gravesande's lavishly illustrated books contributed much to the popularity of physical experiments in eighteenth-century Dutch culture and abroad.[91]

The *Physices elementa mathematica* was 'the first general text of Newtonian science to be published on the Continent and one of the earliest to be published in England'.[92] The book was often reprinted, and translated into English (twice), French and (partly) Dutch. One English edition was translated by Desaguliers (1720–1721, many reprints) and another by Keill (1720; no reprints known).[93] 's Gravesande himself also published an abbreviated version, especially written for students, the *Philosophiae Newtonianae institutiones* (1723). He also edited an edition of Keill's Latin textbook *Introductiones ad veram physicam et veram astronomiam* (Leiden, 1725) and, last but not least, in 1732 issued a Latin edition of Newton's mathematical tract, the *Arithmetica universalis*. By then he was seen throughout Europe as the leading expert in Newton's mathematics and physics.

But 's Gravesande's greatest achievement was his extreme success in popularizing Newtonian science. Telling in this respect is what he wrote to Newton in 1718, after having received an author's copy of Newton's last book:

> A few days ago I received [...] the second edition of your *Opticks.* [...] I am infinitely obliged to you for this present, so valuable to me both for itself and for its giver. I begin to hope that the way of philosophizing that one finds in this book will be more and more followed in this country, at least I flatter myself that I have had some success in giving a taste of your philosophy in this university; as I talk to people who have made very little progress in mathematics, I have been obliged to have several machines constructed to convey the force of propositions whose demonstrations they had not understood. By experiment I give a direct proof of the nature of compound motions, oblique forces and the principle propositions respecting central forces.[94]

This last remark is revealing. It demonstrates that in spite of 's Gravesande's admiration for Newton's mathematical-empirical method, in his own adaptation of Newton the experimental demonstration for lay people was just as important as the initial mathematical analysis of nature. Again this underpins 's Gravesande's firm distinction between pure and applied mathematics. So thanks to the demonstration devices designed by 's Gravesande and Jan van Musschenbroek, even those without any mathematical training could receive an introduction to the achievements of 'modern' natural philosophy.

Dutch 'Newtonianism' and physico-theology

Thanks to the efforts of Le Clerc, 's Gravesande, Nieuwentijt, Ten Kate and others, the study of nature appeared to be liberated from the dangers of atheism, simply by arguing that Newton and his epigones had restored by their philosophical principles the possibility of a 'Divine Providence'; this 'Newtonian message' was very welcome in the Protestant Dutch Republic. The message was clear and simple: the laws of nature could be attributed to the reliability of God's Providence alone. Thus, in addition to studying the Bible, the study of nature was another way to learn about God's meaning and his purposes with the world. Investigating nature with an air-pump, telescope, microscope or barometer became identical with gloryfiing the divine Creator.

This physico-theological way of reasoning was not new in the Republic, quite the contrary. As we have already seen, there existed a long and deeply-rooted tradition of natural theology, as well as an empirical attitude towards nature.[95] If the notion of the 'Book of Nature' was a commonplace among all members of Dutch society, its corollary science, physico-theology, was to become very successful, precisely because it appealed both to orthodox biblical literalists, and to Remonstrants, Mennonites, Huguenots, and other dissenting groups who were far less dogmatic in exegetical matters, nor bound by ecclesiastical authorities. What all had in common was the belief that nature was the theatre of God's glory, and that the rationalistic and materialistic philosophy of nature of Descartes and Spinoza would inevitably lead to atheism.

John Ray's book *Three Physico-Theological Discourses* (1693), in which the term 'physico-theology' was coined, had already been translated into Dutch as early as 1694.[96] Still, the Dutch physico-theological movement only became a trend in the late 1720s, as an integral part of a general physico-theological wave in Europe, represented by foreign authors such as John Ray, William Derham or Noel-Antoine Pluche, but also as a result of a native tradition. Alongside Nieuwentijt's *Het regt gebruik,* British physico-theological literature was received with great enthusiasm. Derham's *Physico-Theology* was translated into French by the Rotterdam Huguenot and professor of mathematics Jacques Lufneu (published in 1726; reprinted 1730), and into Dutch by the Amsterdam Mennonite physician Abraham van Loon (published in 1728; reprinted 1739; 1742). Both translators had studied in Leiden during 's Gravesande's professorship.[97] In return *the* main Dutch work on the subject, *Het regt gebruik*, also found its way to the European book market. Nieuwentijt's work was translated into English (London 1719; by John Chamberlayne, with a preface by John Theophilus Desaguliers); into French (Paris 1725; Amsterdam 1727) and into German (Frankfurt and Leipzig 1732, with a preface by Christian Wolff).

Pierre Coste's French translation of Newton's *Opticks* (1720)

Completely in line with the Dutch Newtonian offensive in the years 1715–1720 is the publication, early in 1720, of the first French translation of Newton's *Opticks*, issued in Amsterdam. With the notable exception of Lambert ten Kate, discussed in the chapter by Fokko Jan Dijksterhuis, the publication of the *Opticks* in 1704 and its Latin translation in 1706 aroused little attention in the Dutch Republic. The latter was reviewed only in Le Clerc's *Bibliothèque choisie* and its Dutch counterpart the *Boekzaal der geleerde waerelt*. However, in the wake of the success of the second edition of the *Principia* (and its pirated Amsterdam reprint), renewed attention was paid to the *Opticks*, of which a second edition was issued in 1718. Soon afterwards, Pierre Coste (1668–1747), a Huguenot who had lived for a long time in Amsterdam and had served there as a Walloon minister, started to work on a French translation.[98] In Amsterdam, in the 1680s, Coste had met John Locke, a meeting which resulted in a close and lasting relationship. Coste more or less became Locke's secretary and the French translator of Locke's main works. When Locke returned to England in 1689, Coste joined him, and he would stay in Britain for the rest of his life, although he never really felt at home there.[99] In 1715 Coste met John Theopilus Desaguliers (1683–1744), who just had finished a series of experiments for the Royal Society which had improved the practical demonstration of Newton's 'Experimentum Crucis'. In this famous experiment, the composition of white light into different colours was demonstrated.[100] With Desaguliers' assistance Coste took up the job of translating the *Opticks*, which was printed in Amsterdam, in October 1719.[101] The *Traité d'optique sur les réflexions, réfractions, inflexions, et les couleurs, de la lumière* was issued in two volumes by the Amsterdam Huguenot publisher Pierre Humbert – again, one of the members of the *Vis unita major* company. In his preface Coste underlined the message which was repeated again and again by the Dutch and English Newtonians, viz. that Newton's philosophy 'leads us necessarily to God, the author and conserver of things'.[102]

Physico-theology and its appeal to the Mennonite community

This international physico-theological wave, with its 'Newtonian' flavour, in the transmission of which the French Huguenots both in Britain and Holland were so instrumental,[103] was first appreciated among members of the Dutch Mennonite community. In the Netherlands the members of this pious – but dissenting – religious group were excluded from government offices, but by trade and manufacture many of them had become very wealthy. Nevertheless, Mennonites had a plain lifestyle, with a very personal spiritual perception of their belief. In Mennonite thought the awareness of a divine scheme for mankind had been present for a long time. So for Mennonites the idea of a nature regulated by divine laws was readily acceptable. The physico-theological aspect of Newtonianism legitimized the study of nature. Not only did this study offer these dissenters the possibility of spiritual contemplation, but their open mind for the application of scientific findings also promoted economic innovation and social emancipation.[104] We already encountered two early Dutch advocates of Newton, Adriaan Verwer and Lambert ten Kate, who both were Mennonites. In view of this, it may not come as a surprise that in 1718 a group of wealthy 'Mennonite enthusiasts' gathered in Amsterdam, to follow a course in experimental philosophy from the Danzig-born instrument maker Daniel Gabriel Fahrenheit (1686–1736), who had settled in Amsterdam the year before. Right from the start Fahrenheit became acquainted with Herman Boerhaave in Leiden and Lambert ten Kate in Amsterdam.[105] It was probably Ten Kate who introduced Fahrenheit to the Mennonite circle in Amsterdam. In 1721 he issued a prospectus for his lessons from which we learn that he had chosen to follow 'the recently published Latin tract of Professor 's Gravesande, called *Physices elementa mathematica,* to be added to some findings from my own experience'.[106] These physics lessons for Mennonite enthusiasts would continue far into the eighteenth century.[107]

It was also a Mennonite who was responsible for the only Dutch translation of one of Newton's books. In 1736 the Mennonite merchant Abraham de Vryer translated Newton's last and posthumously published works, *The Chronology of Ancient Kingdoms Amended* and the


DE HISTORI DER ALOUDE VOLKEREN OPGEHELDERT,
EN IN EENE NAAUKEURIGE TYDORDE GEPLAATST:
Benevens eene KORTE KRONYK van de eerste bekende gebeurtenissen in Europe, tot de verovering van Persie door Alexander den Grooten.
In 't Engelsch beschreven door den vermaarden Ridder
IZAAK NEWTON,
En vertaalt door
ABRAHAM DE VRYER.
Dienende dit Werk tot eenen Sleutel van de meeste oude Geschiedenissen.
TE DELFT,
By PIETER VANDER KLOOT, 1737.

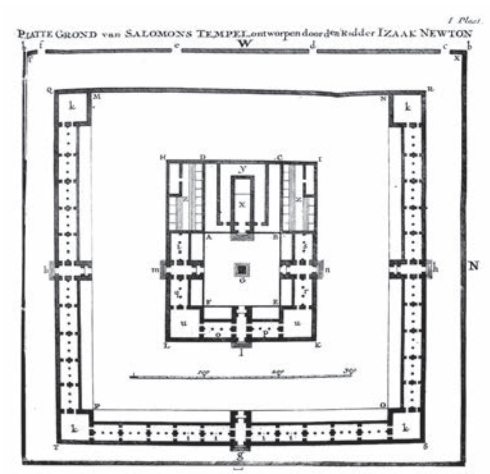
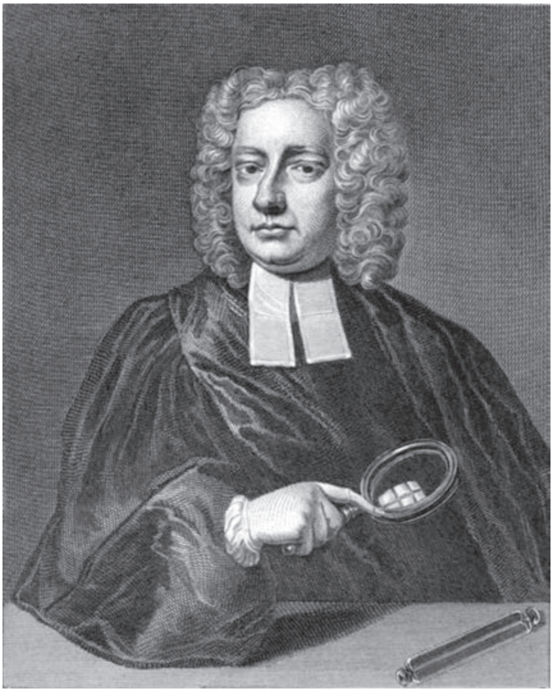
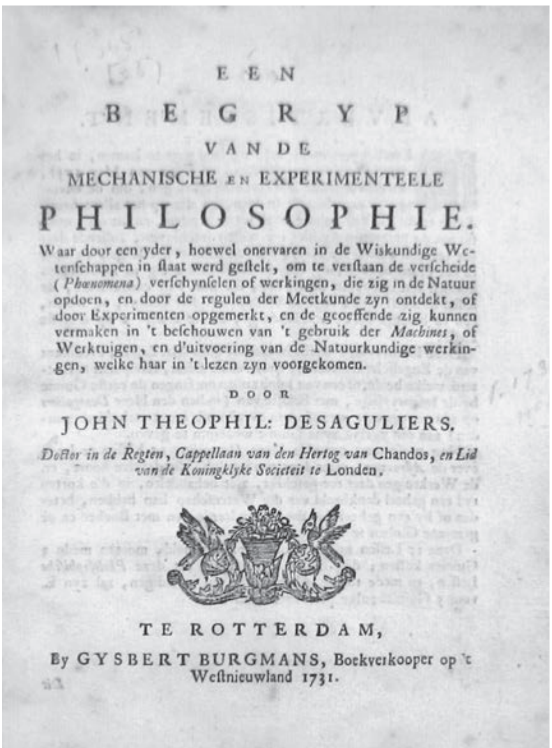


Fig. 4a & 4b: The only book by Isaac Newton translated into Dutch: the *Historie der aloude volkeren opgeheldert* (1736), with Newton's reconstruction of Solomon's Temple, demonstrating Newton's search for a divine standard measure of length.





EEN

BEGRYP

VAN DE

MECHANISCHE EN EXPERIMENTEELE

PHILOSOPHIE.

Waar door een yder, hoewel onervaren in de Wiskundige Wetenſchappen in ſtaat werd geſtelt, om te verſtaan de verſcheide (*Phænomena*) verſchynſelen of werkingen, die zig in de Natuur opdoen, en door de regulen der Meetkunde zyn ontdekt, of door Experimenten opgemerkt, en de geoeffende zig kunnen vermaken in 't beſchouwen van 't gebruik der *Machines*, of Werktuigen, en d'uitvoering van de Natuurkundige werkingen, welke haar in 't lezen zyn voorgekomen.

DOOR

JOHN THEOPHIL: DESAGULIERS,

Doctor in de Regten, Cappellaan van den Hertog van Chandos, *en Lid van de Koningklyke Societeit te* Londen.

TE ROTTERDAM,

By GYSBERT BURGMANS, Boekverkooper op 't Weſtnieuwland 1731.

Fig. 5 & 6:
John Theophilus Desaguliers (1683–1744) and a leaflet issued in 1731 in Rotterdam, announcing his lectures on experimental physics and astronomy.

Short Chronicle from the First Memory of Things in Europe (London 1728) into Dutch.[108] Newton had been engaged for a long time in this study of ancient chronology, in an attempt to prove the authenticity of biblical events with astronomical phenomena. His view that the Bible could be read as a kind of cryptogram, in which God's purpose with the world was hidden, had led him to an extensive study of Solomon's Temple, whose length could be seen as a God-given unit of measurement. The fact that this was the only one of Newton's books then translated into Dutch, indicates that the Dutch were far more interested in Newton's theology than in his science. Although little is known about De Vryer, his translation must be seen against the background of the non-dogmatic, very personal attitude of the Mennonites towards the Bible.[109]

Desaguliers and the popularization of 'experimental philosophy' in the Dutch Republic

In 1715 Newton was launched as a useful icon for studying nature in a mathematical-empirical way, with room for divine intervention. This kind of experimental philosophy became widely accepted in the 1720s, at least in academic circles. Widespread popularization of experimental physics in the Northern Netherlands only came into being in the 1730s, however, thanks to the Dutch tour of John Theophilus Desaguliers. In England he had acquired great fame. Desaguliers had studied at Oxford, and had served as an experimental assistant to Sir Isaac Newton. He was a skilled experimenter and an accomplished technician, but above all else he was renowned as a public lecturer. Desaguliers amazed his lay audience – men as well as women – with spectacular demonstrations, in which entertainment and commerce seemed to be as important as science. In the early 1730s Desaguliers crossed the North Sea a few times, visiting a number of Dutch cities, lecturing at least in Rotterdam, The Hague and Amsterdam.[110] The reason for these travels is not known, although one of Desaguliers' relatives – probably an uncle – worked as a mathematician in Amsterdam, so contacts with Holland were close.[111]

A decade or so before his Dutch tour Desaguliers had made some efforts to introduce Dutch books to the English market. In 1718 he had written a commendatory preface to an English edition of the Dutch physico-theological book of Nieuwentijt, and three years later he had prepared an English translation of 's Gravesande's textbook.[112] The two knew each other personally, for Desaguliers had met 's Gravesande during his visit to London in 1715.

Desaguliers' Dutch tour was very well organized and surrounded by considerable publicity. A prospectus of Desaguliers' Rotterdam lessons shows that he performed his lectures in three languages every day: 'in the morning from seven thirty until nine o'clock in French, from ten o'clock in English, and in the afternoon at four in Latin'.[113] For a series of fifteen lessons the amount of three golden guineas had to be paid. On some days he also lectured in astronomy, for an additional amount of two or three guineas per person. We have calculated that in Holland during the period August 1731 until February 1732 Desaguliers reached a popular audience of more than a thousand listeners, bringing him revenue of at least 3,000 guineas, a considerable amount.[114] This fact alone underscores that Desaguliers' tour was above all a clever way to earn money, not a tour to spread Newton's gospel.

It is not surprising that the first textbook in Dutch on experimental physics was a short outline of Desaguliers' lessons, produced by a member of his audience, noted down probably in Rotterdam or The Hague. In 1731 the booklet was published at Amsterdam by the Mennonite publisher Isaac Tirion (1705–1765). It was entitled *Korte inhoud der philosophische lessen, vervattende een kort begrip van de beginselen en gronden der proef-ondervindelijke natuurkunde* (Short Outline of the Philosophical Lessons, Containing a Short Understanding of the Principles and Foundations of Experimental Physics). The illustrated booklet contains references to some Latin words used by Desaguliers, so the scribe must have visited an afternoon session and been capable of grasping Latin. Already in 1732 a reprint was needed.[115]

'Newtonian' enthusiasts

Shortly after Desaguliers' lecture tour, experimental physics became extremely popular in the Netherlands. Driven by the effect of Desaguliers' tour, two Mennonite publishers launched their own quarterly journal, both with the intention of creating a forum in the Dutch language for all kinds of news in the field of natural knowledge. Every town of any importance established a physics society. Some of these groups of *konstgenoten* (lovers of the arts) – as they called themselves – even organized their own housing, in some cases including a well-equipped cabinet of scientific instruments and an astronomical observatory. In cities like Amsterdam, Haarlem and Middelburg these *konstgenoten* even participated in serious astronomical research, of which the observational results were exchanged with foreign institutions like the Observatoire de Paris or the Royal Society of London.[116]

A good example is the aforementioned Nicolaas Struyck. After reading Newton's *Principia*, as well as Edmund Halley's *Synopsis,* a list of twenty-four cometary orbits published in 1705, Struyck started a long research program on cometary orbits. As the supposed elliptical trajectory of comets was generally seen as the ultimate test of Newton's (mathematical) theory of gravity, this was an important subject for research. In 1722 Struyck announced his ambition to extend Halley's work on comets, 'imitating that great astronomer'.[117] It took nearly twenty years, however, before he could present any results. In 1740 Struyck published an impressive quarto volume with original work in the field of so-called 'mixed mathematics', presenting not only research on comets, but also on geography, cartography, demography, astronomy and entomology.[118] With this emphasis on applied mathematics Struyck had become a Dutch 'Halley'. In later years Struyck continued his 'Newtonian' work, for instance by cooperating in the

Fig. 7:
Nicolaas Struyck

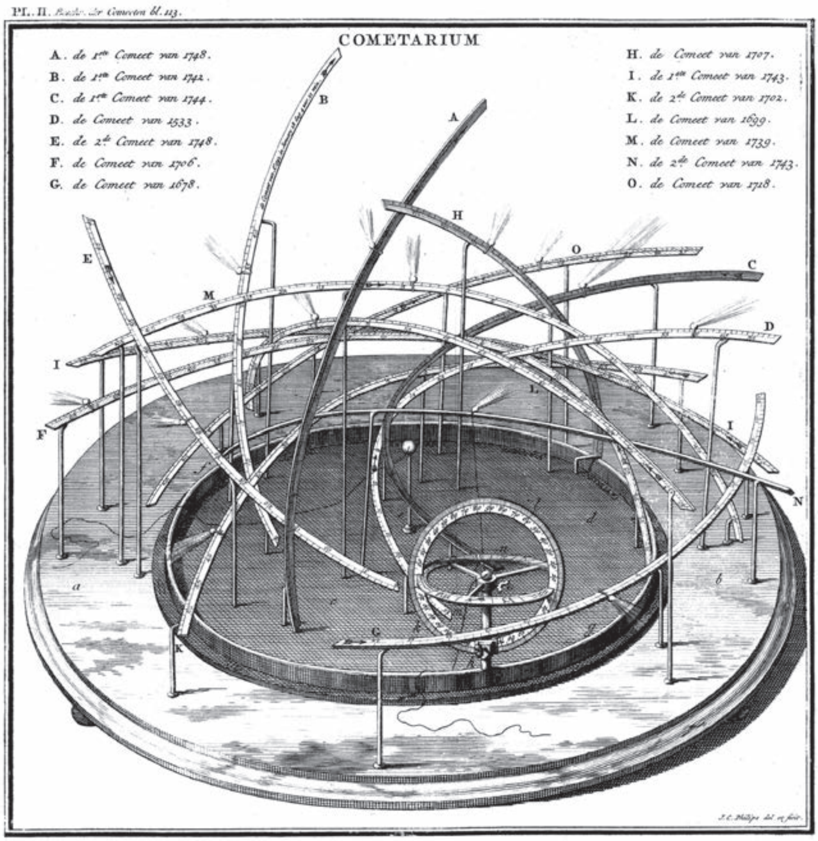


Fig. 8: Nicolaas Struyck's three-dimensional 'Cometarium', designed and built in 1745 to check Newton's gravitational theory on comets. (Source: Struyck, *Vervolg* [1753]).

Dutch translation of Newton's adaptation of Bernhard Varenius' *Geographia generalis*.[119]

Struyck was not the only Dutchman fascinated by comets. In the years leading up to the expected return of Halley's Comet, which, when it came, was seen by contemporaries as a triumph for Newton's gravitational theory, several Dutch enthusiasts participated in the search for astronomical discoveries.[120] The surveyor Dirk Klinkenberg, living in Haarlem and later in The Hague, was not only a very successful astronomical observer (he independently observed at least fifteen comets, five of which as the first recorded observer), but was also a skilled mathematician. In 1755 he published a search table and map, in which he calculated, for every month in the years to come, which part of the night sky Halley's Comet would appear in.[121] This initiative was the first of its kind in Europe. However, soon afterwards, this was imitated in several other countries.[122] Intrigued by the same event, and on the basis of Newton's gravitational theory, the wine merchant Jan Schim from Maassluis tried to calculate the possible perturbations on the comet's orbit caused by the larger planets, concluding that the comet's orbit could be changed considerably.[123]

The Dutch universities

Meanwhile, in the Dutch Republic 'Newtonianism' had become a synonym for 'experimental philosophy'. This meant that other accents could be incorporated. As De Pater has noted, Petrus van Musschenbroek (1692–1761), who graduated from Leiden in 1715, tended more towards an overall empirical approach with respect to nature, much in the spirit of Francis Bacon.[124] His scientific activities mainly consisted of the collection of data of all sorts of phenomena, such as electricity, magnetism, hydrostatics and meteorology, thereby giving 'Newtonianism' a far less mathematical dimension. This approach was more in line with the German way of undertaking natural philosophy as adopted by Christian Wolff (1679–1754). This may be corroborated by the fact that from 1719 until 1721 Van Musschenbroek lectured in the German city of Duisburg. In spite of this broader approach, Van Musschenbroek still considered himself a Newtonian, as he said in his letter to an aged Newton in 1726:

> Being an admirer of your wisdom and philosophical teaching, of which I had experience while in Britain in familiar conversation with yourself, I thought it no error to follow in your footsteps (though far behind), in embracing and propagating the Newtonian philosophy. I began to do so in two universities where the triflings of Cartesianism flourished, and met with success, so that there is hope that the Newtonian philosophy will be seen as true in the greater part of Holland, with praise of yourself.[125]

We see the same tendency towards an eclectic interpretation of 'Newtonianism' among other students of 's Gravesande. Several of them were appointed to Dutch universities and illustrious schools: Johan Hendrik van Lom (1704–1763) at the somewhat marginal University of Harderwijk; Johannes Oosterdijk Schacht (1704–1792) and Godefridus du Bois (1700–1747) at Franeker University, and Elie de Joncourt (1697–1765) at the illustrious school in 's-Hertogenbosch (Bois-le-Duc). They all held orations in which they stressed the importance of 'the' Newtonian method and praised the Englishman's virtues.[126] In college, they read 's Gravesande's textbook, in which experiments were crucial.

This same emphasis on the importance of experimental philosophy was followed at the University of Groningen. But here, influenced by the nearby German states, Newton was replaced as a scientific icon by Leibniz and Wolff. This way of lecturing had started with the tumultuous professorship of Johann Bernoulli (1667–1748). His successors Nicolaus Engelhard (1696–1765) and Friedrich Adam Widder (1724–1784) continued this German-oriented philosophical direction with great enthusiasm.[127] Perhaps this orientation also accounts for the lack of Cartesian-Spinozist troubles at Groningen.[128]

Utrecht University also demonstrated a dual German-English orientation. In 1740 the Utrecht curators even tried to appoint Christian Wolff, the great master himself, to the chair of experimental philosophy, left vacant after Petrus van Musschenbroek's move to Leiden.[129] One of his successors was Jean François Salvemini de Castillon (1709–1791), a Swiss mathematician who had edited three volumes of Newton's mathematical works (published in 1744 in Lausanne and Geneva). From 1751 onwards he lectured on mathematics and astronomy in Utrecht, being appointed full professor of philosophy in 1755. During his professorship, Castillon continued his scholarly work, producing in 1761 a Latin edition of Newton's *Arithmetica universalis*. When he left Utrecht, he was succeeded by a German educated-scholar, Johann Friedrich Hennert (1733–1813). This example demonstrates that for many scholars in the Netherlands 'experimental philosophy' in itself was more important than the label attached to it. Either Newton or Wolff could serve as icons for the scientific course, depending on local circumstances. Franeker University, in the north of the country, also demonstrates this dual approach. Here two 'Newtonians' had lectured since the early 1740s, but in 1746 an epigone of Wolff was also appointed as a professor of philosophy. This was the Swiss mathematician Samuel Koenig (1712–1757), well known for his fierce dispute with his French colleague Maupertuis. Koenig also acted as a scientific advisor to the – then only Frisian – Stadtholder William IV of Orange-Nassau. In 1747 he moved with the court to The Hague, where he continued delivering his lectures on experimental philosophy.[130]

Throughout the century, Leiden would remain the Republic's undisputed centre of 'Newtonianism', as fashioned in the 1710s by Boerhaave and 's Gravesande. As we have argued above, this 'Newtonianism' was for a large part an almost unaltered continuation of the Dutch form of experimental philosophy introduced by De Volder and Senguerd in the late seventeenth century. In Leiden Newton had been introduced, especially for convincing the orthodox Calvinist clergy that this way of studying nature was very different from the deductive physics and metaphysics preached by Descartes and Spinoza. Still, in 1726 Petrus van Musschenbroek would write to Newton that in Holland 'Newtonian philosophy [...] would flourish even more but for the resistance of certain prejudiced and casuistical theologians'.[131] Later Leiden professors, such as Johannes Lulofs (1711–1768) and Jean Nicolas Sébastien Allamand (1713–1787), continued to pay tribute to Newton.[132] Leiden graduates, such as Jean Henri van Swinden (1746–1823), later a professor at Franeker and at the Amsterdam Illustrious School, and Petrus Camper (1722–1789), later at Franeker, Amsterdam and Groningen, did so too. They all identified 'Newtonianism' with experimental physics, empiricism and even natural history.[133] The scientific enterprise as such also became an instrument of natural theology.

Professors such as Van Musschenbroek and Lulofs considered it their vocation to publish books on this kind of 'Newtonian' natural philosophy in the vernacular, in order to enlighten their countrymen. All these works basically contained the same message: God's works were incomprehensible, but his endless power and majesty could be discerned and demonstrated by the study of his works of creation. The 'argument from design', as advocated by Nieuwentijt, Ray and Derham (all available in Dutch) was propagated by many and seemingly contested by no one. Words like 'Newtonianism', 'experimental philosophy', 'physico-theology' and 'natural theology' were interchangeable, and used to describe the same set of ideas, values and practices.

In time, Newton became less important as the only role model for Dutch experimental philosophy. In the second half of the eighteenth century a growing market emerged for other books, with a non-Newtonian background. Translations of books on experimental philosophy written by Christian Wolff, Johann Heinrich Winkler, Jean Antoine Nollet and Leonhard Euler also became popular.[134] Not everyone was pleased with this trend, as is shown by an anonymous comment in the journal *De denker*, published in 1765:

> Newton gave us 's Gravesande and Musschenbroek, and both of those have given us men who still today excel in the government of the state, and at our universities. How many merchants do we find [today] educated in that period, being busy with optical experiments and making improvements? We can still boast regents whose rooms are filled with the finest instruments for demonstrating mechanics, hydrostatics, and their properties, being busy performing astronomical observations. Thus was the state of our country in the last century and the beginning of this one. A thousand discoveries, glorifying the Supreme Being, were made daily in Astronomy as well as Natural History. The great Boerhaave, the champion, the example of good taste, was hardly dead or everything tumbled down. Winkler let us exchange the sublime astronomical researches for foolish electrical experiments. [...] How far has miserable Wolf [*sic*] destroyed the good taste of Newton and Locke![135]

So Newton was popular, but not undisputed. Perhaps surprisingly, the increasing terminological vagueness about Dutch 'Newtonianism' and the dilution of its epistemological foundation coincided with a growing praise for Newton himself. The cultivation of Newton as the pious, even supernatural mathematician and philosopher, started by Verwer and Le Clerc, reached its peak at the end of the eighteenth century.[136] The astronomer Petrus Nieuwland (d. 1795) sang the praises of Newton's genius. The philosopher Frans Hemsterhuis (1721–1790) considered Socrates and Newton the two greatest men that had ever lived.[137] Betje Wolff (1738–1804) translated Pope's 'Ode to Newton' into Dutch, and remarked that the universal law of gravitation was an *exemplum* for the behaviour of good citizens in a truly Christian society. The nearly blind female poet Petronella Moens (1762–1843), a person most unlikely to have digested the *Principia*, wrote: 'O Great Newton! Who knew how to calculate the forces of Nature, its eternal laws, most carefully.'[138] In a way which reminds us of the later cult surrounding Albert Einstein, Newton was worshipped, not only because of his scientific work, but most of all because he became an icon, onto which all kinds of values could be projected: piety, reasonableness, peacefulness, and modesty.[139] Apparently, Newton had driven out the ghost of Spinoza.

Concluding remarks

In the last few decades, historians of science have shown a growing awareness of the importance of concepts such as the circulation of knowledge, and the social, rhetorical and geographical dimensions of early modern scientific culture. In this article we hope to have demonstrated that 'Newtonianism' was not a stable system, waiting to be shipped from England to the Dutch Republic.[140] On the contrary, Newton's philosophy was modelled in such a way that it fitted into an already existing system of experimental philosophy. In the Republic Newton was introduced as a pious mathematical genius, whose message was of relevance to the whole of Christianity. Ironically, very few people were aware of Newton's own highly heterodox ideas. In the Republic, the Newtonian system was developed and adapted because it seemed to pose no religious threat, and because it arrived at the right moment. As Rienk Vermij has provocatively written:

> It seems unlikely that Newton's theories were inherently more in accordance with religious orthodoxy than Descartes'. They were based on mathematical demonstrations in a way Descartes had only dreamed of. If they could be used to attenuate tensions, that was probably just because people were tired of continuous struggles. [...] The main merits of Newton's theories from a religious point of view were that they were untainted by previous denunciations and provocations, and that there were no ecclesiastical reputations at stake in their acceptance or rejections. *Any other new theory could have done.*[141]

Dutch Newtonianism was a construction that was created as an answer to local problems and debates. Newton was consciously put on the map, as well as on the market, as the outburst of 'Newtonian' books following the second edition of the *Principia* in 1713 and its pirated Amsterdam edition of 1714 shows. 'Newtonianism' was a label, a newly coined umbrella term for two longer trends in Dutch natural philosophy: the use of mathematics, and the empirical and experimental tradition. It was Newton who was considered a suitable antidote to the poisonous rationalistic and materialistic systems of Descartes and – most of all – Spinoza. The person of Newton, and the system he seemed to represent, strongly appealed not only to orthodox Calvinists, but to many religious dissenters as well. We noted the important role played by Mennonites and Huguenots in the propagation of Newton and his works, a role we must understand from the emphasis they put on God's hand in nature.

In the Dutch context, Newton overcame the boundaries between the religious denominations, as well as between the disciplines. To an academic, as well as a lay audience (including an increasing number of women), Newton seemed the most Christian of philosophers. It is striking to note how, in a sense, Newton himself became even more popular than his philosophy. 'Newtonianism' was an increasingly vague term, more or less synonymous with physico-theology or experimental philosophy. 'Newtonianism', so successful because of its reconciliatory character, gradually smoothed away the factors that were responsible for the remarkable Dutch intellectual culture of the seventeenth century: its pluriformity, lack of central authority and relative openness to unorthodox and controversial ideas.

Notes

The authors would like to thank Rienk Vermij, Daan Wegener and Fokko Jan Dijksterhuis for their comments on earlier versions of this paper, and Anthony Ossa-Richardson for correcting their English as well as for his additional remarks.

1 See, for example: E. Ruestow, *Physics at 17th- and 18th-century Leiden* (The Hague 1973), pp. 113–140; C. de Pater, *Petrus van Musschenbroek (1692–1761), een Newtoniaans natuuronderzoeker* (PhD-thesis, Utrecht 1979); K. van Berkel, *In het voetspoor van Stevin: geschiedenis van de natuurwetenschap in Nederland 1580–1940* (Meppel 1985), pp. 69–98; H.J. Cook, 'The new philosophy in the Low Countries', in: R. Porter and M. Teich (eds), *The scientific revolution in national context* (Cambridge 1992), pp. 115–149, esp. 136; K. van Berkel, A. van Helden and L. Palm (eds), *A history of science in the Netherlands: survey, themes and reference* (Leiden 1999), pp. 69–76 and 450–451.

2 K. van Berkel, 'Newton in the Netherlands' in: *The Low Countries: arts and society in Flanders and the Netherlands*, yearbook published by the Flemish-Netherlands Foundation Stichting Ons Erfdeel (Rekkem 1993–1994), pp. 186–191; quotation p. 186.

3 E. Kegel-Brinkgreve and A.M. Luyendijk-Elshout (trans.), *Boerhaave's orations* (Leiden 1983), pp. 160–162.

4 J. Bots, *Tussen Descartes en Darwin. Geloof en natuurwetenschap in de achttiende eeuw in Nederland* (Assen 1972); R. Vermij, *Secularisering en natuurwetenschap in de zeventiende en achttiende eeuw: Bernard Nieuwentijt* (Amsterdam 1991).

5 For a general survey see: J. Israel, *The Dutch Republic: its rise, greatness, and fall, 1477–1806* (Oxford 1995); H.J. Cook, *Matters of exchange: commerce, medicine, and science in the Dutch Golden Age* (New Haven, London 2007); E. Jorink, *Reading the Book of Nature in the Dutch Golden Age, 1575–1715* (Leiden 2010).

6 See, amongst others, R. Halleux, C. Opsomer and J. Vandersmissen (eds), *De geschiedenis van de wetenschappen in België van de Oudheid tot 1815* (Brussels 1998); K. van Berkel, 'The legacy of Stevin: a chronological narrative', in: Van Berkel, Van Helden, Palm (eds), *History of science in the Netherlands* (note 1), pp. 3–238; Cook, *Matters of exchange* (note 5); D. van Netten and A. de Bruckere, "Zodat mijn verbanning tegelijk jouw straf is'. Bloei, verval en migratie van wetenschap in de Republiek en de Spaanse Nederlanden', *Bijdragen en mededelingen betreffende de geschiedenis der Nederlanden* 123 (2008), pp. 3–30; C.A. Davids, *The rise and decline of Dutch technological leadership: technology, economy and culture in the Netherlands, 1350–1800* (Leiden 2008); S. Dupré, 'Trading luxury glass, picturing collections and consuming objects of knowledge in early-seventeenth-century Antwerp', *Intellectual history review* 20 (2010), pp. 53–78; E. Jorink and B. Ramakers (eds), *Art and science in the early modern Low Countries,* Netherlands Yearbook for History of Art/Nederlands Kunsthistorisch Jaarboek 61 (Zwolle 2011).

7 S. Dupré and C. Lüthy (eds), *Silent messengers: the circulation of material objects of knowledge in the early modern Low Countries* (Berlin 2011), pp. 1–2.

8 See, for example: G.A. Lindeboom, *Herman Boerhaave: the man and his work* (Leiden 1968; Rotterdam 2007^{2}); E. Ashworth Underwood, *Boerhaave's men at Leyden and after* (Edinburgh 1977); T. Huisman, *The finger of God: anatomical practice in seventeenth-century Leiden* (Leiden 2009).

9 J.N. Bakhuizen van den Brink, *De Nederlandse belijdenisgeschriften in authentieke teksten* (Amsterdam [1940^{1}] 1976^{2}), p. 73.

10 Much has been written on the reception of Descartes in the Dutch Republic, for example: Th. Verbeek, *La querelle d'Utrecht: René Descartes et Martinus Schoock* (Paris 1988); idem, *Descartes and the Dutch: early reactions to Cartesian philosophy, 1637–1650* (Carbondale 1992); J.A. van Ruler, *The crisis of causality: Voetius and Descartes on God, nature and change* (Leiden 1995); W. van Bunge, *From Stevin to Spinoza: an essay on philosophy in the seventeenth-century Dutch Republic* (Leiden 2001).

11 R. Vermij, *The Calvinist Copernicans: The reception of the new astronomy in the Dutch Republic, 1575–1750* (Amsterdam 2002).

12 J. Yoder, *Unrolling time: Christiaan Huygens and the mathematization of nature* (Cambridge 1988); F.J. Dijksterhuis, *Lenses and waves: Christiaan Huygens and the mathematical science of optics in the seventeenth century* (Dordrecht 2004).
13 J. Israel, 'The banning of Spinoza's works in the Dutch Republic (1670–1678)', in: W. van Bunge and W. Klever (eds), *Disguised and overt Spinozism around 1700: papers presented at the International Congress held at Rotterdam, 5–8 October 1994* (Leiden 1994), pp. 3–13, esp. 11–13.
14 P.C. Molhuysen, *Bronnen tot de geschiedenis der Leidsche universiteit*, 7 vols, (The Hague 1913–1924), vol. 3, p. 337.
15 J. Freudenthal, *Die Lebensgeschichte Spinoza's in Quellenschriften, Urkunden und nichtamtliche Nachrichten* (Leipzig 1899), pp. 179–180.
16 P. Bayle, *Dictionaire historique et critique* (Rotterdam 1697) and later editions; idem, *Het leeven van B. de Spinoza, met eenige aanteekeningen over zyn bedryf, schriften, en gevoelens* (Utrecht 1698).
17 Johannes Colerus [= J. Köhler], *Korte, dog waarachtige levensbeschrijving van Benedictus Spinoza, uit autentique stukken en mondelinge getuigenis van nog levende personen opgesteld* (Amsterdam 1705; rpt The Hague 1880).
18 Cf. J. Israel, *Radical Enlightenment: philosophy and the making of modernity, 1650–1750* (Oxford 2001).
19 *Journal des sçavans* (1673). This annual contained articles not only on the 'Nouvelle lunette catoptrique inventée par M. Newton' (pp. 19–22 and 121–123), but also Huygens' remarks on the subject (pp. 22–33), as well as news about competing designs by Laurent Cassegrain (pp. 80–84, fig. 1) and David Gregory (pp. 43–49).
20 Oldenburg to Huygens, 11 March 1672 (O.S.), referring to I. Newton, 'A letter ... containing his new theory about light and colors', *Philosophical transactions of the Royal Society* 80 (19 Feb. 1672), pp. 3075–3087.
21 Huygens to Oldenburg, 1 July 1672: '*Je trouve l'hypothese des couleurs de Monsieur Newton jusqu'icy fort probable. l'Experimentum crucis est delivrè un peu obscurement, mais si je l'entens bien il confirme beaucoup sa nouvelle opinion*.'
22 R. Vermij, 'Christiaan Huygens and Newton', in: S. Mandelbrote and H. Pulte (eds), *The reception of Isaac Newton in Europe* (in press).
23 Christiaan Huygens to Constantijn Huygens Jr, 30 December 1688: '*Je voudrais estre a Oxford, seulement pour faire connoissance avec Mr. Newton de qui j'admire extremement les belles inventions qui je trouve dans l'ouvrage qu'il m'a envoiè.*' See also: E.A. Fellmann, 'The *Principia* and continental mathematicians', *Notes and records of the Royal Society of London* 42, special issue on Newton's *Principia* and its legacy, edited by D.G. King-Hele and A.R. Hall (1988), pp. 13–34, esp. 14–15.
24 Huygens to Hudde, 24 April 1688: '*Aengaende het gemelte effect van het*

draeijen der aerde sal V Edt. misschien gesien hebben 't geen onlanghs daervan geschreven is door den Professor Newton in sijn boeck genaemt Philosophiae Naturalis principia Mathematica, stellende verscheyde hypotheses die ick niet en kan approberen.' Nothing is known about Hudde's reception of Newton, since most sources concerning his life and work are lost. For example, we do not know if he owned a copy of the *Principia*, although one is tempted to think he did. On Hudde, see: R. Vermij, 'Bijdrage tot de bio-bibliografie van Johannes Hudde', *Gewina. tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 18 (1995), pp. 25–35.

25 Christiaan Huygens, *Oeuvres complètes de Christiaan Huygens publiées par la Société Hollandaise des Sciences*, 22 vols (The Hague 1888–1950), vol. 9, p. 267.

26 Gerhard Wiesenfeldt, *Leerer Raum in Minervas Haus. Experimentelle Naturlehre an der Universität Leiden, 1675–1715* (Amsterdam 2002).

27 Molhuysen, *Bronnen* (note 14), vol. 3, p. 298.

28 Nevertheless, two of De Volder's former mathematics students visited Newton personally. In 1684 De Volder wrote a letter of introduction for Johann Christopher Zimmerman, a nephew of his colleague in theology, Christoph Wittich. It was the same Zimmerman who in 1687 transported Newton's presentation copy of the *Principia* to De Volder. In 1702 another of his former students, Frans Burman (1671–1716), also visited Newton. Burman discussed the trajectory of comets with this great mathematician, and received from Newton a personal letter of recommendation to Edmund Halley. Cf. De Volder to Newton, 24 November 1684 and 14 August 1687. Both letters printed in: A. Rupert Hall, 'Further Newton correspondence', *Notes and records of the Royal Society of London* 37:1 (1982), pp. 7–34, esp. 11–12. Burman's Latin journal was published by A. Capedose, *Francisci Burmanni, V.D.M. viri clarissimi itineris anglicani acta diurna* (Amsterdam 1828), pp. 9–10, 21 and 37. An English translation can be found in: J.E.B. Mayor, *Cambridge under Queen Anne* (Cambridge 1911), 311–324, esp. 314–315.

29 R. Vermij, 'The formation of the Newtonian philosophy: the case of the Amsterdam mathematical amateurs', *British journal for the history of science* 36 (2003), pp. 183–200, esp. 185–186; Cf: Anita Guerinni, 'Archibald Pitcairne and Newtonian medicine', *Medical history* 31 (1987), pp. 70–83.

30 P.G. Hoftijzer, 'Het Nederlandse boekenbedrijf en de verspreiding van de Engelse wetenschap in de zeventiende en achttiende eeuw', *Jaarboek voor Nederlandse boekgeschiedenis* 5 (1998), pp. 59–72.

31 On Vossius, see E. Jorink and D. van Miert (eds), *Isaac Vossius (1618–1689) between science and scholarship* (Leiden 2012). Vossius' copy is still in Leiden, shelf number 1369D19. It might have been an author's copy, since both Newton and Vossius were fellows of the Royal Society. There are no

indications that Vossius ever read the book.

32 Z. C. von Uffenbach*, Merkwürdige Reisen durch Niedersachsen, Holland und Engelland*, 3 vols. [1711] (Ulm 1754), vol. 3, p. 472.

33 Vermij, 'Amsterdam mathematical amateurs' (note 29).

34 J.A.M Slenders, *Het theatrum anatomicum in de Noordelijke Nederlanden, 1555–1800* (Nijmegen 1989); J.C. Rupp, 'Matters of life and death: the social and cultural conditions of the rise of anatomical theatres, with special reference to seventeenth-century Holland', *History of science* 28 (1990), pp. 263–287; idem, 'Theatra anatomica. culturele centra in het Nederland van de 17e eeuw', in: J. Kloek and W.W. Mijnhardt, *Balans en perspectief van de Nederlandse cultuurgeschiedenis. de productie, distributie en consumptie van cultuur* (Amsterdam 1991), pp. 13–36; H.J. Zuidervaart, 'Het in 1658 opgerichte theatrum anatomicum te Middelburg. Een medisch-wetenschappelijk en cultureel convergentiepunt in een vroege stedelijke context', *Archief. Mededelingen van het Koninklijk Zeeuwsch Genootschap der Wetenschappen* (2009), pp. 73–140.

35 J.V.M. de Vet, *Pieter Rabus (1660–1702). Een wegbereider van de Noordnederlandse Verlichting* (Amsterdam 1980); B.C. Sliggers, 'Honderd jaar natuurkundige amateurs in Haarlem', in: A. Wiechmann (ed.), *Een elektriserend geleerde: Martinus van Marum, 1750–1837* (Haarlem 1987), pp. 67–102.

36 On Makreel, see: Vermij, 'Amsterdam mathematical amateurs' (note 29). On Verwer, see: I. van de Bilt, *Landkaartschrijvers en landverdelers. Adriaen Verwer (ca. 1655–1717), Adriaan Kluit (1735–1807) en de Nederlandse taalkunde van de achttiende eeuw* (Amsterdam 2009). On Nieuwentijt, see: Vermij, *Secularisering* (note 4).

37 Fellmann, 'The *Principia* and continental mathematicians' (note 23), pp. 25–26.

38 See, for example: E. van der Wall, *De mystieke chiliast Petrus Serrarius (1600–1669) en zijn wereld* (Leiden 1987); Jorink, *Reading the Book of Nature* (note 5).

39 [Adriaan Pietersz Verwer], *'t Mom-aensicht der atheistery afgerukt door een verhandeling van den aengeboren stand der menschen, vervattende [...] een grondige wederlegging [...] van de geheele sede-konst, van Benedictus de Spinoza* (Amsterdam 1683).

40 University Library Utrecht, shelf mark N 1048.

41 [Verwer], *Mom-aensicht* (note 39), p. 13; here quoted after Vermij, 'Amsterdam mathematical amateurs' (note 29), p. 193.

42 Vermij, 'Amsterdam mathematical amateurs' (note 29), pp. 193–194. The quote is from a letter by Verwer (explaining the formulae) to Gregory, January 1703.

43 M.J. Petry, *Frans Hemsterhuis. Waarneming en Werkelijkheid* (Baarn 1990), p. 27.

44 Vermij, 'Amsterdam mathematical amateurs' (note 29).

45 E. van der Wall, 'Newtonianism and religion in the Netherlands', *Studies in history and philosophy of science* 35 (2004), pp. 493–514.

46 S. Mandelbrote, 'Newton and eighteenth-century Christianity', in: I.B. Cohen and G.E. Smith (eds), *The Cambridge companion to Newton* (Cambridge 2002), pp. 409–430, esp. 422 and 430.

47 Ibidem. As Mandelbrote points out, versions of the manuscript circulated after Le Clerc's death in 1736. One of these was the basis for the first, inaccurate, edition the *Two Letters of Sir Isaac Newton to Mr. Le Clerc* (London 1754). See: Le Clerc to Locke, 11 April 1691, in: M. Grazia and M. Sina (eds), *Epistolario*, Part 2 (Florence 1991), pp. 50–52.

48 Cf. E. Jorink, "Horrible and blasphemous": Isaac la Peyrère, Isaac Vossius and the emergence of radical biblical criticism in the Dutch Republic', in: J. van der Meer and S. Mandelbrote (eds), *Nature and Scripture in the Abrahamic religions: up to 1700* (Leiden 2009), pp. 429–450; Jorink and Van Miert, *Isaac Vossius* (note 31).

49 Vermij, 'Amsterdam mathematical amateurs' (note 29), pp. 196–199.

50 *Bibliothèque universelle* 8 (1688). On the authorship of the review see: James L. Axtell, 'Locke's review of the *Principia*', *Notes and records of the Royal Society of London* 20:1 (1965), pp. 152–161. On Locke's impact on continental Europe, see: J. Israel, *Enlightenment contested: philosophy, modernity, and the emancipation of man, 1670–1752* (Oxford 2006), pp. 51–62 and 135–144.

51 J. Le Clerc, *Physica sive De rebus corporeis libri quinque* (Amsterdam 1696). The first edition was published in Amsterdam by Galet; later editions were published by De Lorme (1700, 1704, 1710) and R. and G. Wetstein (1722). See about these editions: I.H. van Eeghen, *De Amsterdamse boekhandel 1680–1725*, 5 vols (Amsterdam 1960–1978), vol. 2, pp. 152–155 and 184–186. About the content, see: Vermij, *The Calvinist Copernicans* (note 11), pp. 350–352.

52 The Amsterdam publisher Johannes Wolters was an acquaintance of Bernard Nieuwentijt. In the years 1694–1696, Wolters had published three mathematical tracts by Nieuwentijt. In 1715 Wolters' widow and stepson issued Nieuwentijt's *Het regt gebruik*.

53 Rohault's original *Traité de la physique* (Paris 1671) had been pirated in Amsterdam the next year, and again in 1676, by 'J. le Jeune' (a nickname for Daniel Elsevier). The Latin translation made by Bonet in 1672, and annotated in 1682 by Antoine Le Grand in Cambridge, also was pirated in Amsterdam. Reprints were issued in 1682 and 1691 by Jean Pauli, and in 1700 by Johannes Wolters. In 1708 the latter included in this edition the 'Newtonian footnotes' (version 1702) made by Samuel Clarke, but also retaining Le Grand's remarks. A final edition of the 'Newtonian' version of the Latin translation of Rohault's texbook was published in 1738 by the

Leiden publisher Johannes Arnoldus Langerak.

54 *Bibliothèque ancienne et moderne* 1:1 (1714), pp. 69–96. See at length: M. Evers 'Pro Newtone et religione: de receptie van Newton en de Engelse fysicotheologen in de *Bibliothèque ancienne et moderne* (1714–1727)', *Documentatieblad werkgroep achttiende eeuw* 20 (1988), pp. 247–267; esp. 247–248..

55 Vermij, *The Calvinist Copernicans* (note 11), p. 351.

56 Ibidem and *Bibliothèque ancienne et moderne* 3:1 (1715), pp. 42–44.

57 See, for example: H. Guerlac, *Newton on the Continent* (Cornell 1981).

58 I. B. Cohen, *Introduction to Newton's* Principia (Cambridge, MA 1978), pp. 246–247. As far as can be ascertained, all four of these presentation copies are still present in Dutch libraries.

59 Ibidem, pp. 256–257.

60 *Journal littéraire de La Haye* 1 (July-August 1713).

61 Isabella van Eeghen has shown that most likely the following publishers participated in the *Vis unita major* company in 1711: (1) Estienne Roger, (2) Jan Wolters for his stepson Joannes Pauli, (3) R. and G. Wetstein, (4) Hendrik Schelte, (5) Jaques Desbordes, (6) Francois l'Honoré, (7) Pieter le Coup, (8) Johannes van Waesberge, (9) Pierre Brunel and (10) Pierre Humbert. They all had been participants in the agreement between the 54 Dutch book sellers. Cf. Van Eeghen, *De Amsterdamse boekhandel* (note 51), vol. 5:1, pp. 326–327.

62 One of the Amsterdam members of the *Vis unita major* publishing company, Estienne Roger, died in 1722, before the delivery of his share in the second pirated edition of Newton's *Principia*. His heirs received these 75 copies. Van Eeghen has shown that in 1722 fourteen publishers were united in the *Vis unita major* company, which makes a total print run of 1,050 copies for the second printing. In 1714 only ten booksellers had joined the company, which – with the same share – makes an estimated print run of 750 copies. The Cambridge edition of 1713 also counted an estimated 750 to 1,000 copies; the *editio princeps* of 1687 had a print run between 250 and 400. Cf. Van Eeghen, *De Amsterdamse boekhandel* (note 51), vol. 4, p. 70; idem, vol. 5:1, pp. 326–327, and Cohen, *Introduction to Newton's* Principia (note 58), pp. 138 and 256–258.

63 Evers, 'Pro Newtone et religione' (note 54) pp. 256–257.

64 See at length the special issue devoted to the history of the *Journal littéraire* of *Documentatieblad werkgroep achttiende eeuw* 18 (1986), part 2, esp. 145; see also: L. Maass, *Het* journal littéraire de La Haye *(1713–1723). de uitwendige geschiedenis van een geleerdentijdschrift* (Deventer 2001).

65 *Recueil de diverses pieces* (1720). This Dutch edition under the direction of Pierre des Maizeaux with personal advice by Isaac Newton, was an elaboration of the French translation by Michel la Roche of this famous dispute, published in London in 1719. La Roche was the editor of the *Bib-*

liothèque angloise, where he reviewed the original English version of the dispute, issued by Samuel Clarke in 1717. In his review he also announced the Dutch printing, which would be executed by the publisher Henri du Sauzet in The Hague. Since 1714 Du Sauzet had been editing a French weekly, the *Nouvelles littèraires*, for which Jean Le Clerc had recommended Des Maizeaux as the English correspondent. But as Du Sauzet moved to Amsterdam shortly before 1720 the book was eventually published in Amsterdam. In 1740 an elaborated reprint was issued by François Changuion, one of the co-publishers of 1720. Cf. Van Eeghen, *De Amsterdamse boekhandel* (note 51), vol. 2, pp. 251–254; E.M. van Meerkerk, 'De 'Nouvelles littéraires': een spraakmakend debuut van een jonge uitgever, 1715–1720', *TS: tijdschrift voor tijdschriftstudies* 8 (2000), pp. 11–20. See also: J.-F. Baillon, 'Early eighteenth-century Newtonianism: the Huguenot contribution', *Studies in history and philosophy of science,* part A, 35:3 (2004), pp. 533–548, esp. 539.

66 O.S. Lankhorst, 'De uitgevers van het Journal Litéraire', *Documentatieblad werkgroep achttiende eeuw* 18 (1986), pp. 143–164, esp. 145.

67 Van Eeghen, *De Amsterdamse boekhandel* (note 51), vol. 2, p. 185.

68 Maass, *Het* journal littéraire (note 64). 's Gravesande himself published an article on the theory of air-pump construction.

69 H. Bots and J. de Vet, 'De fysico-theologie in het *Journal litéraire*: Haagse journalisten ten strijde tegen het ongeloof', *Documentatieblad werkgroep achttiende eeuw* 18 (1986), pp. 213–226; The journal also had the honor of publishing the many articles related to the Newton-Leibniz controversy, including John Keill's *Défense du Chevalier Newton.*

70 Vermij, *Secularisering en natuurwetenschap* (note 4), pp. 118–119.

71 For instance, after the preface, a vignette is printed with a cartouche which contains the printer mark '4 G.W.' This vignette is identical to one in Nieuwentijt's *Het regt gebruik*, published by the widow of J. Wolters and J. Pauli (1717 edition) on p. 74. It is also present in the edition of Nieuwentijt's *Gronden der zekerheid*, published by J. Pauli (1728 edition), after the '*bladwijser*', before page 1. The 1723 edition of the *Principia* has a few more vignettes than the 1714 edition. For instance, the last page contains a vignette representing an unidentified coat of arms with three rising chevrons. This vignette is also present in Nieuwentijt's *Het regt gebruik*, published by the widow of J. Wolters and J. Pauli. (1717 edition) on p. 719.

72 In 1732 Nicolaas Struyck edited on his own the fifth edition of S. Ricard, *Traité general du commerce* (Amsterdam), *'aux depens de la compagnie'*. This accounting manual was published by the *Vis unita major* company. In 1722 – when Struyck wrote his letter – the fourth edition of Ricard's *Traité* just had been published by the widow of Jacques Desbordes, whose son and successor with the same name was one of the members of this publishers' company. This fourth edition had been edited by the Amster-

dam mathematician Henri Desaguliers, a relative – perhaps an uncle – of the English Newtonian John Theophilus Desaguliers, probably already with the assistance of Nicolaas Struyck, who at that time was established as a teacher of mathematics and accounting. Cf. H.J. Zuidervaart, 'Early quantification of scientific knowledge: Nicolaas Struyck (1686–1769) as collector of empirical gathered data', in: P. Klep and I.H. Stamhuis (eds), *The statistical mind in a pre-statistical era: the Netherlands, 1750–1850* (Amsterdam 2002), pp. 125–148.

73 N. Struyck to J.N. de l'Isle, 4 April 1722: *'Par cette occasion j'ai aussi decouverte des fautes dans le livre de Mr. Newton Philo: Nat: Princ: Math: qui sont dans la premiere & deuxieme edition & parce qu'on en fait ici une Troisième dont Le Professeur s'Gravesande (qui est Membre de La Societé Royale de l'Angleterre) aura le soin, je le lui ai fait savoir'* (Observatoire de Paris, Corr. Delisle, vol. II, no. 41). Cf. H.J. Zuidervaart, *Van 'konstgenoten' en hemelse fenomenen. Nederlandse sterrenkunde in de achttiende eeuw* (Rotterdam 1999), p. 26 note 13; p. 99 note 1.

74 The second Amsterdam printing of 1723 has an addendum containing Newton's *Analysis per quantitatum series, fluxiones, ac differentias, cum enumeratione linearum tertii ordinis*. This section of 10 + 107 pages has its own title page (Amsterdam: Sumptibus Societatis, MDCCXXIII) and a preface by W. Jones. This part is a reprint of a book published in London in 1711. Cf.Cohen, *Introduction to Newton's* Principia (note 58), pp. 256–257.

75 *Bibliothèque ancienne et moderne* 3:1 (1715), pp. 42–44. Cf. Vermij, 'Amsterdam mathematical amateurs' (note 29), p. 197.

76 On Ten Kate, see: H. Th. van Veen, 'Devotie en esthetiek bij Lambert ten Kate', *Doopsgezinde bijdragen* 21 (1995), pp. 63–96; J. Noordegraaf and M. van der Wal, 'Lambert ten Kate and Linguistics', in: Ten Kate, *Aenleiding tot de kennisse van het verheven deel der Nederduitse sprake*, facsimile edition with an introduction (Alphen aan den Rijn 2001), pp. 2–32; H. Miedema, *Denkbeeldig schoon. Lambert ten Kates opvattingen over beeldende kunst* (Leiden 2006); and the contribution by Dijksterhuis in this volume.

77 L. ten Kate, *Den Schepper en Zyn bestier te kennen in Zyne schepselen; volgens het licht der reden en wiskonst. ter opbouw van eerbiedigen godsdienst, en vernietiging van alle grondslag van atheistery; alsmede tot een rechtzinnig gebruyck van de philosophy* (Amsterdam 1716).

78 Ibid., page no **2/r.

79 Ibid., pages no. **2r-**2/v. Ten Kate refers also to the *Scholium.*

80 See Knoef in this volume.

81 Kegel-Brinkgreve and Luyendijk-Elshout, *Boerhaave's Orations* (note 3), pp. 160–162.

82 Ibid. 176.

83 J. van Sluis, *Herman Alexander Röell* (Leeuwarden/Ljouwert 1988), pp. 62–63 and passim.

84 Bots, *Tussen Descartes en Darwin* (note 1). In many aspects, Nieuwentijt's work resembled John Ray's *The wisdom of God* and William Derham's *Physico-theology*, but in the 'Voorrede' of his *Het regt gebruik der wereldbeschouwingen* (1715), Nieuwentijt writes that he only saw the works of Ray and Derham when his own book was nearly finished. See also: Vermij, *Secularisering* (note 4).

85 On 's Gravesande, see: C. de Pater, *Welzijn, wijsbegeerte en wetenschap: Willem Jacob 's Gravesande* (Baarn 1990); P. Schuurman, *Ideas, mental faculties and method: the logic of ideas of Descartes and Locke and its reception in the Dutch Republic, 1630–1750* (Leiden 2004), pp. 129–155.

86 De Volder's real successor had been Jacques Bernard (1658–1718), a Leiden Walloon minister, who was appointed a lector in mathematics and philosophy in 1705, being promoted to full professor in 1712. 's Gravesande was also appointed professor in philosophy in 1734.

87 W.J. 's Gravesande, *De matheseos in omnibus scientiis praecipue in physicis usu* (Leiden 1717), p. 14.

88 Ibidem, p. 16.

89 's Gravesande, *Physices* (1719–1721), vol. 1, 'Praefatio', sig *3. See also the Dutch translation by J. Engelman, *Wiskundige grondbeginselen der natuurkunde [...] ofte inleiding tot de newtoniaanse wysbegeerte* (1743), 'Voorrede': '*Al wie de schriften [...] over de natuurkunde [...] vergeleken heeft, zal naulyks in twyffel kunnen trekken, of met dien naam worden geheel verschillende wetenschappen bedoeld, terwyl ze allen voorgeven de waare oirzaak der natuurlyke verschynselen te onvouwen.*' On Engelman, see R. van Raak, 'De sneeuwtheologie van Jan Engelman. Een poging tot een newtoniaanse wijsbegeerte', *Geschiedenis van de wijsbegeerte in Nederland* 7 (1996), pp. 99–116.

90 P. de Clercq, *At the sign of the oriental lamp: the Musschenbroek workshop in Leiden, 1660–1750* (Rotterdam 1997), pp. 73–102.

91 G. V. Sutton, *Science for a polite society: gender, culture and the demonstration of Enlightenment* (Boulder 1995), pp. 213–232.

92 R. E. Schofield, *The Enlightenment of Joseph Priestley: a study in his life and work from 1733 to 1773* (University Park, PA 1997), p. 24.

93 A bibliography can be found in: De Pater, *Welzijn, wijsbegeerte en wetenschap* (note 85), p. 152. Two translations were made by former students of 's Gravesande: a French translation by Elie de Joncourt, professor in Bois-le-duc, was issued in 1743–1746 and a Dutch translation by Jan Engelman, a physician and leader of the Haarlem Natuur- en Sterrenkundig Collegie, was published in 1743. Work on the Dutch edition stalled, however, and the second volume was never published, probably due to a disappointing turnover. This is perhaps an indication of a lack of interest in the mathematical approach of Newtonianism among most Dutch enthusiasts.

94 's Gravesande to Newton, 1/24 June 1718. Published in: Hall, 'Further New-

ton correspondence' (note 28), pp. 7–34, esp. 32.

95 On natural theology and the turn to physico-theology in the Dutch Republic, see: Bots, *Tussen Descartes en Darwin* (note 4); Vermij, *Secularisering en natuurwetenschap* (note 4); H.J. Zuidervaart, 'Het Natuurbeeld van Johannes de Mey (1617–1678), hoogleraar filosofie aan de Illustere School te Middelburg', *Archief. Mededelingen van het Koninklijk Zeeuws Genootschap der Wetenschappen* (2001), pp. 1–40; Van der Wall, 'Newtonianism and religion in the Netherlands' (note 42); Jorink, *Reading the Book of Nature* (note 5).

96 J. Ray, *De werelt van haar begin tot haar einde. of dry natuurkundige godgeleerde redeneringen* (Rotterdam 1696).

97 Jacques Lufneu had finished his study at Leiden University in 1718 and Abraham van Loon in 1720.

98 Cf. Baillon, 'Early eighteenth-century Newtonianism' (note 65), pp. 533–548.

99 Cf. G. Bonno, 'Locke et son traducteur français Pierre Coste, avec huit lettres inédites de Coste à Locke', *Revue de littérature comparée* 33 (1959), pp. 161–179; G.A.J. Rogers, S. Hutton and P. Schuurman, 'Pierre Coste, John Locke, and the Third Earl of Shaftesbury', in: S. Hutton and P. Schuurman (eds), *Studies on Locke: sources, contemporaries, and legacy,* International Archives of the History of Ideas/Archives Internationales d'Histoire des Idées, no. 197 (Dordrecht 2008).

100 S. Schaffer, 'Glass works: Newton's prism and the uses of experiment', in: D. Gooding, Trevor J. Pinch and S. Schaffer (eds), *The uses of experiment: studies in the natural sciences* (Cambridge 1989), p. 96.

101 The printing date is marked at the end of volume 2. Desaguliers' assistance is credited in the author's preface. Cf. I. Newton, *Traité d'optique sur les réflexions, réfractions, inflexions, et les couleurs, de la lumière [...] traduit de l'anglois par M. Coste sur la seconde édition, augmentée par l'auteur* (Amsterdam: Pierre Humbert 1720).

102 Coste, 'Preface du traducteur' in: Newton, *Traité d'optique* (note 101), xxii-xiii.

103 Baillon, 'Early eighteenth-century Newtonianism' (note 65).

104 A nice example is the Mennonite David van Mollem, who used physical principles in his silk factory. A family portrait of Van Mollem is adorned with scientific instruments, such as a pyrometer and a tellurium. In 1736 Petrus van Musschenbroek dedicated his *Beginsels der natuurkunde* to Van Mollem.

105 Van der Star, *Fahrenheit's letters to Leibniz and Boerhaave* (Amsterdam 1983); Lambert ten Kate, 'Lettre', in: *Bibliothèque ancienne et moderne* 7:2 (1717), pp. 223–231. See in more detail the contribution of Fokko Jan Dijksterhuis to this volume.

106 The text of the prospectus of Fahrenheit's lessons for 1721–1722 is pub-

lished by E. Cohen and W.A.T. Cohen-De Meester, 'Daniël Gabriel Fahrenheit (geb. te Dantzig 24 mei 1686, overl. te 's-Gravenhage 16 sept. 1736), [part] I', *Chemisch weekblad* 33 (1936), pp. 1–58; [part] II, *Chemisch weekblad* 34 (1937), pp. 1–11.

107 Cf. H.J. Zuidervaart, 'Meest alle van best mahoniehout vervaardigd. Het kabinet van filosofische instrumenten van de doopsgezinde kweekschool te Amsterdam, 1761–1828', *Gewina. tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 29 (2006), pp. 81–112, rpt in: *Doopsgezinde bijdragen,* new series 34 (2008), pp. 63–104.

108 I. Newton, *De historie der aloude volkeren opgeheldert, en in eene naauwkeurige tydorde geplaatst: benevens eene korte kronyk van de eerste bekende gebeurtenissen in Europe, tot de verovering van Persië door Alexander den Grooten* (Delft 1737). This book was reissued with an altered title page in 1763. The Dutch edition was already announced in the *Leydsche courant* of 29 October 1736.

109 Abraham de Vryer from Delft, the Dutch translator of Newton's *De historie der aloude volkeren opgeheldert*, was a Mennonite merchant, broker and, possibly, a '*vermaner*' (preacher). For the same Delft publisher, Pieter van der Kloot, he also translated another (original English) work: [Sherlock], *Pleidooi over de geloofwaerdigheid der getuigen* (1736). In the late 1730s De Vryer moved to Amsterdam where he adapted two disputed biographies: the *Histori van François Eugenius, prins van Savoije-Soissons* (Amsterdam 1737) and the *Histori van Joan Churchil, hertog van Marlborough en prins van Mindelheim*, 4 volumes (Amsterdam 1738–1740), both published by J. Loveringh and J. Roman de jonge. He also worked on the disputed translation of George Anson, *Reize rondsom de werreld, gedaan in de jaaren 1740 tot 1744* (Amsterdam 1748), published by Isaac Tirion. De Vryer's work was fiercely attacked by the Delft publisher Reinier Boitet. See: the *Leydsche courant*, 13 February 1737, and the 'Opdragt aan de Nederlandsche boekhandelaars', page xvi, in: George Anson, *Echt verhael der reistogt rondsom den aardkloot* (Delft 1749). De Vryer died in 1748 as a broker in Amsterdam.

110 For Desaguliers' tour in Holland, see: M.J. van Lieburg, 'De geneeskunde en natuurwetenschappen binnen de Rotterdamse geleerde genootschappen uit de 18e eeuw', *Tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 1 (1978), pp. 14–22 and 124–143; and Zuidervaart, *Konstgenoten* (note 69).

111 This relative was Henri Desaguliers, born around 1662 in La Rochelle, France, the same city where John Theophilus Desaguliers' father, Jean (1644–1699), originated. Jean had fled to England in 1692, where he kept a French boarding school in Islington. Henri probably had settled around the same time as an 'accountant' in Amsterdam, where on 18 December 1700 he married Elisabeth Hoguel (1677–1731), from Dieppe. From 1701

onwards he published several books on accounting as well as on navigation. He must have died shortly before 1732, for in July of that year his son Carel Hendrik Desaguliers (*1704) placed an advertisement in the *Amsterdamsche courant*, stating that he would continue the mathematics lessons given by his deceased father. Persons interested in these lessons were requested to subscribe in the bookshop of Jacques Desbordes, one of the publishers from the *Vis unita major* company and in 1738 one of the publisher of Voltaire's *Elemens de la philosophie de Newton*. Cf. Zuidervaart, *Konstgenoten* (note 69), pp. 448 and 472; and P.C.J. van der Krogt, *Advertenties voor kaarten, atlassen, globes, e.d. in Amsterdamse kranten, 1621–1811* (Utrecht 1985), pp. 352 and 605.

112 B. Nieuwentyt, *The religious philosopher, translated from the Dutch by John Chamberlayne, with a prefatory letter by J.Th. Desaguliers* (London 1718–1719); W.J. 's Gravesande, *The mathematical elements of natural philosophy, confirmed by experiments, or an introduction to Sir Isaac Newton's philosophy, translated from the Latin by J.Th. Desaguliers* (London 1721).

113 J. Th. Desaguliers, *Een begryp van de mechanische en experimentele philosophie. Waar door een yder, hoewel onervaren in de wiskundige wetenschappen in staat werd gestelt, om te verstaan de verscheidene (phaenomena) verschynselen of werkingen, die zig in de natuur opdoen* (Rotterdam 1731). The only known copy is in the Municipal Library of Rotterdam, pamphlet 1731, no. 16. See also: J.A. van Reijn, 'John Theophilus Desaguliers', *Thoth, tijdschrift voor vrijmetselaren* 34:5 (1983), pp. 165–203, esp. p. 193, who cites a printed announcement ('*bekentmakinge*'), which was collated into a manuscript with notes of Desaguliers' course – until 1940 this was present in the library of the Bataafsch Genootschap der Proefondervindelijke Wijsbegeerte (Batavian Society of Experimental Philosophy) at Rotterdam.

114 Zuidervaart, *Konstgenoten* (note 69), pp. 71–77.

115 H.J. Zuidervaart, 'Science for the public: the translation of popular texts on experimental philosophy in the Dutch language in mid-eighteenth century', in: S. Stockhorst (ed.), *The circulation of Enlightened thought in Europe by means of translation* (Amsterdam, New York 2010), pp. 231–262, esp. pp. 243–247. See also the prospectus for this Dutch edition in the Amsterdam University Library, shelf mark KVB PPA 645:20.

116 Zuidervaart, *Konstgenoten* (note 69). See also: idem, 'Cabinets for experimental philosophy in the Netherlands', in: J.Bennett and S. Talas (eds), *Making science public in 18th-century Europe: the role of cabinets of experimental philosophy* [provisional title], History of Science and Medicine Library: Scientific Instruments and Collections, vol. 3 (Leiden/Boston in press).

117 N. Struyck to J.N. de I'Isle, 4 April 4 1722 (Observatoire de Paris, Corr. Delisle, vol. II, no. 34).

118 N. Struyck, *Inleiding tot de algemeene geographie, benevens eenige sterrekundige en andere verhandelingen* (Amsterdam 1740).

119 B. Varenius, *Geographia generalis* (Amsterdam 1650) was enlarged by Isaac Newton in the edition of 1672. The Dutch translation of 1750 was edited by Nicolaas Struyck, in cooperation with two fellow mathematicians from Haarlem, Dirk Klinkenberg and Jacob de Bucqoy. Cf. Varenius (1650).

120 Zuidervaart, *Konstgenoten* (note 69); idem, 'Astronomische waarnemingen en wetenschappelijke contacten van Jan de Munck (1687–1768), stadsarchitect van Middelburg', *Archief. Mededelingen van het Koninklijk Zeeuws Genootschap der Wetenschappen* (1987), pp. 103–170; idem, *Speculatie, wetenschap en vernuft. Fysica en astronomie volgens Wytze Foppes Dongjuma (1707–1778), instrumentmaker te Leeuwarden* (Leeuwarden/Ljouwert 1995).

121 D. Klinkenberg, 'Kort berigt wegens eene comeet-sterre, die zich in den jaare 1757 of 1758, volgens het systema van Newton, Halley, en andere sterrekundigen, zal vertoonen', *Verhandelingen, uitgegeeven door de Hollandsche Maatschappij der Wetenschappen* 2 (1755), pp. 275–318.

122 C.B. Waff, 'The first international Halley Watch: guiding the worldwide search for Comet Halley, 1755–1759', in: N. J.W. Thrower (ed.), *Standing on the shoulders of giants: a longer view of Newton and Halley* (Berkeley 1990), pp. 373–411; Zuidervaart, *Konstgenoten* (note 69).

123 J. Schim, 'Aanmerkingen over den loop der staartster, die eerlang verwagt wort, en in 't jaar 1682 verscheenen is', *Verhandelingen, uitgegeeven door de Hollandsche Maatschappij der Wetenschappen* 4 (1758), pp. 490–505. Interestingly, in February 1759 the German mathematician Johann Friedrich Hennert, then living in The Hague, communicated Schim's results to the French mathematician Alexis-Claude Clairaut, who was also engaged in a large calculating project to estimate the comet's perturbations. Clairaut's prediction of the perihelion passage for April 1759 appeared to be very accurate. Cf. Zuidervaart, *Konstgenoten* (note 69), pp. 188–190.

124 De Pater, *Petrus van Musschenbroek* (note 1).

125 Van Musschenbroek to Newton, 12/23 February 1726. Published in: Hall, 'Further Newton correspondence' (note 28), pp. 7–34.

126 A.A.M. de Haan, *Het wijsgerig onderwijs aan het gymnasium illustre en de hogeschool te Harderwijk, 1599–1811* (Harderwijk 1960); idem, 'Geschiedenis van het wijsgerig onderwijs te Deventer', in: H.W. Blom et al., *Deventer Denkers* (Hilversum 1993), pp. 29–122; S.H.M. Galama, *Het wijsgerig onderwijs te Franeker, 1585–1811* (Franeker 1954), and F. Sassen, *Het wijsgerig onderwijs aan de Illustre School te 's-Hertogenbosch (1636–1810)* (Amsterdam 1963).

127 C. de Pater, 'Nicolaus Engelhard (1696–1765) en zijn kritiek op de *Begin-*

selen der natuurkunde van Petrus van Musschenbroek (1692–1761): wolffianisme versus newtonianisme', *Tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 13:2 (1990), pp. 141–162; Schuurman, *Ideas, mental faculties and method* (note 85).

128 E. Jorink. 'In conflict met de Groningse theologen' in: J. van Maanen (ed.), *Een complexe grootheid. leven en werken van Johann Bernoulli, 1667–1748* (Utrecht 1995), pp. 49–68; H. A. Krop, J.A. van Ruler and A.J. Vanderjagt (eds), *Zeer kundige professoren. beoefening van de filosofie in Groningen van 1614 tot 1996* (Hilversum 1997).

129 G.W. Kernkamp, *Acta et decreta senatus. vroedschapsresolutien en andere bescheiden betreffende de Utrechtse Academie*, 2 vols (Utrecht 1938), vol. 2, p. 367; C. Hakfoort, 'Christian Wolff tussen Cartesianen en Newtonianen', *Tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 5 (1982), pp. 27–38.

130 P. de Clercq, 'Science at court: the eighteenth-century cabinet of scientific instruments and models of the Dutch stadholders', *Annals of science* 45 (1988), pp. 113–152.

131 Van Musschenbroek to Newton, 12/23 February 1726. Published in: Hall, 'Further Newton correspondence' (note 28), pp. 7–34.

132 R. Vermij, 'Johannes Lulofs als vertegenwoordiger van het newtonianisme in de republiek', *Gewina. Tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 22 (1999), pp. 136–150.

133 See for instance: W. Hackman, 'Electricity in eighteenth-century Holland: a Newtonian legacy', in: P.B Scheurer and G. Debrock (eds), *Newton's scientific and philosophical legacy* (Dordrecht 1988), pp. 175–182.

134 Popular Dutch translations referring to Newtonianism, published in the second half of the century, included [John Newberry], *Philosophie der tollen en ballen of het Newtoniaansche zamenstel van wysbegeerte [...] door Tom Telescope* (Middelburg 1758; reissued 1783) and Francesco Algarotti, *De newtoniaansche wysbegeerte voor de vrouwen, of samenspraaken over het licht, de kleuren en de aantrekkingskragt* (Amsterdam n.d. [c. 1768]; Utrecht 17752). For these and other translations of experimental philosophy, see: M.R. Wielema, 'Christiaan Wolff in het Nederlands. de achttiende-eeuwse vertalingen van zijn Duitstalig oeuvre (1738–1768)', *Geschiedenis van de wijsbegeerte in Nederland* 1 (1990), pp. 55–72; idem, *Ketters en verlichters: de invloed van het spinozisme en wolffianisme op de Verlichting in gereformeerd Nederland* (Thesis, VU University Amsterdam, 1999), and Zuidervaart, 'Science for the public' (note 109).

135 'Een Newton deedt ons eenen 's Gravesande zien, eenen Musschenbroek, en deeze beide hebben ons mannen uitgeleverd, welke nog heden uitblinken in Staats regeering, en aan onze hooge Schoolen. Hoe veele Kooplieden vindt men niet nog van dien tyd, welke zig bezig houden met Optische proeven te doen, en die te verbeteren? Wy moogen nog

op enkele Regenten roemen, welker voorkameren opgevuld zyn, met de schoonste konst stukken om de Mechanica, de Hydrostatica, en derzelver eigenschappen te toonen, en Astronomische waarneemingen te doen. Dus was de staat van ons land in de verledene eeuw, en in het begin van deeze. Duizend ontdekkingen, welke eer doen aan het Opperwezen, en eene kroon zyn voor het menschelyk vernuft, wierden dagelyks gemaakt in de Sterrekunde zoo wel als natuurlyke historie. De Groote Boerhaave, de voorstander, de beschermer, het voorbeeld van goeden smaak, was naulyks dood, of alles verviel. Winkler deedt ons de verhevene Astronomische onderzoekingen verruilen tegen de onnoozele Electrische proefneemingen: [...] Hoe ellendig Wolf den goeden smaak van Newton en Locke bedorven heeft, zult gy beter, dan ik, beoordeelen konnen.' *De Denker*, no. 133 (15 July 1765), pp. 217–218.

136 Cf. P. Fara, *Newton: the making of genius* (London 2001).

137 Cf. Petry, *Hemsterhuis* (note 41).

138 '*Ô Groote Newton! die de kragten der Natuur, Haare eew'ge wetten op 't naauwkeurigst kost bereeknen*', Moens (1802), p. 19, quoted in Van der Wall, 'Newtonianism and religion in the Netherlands' (note 42), p. 493.

139 Isaac Newton was, for instance, used as an iconic figure by the Amsterdam Mennonite publisher Frans Houttuyn (c. 1719–1765), who named his bookshop 'Isaac Newton', and included Newton's portrait in his printer's mark.

140 See: L. Stewart, *The rise of public science: rhetoric, technology and natural philosophy in Newtonian Britain, 1660–1750* (Cambridge 1995), for the locally adapted use of Newtonianism in England.

141 Vermij, *The Calvinist Copernicans* (note 11), p. 349, emphasis added.

Servant of Two Masters

Fatio de Duillier between Christiaan Huygens and Isaac Newton

ROB ILIFFE

For a brief period at the end of the seventeenth century, the young Swiss scholar Nicolas Fatio de Duiller (1664–1753) appeared to be on the brink of joining the front rank of mathematicians and natural philosophers. An acknowledged expert in differential and integral calculus at a time when mathematicians were forging foundational techniques in these areas, he was also in possession of a theory of gravitation that synthesized the best elements of the work of the two outstanding natural philosophers of the period, Christiaan Huygens (1629–1695) and Isaac Newton (1642–1727). Indeed, Fatio benefitted from an exceptionally close intellectual relationship between the two men, and was able to work in intimate collaboration with two very different individuals, whose interests spanned a wide range of subjects. Initially Huygens' chief representative in England, he later became a passionate advocate of Newton, whose mathematical and scientific achievements he valued more highly than those of anyone else. A number of historians have suggested that Fatio and Newton had some sort of physical relationship, although there is no evidence for this. However, it is true that the latter exhibited far more concern over the health and well-being of Fatio than for any other individual on record.[1]

Fatio evidently had a plan for a meteoric career and for five years he managed the apparently impossible task of serving two powerful masters. However, he had to balance a requirement to impress and represent his patrons with the need to develop a proper standing in the field. For some time in the early 1690s he was apparently close to having his own theory of gravity appear at the front of a new edition of the *Principia mathematica* — which was to be completely transformed under his editorship. In this essay I examine the difficulties Fatio encountered in creating and maintaining his own intellectual property in a highly competitive philosophical and mathematical environment. I show that although he enjoyed unrivalled access to Huygens and Newton, he lacked the personal and financial resources to obtain the independence from them that he needed to forge his own career. His early proximity to Huygens enabled him to become the chief representative of the Huygenian philosophy when he went to England in 1687. A few years later, the roles were reversed, and he became the chief source of information for Newton's science and mathematics in the Netherlands.

Fatio's relationship with Huygens has received much less attention than his dealings with Newton, but it is equally interesting. The Dutchman showed a great concern and respect for Fatio over a number of years and he worked closely with the Swiss scholar when the latter stayed with him in 1691. However, their mutual regard lessened when Huygens tried to broker an exchange of integration techniques between Fatio and Gottfried Leibniz (1646–1716) at the end of 1691. Both Fatio and Leibniz had made progress in one of the most difficult areas of calculus, and each had developed techniques that they guarded jealously. However, Fatio's attitude to both his own and Leibniz's achievements was dramatically transformed by his encounter with Newton's mathematical work at the end of 1691, and his views of Leibniz's originality and intellectual virtue, already less than positive, were severely diminished as a result. To his chagrin, Huygens failed to facilitate communication between the younger scholars and he died in 1695, having played a major role in instigating the great priority dispute over the invention of the calculus that was soon to erupt between Leibniz and Newton.

The prodigy

Born into a wealthy family in 1664, Fatio attended the Académie de Genève, where his talent was nurtured by John-Robert Chouet (1642–1731), rector of the Academy from 1679. Chouet was a pronounced Cartesian whose influence on the curriculum resulted in a much greater emphasis on physics and mathematics. With the support of Chouet Fatio made his way to Paris in early 1683, where he learned sophisticated astronomical theory and practice with the director of the Observatoire, Jean-Dominique Cassini (1625–1712). In 1685 Chouet communicated Fatio's work on the zodiacal light recently discovered by Cassini to the journal *Les nouvelles de la république*, and its editor, Pierre Bayle (1647–1706), commented on Fatio's excellent mathematical training. Cassini himself commented that Fatio had all the qualities essential to a gentleman.[2]

Although it went against the wishes of his parents, Fatio set out to forge an identity as a major player in the scientific Republic of Letters. A chance encounter offered him a very different source of patronage and he became associated both with the Dutch States-General and with the court of William of Orange (1650–1702). Having returned to his father's estate in 1685 as a result of the Revocation of the Edict of Nantes, he came into conversation with a Count Fenil, who apparently told Fatio of a plan to kidnap the prince. Fatio relayed this information to Gilbert Burnet (1643–1715), by then a close confidant of William. Fatio travelled back to Holland with Burnet in the spring of 1686, and as a result of his information the States-General tried to set up a chair in mathematics for Fatio. This idea, resurrected a few times over the following decade, never came to fruition.[3]

Nevertheless, Fatio's sojourn in the Netherlands did enable him to meet Christiaan Huygens at The Hague, and for a number of months over the winter of 1686–1687 they worked closely together on various topics, including the shape of snowflakes and finding tangents to complex curves. Huygens recognized Fatio as an outstandingly talented younger mathematician whose work and career he could support, and got Fatio to locate and publish errors in the recently published works on tangents (i.e. differentiation techniques) of Ehrenfred Walther von Tschirnhaus (1651–1708). This brought Fatio to the attention of the mathematical community but it was his work on the 'inverse problem of tangents' (the solution of differential equations, i.e. finding the equation of a curve whose tangent is given), whose results he sent in a letter to Huygens in June 1687, that was most significant and which would soon bring him into conflict with Leibniz.[4]

At some point early in 1687 Fatio decided to visit England, a move prompted both by a delay in organizing his professorial position, and also by a wish to acquire the patronage of Robert Boyle (1627–1691). He already cut an impressive figure, and Burnet told Boyle in early 1687 that Fatio was 'one of the greatest men of this age [who] seems born to carry learning far beyond what it has attained'. Fatio duly met

Boyle and learned of the content of the imminent *Principia mathematica*. When it appeared in the summer it was the talk of the town. Its first readers were stunned by its contents, for Newton's three laws of motion and his theory of universal gravitation united the laws that governed celestial and terrestrial phenomena and accounted for the tides, the shape of the Earth and the paths of comets and planets. In the same letter in which he revealed his solution to the inverse method of tangents, Fatio informed Huygens that he had already been to three meetings of the Royal Society and that he had been reproached for being too much of a Cartesian. Fatio clearly wrote as a client when he remarked that Newton should have consulted Huygens over the principle of attraction, and he reminded Huygens that while in Holland he had stated that the latter's explanation of gravity would give sufficiently probable reasons to explain the tides. In his well-known reply to Fatio, Huygens noted that he hoped Newton did not make use of the doctrine of attractions.[5]

Fatio sought to stay in London but his father urged him to return to Geneva and apparently withdrew financial aid, an action that would have serious consequences for Fatio's later career. Having realized that the Royal Society did not give financial support for research, even to scholars as talented as himself, Fatio redoubled his efforts to procure patronage, and wrote to Boyle in January 1688 to see if he could gain employment as a tutor. In May 1688 he informed Huygens that he had made plans to stay in England for another year but this involved tutoring the son of one of his friends. It would be preferable, he said, if at the end of this period he could return to work with Huygens at The Hague.[6]

As England lurched towards political revolution in the summer and autumn, Fatio spent much of his time as a tutor, working when he could on mathematical problems and his theory of gravity. He gave a talk on the latter subject at the Royal Society in June 1688, claiming that his notions had been 'embraced' by Huygens, although in later notes he remarked that he had also added his own thoughts. In July he read a more detailed account of the theory at one of their meetings, explaining gravity in terms of an aetherial vortex that revolved around the Earth every eighty-five minutes. As before, it was difficult to separate his own views from those of Huygens, although he told his audience that he was essentially presenting Huygens' theory. Over the next year and a half he would develop a much more extensive theory of his own, this time incorporating a number of Newtonian elements.[7]

Ironically, just as news filtered through from Fatio about the contents of the *Principia*, Huygens completed a major rewriting of a theory of gravitation that he had initially composed in 1669. He received a presentation copy of Newton's work in September or October 1687 and immediately reconsidered his explanations of gravitation and the shape of the Earth. In December 1687 he endorsed Newton's claim that he had destroyed Cartesian vortices and lauded Newton for his treatment of comets. Throughout 1688 he spent a great deal of time immersed in the *Principia*, and he praised Newton for showing that gravitation was centripetal and operated according to an inverse square law that retained planets in elliptical orbits. Nevertheless, his commitment to the ontological and epistemological demands of the mechanical philosophy meant that he could not allow the existence of an immaterial *universal* gravitation, especially one that operated between tiny particles separated at incomprehensibly large distances. At the same time, he filtered data from the ongoing trials of his pendulum clocks aboard the Dutch East India Company (Vereenigde Oost-Indische Compagnie [VOC]) ship *Alkmaar*, which provided him with information about the shape of the Earth suggesting that the planet was an oblate spheroid, but not as flat as Newton had suggested. He referred to this data in a report written to the directors of the VOC in April 1688.[8]

Fatio's prospects improved in January 1689, in the immediate wake of the Glorious Revolution, when the author of the *Principia* came down to London in a political capacity. Newton had stood as a candidate for the Convention (as one of the two representatives of the university) and against the odds, had won a seat. Probably no earlier than the spring, he made contact with Fatio and they undoubtedly discussed a range of issues in optics, mechanics and mathematics. The subject of alchemy formed a significant part of their discussions and indeed they corresponded on the subject, although these letters are now lost. By October Newton was sufficiently familiar with Fatio that he could confide to him exceptionally impolitic comments about Boyle, and he asked what must have been a delighted Fatio whether he could lodge with him during the imminent session of Parliament.[9]

Newton and Fatio were also close at this time to the radical Whig MP John Hampden (1631–1695), a remarkable man who had studied with Richard Simon (1638–1712) while in Paris in the early 1680s, and who had later sponsored some of his researches. Fatio and Hampden were in Newton's company on many occasions over the summer, and were instrumental in pushing for Newton's ultimately unsuccessful attempt to become provost of King's College, Cambridge, in the summer of 1689. By November, Fatio was an ardent admirer of Newton, describing him to Chouet in November as '*le plus honnête homme*' he had met, and the ablest mathematician who had ever lived. If he had 100,000 écus, he told Chouet, he would erect great statues and a monument to Newton. Fatio lodged in Hampden's London residence over the winter of 1689/90, called Hampden his 'intimate friend', and earned a small salary from tutoring one of Hampden's nephews. He would remain in close contact with Hampden for the following two years.[10]

The Dutch contribution to the Glorious Revolution provided further patronage opportunities. In the first place, Fatio's champion, Gilbert Burnet, was one of the chief advisors to William of Orange, and Fatio could look forward with confidence to Burnet's support after the Revolution. Secondly, as William quickly gained control in England and Scotland at the end of 1688, Christiaan Huygens realized that the central position of his brother, Constantijn (1628–1697) in William's entourage paved the way for his own translation to London. In the middle of November 1688 he told Constantijn that he was pleased with the progress of the expedition and on 20 December (O.S.) he confessed how delighted he was that the venture had turned out so well. He outlined his desire to move to England, and emphasised his wish to meet Newton, a man who had made 'beautiful discoveries'. In March, with the overwhelming success of the Williamite revolution now ensured, Huygens told his brother that he would be leaving for England before long, not for the coronation but in order to see what was going on in the scientific world. There was little chance of conversation on scientific matters in the Netherlands, and he told Constantijn that he had spent the previous days in Leiden trying to publish treatises on light and gravity that he had been polishing off over the winter. However, paper was prohibitively dear and the world seemed more interested in political news.[11]

Huygens arrived at Harwich on 1 June 1689 and was in London (lodging with Constantijn at Hampton Court) five days later. On 10 June (O.S.) he met Boyle, then in the midst of his fascination with the alchemical 'red earth', and indeed the possibility of turning lead into gold featured heavily in their conversation. He met Newton and Fatio at the meeting of the Royal Society on 12 June (O.S.) where he gave presentations on his theory of gravity and on birefringence in Iceland crystal (calcite). He and Newton discussed the nature of light, doubtless smoothing over the differences that had emerged when Newton had first published his theory of light and colour in the early 1670s. At this encounter, and probably at another on 30 June (O.S.) they must have discussed their mutual theories of gravity as well as various concepts and propositions in the *Principia*. In July Fatio, Newton and Christiaan rode from Hampton Court to London (presumably having met the day before), and in August Newton sent Huygens two small demonstrations on motion in resisting media. The July meeting had been convened in connection with the efforts by Fatio and John Hampden to enlist the support of the Huygens brothers in the great quest to gain Newton the provostship at King's College. Through Constantijn, they gained the support of William himself, but as we have seen, this had little effect on the outcome. Huygens returned to the Netherlands at the end of August, and for a while tried to obtain a senior administrative position. Despite the efforts of Constantijn, William apparently decided that Christiaan was unsuitable for such a position.[12]

The intermediary

The personal encounter with Newton forced Huygens to once more alter his theories of light and gravity, and he composed an extensive 'Addition' to his recast theory of gravity. Here he referred to the way that the VOC data affected his account of the shape of the Earth; he argued that it supported his own theory rather than Newton's, though he did not rule out the possibility that further data would give more robust support for universal gravitation. He completed the revisions to his treatises on light and gravity in The Hague, in a location that was preferable to the 'overly melancholic solitude' of Hofwijk, the country estate of the Huygens family at Voorburg. The single tome consisting of the *Discours sur la cause de la pesanteur* and the *Traité de la lumière* was published at the end of January 1690 and he immediately dispatched copies to English scholars. In the volume intended for Fatio, Huygens marked two passages in the 'Addition' in which he denied there could be a mechanical cause of universal gravitation, and where he asserted his wave theory of light. He told Fatio that he had crafted his comments in such a way that he believed Newton would not take them badly, and pointed out that Fatio would almost certainly need to help Newton with the French.[13] In his letter Huygens remarked on the fact that he had not heard from Fatio for a substantial period of time, and indeed, Fatio was already providing indications of his unreliability as a correspondent. Constantijn was unable to locate Fatio when he tried to deliver Fatio's copy of the *Traité* to him in February 1690. Fatio was no longer at the Suffolk Street address where he had been when Christiaan had visited him in 1689, and was by now staying with Hampden. The other copies ultimately reached their intended recipients through William Stanley, Queen Mary's clerk of the closet and Christiaan's major contact in London. Believing that Fatio was lost somewhere in Europe, Huygens showed extraordinary concern for his protégé, telling Constantijn that if he failed to hear about Fatio from Stanley, he (Christiaan) would have to write directly to Newton.[14]

On 24 February 1690 Fatio told Huygens that he had read his work (actually Hampden's copy) a number of times and with a singular pleasure. With reference to Huygens' overtly probabilistic stance, he remarked that it would be a shame if the theory were not true. However, the same letter contained a new theory of his own, elements of which must have been composed in great speed after reading Huygens' work. Two days later he read the letter as a paper at a meeting of the Royal Society. Fatio had removed the notion of a circulating vortex and had injected a number of Newtonian elements into his new theory, in particular the notion that tiny, secondary particles were 'agitated' in every direction. These particles were subject to innumerable impacts caused by being first attracted and then reflected less powerfully. Their interaction with the hard, massive parts of macro-objects ultimately gave rise to the observed inverse square law. On 19 March he got the endorsing signatures of Edmond Halley (1656–1742) and Newton on his manuscript of the theory, and later added that of Huygens.[15]

Fatio also relayed Newton's views to Huygens, especially regarding the question of what Newton thought about the cause of gravity. He told Huygens that Newton would take perfectly well (*'recevra parfaitement bien'*) what Huygens had said about his work and claimed that Newton had 'been ready on many occasions to correct his book on the topics about which we have spoken; I can't sufficiently admire his dexterity, especially in the places you attack'. Fatio showed a fair degree of presumption in speaking on behalf of Newton, since the latter had recently returned to Cambridge after his stint as an MP. Nevertheless, Newton had told Fatio he was about to return to London, and on the same day that he wrote to Huygens Fatio passed on to Newton Huygens' sound advice about the need to read the French texts in London with himself. Newton arrived in London on about 10 March and remained for over a month. He almost certainly lodged with Fatio and the two of them worked closely on various topics. Fatio relayed the tenets of the *Discours* to Newton and they collaborated in compiling a list of errata from the *Principia*.[16]

Huygens' response to Fatio's theory of gravity was hardly ecstatic, and he asked Fatio not to condemn him before understanding him. Especially troubling was the excessive amount of void that Fatio had designed into his system, and the fact that over time Fatio's theory entailed an increasing build up of matter on the surface of the planet. In his reply Fatio defended his theory with vigour but was effusive with compliments for Huygens. Nevertheless, he was forced to say that Huygens had mistaken his comments as an objection to his treatise; Huygens had done him a great honour in proposing objections to his theory, and infelicities in his responses to Huygens' own theory of Iceland crystal and gravity should be put down to the lack of time he had had to prepare his text. He added that since he had seen Hampden's presentation copy very early on, he had also hoped that his speedy response to Huygens' objections might have been incorporated into the standard print version of the text.[17]

Collaboration

Fatio left for the Netherlands in the spring of 1690 as tutor to two of Hampden's nephews, bearing his theory of gravity and a list of errata to Newton's *Principia*. The need for financial support was clearly pressing, and as before, he viewed his new employment as an unwelcome diversion from his vocation. He complained to his brother Jean-Christophe on 9 June that he had lost the opportunity to write up his treatise on the cause of gravity, while there is an apocalyptic tone in a letter written to his friend Nicolas Tourton soon afterwards, instructing Tourton to leave a box of Fatio's mathematical papers with Newton as a sort of 'mathematical legacy'. In two letters written in July he told Huygens that his entourage had decided to stay a few months in Utrecht, and that his teaching duties no longer left him master of himself. Huygens, he wrote, should know how badly Fatio wanted to be close to him, preferably in the 'Hermitage' at Hofwijk. Although there is evidence that Fatio was suffering from depression and religious doubts for much of this period, his letters indicate that he perceived the lack of space and time for producing his own scholarly work as the chief cause of his existential angst — a situation that could only be assuaged by being close to a patron.[18]

Fatio's wish was granted early in the following year. From February 1691 he and Huygens worked closely together on a series of different topics, including discussing errata to the *Principia*, the cause of colours and gravity, and most importantly, mathematical techniques. These concerned the determination of methods for finding tangents and the development of Fatio's 'Rule' for finding exact differential equations by multiplying equations by the integrating factor $x^m y^n$. In May Fatio told Boyle that he had reawakened Huygens' passion for physics and mathematics, which had been stifled due to a lack of suitable encouragement from other people. However, whether or not Fatio knew it, his contribution was not as great as he had wished. Huygens had been engaged in serious mathematical and scientific discussions with Leibniz for over a year, much of which concerned their responses to themes in Newton's *Principia*. Moreover, under the tuition of Johann Bernoulli (1667–1748), the Marquis de l'Hôpital (1661–1704) had emerged as a major mathematical correspondent who gradually supplanted Fatio's place in Huygens' world.[19]

Mathematical secrecy and a proliferation of circulating problems and solutions characterised correspondence between mathematicians in this period. Since Leibniz had referred to his own excellence in the area of the inverse problem of tangents, Huygens told him at the end of 1690 about Fatio's work on the same topic. When Leibniz asked him the following February if Fatio's work in this area had satisfied him, Huygens informed Leibniz that Fatio was now at The Hague and had visited him several times. Fatio had apparently perfected his method up to a certain point; it did not require tables (which Leibniz had claimed were required for his own method), but it could not deal with roots containing unknowns. Leibniz was unwilling to release his own technique but Huygens asked him if he could provide an integral solution to a curve that Huygens had nominated, and which Fatio had been unable to solve. This would at least clarify the issue as to how their techniques differed. Leibniz in turn mentioned his esteem for Fatio and indicated that some sort of exchange of methods would also be congenial. Having said that, to show Fatio that the curve in question was squarable, Leibniz included his own solution, recasting

Huygens' original remarks to make it appear that Fatio had thought it could not be done *because* he himself had not succeeded.[20]

Huygens' personal journal shows how closely he and Fatio cooperated on different problems in the spring of 1691, many of which were on applications of Fatio's 'Rule'. At various points he indicated to Leibniz that he and Fatio were engaged in collaborative work, although Fatio's notes indicate that he operated more easily in the language of fluxions. In early May Huygens implied that both the methods of Leibniz and Fatio were equally meritorious, and again called for Leibniz to send the explication of his technique. While he admired the power of Leibniz's method, he told Leibniz that he should be less opaque in what he sent and should not assume that Huygens and Fatio understood his differential calculus. Throughout the summer, Fatio continued to work with Huygens, and all three men consistently raised the question of exchanging methods. Recognizing how close Fatio was to Huygens, Leibniz suggested in September that both he and Fatio should send their methods to an independent person in Bremen, so that the transaction could be effected.[21]

Mathematical merchandise

Fatio returned abruptly from The Hague at the start of September 1691, lodging once more in Suffolk Street. He explained his return to Newton as being caused by the death of one of his pupils from consumption and offered to travel to Cambridge to let Newton in on the marvellous secret of some 'metallick remedys' that had been prepared by a friend of his. A few days later he told Huygens that he had left The Hague in such a hurry that he had not had time to pick up Huygens' 'orders' for his visit to England; moreover, he had left behind his list of *Principia* errata and asked Huygens to send it, presumably in preparation for his meeting with Newton. In reply Huygens mentioned that he had searched for Fatio a fortnight earlier in order to give him the errata, but had failed to locate him. He did prompt Leibniz about the exchange of methods in November, noting that Fatio had taken back with him the original letter explaining his rule. This letter, he said, had been so seriously altered as a result of their collaborative work over the summer, that it had become something entirely different from the original. Now he lacked a clear statement of Fatio's rule, and would have to deduce it from the various problems on which they had been working.[22]

Fatio's return to England coincided with Newton's resumption of intense mathematical activity. On the one hand he had been spurred into action by the imminent publication by the Scottish mathematician David Gregory (1659–1708) of a general method for integration by series, a move that was embedded in a complex and sensitive web of intellectual property issues. Fatio himself now drew a willing Newton into his own campaign against Leibniz, and as a result of these twin promptings Newton was galvanized into writing a general treatment of integration ('De quadratura curvarum'). In this he developed some of the techniques underlying the second letter he had sent Leibniz in 1676 (the 'Epistola posterior') and he dealt extensively with the inverse problem of tangents.[23]

In a letter to Fatio of early December, Huygens also mentioned that he had now received an account – of sorts – of Leibniz's inverse method of tangents. This was prompted by his irritation at Leibniz's offer to have the matter handled by a third party, as if, Huygens noted, Leibniz doubted Huygens' word. However, Huygens told Fatio that Leibniz's explanation was obscure, and that he hadn't yet got to the bottom of it. Ominously, he told Fatio that since the latter was less versed than Huygens in the differential calculus, it would not be useful to pass on what Leibniz had sent him, at least until he got clarification from Leibniz. Again Huygens noted diplomatically that although Leibniz's method did not exclude roots, Fatio's technique could resolve 'an infinity' of different cases.[24]

Fatio had presumably already seen some or all of 'De quadratura' by the time he replied to Huygens in the middle of December. For the first time he displayed irritation with Huygens, noting that he *did* understand the differential calculus '*fort bien*'. This was despite the notorious errors that had marred the initial printing of Leibniz's method for the differential calculus in 1684 – so numerous, Fatio claimed, that one could almost believe they had been made by design. Referring to the famous 'fluxions' Lemma (book 2, lemma 2) in the *Principia*, he stated that he believed Newton was '*sans difficulté*' the first author of the differential calculus, and that he knew it as well as or better than Leibniz did. At the end of December Fatio was making these views known to David Gregory, adding for good measure that he knew the inverse problem of tangents better than Leibniz. However, Newton knew everything.[25]

Trouble with Newton

As Fatio ignited the first flames of the priority dispute over the invention of calculus, Newton's intellectual rigours and his failure to obtain a key position in London both took their toll. In December he had a brief exchange with Locke over the possibility of obtaining a position at Charterhouse and at the end of the month he travelled to London for the funeral of Robert Boyle. He dined with Samuel Pepys (1633–1703) and John Evelyn (1620–1706) on 9 January but fell into a paranoid and melancholy mood soon afterwards. A week later, Locke's friend Robert Pawling told him that he had seen Newton 'up two pairs of Stairs in a pittifull room' in Suffolk Street, presumably in Fatio's lodgings. Pawling clearly implied that the source of Newton's angst was his inability to land a senior position in the capital but aside from this, there were a series of intellectual problems that vexed him at this time. Some of these involved Locke, who had been left a recipe for Boyle's 'red earth' along with some specimens. Over the next few months Newton and Locke exchanged letters on the topic, and also on the issue of suppressing Newton's provocative essay on the Trinitarian corruption of Scripture.[26]

Newton had also embarked on the preparation of a second edition of the *Principia*. Huygens asked Fatio about this in early December 1691, partly as a way of accommodating the growing number of errata (most of which Fatio had passed on to him). Fatio in turn gave an impression of great intimacy with Newton, emphasizing his own central role in any future edition. Mixing boastful comments with expressions of humility, he told Huygens that he would want to add certain elements to the edition — by which he undoubtedly meant his own theory of gravitation. There was also the issue of the list of errata, which was expanding as he ploughed his way through it. Nor was this all, for most ambitiously he proposed a truncated folio edition that could be read in a fraction of the time that one required to read the present quarto. He doubted, however, whether his health or financial situation would allow him to have the leisure required for the work. Gregory heard from Fatio at the end of the month that such an edition was being planned, along with a preface by Fatio that gave a physical explanation of gravity. Gregory took down a detailed description from Fatio of his theory but also recorded, presumably from the lips of Halley, that Newton and Halley mocked it.[27]

In early February 1692 Huygens relayed the less inflammatory contents of Fatio's letter to Leibniz and immediately afterwards told Fatio that undertaking a new edition of the *Principia* should not be carried out to the detriment of his health. As for underwriting the edition, there were surely English booksellers who would back an enterprise of this nature — such people certainly existed in Holland. In any case it could be done by subscription. As for the exchange, Huygens lamented that both men believed they could find what was lacking from the other's method with a minimum of effort. He added that he hoped Fatio's work would appear in the forthcoming book on curves by Newton that Fatio had mentioned to Constantijn. Finally, he noted — not unreasonably — that he thought that in the place in the *Principia* to which Fatio had referred, Newton had recognized that Leibniz had arrived at the same thing at roughly the same time as him (*'a peu pres que luy'*).[28]

Fatio's request to Huygens in early February 1692 that he locate Fatio's manuscript on gravity (which like the errata, he assumed he had left in the Netherlands), indicates that it was only now that he had resumed serious work on the topic. However, Huygens' lukewarm comment about Newton's chronological priority in formulating the core elements of the differential calculus provoked Fatio into developing more extreme remarks regarding the way in which Leibniz had likely come across the basic theorems of the calculus. The route, Fatio went on, must have been via the two *'epistolae'* sent to Leibniz by Newton in 1676 — Leibniz's 'rules' appeared soon afterwards, without rendering to Newton the just credit that he deserved. In driving home the additional point that the Leibnizian calculus was an imperfect copy, Fatio was even prepared to destroy his own claims to originality, since (he continued) Newton had everything Leibniz 'seemed' to have as well as everything Fatio had that Leibniz did not. Newton had gone 'infinitely further than us', Fatio said, both as regards quadratures and also on the inverse problem of tangents. He could find the equation of a curve from the fluxion of a fluxion (Fatio said that he was using Newton's terms) and even from the fluxion of a fluxion of a fluxion. In Newton, Fatio continued, he had found 'an incomparable guide', both more enlightened and more generous than Leibniz. He was not, he said, upset to have avoided engaging in an exchange of mathematical propositions as if they were merchandise, for Leibniz always set a very high price on his commodities.[29]

As remarkable as the claims about Leibniz's unacknowledged debt to Newton was Fatio's revelation to Huygens that Newton had produced a number of additional 'classical scholia' for the second edition of the *Principia*. He apparently believed that Pythagoras, Plato and others possessed all the demonstrations he had given in the *Principia*, and that these were all grounded on the inverse square law. In reply Huygens noted that despite the fact that the ancients had access to the Copernican system, Newton had given them far too much credit. In early March 1692 Fatio wrote to say that Newton had gone cold on the idea of publishing his tract on quadratures. This was, he said, because of the latter's unwillingness to engage in the trouble that would result, though the mathematical world would lose greatly if it did not appear. If he hadn't leafed through it he would have liked to pursue the mathematical ideas he had been working on in Holland, which – he reminded Huygens – they had often undertaken together. He didn't despair of finding everything that Leibniz's method lacked, and even more. But he had been chilled (*'glacé'*) seeing the work of Newton, and had reproached him for rendering all Fatio's own work useless, and for not wanting to leave anything to do by his friends who came after him.[30]

Huygens replied at the end of March to say that there was no excuse for Newton's mathematical treatise not to appear, and that Fatio himself should take care of the publication, implying that it would be much easier than the task he had set himself with the *Principia*. He added that he had offered to explain Fatio's method to Leibniz ('because I wanted him to acknowledge that he didn't know it') but was still waiting for his response. Leibniz told Huygens that he was grateful to Fatio for the offer but because he believed he knew the basis of it, and was after a more general method, he wouldn't bother him about it. Huygens lamented at the start of May that both Fatio and Leibniz had distanced themselves from wanting to learn from each other, whereas he himself had wanted to learn from both of them.[31]

Personal business

By March 1692, Fatio's interests had begun to lurch sideways. He told the Count of Monros that he was interested in buying a tower in Delft with various tools that were being used for working on the lenses of simple microscopes. He may have wanted to involve himself in the construction of lenses, a subject on which Huygens and his brother were experts – and if so, Huygens told him, he was wasting his talents. More likely, Fatio was already interested in teaming up with Huguenot watchmakers in London, an activity that he would take very seriously over the following decade. However, in early May academic employment beckoned once more and Huygens wrote saying that he strongly supported a renewed effort to procure a chair in mathematics for Fatio in the Athenaeum Illustre (Illustrious School) of Amsterdam, which the representative of the Court of Brabant in The Hague, Salomon Dierquens, was trying to arrange.[32]

Fatio now reconsidered his aloofness regarding the editorship of the *Principia*. Idleness or 'other studies' often distracted him, he told Huygens, but after these had abated, his desire to see the new edition to press was redoubled. He had come to terms with many of the most intractable parts of the book, which led him to believe that if he had the time to give it the necessary attention he could understand the book perfectly. Perhaps the old team could be reassembled. Huygens could undertake some of the other sections and it would not be difficult to complete the entire task in a short space of time. They could inform each other about the difficult sections they had encountered and jointly come to terms with the book that was assuredly very excellent but at the same time extremely obscure. Perhaps, when the book was nearly ready, Fatio could spend some time in Amsterdam.[33]

Immediately after he had tantalized Huygens with his possible translation to the Netherlands, Fatio was in contact with his other patron, perhaps to inquire about some of the passages he had mentioned to Huygens. In the middle of May he wrote to Newton asking him if he could take a room near Trinity College and presumably this request was granted. His precise movements over the summer of 1692 are unknown, although almost certainly he spent it in London. In September Fatio again enjoyed a brief visit to Cambridge, but on his return to the metropolis he told Newton that he had contracted a serious cold, which had worsened to the point where he was probably gravely ill. In a melodramatic flourish he told Newton that despite immense physical turmoil his soul was at rest, a fact that he largely attributed to Newton. None of the conventional remedies had worked, though an emergency ventral paracentesis might do the trick; if he were to die, he wished that Newton would take care of his brother.[34]

Fatio's problems elicited an immediate reply from Newton, who showed great concern for his well-being and asked for more details about his brother. Fatio recovered somewhat towards the end of 1692 but his friend Jean Alphonse Turretini told Newton in January 1693 that Fatio was still suffering from a serious cold, and was considering returning to Geneva. Newton invited him to Cambridge in order to escape the dank London air, but Fatio replied that the recent death of his mother made the trip to Geneva more pressing. However, Dierquens' son visited Newton in early February and informed him that the offer of the Amsterdam professorship was still live. In a comment that is difficult to interpret, Newton told Fatio soon afterwards that if he did get the Dutch position, Newton would be glad to have him so close to England.[35]

Perhaps all this could be avoided. In March 1693 Newton revealed that he had been trying to organize financial support to keep Fatio at Cambridge, and the latter confirmed that he would prefer to stay in England rather than return to Switzerland. Hopefully, he said, he could stay in the Trinity chamber next to Newton's and in April he remarked: 'I could wish Sir to live all my life, or the greatest part of it, with you, if it was possible'. Over the spring Fatio's poor health, particularly his chronic cold, various schemes to make money through alchemical knowledge, and his lack of money remained central themes in a flurry of correspondence between the two men. Newton left for London on 30 May, presumably to spend time with Fatio and chat about the latter's medical and alchemical projects. He returned to Cambridge after a week, but what happened in the next few months remains shrouded in mystery. By the late summer he was in a full-blown mental crisis, which was not resolved until much later in the year, although a letter written by Fatio in August makes it highly unlikely that his problems were caused by any friction between them. Nevertheless, they were never on such close terms again, and indeed evidence of any personal contact between them after this point is sparse.[36]

On the European mathematical scene, Fatio was now fading from view, although Newton's work moved to the centre of attention. From late 1692, De l'Hôpital probed Huygens for information about what Newton had to say about the inverse method of tangents. In a letter to De l'Hôpital in October, Huygens had placed Fatio's and Leibniz's work on the topic in the same bracket as Newton's, adding, however, Fatio's remark that Newton knew more on the subject than Leibniz and Fatio combined. Soon afterwards the Marquis heard that a new edition of the *Principia* was to appear *'plus à la porté de tout le monde'* and that a treatise by Fatio on gravity was imminent. Indeed, Fatio was reworking his (apparently rediscovered) treatise on gravity in October

1692, in another abortive attempt to resurrect the idea of a new edition of the *Principia*, and he was probably the source for the Marquis' information.[37]

In the gap created by Fatio's apparent departure from the Republic of Letters, David Gregory now emerged as chief spokesman for Newton and as the likely editor for the second edition of the *Principia*. Gregory spent time in May and June 1693 with Huygens at Hofwijk, discussing mathematics, relative and absolute motion, and Newton's theory of light. He sent Huygens his own series method of quadratures in July, and the following month sent Huygens the 'method' of Newton that was about to appear in Wallis' imminent publication. By now Fatio's method was no longer secret and indeed Huygens had suggested to De l'Hôpital the previous December that the latter had probably discovered it independently. In May Huygens had failed to use it in order to solve a problem posed by De l'Hôpital, and he passed on the rule to the Frenchman in July; in turn, the latter wrote that it was much more restricted in its use than what he himself had sent Huygens. Having removed its protective cover of secrecy, Huygens tried to safeguard Fatio's priority and referred to fruitful work he had done together with Fatio two years earlier, arguing that the rule was useful and might work in cases where De l'Hôpital's did not. It continued to receive equal billing with Leibniz's 'method' in another letter sent by Huygens to De l'Hôpital in September 1693.[38]

Retreat

Fatio's break from Newton did not result in a closer relationship with Huygens. Indeed, there is no evidence of communication between them between May 1692 and November 1693, when Huygens wrote to Fatio saying that he had not heard from him for some time. Huygens said that he had feared that Fatio had contracted a new illness, though he added that he had been occasionally kept up to date with Fatio's news by Monros. However, as Fatio probably surmised, it was Newton, rather than himself, who seems to have been the focus of Huygens' interest. He prompted Fatio to say more about whether he was to edit a new edition of the *Principia*, and whether he'd learned anything from conversations with this 'excellent man'. He also asked Fatio to let him know Newton's thoughts touching quadratures and the inverse rule of tangents.[39]

Fatio received the letter and made notes on it, but with a sense of déjà vu Constantijn told his brother that he had struggled to deliver it after trying for some time to 'disinter' the Swiss from the great city. Fatio, he said, was now a tutor to an aristocrat whose name Constantijn had forgotten (actually the Duke of Bedford), and he lamented that fortune did not do justice to merit. For the first time Christiaan displayed a high degree of exasperation with Fatio, for he had presumably been told to expect the letter and Christiaan had supposed he would fetch it from Constantijn himself. Huygens never wrote to him again but, surprisingly, Fatio was contacted in the spring of 1694 by Leibniz, who had asked Herr de Beyrie, resident in London for the House of Brunswick, to probe Fatio for information on Newton's opinion regarding various points articulated by Huygens in his *Traité*. In his reply, Fatio rehearsed the main points of agreement between himself and Newton and noted that Huygens had been persuaded by Fatio's response to criticisms of his theory of gravity.[40]

Leibniz conveyed the contents of Fatio's letter to Huygens at the end of April 1694, adding his own doubts about the Newtonian system. Huygens in turn told him that he admired the power of Leibniz's calculus, and had just received the new edition of Wallis' *Algebra* containing some new material on series by Newton. These had differential equations that resembled Leibniz's except for the notation. Fatio's mechanical account of gravity was dismissed by Huygens as even more 'chimerical' than his theory of light. As for Fatio's claim that Huygens had been satisfied by his response to the Dutchman's criticisms of his theory, this was readily dismissed. Fatio's suggestion that the deposition of material on the surface of the Earth would never result in a considerable bulk on account of its fineness, was neither reasonable nor probable.[41]

As his antipathy to the views of Newton and Fatio hardened, Huygens received the dramatic news at the end of May 1694 that Newton had suffered an '*atteinte de phrenesie*', which had incapacitated him for the previous eighteen months. On receiving the news, Leibniz remarked that he thought the comments by Fatio he had sent on earlier had been 'reserved' and 'enigmatic', and indeed they were simply a curt rehash of what he had told Huygens over the previous three years. Fatio had seemingly cut off contact with his erstwhile patrons for almost a year, although he did compose a letter explaining his situation as a tutor to Huygens in September 1694, ostensibly in response to the one sent almost a year earlier.[42]

Patronage games

The relationship between Fatio, Newton and Huygens constituted a highly significant two-way conduit for the flow of ideas between Britain and the Netherlands. Apart from very occasional releases of information in books and correspondence, Newton used disciples such as Fatio and Gregory to disseminate some of his private findings and beliefs to continental scholars. Huygens had closer connections with French, Dutch and German scholars, but used intermediaries such as Fatio, William Stanley and his own brother to communicate his ideas and publications. There were other Anglo-Dutch networks at the time, including the correspondence between Antoni van Leeuwenhoek (1632–1723) and the Royal Society, and the regular pilgrimages made by Scottish students to study medicine at Leiden. Nevertheless, the nexus created by Fatio's intimate proximity to both Newton and Huygens, facilitated by his ability to gain their utmost trust, constitutes a very rare event in the history of science. Thanks to Fatio, the two dominant intellectual figures of the day could communicate without ever having to correspond, or with the exception of the summer of 1689, meet with each other.

Fatio proved unable to sustain the role he had carved out for himself as go-between and client of the two super-patrons. By 1693 or even earlier, his dreams of being a big player in the scholarly firmament had evaporated. Although Fatio was no longer Newton's favourite, he was not completely expunged from Newton's wider circle of acolytes and for a number of decades he was linked to key members of Newton's circle. Huygens' death in 1695 prevented any further connection between them but in any case they had had little or no serious contact for some years. It is important to view Fatio's career from the perspective of Huygens and Newton. For many years he was the spokesman for both men. He translated Huygens' work into English for Newton, and communicated Newton's views to Huygens; to both of them he appeared to be an inordinately talented disciple. Fatio communicated with each scholar in a language of intimacy, frequently asking if he could lodge and work in close proximity to both bachelors, and he moulded himself into a trustworthy collaborator. Newton and Huygens freely reciprocated this attentiveness, and both were intensely and actively concerned about Fatio's well-being.

Proximity to Newton was not for the faint-hearted. The new edition of the *Principia* offered Fatio a chance both to transform the master-piece, and to incorporate into it his theory of gravity. This would have made the *Principia* much more of a work of his own, and would have made it accessible to a much larger audience. There is no unambiguous evidence concerning what Newton thought about this undertaking, since Fatio's letters are the chief source of our evidence for this episode. Newton seems briefly to have supported the project at the end of 1691 but very soon afterwards thought Fatio's theory of gravity was risible. In any case, having frequently advertised his role in a forthcoming edition, it did Fatio's reputation no favours when the edition failed to materialize. As for the theory of gravity, it proved impossible to concoct a plausible hypothesis that could satisfy the twin demands of both mechanical and attractionist approaches. Regarding mathematics, as Fatio correctly surmised, Newton had almost nothing to learn from him.

Huygens initially nurtured Fatio's talent, and in the late 1680s the latter enjoyed a reputation on the circuit as an expert in the business of determining tangents to complex curves. However, Fatio's most valuable intellectual property involved his rule for giving solutions to some inverse tangent problems. Their 1691 collaboration on various applications that stemmed from this reprised the working relationship they had enjoyed four years earlier. However, Fatio was unable to generate academic credibility from this partnership and indeed, lost the favour of his patron. Huygens found him to be an untrustworthy correspondent whose shifting addresses made it impossible to communicate with him on a sensible basis. Moreover, Huygens never accepted the solidity of his theory of gravity. Although he continued to value and defend Fatio's method for the inverse problem of tangents, he was responsible for revealing it to De l'Hôpital, thus neutering its value.

Much of Fatio's downfall should be attributed to the irreconcilable demands of wanting to serve and please his two masters, while needing distance from them to make his own way. However, arguably the central relationship in this period was with Leibniz, and it was Fatio's misfortune to have tried to strut the mathematical stage at the same time as Leibniz and his disciples. Fatio's mathematical capital was relatively worthless once Leibniz refused to engage in an exchange of methods, and was absolutely so after he had seen Newton's 'De quadratura'. As Fatio's credit withered, he could at least ensure that Leibniz was brought down with him. The letters to Huygens in the winter of 1691–1692 show that diminishing Leibniz's credibility to the infinitely small required elevating Newton's reputation to the infinitely large. Fatio's dual claims about Leibniz's scurrilous behaviour and Newton's transcendent genius must have rung hollow to Huygens, for thanks to Newton's decision to withhold much of his work, he was unable to appreciate just how far Newton had progressed in mathematics. That said, he had been given an insight into the way things would develop after his own death. Two decades later, Newton, by now president of the Royal Society, assailed Leibniz using exactly the same arguments and tactics adopted by Fatio in his letters to Huygens.

Notes

1 For Fatio's career, see: C. Domson, *Nicolas Fatio de Duillier and the prophets of London* (New York 1981); F. Manuel, *A portrait of Isaac Newton* (Cambridge, MA 1968), pp. 191–202; S. Mandelbrote, 'The heterodox career of Nicolas Fatio de Duillier' in: J. Brooke and I. Maclean (eds), *Heterodoxy in early modern science and religion* (Oxford 2005), pp. 263–296. I am extremely grateful to the editors of this book for various comments on earlier drafts.

2 See Domson, *Fatio* (note 1), pp. 6–14 and Mandelbrote, 'Heterodox career' (note 1), pp. 273–277.

3 For his parents' views on a suitable career, see Mandelbrote, 'Heterodox career' (note 1), pp. 273–274.

4 See Ch. Huygens, *Oeuvres complètes de Christiaan Huygens,* 22 vols (The Hague, 1888–1950), vol. 9, pp. 117–120 (cf. 9: 169 for the inverse problem), 167–171 and 219–221 (footnote 14).

5 See G. Burnet, *Bishop Burnet's Travels Through France, Italy, Germany, and Switzerland* (London 1750), p. 14; Domson, *Fatio* (note 1), p. 15; Huygens, *Oeuvres complètes* (note 4), vol. 9, pp. 167–169 and 190–191. All dates in the main text are Old Style (O.S.) unless otherwise indicated.

6 Fatio to Boyle, 21 January 1687/1688; M. Hunter et al. (eds), *The correspondence of Robert Boyle,* 6 vols (London 2001), vol. 6, p. 246; Fatio to Huygens, 28 April/9 May 1688; Huygens, *Oeuvres complètes* (note 4), vol. 9, pp. 296–297.

7 Domson, *Fatio* (note 1), p. 17; R. Gagnebin, 'De la cause de la pesanteur. Mémoire de Nicolas Fatio de Duillier. presenté à la Royal Society le 26 février 1690', *Notes and records of the Royal Society* 6 (1948), pp. 114–115.

8 See H.M. Snelders, 'Christian Huygens and Newton's theory of gravitation', *Notes and records of the Royal Society* 43 (1989), pp. 209–222, esp. pp. 210–211 and 215–219; C.D. Andriesse, *Huygens: the man behind the principle* (Cambridge 2005), pp. 352–353. Huygens' comments on Newton's

treatment of vortices are at Huygens, *Oeuvres complètes* (note 4), vol. 21, pp. 143, 408–412 and 437; for the report, see ibidem, vol. 9, pp. 272–291. In the latter Huygens claimed optimistically that by means of his pendulums one might determine longitude to within about 20 miles.

9 See H.W. Turnbull et al. (eds), *The correspondence of Isaac Newton*, 7 vols (Cambridge, 1959–1981), vol. 3, p. 45.

10 See Domson, *Fatio* (note 1), pp. 32–33 and 46; Fatio's figure was worth about 25,000 UK pounds in contemporary money.

11 See Huygens, *Oeuvres complètes* (note 4), vol. 9, pp. 305 and 312–313. In the seventeenth century the Old Style (O.S.) Julian calendar used in England was ten days behind the Gregorian calendar generally in use in the Republic of Letters; the dates used in this paper are Gregorian unless otherwise stated.

12 Huygens, *Oeuvres complètes* (note 4), vol. 9, pp. 321–330 (for Newton's proof), 333–334 and 334–355; vol. 22, pp. 743–749 (for Christiaan's diary); Andriesse, *Huygens* (note 8), pp. 355–360 and 366–368; R.S. Westfall, *Never at rest. a biography of Isaac Newton* (Cambridge 1980), p. 520. See also L. Jardine, *Going Dutch: how England plundered Holland's glory* (London 2008).

13 Huygens, *Oeuvres complètes* (note 4), vol. 9, pp. 353–354 and 357–359. Huygens' father, Constantijn Huygens Sr, had died in March 1687.

14 See Huygens, *Oeuvres complètes* (note 4), vol. 9, pp. 86, 361–362, 370–371 and 373–374. For the various addresses in which Fatio lodged during his stays in London, see ibidem, vol. 9, pp. 171, 190, 360 and 380–381; Turnbull, *Correspondence of Isaac Newton* (note 9), vol. 3, pp. 241 and 243, and Bloomsbury Book Auctions Sale, 14 February 1991 (lot 390). I am grateful to Scott Mandelbrote for bringing this letter to my attention. For Fatio's forwarding address at Tourton and partners, see ibidem, vol. 3, pp. 45 and 233.

15 Gagnebin, 'Mémoire' (note 7), pp. 115–118; Huygens, *Oeuvres complètes* (note 4), vol. 9, pp. 381–389. For an analysis of Fatio's theory, see H. Zehe, 'Die Gravitationstheorie des Nicolaus Fatio de Duillier', *Archives for the history of the exact sciences* 28 (1983), pp. 1–23.

16 Huygens, *Oeuvres complètes* (note 4), vol. 9, pp. 379–380, 381–389 and 407–408; Turnbull, *Correspondence of Isaac Newton* (note 9), vol. 3, pp. 390–391. See Westfall, *Never at rest* (note 2), p. 496 and I.B. Cohen, *Introduction to Newton's* Principia (Cambridge 1971), pp. 177–179, esp. 179n3 and 184–188.

17 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 388–389, 391–393, 408–411 and 413.

18 Huygens, *Oeuvres complètes* (note 4), vol. 9, pp. 388, 392, 444–445 and 464; Gagnebin, 'Mémoire' (note 7), p. 110; Manuel, *Portrait* (note 1), pp. 193–195; Domson, *Fatio* (note 1), pp. 43–44.

19 Turnbull, *Correspondence of Isaac Newton* (note 9), vol. 3, p. 79; Hunter*, Correspondence of Robert Boyle* (note 6), vol. 6, p. 333. For Leibniz's response to the *Principia,* see D. Bertoloni Meli, *Equivalence and priority: Newton versus Leibniz* (Cambridge 1992). For Fatio's rule, see Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 21 and 74–76 (footnotes 5 and 9), and Turnbull, *Correspondence of Isaac Newton* (note 9), vol. 3, pp. 78n4 and 195n7.

20 Huygens, *Oeuvres complètes* (note 4), vol. 9, p. 571, 10, pp. 15, 21–22 and 50–51.

21 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 76–77 (for Fatio's use of fluxions), 77–78, 86–88, 93–94, 99, 109–112, 127–129 and 161–162. For Huygens' reference to his joint work with Fatio, see ibidem, vol. 10, pp. 22, 87n9 and 190.

22 See William Andrews Clark Memorial Library, Ms. F253L 1691; Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 145–146, 163 and p. 76 note 10.

23 Turnbull, *Correspondence of Isaac Newton* (note 9), pp. 169–170, 170–171 (with the series at 172–176), 181 and 181–183 (the surviving version of Newton's letter is a draft). For the original treatise, see D.T. Whiteside (ed.), *The mathematical papers of Isaac Newton*, 8 vols (Cambridge 1967–1981), vol. 7, pp. 24–48 and 48–128 (and p. 79 for a reference to Fatio). Compare with Westfall, *Never at rest* (note 10), pp. 513–516.

24 Huygens, *Oeuvres complètes* (note 4), vol. 10, p. 190, pp. 196–197 (and cf. 197–202 for Leibniz's method) and pp. 209–210.

25 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 213–215; Gregory memorandum, 28 December 1691; Turnbull, *Correspondence of Isaac Newton* (note 9), vol. 3, p. 191.

26 Turnbull, *Correspondence of Isaac Newton* (note 9), vol. 3, pp. 184–185 and 185–186; Pawling to Locke, 16 January 1691/2, E.S. de Beer (ed.), *The correspondence of John Locke,* 8 vols (Oxford 1976–1989), vol. 4, pp. 353–354. The Trinity College Exit/Redit book indicates that Newton returned to Cambridge on 21 January.

27 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 209–210 and 213–215; David Gregory memorandum, 28 December 1691 (O.S.), in Turnbull, *Correspondence of Isaac Newton* (note 9), vol. 3, p. 191 (and ibidem, vol. 3, p. 70n1, for the memorandum of 27 December recording Fatio's detailed description). Cohen points out that Fatio's improvements, visible in his own copy, would have made a significant improvement to the 'look' of the *Principia*; see Cohen, *Introduction* (note 16), pp. 181–183.

28 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 239, 241–242, 257 and 271. Constantijn mentioned Newton's treatise in a letter of 16/26 January, presumably as a result of a visit by Fatio on 16/26 December; see ibidem, 10, pp. 236 and 214n4.

29 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 257–259. Huygens

responded that he did not understand what was meant by a fluxion of a fluxion; see Gagnebin, 'Mémoire' (note 7), p. 159.

30 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 241–242, 257, 268–270 and 271–272; Gagnebin, 'Mémoire' (note 7), pp. 158–60.

31 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 276–280, 285 and 287. For Huygens' view of Leibniz's behaviour see ibidem, vol. 10, p. 439.

32 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 276–280, 285 and 287–288; for the 'lost' treatise see ibidem, vol. 10, pp. 257, 271.

33 Ibidem, vol. 22, pp. 158–159; Cohen, *Introduction* (note 16), pp. 181–183.

34 William Andrews Clark Memorial Library, Ms. F253L 1692; Turnbull, *Correspondence of Isaac Newton* (note 9), vol. 3, pp. 229–230. Newton's (undated) suggestion that Fatio lodge with him is to be found at New College Ms. 361.3 fol. 34r. More generally, see Westfall, *Never at rest* (note 12), pp. 531–539; Manuel, *Portrait* (note 1), pp. 192–204.

35 Turnbull, *Correspondence of Isaac Newton* (note 9), vol. 3, pp. 231–233, 241–244 and 245; Bloomsbury Book Auctions Sale, 14 February 1991 (lot 390).

36 Turnbull, *Correspondence of Isaac Newton* (note 9), vol. 3, pp. 262, 263 and 391; William Andrews Clark Memorial Library, Ms. F253L 1693. See also Westfall, *Never at rest* (note 11), pp. 533–535.

37 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 327, 346 and 393.

38 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 350, 393, 447n6, 452 and 464–468 (for Fatio's rule and cf. 491–4), 471–473, 485 and 493–494; Turnbull, *Correspondence of Isaac Newton* (note 9), vol. 3, pp. 272–274 and 275–278. See also R. Vermij and J. van Maanen, 'An unpublished autograph by Christaan Huygens: his letter to David Gregory of 19 January 1694', *Annals of science* 49 (1992), pp. 507–523, esp. 511 and 517–518.

39 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 567–569.

40 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 581–582, 583–584, 598–599, 599–600, 605–606 and 606–608; and vol. 22, pp. 162–163.

41 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 600–605 and 609–615; and vol. 22, pp. 162–163.

42 Huygens, *Oeuvres complètes* (note 4), vol. 10, pp. 615–616, 617–619 and 639–646, esp. 643–644.

How Newtonian Was Herman Boerhaave?

RINA KNOEFF

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-

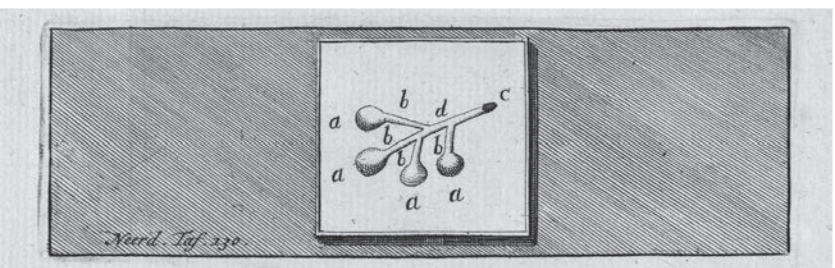


Fig. 2: Boerhaave's image of a gland represented as a closed-off vessel. Note that the extremities of the gland look like chemical retorts.

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.

The Man Who Erased Himself

Willem Jacob 's Gravesande and the Enlightenment

AD MAAS

It is a well-known fact that the Leiden professor Willem Jacob 's Gravesande was one of the most influential advocates of Isaac Newton. It is equally well-known that he was the author of the first 'Newtonian' physics handbook and attracted large numbers of students from all over Europe to Leiden University with his courses on experimental physics, in which he demonstrated the laws of nature with his self-designed instruments. Several of his students followed in his footsteps, spreading Newton's word at the universities of the Dutch Republic and abroad.[1] As recent research has revealed, 's Gravesande was also actively involved in the diffusion of the *Principia* in the Netherlands.[2] In addition, 's Gravesande's lesser known metaphysical and philosophical views have also been the subject of historical investigation: see in particular the clear expositions by Kees de Pater and Paul Schuurman.[3]

's Gravesande was indeed a leading figure, not only as a champion of Newton, but also in a broader sense as a pioneer of the so-called mainstream, or 'moderate' Enlightenment, which sought to harmonize reason, science and rationality with religion. Jonathan Israel describes him as 'the Leiden professor who did more than anyone else to engineer the triumph of English philosophy and science in the Dutch mainstream Enlightenment in the 1720s'.[4] However, his influence went far beyond the Dutch Republic. 's Gravesande was one of the main initiators of Anglomania – the absorbing hunger for English ideas and achievements in Europe in the 1730s and 1740s.[5]

In the literature, 's Gravesande's Newtonianism is mainly (and

Fig. 1:
Willem Jacob 's Gravesande. (Etching by J. Houbraken, after a drawing by J. Wandelaar, 1725–1750)

implicitly) described as the outcome of his personal considerations, namely as the fruits of his own convictions, consciousness, inner development and reasoning. In addition to this 'conceptual' approach, I would like to consider 's Gravesande in this article as a man of his time and culture. I will regard him and his ideas more particularly against the background of the political situation, rivalling scientific factions, religious sensitivities and the developments in the Republic of Letters in general and Leiden University in particular. This article will focus on 's Gravesande as a natural philosopher and will not address his less influential philosophical work.

To what extent, then, can we relate the development of 's Gravesande's convictions, preferences and way of reasoning to the cultural, political and academic circles in which he lived and functioned? In answering this question, I will look at his family background and youth, his experiences in the world of higher politics, his role in the

Republic of Letters and his performance as a professor at Leiden University. In my conclusion, I will further elaborate on what appears to be 's Gravesande's leitmotiv: the pursuit of 'unprejudiced', 'true' knowledge. But first I will briefly set out what 's Gravesande's Newtonianism actually involved: there do appear to be reasons to look beyond the workings of his inner self.

The invisible philosopher[6]

In his works, 's Gravesande expressed the conviction that the natural philosopher's task was to investigate the natural laws with which God had created an orderly world for mankind to live in. Empirical studies and analogical and mathematical reasoning were the sources (and the *only* sources) to obtain 'true' knowledge of the natural world. All other means of arriving at higher truths are to be rejected, in particular deductive reasoning not sustained by observation as advocated by Descartes. Newton's physics proved to be useful for 's Gravesande in his attempt to harmonize modern natural philosophical ideas with his religious views.

's Gravesande elaborated his epistemology in his *Oratio de evidentia* (1724). In his view, God had given man the use of his five senses to observe the outside world and had granted him the capacity for reasoning by analogy to detect the regular patterns in these observations. In this way, we are able to derive useful information from the outside world. We can, for instance, watch the sun set and the sun rise and establish, by analogical reasoning, that each sunset is always followed by a sunrise. Thanks to a third tool, testimony by others, we are also able to obtain knowledge about events that happened in other places and in the past. We know, for instance from the reports of others, that Leiden University was founded in 1575.

It would be absurd to assume that an 'infinitely good' God created an entire world for humans to live in, without allowing them the skills to make optimal use of that world. Indeed, our senses, our ability to draw analogies and the testimonies of others enable us, when used with discrimination, to gather information from the outside world that is 'obviously' true. Knowledge thus obtained is 'morally evident'. 's Gravesande even regarded knowledge based on moral evidence no less irrefutable than the unshakable truths that can be obtained by 'mathematical evidence', which is the other source of 'certain' knowledge.

By giving a prominent role to moral evidence in his epistemology, 's Gravesande argued that the outside world, God's creation, was a main source of irrefutable knowledge. At the same time, he limited the role of the philosopher's own imagination, or hypotheses as he would call it. 's Gravesande pleaded for a type of modest philosopher, which is evident also from his interpretation of Newton's body of ideas.

As several contributions in this volume show, there is no such thing as a universal, monolithic Newtonianism. When we speak of 's Gravesande's Newtonianism, we speak of his personal interpretation of Newton's ideas. A brief glance at 's Gravesande's famous handbook *Physices elementa mathematica* (first edition 1720–1721), for instance, immediately makes clear that the book was not Newtonian in the sense that it simply explained Newton's theory: 's Gravesande's book was much wider in scope; it was really a handbook on mathematical physics, and it was 'Newtonian' because it pursued the Newtonian method of looking for mathematical regularities in nature on the one hand, and sought to establish the primacy of experiment and observation on the other. Accordingly, it contained systematic descriptions of experiments to support the theoretical expositions, and only brief treatments (or the omission) of topics that could not be treated mathematically (electricity, magnetism, meteorology).

Some aspects of 's Gravesande's interpretation of Newton are worth noting. Firstly, he consistently rejected 'feigning hypotheses' (i.e. not based on mathematical reasoning or empirical data)[7] even more than Newton himself – for example, he disregarded Newton's particle interpretation of light, which he must have considered too hypothetical.[8] Secondly, his preoccupation with finding true, unprejudiced knowledge excluded arguments simply based on the authority of a revered scholarly person, even if this was no less a figure than Isaac Newton. His point of view in the *vis viva* question, for instance, is striking. In the debate on whether the 'force' of an accelerated object increased proportionally with the velocity (*quantitas motus*) or with the square of the velocity (*vis viva*) 's Gravesande – convinced by his own experiments – publicly sided with Leibniz *cum suis*, thereby defying his idol and mentor Isaac Newton. Figure 2 shows the fall apparatus 's Gravesande used. It contained a layer of clay in a tray, in which 's Gravesande dropped brass balls of varying weights; he found that the same product of height and weight caused identical impressions in the clay.

Fig. 2:
's Gravesande's fall apparatus. (Museum Boerhaave, V09630)

These two examples show us that in his search for truth, 's Gravesande tried as much as possible to limit human interference – he did not accept assumptions simply based on authority, or any *hypotheses* – as they only served to corrupt the study of nature. The only safe ways to arrive at higher truths were to observe nature and to employ both mathematical rigour and an innate, rather commonsensical use of analogical reasoning. The results of natural philosophy should not bear the marks of individual imagination, prejudice or personality. The natural philosopher ought to be invisible in his work, so to speak. 's Gravesande's objective, therefore, was – in my words – to 'depersonalize' the study of nature. It even landed him in conflict with a few fanatical British Newtonians (like Samuel Clarke) and orthodox Calvinist ministers, who felt his epistemology could be interpreted as a limitation of the free will. Eventually, 's Gravesande was even accused of being a 'Spinozist'.[9]

There were limits to 's Gravesande's 'depersonalization'. His personal praise of Newton was both consistent and sincere. Yet above all he remained an independent spirit who apparently managed to maintain a strict divide between epistemological views on the one hand and metaphysical and religious views on the other. If we wish to trace the roots of 's Gravesande's Newtonianism, we will not necessarily find them in his religious and metaphysical convictions. We will also have to look for them elsewhere.[10]

Youth

Willem Jacob 's Gravesande was born in 's-Hertogenbosch (Bois-le-Duc), a town in the Catholic south of the Dutch Republic, in 1688. Yet the 's Gravesandes – or Storm van 's Gravesande as the full family name was – were not Catholics. The family belonged to the Protestant administrative upper echelon of 's-Hertogenbosch (the Catholic areas in the south, the so-called 'Generality Lands', were treated like occupied territories and were governed by the States-General). The roots of the Storm van 's Gravesande family can be traced to the province of Holland, more specifically to the city of Delft.[11] Willem Jacob's ancestors were already Calvinists when the Beeldenstorm (the Iconoclastic Fury) raged over the Low Countries in 1566. Some of them were convicted and banned from Delft because they had taken part in the uprising. Following the successful expulsion of the Catholics in 1572, however, members of the 's Gravesande family succeeded in obtaining vacant positions in Delft's city government. Half a century later, the 's Gravesandes in Delft apparently had lost some of their influence. It was Willem Jacob's grandfather Laurens who moved to 's-Hertogenbosch, as by this time he and his relatives were no longer able to secure places in Delft's city administration.[12]

The move took place after the conquest of 's-Hertogenbosch by stadtholder Frederik Hendrik in 1629. According to 's Gravesande's biographer (and successor) Jean Nicolas Sébastien Allamand (1713–1787), it was the stadtholder who offered Laurens 's Gravesande a number of posts in the administration.[13] In 's-Hertogenbosch, the pious Calvinist 's Gravesandes had to maintain themselves as part of a small Protestant minority and preserve their Protestant identity in a 'hostile', Catholic area. From his earliest youth, Willem Jacob must have been aware of religious dissent.

As a patrician's son, Willem Jacob was educated by a private teacher called Isaac Tourton. According to Allamand (whose biographical description does not appear reliable in every respect), Tourton's lessons encouraged 's Gravesande's talents and interest in mathematics. Together with two of his brothers, however, Willem Jacob was destined for the study of law at Leiden University. Perhaps his later, characteristic, preoccupation with obtaining 'unprejudiced' judgements was fostered by his legal education. He studied law from 1704 to 1707, during which period he is also said to have written his first mathematical treatise: *Essai de perspective*. This, however, was not published until 1711.

He did not receive a degree in the faculty of philosophy. There is also no evidence that he ever attended the courses and demonstrations of the philosophy professors Burchardus de Volder (1643–1709) and Wolferd Senguerd (1646–1724); in any case he never appears to have defended a philosophical or mathematical disputation under their direction.[14] 's Gravesande did not seem to considering an academic career in this field by this time. After finishing his thesis on suicide – he maintained that it was a reprehensible deed[15] – he set up practice as a barrister in The Hague. His contacts with the Swiss mathematician Nicolaus (I) Bernoulli (1687–1759) and the physician and mathematician Bernard Nieuwentijt (1654–1718) show that he was still engaged in mathematics at the time.[16]

Higher politics

The Dutch Republic was torn by an ongoing battle between the stadtholders and their followers, the Orangists, and the Republican States Party which – as the champions of *'Ware Vrijheid'* (True Freedom) – sought to limit the stadtholder's powers, or even eliminate the stadtholderate altogether. The latter faction dominated in the first stadtholderless period, which lasted from 1650 to 1672. After the *'Rampjaar'* (Disaster Year) of 1672, however, the Orangists gained the upper hand when the powerful William III (1650–1702) became stadtholder (assuming also the crowns of England, Scotland and Ireland after the Glorious Revolution of 1688–1689). William III died in 1702, two year before 's Gravesande enrolled in Leiden. The Orangists did not manage to have a new stadtholder elected and 's Gravesande would spend the rest of his life in a stadtholderless Dutch Republic (the Frisian stadtholder did not have much power).

Immediately after the death of William III, the Republic had to cope with the War of the Spanish Succession, which broke out in 1702 and ended with the Treaty of Utrecht in 1713. This war proved to be financially disastrous for the Dutch Republic; in fact, it was the last pan-

European conflict in which the Dutch Republic played an important, leading role and marked the end of the Republic as a major player on the European stage.[17]

In the aftermath of this conflict two camps were formed with opposing ideas on the Republic's foreign policy. The first sought to increase the military strength of the Republic, combined with a pro-British stance, in order to check French expansionism. The other camp was more concerned with Dutch trade opportunities than with French threats and tried not to involve the Republic in Britain's international intrigues against France and Bourbon Spain, in particular, which would only harm Dutch commercial interests. Some feared that England was heading for a new war with France. These two camps — the pro-British and the pro-trade parties — incidentally did not necessarily overlap with the traditional Orangist and Republican factions in Dutch society.[18]

Someone who definitely belonged to the pro-British party was Arent Wassenaer van Duyvenvoorde (1669–1721). This powerful Dutch nobleman, a great favourite of William III (he had been chosen to join William in his victorious voyage to Britain during the Glorious Revolution) was married to Anna Margaretha Bentinck (1683–1763), a daughter of William III's bosom friend Hans Willem Bentinck (c. 1649–1709), created 1st Earl of Portland in 1689. Wassenaer van Duyvenvoorde's brother-in-law was one of the powerful 'Whig lords' under George I (1660–1727). Van Duyvenvoorde regarded the alliance with England not only in political but also in religious terms; it was his strong conviction that the two Protestant states had to join forces to resist the Catholic threat from France.

Everything in Wassenaer van Duyvenvoorde's personality negated the stereotypical image of the 'enlightened', well-balanced man of reason. The Scottish diplomat J. Drummond called this staunch Protestant nobleman an 'unmanageable, turbulent, interested spirit', who inspired fear in many. Shrewdly combining intrigue, corruption and power politics, he tried to consolidate his position in the world of Dutch higher politics. His opponents called him 'proud', 'hot-tempered', and 'money-mad'.[19]

In 1715 the States-General sent Wassenaer van Duyvenvoorde to England as a special envoy to congratulate George I on his accession to the throne. His second mission was to try and muster British support for the tough negotiations with Emperor Charles VI (1685–1740) regarding the 'Dutch barrier' in the Southern Netherlands. This barrier involved a line of fortified towns in Belgium to protect the Republic against a possible French invasion. With George's accession, the Whigs ousted the Tories in the British government, making Wassenaer van Duyvenvoorde with his Whig connections the obvious person to assume the ambassadorship (even though his enemies in the *ridderschap* of Holland, one of the seven colleges of nobles in the Republic, strongly opposed his appointment).[20]

Wassenaer van Duyvenvoorde decided to take the young lawyer Willem Jacob 's Gravesande with him as his 'first secretary'. It is not clear why he asked 's Gravesande. The two families were not related by marriage, nor have I found evidence of any other contacts existing between the two men. Even so, the journey would prove to be a turning point in the life of Willem Jacob.

Besides the administrative work involved in the job of secretary, 's Gravesande in London took part in the ongoing round of visits, audiences, official dinners and other ceremonies regulated by complex protocols, which made up a great part of the delegation's obligations.[21] In addition, he sometimes also acted as a private teacher to Duyvenvoorde's son Brilanus. He taught the boy mathematics, a discipline beyond the competence of the 'second secretary' of van Duyvenvoorde's delegation, Justus van Effen (1684–1735), who was the boy's main tutor. Van Effen was no stranger to 's Gravesande, because both men were on the editorial staff of the *Journal littéraire* (see next section). Duyvenvoorde apparently wanted only the best teachers for his son: a third tutor hired by him was no less a figure than John Theophilus Desaguliers (1683–1744), fellow of the Royal Society, and performer of spectacular demonstrations. Desaguliers became friends with 's Gravesande and later translated his physics handbook into English.[22]

A few months after arriving in England, 's Gravesande was elected as a member of the Royal Society. It was not – as one might expect – Desaguliers who introduced him, but an old university friend, William Burnet (1687–1729). 's Gravesande met president Isaac Newton in person at the Royal Society. Unfortunately, no account exists of this meeting. In view of his attempts to 'depersonalize' the study of nature, 's Gravesande will have regarded with special interest the way in which the Royal Society used the experimental method to avoid an 'ad hominem' type of debate and to reduce human interference in natural philosophy.[23]

William Burnet is an interesting member of 's Gravesande's network. He was the son of Bishop Gilbert Burnet (1643–1715), a Whig who had been among the first English subjects to transfer his allegiance to William and Mary. As one of the closest confidants and trusted counsellors of William, Gilbert Burnet became the head of his propaganda machine, which coordinated the efforts to win the hearts and minds of the British people for the new royal couple in the aftermath of the Glorious Revolution. It is almost certain that Gilbert must have known Duyvenvoorde from these days. Gilbert Burnet, incidentally, was also acquainted with Newton, who likewise opposed the policy of James II (1633–1701), the king who was ousted during the Glorious Revolution. Newton's good standing with the new regime turned out well for his career and his public status.[24]

William Burnet was born in the Dutch Republic, where his father lived as an expatriate between 1686 and 1688.[25] He was named after William III, who was his godfather. In 1707 William studied at Leiden University, where he became acquainted with 's Gravesande.[26] As a member of the Royal Society, William Burnet was able to provide him with an introduction.

Allamand claimed that his personal encounter with Newton had far-reaching consequences for 's Gravesande's ideas about natural philosophy. However, he certainly knew of Newton's work before.[27] In May 1714 — a year before he went to England — he had already written to the English scholar. In this case, too, it was Burnet who paved the way. Burnet already acted as an intermediary between Newton and the latter's criticaster Johann Bernoulli (1667–1748) (at the time professor in Groningen). Bernoulli had published his criticism of the *Principia* in the *Acta eruditorum* in February and March 1713, but the work in question was not yet available in England. Burnet asked 's Gravesande to send a copy of the *Acta eruditorum* to Newton, which he did, together with a letter, in which he humbly offered his services '*dans toutes les occasions que je pourai vous estre de quelque utilité dans ce pais*'.[28] Apparently it was a ploy of Burnet and 's Gravesande, to give the latter an excuse to get in touch with Newton. 's Gravesande may have become interested in English philosophers through his contacts with the Burnets, or possibly through other British subjects connected to the court in The Hague (or perhaps — as will be mentioned later — by early Dutch 'Newtonians' like Bernard Nieuwentijt).

In spite of his not altogether polished diplomatic bearing, Wassenaer van Duyvenvoorde's mission was a success. The so-called Barrier Treaty was signed with the Austrian emperor with English support, while a new alliance was at the same time forged between England and the Dutch Republic. By May 1716 the mission had been successfully completed.

Had 's Gravesande not been a personal favourite of or politically useful to Wassenaer van Duyvenvoorde, it would have been highly improbable that the latter would have taken efforts to secure him a professorship in Leiden. After all, he was a man who thought in terms of clientelism, power and interests. According to Allamand, it had been Newton himself who had persuaded Duyvenvoorde to recommend the curators in Leiden to appoint 's Gravesande to a chair. Duyvenvoorde was on good terms with his (distant) relative Willem, Baron Wassenaer, Lord Starrenberg and Ruyven (1649–1723), who was chairman of the board of curators of Leiden University. In 1717 the latter seems to have secured the chair in 'astronomy and mathematics' for 's Gravesande, a chair that had been vacant for some years (in 1734 'philosophy' was added to his professorial duties).

's Gravesande's appointment has been taken too much for granted in the research carried out on this topic so far. Whereas Leiden University had a reputation for appointing professors with considerable professional experience,[29] 's Gravesande had no appreciable scientific reputation at the time he was offered a chair. His only published feat was his *Essai de perspective*, which had met with the approval of the scholarly community. He did not have much experience as a teacher, nor did he have a degree in philosophy in his pocket (even though this was not an important requirement at the time).

's Gravesande's appointment, therefore, was a sample of unadulterated nepotism. The parallels with his predecessor Jacques Bernard (1658–1718) are worth mentioning. This French theologian certainly did not have a reputation as a natural philosopher before (or, for that matter, after) his appointment, even though in 1705 he succeeded no less a person than De Volder, who had put experimental physics firmly on the map at Leiden University (see below). It is very likely that De Volder's instruments for experimental demonstrations, which had cost the university curators a considerable sum of money, were completely ignored by Bernard. Interestingly, he seems to have been favoured by the curators because he championed British philosophers.[30]

I set out in the first section why, from the conceptual point of view, Newton's ideas suited 's Gravesande very well. However, embracing the British philosopher may also have been instrumental in securing the patronage of powerful pro-British Dutchmen and English Whigs and a possible chair at one of the most prestigious universities of Europe. We will probably never know the true reason behind 's Gravesande's appointment. We may, however, conclude that the Anglo-Dutch connection, which offered 's Gravesande a stage to unfold his (Newtonian) ideas, indirectly contributed to the mainstream Enlightenment and the Anglomania that swept over Europe in the 1730s and 1740s.

Republic of Letters

After having settled in The Hague as a lawyer – in the years before his trip to England – 's Gravesande moved in the literary and intellectual circles of booksellers, publishers and writers of this city. Quite a few of these men of letters were French (Huguenot) refugees, others were British, and occasionally linked to the court like the Burnets. 's Gravesande married the daughter of a French refugee family, Anne Sacrelaire. In 1713 he was involved in founding the *Journal littéraire de La Haye* and joined its editorial staff. At the time similar learned periodicals were published in the Republic, mostly run by French Huguenot refugees, aimed at informing the Republic of Letters, in French, about what was going on in the scholarly world. A large section of the *Journal littéraire* was devoted to book reviews. In addition, there were sections containing news about books and the Republic of Learning. Also, the journal offered room for discussion among readers.

An interesting feature of the *Journal littéraire* – and a novelty as well – was that the editors acted as a collective. They spoke with one voice, which meant that contributions were never signed with the name of an individual editor or the chief editor; all these remained anonymous. Book reviews written by one of the editors were commented on during the weekly meetings. In this way, the editorial staff hoped (besides benefiting from the specific expertise of the individual editors) to eliminate any personal preoccupations on the part of the reviewer and present an unbiased review. By not signing their contributions, the editors were able to avoid the risk of being considered as the spokesman of a certain group. It was imperative to shun every appearance of partisanship.

The journal started with a board of six editors. Four of them – Prosper Marchand (1678–1756), Henry Alexandre, Albert Henri de Sallengre (1694–1723) and Thémiseul de Saint-Hyacinthe (1684–1746) — had French roots (although Sallengre was born in The Hague). A few of them had quite radical opinions. The other two were Dutch — 's Gravesande and Justus van Effen. The publisher, Thomas Johnson (1677–1735), was Scottish.[31]

For the *Journal littéraire* 's Gravesande wrote reviews on physical and mathematical works and probably on physico-theological publications, as well.[32] His (naturally anonymous) review of Nicolas Hartsoeker's *Suite des conjectures physiques et des eclaircissemens sur les conjectures physiques* (1712) led to a debate with the author about Newton's theory of planetary motion. But 's Gravesande also published articles relating to his own studies, as for instance his exposition on improvements of the air-pump and his contribution to the hotly debated *vis viva* question. Finally, he also published on ethical issues (such as liberty and falsehood) in the *Journal littéraire*.[33]

It looks as if his Leiden professorship in 1717 marked the end of 's Gravesande's editorship of the *Journal littéraire*. Nevertheless, he always remained loyal to the magazine's principles. In 1729 's Gravesande, together with his friend Prosper Marchand, attempted to revive the *Journal littéraire*. Again they opted for a collective editorship — even though in the past this lofty formula for unprejudiced journalism had sometimes proved a little over-idealistic.

The *Journal littéraire* was founded at a time of growing unease in the Republic about French influence, or the 'Frenchification' of Dutch culture. Critics, for instance, discerned a culture of imitation in the field of literature, which was dominated by French classicism. Architecture, painting, fashion in clothes, even in wigs, gardening, interior decorating, and the style of conversation of the upper classes were also copied from the French. Many opponents to the trend of Frenchification, which was regarded as a threat to native Dutch culture, believed that French immigrants, in particular, were responsible for the dreaded invasion.

These adversaries tried to counter the taste for French customs by stressing the roots of national cultural identity, which they believed was especially to be found in Dutch literature adhering to classical principles.[34] In addition, English culture was enlisted to stop Frenchification. Van Effen for instance, who strongly denied the superiority of French culture, asserted in 1711 that the 'new' English philosophers who were emerging on the European scene, in particular Newton and

John Locke (1632–1704), might counterbalance French cultural domination.[35] 's Gravesande, closely associated with Van Effen as a fellow editor of the *Journal littéraire* and fellow secretary of Duyvenvoorde, never publicly expressed an opinion about Frenchification or the 'strategic' values of the English culture. However, by propagating the English philosopher Newton, he was in actual fact second to none in strengthening the desired English cultural 'counterbalance'.[36] As was the case in the world of higher politics, Dutch cultural and scholarly communities had their reasons to embrace English scholars and writers.

The position taken by Van Effen and 's Gravesande was of course an ambivalent one. As editors of the *Journal littéraire* they contributed to a 'French' periodical (one which was even produced on Dutch soil). The *Journal littéraire* was in fact the first French journal in the Republic to employ Dutch editors. Thus especially Van Effen, who made no secret about his low opinion of the state of Dutch literature, ironically became one of the chief targets for the adversaries of the Frenchification of Dutch culture.[37]

Van Effen and 's Gravesande apparently regarded the use of French with greater nuance than did the criticasters of the *Journal littéraire*. They realized that to write in French was not paramount to accepting the superiority of French culture in all respects. In fact, by writing in the very language that was fast growing into the *lingua franca* of the eighteenth century, their advocacy of English philosophers and writers actually reached the widest possible audience.

Academic world

Being a follower of Newton offered a very practical advantage for the way 's Gravesande managed to organize his classes: the characteristic emphasis on mathematics and empiricism in Newton's natural philosophy coincided perfectly with his own interests. 's Gravesande's fondness for designing and improving instruments supported the empirical part of his courses. 's Gravesande had been experimenting with air-pumps since he was a student. As a professor – together with instrument maker Jan van Musschenbroek (1687–1748) – he would devise many innovative machines.[38]

It must be emphasized that the use of demonstration instruments in Leiden University's physics classes was not introduced by 's Gravesande. It was one of his predecessors, the professor of philosophy and (eclectic) Cartesian Burchard de Volder, who first made use of demonstration experiments in his (public) courses in 1675. He founded a *'theatrum physicum'* (physics theatre) with the financial support of the governors of the university. De Volder's colleague Wolferd Senguerd, appointed extraordinary professor in peripatetic philosophy in 1675, likewise conducted experiments in the presence of his students.[39]

's Gravesande, officially appointed professor of astronomy and mathematics in 1717, was only able to use the *theatrum physicum* for public lectures after the death of Senguerd in 1724, when he became its director. In his early days as a university professor, however, he demonstrated physics instruments at home during his lucrative private courses (to attend private courses, students had to pay their professors a fee). More than had been the case in De Volder's or Senguerd's courses, experiments were systematically interwoven with the subjects on the curriculum. 's Gravesande acquired great fame, in particular, with these courses.

According to Adriaan Cornelis de Hoog and Gerhardt Wiesenfeldt, De Volder introduced the experimental method to find a way out of the heated metaphysical arguments in which natural philosophy had become hopelessly entangled. From the 1640s onwards, the Dutch universities had been afflicted by religious and philosophical controversies, with orthodox Calvinists confronting their more liberal fellow believers. Roughly along the same divide, scholastics opposed Cartesians. The years 1672–1673 in particular had been troublesome for Leiden University.[40] De Volder, tired of the continuing metaphysical controversy and also increasingly critical of some of Descartes' views, decided to seek refuge in the new experimental natural philosophy coming from Britain. Following the example of the Royal Society, De Volder saw in the experimental method a way of detaching natural philosophy from philosophical and religious arguments. The experimental method yielded empirically obtained, irrefutable 'matters of fact' capable of superseding bitterly contested dogmatic arguments. Thus scientific instruments – the air-pump especially became the paragon of this experimental approach – were employed to get the university, and natural philosophy in particular, out of hot water.[41]

The empirical method, which relied on 'eyes and hands' rather than on 'minds and tongues', was regarded as the pre-eminent tool to reduce human agency in the practice of natural philosophy.[42] If this also applies to 's Gravesande, his use of instruments was in agreement with the other activities discussed above: the collective performance of the editorial staff of the *Journal littéraire* and the 'depersonalized' appreciation of – even – Newton's work. This was yet another example of separating – in modern words – the object from the subject. In his experimental courses it was the machines that produced knowledge, not the mind of the professor.

However, there were also more earthly reasons to found the physics theatre, which, it was hoped, would attract more students. De Volder himself asserted that he was convinced that the 'usefulness and entertainment of the proposed pursuit of experiments' would draw 'many students from other universities and schools elsewhere'.[43] 's Gravesande regarded demonstrations a means to make the physics courses more accessible and attractive to wider audiences. In a letter to Newton, he wrote: 'as I talk to people who have made very little progress in mathematics I have been obliged to have several machines constructed to convey the force of propositions whose demonstrations they had not understood'.[44] 's Gravesande even enchanted his students with a magic lantern, which projected slides showing images of satyrs, dwarfs and Arcadian landscapes, and an anamorphoscope (a distorted picture that takes on a normal appearance only when seen in an appropriately shaped, mostly cylindrical or pyramidal, mirror).[45] Such demonstrations could hardly have served other ends than to lend 's Gravesande's courses a touch of entertainment and spectacle. It will have brought him extra students and, perhaps not unimportantly, extra income.

The various types of instruments used by 's Gravesande are all described in his textbook (down to the magic lantern, to be found in the chapter on telescopes and microscopes), with one notable exception, namely the 'useful' machine models which appeared in the *theatrum physicum* from the 1730s onwards. The windmills, a dredging machine, even a steam engine, and so on, were apparently meant to have an emblematic character and demonstrated 's Gravesande's deep-rooted conviction that God had created nature, and its laws, in the service of humankind. In other words, the models had to show how man might benefit from nature in the pursuit of his own well-being, a theme that cannot be considered typically 'Newtonian'. The presentations in 's Gravesande's physics theatre, in short, offered the audience the cutting edge in physics, combined with entertaining and – religiously inspired – moralistic elements. The students were offered much more than sheer Newtonian physics and philosophy.

From a broader perspective, the ostentatious use of instruments was consistent with the policy of the university governors to enhance the reputation of Leiden University as a Dutch — even European — centre of science and to attract (affluent) students by building rich collections. Thus, the botanical garden was enlarged (1687–1688), important collections of books and manuscripts were purchased (especially the enormous collection of Isaac Vossius in 1690, which among a host of natural philosophical and mathematical works contained a copy of the *Principia*), the observatory was upgraded (1689), the anatomical theatre was fitted out with curiosa and a chemical laboratory was founded (1669). In the Baroque era, Leiden University thus tried to present itself as the most exquisite university of Europe.[46] The spectacular collection of physics demonstration instruments clearly suited this policy.

’s Gravesande made it a point of honour to present difficult subjects in an accessible and clear manner. In the same way as he attracted students with ‘very little progress in mathematics’ by offering experimental courses, his *Physices elementa mathematica* was the first comprehensible handbook to disseminate Newtonian physics. The board of the *Journal littéraire*, too, took considerable efforts to present its contributions in a clear and accessible style; the journal had a reputation for its lucidity. ’s Gravesande regarded it as a main task to communicate difficult topics to wider audiences.

’s Gravesande’s love of mathematics, as we have seen, dated from his youth. Mathematics had traditionally played an important role in Dutch culture, but at the time of ’s Gravesande’s appointment in 1717, the discipline had been discredited by philosophers like Descartes and especially Spinoza, who used the mathematical method to unfold his ‘ungodly’ views.[47] In his inaugural lecture, ’s Gravesande felt a need to defend the use of mathematics by contending that mathematical reasoning, when soundly applied, instead provided only useful insights into the working of nature. He referred to Isaac Newton’s natural philosophy as a prime example of the profitable use of mathematics.[48] Newton, he felt, could help rehabilitate mathematics.

’s Gravesande’s concern for mathematics coincided with that of the ‘Amsterdam mathematicians’ who were among Newton’s first supporters in the Dutch Republic — men like Bernard Nieuwentijt, already mentioned earlier, and Lambert ten Kate (1674–1731; see Dijksterhuis and Jorink and Zuidervaart in this volume) belonged to this small, informal group. Not only did they think Spinoza had damaged the reputation of mathematics, they also worried in particular about the moral dangers inherent in his 'atheist' views. By using (part of) Newton's work, they hoped to offer mathematical arguments to confirm religious truth.[49]

Although 's Gravesande will have appreciated the attempts of the 'Amsterdam mathematicians' to counter Spinoza's blasphemous and geometrical method of reasoning, his own writings do not reveal a similar pious engagement with religious matters.[50] When 's Gravesande refers to Spinoza by name in his oration 'De vera et nunquam vituperate, philosophia' (1734), it is to condemn his 'abuse' of mathematics. In fact 's Gravesande, who as described observed a strict divide between epistemology and metaphysics, quietly (and undetected by historians so far) managed to dissociate Newton's natural philosophy from the metaphysical and theological concerns of Newton's Dutch followers. Bearing in mind the still fresh memories of the bitter metaphysical controversies in the Dutch philosophical faculties in the recent past, it may even have been an important instrument to help introduce Newton's natural philosophical system into the Dutch academic curriculum. Following this line of argument, we may perhaps conclude that 's Gravesande did for Newton's philosophy what De Volder had achieved for natural philosophy at large, by introducing the empirical method forty years before.[51]

Conclusion

From his earliest days on, 's Gravesande lived in places where people of different religious, political and philosophical persuasions had to try and find a *modus vivendi*. In 's-Hertogenbosch he was part of a Protestant enclave in a largely Catholic environment, at Leiden University a delicate balance was kept between strictly orthodox and more religiously moderate scholars and in Leiden and The Hague he moved in circles of expatriate French Huguenots and British subjects closely associated with the court. Perhaps moulded by these experiences, his own attitude was that of an independent thinker. Though he entertained strong convictions, he avoided partisanship and clearly managed to cooperate with people of other religious persuasions. That 's Gravesande firmly embraced Newton's natural philosophy, consequently, did not make him a dogmatic Newtonian.

Adhering to Newton's natural philosophy had beneficial practical effects for 's Gravesande. He obtained both powerful patrons and a professorship as well as a means to award his beloved instruments an essential role in his teaching. In addition, Newton's natural philosophy helped to restore the reputation of mathematics. Also, assuming that, like Van Effen, he wanted to check the Frenchification of Dutch (and European) culture, it was a good strategic choice to promote British philosophers.

There is definitely something unsatisfactory about this conclusion. The problem is that all arguments rest on circumstantial evidence. We have no clear proof whether political or personal interests, rather than 'inner convictions', did or did not motivate his interest in the English natural philosophy of Isaac Newton. We do not know for sure if he was actually an Orangist or if he worried about the contamination of Dutch culture by French customs and style. Furthermore, if he did not accept arguments merely on authority in matters of natural philosophy, would not this conviction also extend into the political and religious spheres? Did he indeed develop deist inclinations, as Israel has recently suggested?[52] Did he use his instruments for intrinsic, methodological reasons, or simply to attract more students and to make money? Did he purposely detach Dutch Newtonianism from religious matters?

No characterization exists which gives us a good impression about what kind of person 's Gravesande was. Who was this exceptional figure, both a prominent journalist and a renowned professor, who as the son of one of the governors of a provincial town frequented circles of French freethinkers and who as a man of reason nevertheless moved in the cynical world of higher, Machiavellian politics? He seems to have been endowed with good social skills. He was deeply struck by the death of his sons and he is said to have been a man with a great sense of duty, but also a man of principle who stood by his opinions. But for the rest? Even the expansive biographical sketch of Allamand, who was very close to 's Gravesande, does not really bring out his personal traits and motives. Nor is it possible to deduce them from other testimonies. Do we have to conclude that our attempts to consider 's Gravesande in the context of his time will not give us a deeper understanding of his personality and convictions?

However, at a closer look, is not precisely the relative 'invisibility' of his personality consistent with his persuasions? Let us briefly summarize the conclusions of the previous sections. In his natural philosophy, 's Gravesande did everything to avoid the interference of the imagination; he 'depersonalized' natural philosophy. His contributions to the *Journal littéraire* remained concealed behind the collective. In his courses, the apparatuses almost physically detracted attention from himself. He kept his natural philosophy separate from his religious sentiments. Another notable thing is the only personal criticism of 's Gravesande I have come across, which was that in the first two editions of his *Physices elementa mathematica* he did not name his sources.[53] Did he, as this criticism seems to suggest, want to appropriate the work of others? Or was this again a perhaps naïve but consistent example of downplaying the personal element? He did not claim intellectual ownership of his instruments, but rather helped to disseminate the designs by describing and drawing them in detail in his handbook.[54] The only thing *De boekzaal van Europa* has to mention about him in the obituary notice is that he did not want a funeral oration (which, incidentally, was not unusual). No personal papers and hardly any correspondence have survived of 's Gravesande (although this might not have been his own, deliberate choice). We know 's Gravesande's work very well, but we do not know the person behind the work: did he — consciously or unconsciously — 'depersonalize' himself?

It is a matter of speculation, but 's Gravesande's experiences with people of different philosophical and religious backgrounds may have taught him not to hold prejudices against people because of their (divergent) ideas. A person and his opinions are two different things. What we see in fact occurring in the activities of 's Gravesande is a principal, idealistic and fundamental separation between the person and his ideas. Nowadays every journalist, scientist and politician is familiar with this separation (or at least should be). Anyone who engages in public debates ought to confront ideas and opinions, but not the person expressing them.

We see 's Gravesande and his contemporaries — like his fellow editors of the *Journal littéraire* — actually attempting in a very deliberate manner to construct a division line between a person and his ideas. Perhaps they were inspired by the British experimentalists around Robert Boyle (1627–1691) to end pedantry and the contentiousness among scholars by introducing 'gentlemanly conventions' in the scholarly community (see also the previous section). Rejection of authority and the seeking of truth by a 'selfless self', who is not chasing celebrity or personal benefit, was part of the values propagated by them.[55] It is interesting to see that 's Gravesande observed the separation between person and ideas more strictly than we do – we tend to allow more of our own personality into our professional work and opinions than he did (twenty-first century journals in general do not have editors who are willing to act as an anonymous collective). It is also interesting to notice that the question has not lost anything of its topicality since the days of 's Gravesande.

Thus, 's Gravesande lives on as an elusive person, a *Mann Ohne Eigenschaften* (man without qualities), whom we mainly know through his work and his ideas. Let us simply respect this and let the person 's Gravesande rest in an undoubtedly peaceful obscurity.

Notes

1 For instance: J.N.S. Allamand, 'Histoire de la vie et des ouvrages de Mr. 's Gravesande', in: J.N.S. Allamand (ed.), *Oeuvres philosophiques et mathématiques de Mr. G.J. 's Gravesande* (Amsterdam 1774), pp. x-lix; P.L. Rijke, 'Levensschets van Willem Jacob 's Gravesande', *Album der natuur: een werk ter verspreiding van natuurkennis onder beschaafde lezers van allerlei stand,* nieuwe reeks 27 (1879), pp. 65–88; C. de Pater, 'Willem J. 's Gravesande', in: A.J. Kox (ed.), *Van Stevin tot Lorentz: portretten van achttien Nederlandse natuurwetenschappers* (Amsterdam 1990), pp. 81–92; C. de Pater, 'Inleiding', in: C. de Pater (ed.), *Willem Jacob 's Gravesande, welzijn, wetenschap en wijsbegeerte* (Baarn 1998), pp. 23–58; P. de Clercq, 'The 's Gravesande collection in the Museum Boerhaave, Leiden', *Nuncius* 1 (1988), pp. 127–137; R. Vermij, *The Calvinist Copernicans: the reception of the new astronomy in the Dutch Republic, 1575–1750* (Amsterdam 2002), pp. 335–348.

2 Jorink and Zuidervaart in this volume.

3 De Pater, *Welzijn* (note 1); C. de Pater, 'Willem Jacob 's Gravesande, een newtoniaans filosoof', *Wijsgerig perspectief op maatschappij en wetenschap* 29 (1988–1989), pp. 7–12; C. de Pater, 'Willem Jacob 's Gravesande (1688–1742) and Newton's *Regulae Philosophandi*, 1742', *Lias: sources and documents relating to the early modern history of ideas* 21 (1994), pp. 257–294; P. Schuurman, *Ideas, mental faculties and method: the logic of Descartes and Locke and its reception in the Dutch Republic* (Leiden, Boston 2004), pp. 129–155.

4 J. Israel, *Radical Enlightenment: philosophy and the making of modernity, 1650–1750* (Oxford 2001), p. 524.

5 Ibidem, pp. 555–568.

6 This section is largely based on: De Pater, *Welzijn* (note 1).

7 On the other hand, in his epistemology 's Gravesande saw wider applications than Newton for using hypotheses to generate knowledge. These, however, ought to be deployed in a strict manner, according to a set of six rules formulated by 's Gravesande: Schuurman, *Ideas* (note 3), p. 153.

8 Fokko Jan Dijksterhuis recently focused on a case whereby 's Gravesande's treatment of optics was actually more 'hypothetical' than Newton's: F.J. Dijksterhuis, 'Reading up on the *Opticks*: Refashioning Newton's theories of light and colors in eighteenth-century textbooks', *Perspectives on science* 16 (2008), pp. 307–327, on 311. Even for inveterate opponents of 'using hypothesis', it sometimes proved difficult in practice not to lapse into speculative arguments: see, in particular, De Pater in this volume.

9 J. Israel, *Enlightenment contested: philosophy, modernity, and the emancipation of man, 1670–1752* (Oxford 2006), pp. 215–222.

10 See also Jorink and Zuidervaart in this volume.

11 The main source of 's Gravesande's biography is the account written by his successor Allamand: Allamand, 'Histoire' (note 1); see also J.N.S. Allamand, ''s Gravesande', in: P. Marchand, *Dictionnaire historique ou mémoires critiques et littéraires*, 2 vols. (The Hague 1759), vol. 2, pp. 224–227. However, as the genealogic research of Koenen has shown in particular, Allamand's description of 's Gravesande's origins is not always accurate: H.J. Koenen, 'Het geslacht van professor 's-Gravesande', *Algemeen Nederlandsch familieblad* 11 (1885), pp. 261–268. See also: A. van der Wijck, 'Bijdrage tot de genealogie der familie Storm van 's Gravesande', *Heraldieke bibliotheek* 2 (1873), pp. 121–144.

12 Koenen, 'Geslacht' (note 11), p. 266.

13 Allamand (ed.), *Oeuvres* (note 1), p. ix-x.

14 G. Wiesenfeldt, *Leerer Raum in Minervas Haus: experimentelle Naturlehre an der Universität Leiden, 1675–1715* (Amsterdam 2002), p. 248.

15 W.J. 's Gravesande, *Dissertatio juridica inauguralis de autocheiria* (Leiden 1707).

16 E. Shoesmith, 'The continental controversy over Arbuthnot's argument for divine providence', *Historia mathematica* 14 (1987), pp. 133–146; R. Vermij, *Secularisering en natuurwetenschap in de zeventiende en achttiende eeuw: Bernard Nieuwentijt* (Amsterdam 1991), pp. 118–120.

17 J. Israel, *The Dutch Republic: its rise, greatness, and fall* (Oxford 1995), pp. 968–975 and 985–986.

18 Ibidem, pp. 988–989.

19 J. Aalbers, 'Factieuze tegenstellingen binnen het college van de ridderschap van Holland na de vrede van Utrecht', *Bijdragen en mededelingen betreffende de geschiedenis der Nederlanden* 93 (1978), pp. 412–445; P.J. Buijnsters, *Justus van Effen (1684–1735): leven en werk* (Utrecht 1992), pp. 48–56.

20 Ibidem; Th. Bussemaker, 'De Republiek der Vereenigde Nederlanden en de keurvorst-koning George I', *Bijdragen voor vaderlandse geschiedenis en oudheidkunde,* 4th series, 1 (1900), pp. 263–344; R. Geikie and I.A. Montgomery, *The Dutch barrier, 1705–1719* (Cambridge 1930).

21 On the tasks of a secretary: J. Aalbers, *De Republiek en de vrede van Europa* (Groningen 1980), pp. 283–286.

22 Buijnsters, *Justus van Effen* (note 19), pp. 99–114. Desaguliers' translation: *Mathematical elements of natural philosophy confirmed by experiments: or an introduction to Sir Isaac Newton's philosophy* (London 1720); on Desaguliers, see also Jorink and Zuidervaart in this volume.

23 S. Shapin and S. Schaffer, *Leviathan and the air-pump: Hobbes, Boyle, and the experimental life* (Princeton 1985).

24 L. Jardine, *Going Dutch: how England plundered Holland's glory* (London 2008), pp. 310–314.

25 Ibidem, pp. 27–52.

26 L. Maass, *Het* Journal littéraire de La Haye *(1713–1723): de uitwendige geschiedenis van een geleerdentijdschrift* (PhD thesis, Katholieke Universiteit Nijmegen, 2001), p. 158n.

27 See also Jorink and Zuidervaart in this volume.

28 W.J. 's Gravesande to I. Newton, 28 May 1714, in: H.W. Turnbull, A.R. Hall and L. Tilling (eds), *The correspondence of Isaac Newton*, 7 vols. (Cambridge 1976), vol. 6, pp. 144–145; W. Burnet to J. Bernoulli, 8 April 1714, in: ibidem, pp. 96–97. See also: R.S. Westfall, *Never at rest: a biography of Isaac Newton* (Cambridge 1980), pp. 741–744.

29 W. Otterspeer, *De vesting van de macht: de Leidse universiteit, 1673–1775. Groepsportret met dame* (Amsterdam 2005), p. 77.

30 Israel, *Contested* (note 9), p. 70.

31 Maass*, Het* Journal littéraire de La Haye (note 26); Buijnsters, *Justus van Effen* (note 19), pp. 75–98.

32 About physico-theology in the *Journal littéraire*: H. Bots and J.J.V.M. de Vet, 'De fysico-theologie in het *Journal littéraire*: Haagse journalisten ten strijde tegen het ongeloof', *Documentatieblad werkgroep achttiende eeuw* 18 (1986), pp. 213–226.

33 Allamand, 'Histoire' (note 1), pp. xii-xxi; De Pater, *Welzijn* (note 1), p. 154; C. Berkvens-Stevelinck, 'Nicolas Hartsoeker contre Isaac Newton ou pourquoi les planetes se meuvent-elles?', *Lias: sources and documents relating to the early modern history of ideas* 2 (1975), pp. 313–322.

34 W.W. Mijnhardt, 'Dutch culture in the age of William and Mary: cosmopolitan or provincial?', in: D.E. Hoak and M. Feingold (eds), *The world of William and Mary: Anglo-Dutch perspectives on the revolution of 1688–89* (Stanford 1996), pp. 219–233.

35 Buijnsters, *Justus van Effen* (note 19), p. 71.

36 Israel, *Radical Enlightenment* (note 4), pp. 515–527.

37 Mijnhardt, 'Dutch culture' (note 34), pp. 229–230.

38 P. de Clercq, *At the sign of the Oriental Lamp: the Musschenbroek workshop in Leiden, 1660–1750* (Rotterdam 1997), pp. 73–102; P. de Clercq, *The Leiden Cabinet of Physics: a descriptive catalogue,* Museum Boerhaave Communications 271 (Leiden 1997).

39 E.G. Ruestow, *Physics at 17th- and 18th-century Leiden* (The Hague 1973); Wiesenfeldt, *Leerer Raum* (note 14); A.C. de Hoog, *Some currents of thought in Dutch natural philosophy, 1675–1720* (PhD thesis, Oxford University, 1974), pp. 122–256.

40 For this controversy, see also: W. van Bunge, *From Stevin to Spinoza: an essay on philosophy in the seventeenth-century Dutch Republic* (Leiden, Boston, Köln 2001); Th. Verbeek, *Descartes and the Dutch: early reactions to Cartesian philosophy, 1637–1650* (Carbondale, Edwardsville 1992); J.A. van Ruler, *The crisis of causality: Voetius and Descartes on God, nature and change* (Leiden, New York, Köln 1995).

41 De Hoog, *Some currents* (note 39), p. 143; Wiesenfeldt, *Leerer Raum* (note 14), pp. 7 and 111–112; Otterspeer, *Vesting* (note 29), pp. 54 and 108.

42 Shapin and Schaffer, *Leviathan* (note 23).

43 Wiesenfeldt, *Leerer Raum* (note 14), p. 62.

44 's Gravesande to Newton, 13/24 June 1718, in: A. Rupert Hall, 'Further Newton Correspondence', *Notes and records of the Royal Society of London* 37 (1982–1983), pp. 7–34 [original in French].

45 De Clercq, *Leiden Cabinet of Physics* (note 38), pp. 108–124.

46 Otterspeer, *Vesting* (note 29), pp. 95–145.

47 Van Bunge, *Stevin to Spinoza* (note 40); R. Vermij, 'The formation of the Newtonian philosophy: the case of the Amsterdam mathematical amateurs', *British journal for the history of science* 36 (2003), pp. 183–200.

48 'Oratio inauguralis de Matheseos on omnibus scientiis, praecipue in Physicis, Usu, nec non de Astronomiae perfectione ex Physica haurienda'; Dutch adaptation in: De Pater, *Welzijn* (note 1), pp. 72–86.

49 Vermij, 'Formation' (note 47).

50 By the time's Gravesande had been appointed, 'Amsterdam mathematicians' like Nieuwentijt and Ten Kate had come to realize the fruitlessness of their attempts to support religion by mathematical argument. They now directed their attention to physico-theological reasoning, which aimed at providing a more 'empirical' evidence for God's providence. See: Vermij, 'Formation' (note 47), pp. 194–196. For Ten Kate see Dijksterhuis in this volume.

51 On the other hand, before 's Gravesande entered the stage, the religious and metaphysical aspects inherent in Dutch Newtonianism may also help to explain the 'remarkable consensus' among professors like Senguerd, De Volder and Jacob le Mort (1650–1718) that 'Newtonian philosophy [...] was not considered an appropriate alternative for the purposes of

Leiden University', in: Wiesenfeldt, *Leerer Raum* (note 14), p. 10.

52 Israel, *Contested* (note 9), pp. 215–222 and 395.

53 G.A. Lindeboom, *Herman Boerhaave: the man and his work,* 2nd ed. (Rotterdam 2007), p. 216.

54 De Clercq, 'Collection' (note 1), p. 129.

55 S. Shapin, *A social history of truth: civility and science in seventeenth-century England* (Chicago, London 1994), esp. pp. 123–124.

‘The Wisest Man to Whom this Earth Has as Yet Given Birth’

Petrus van Musschenbroek and the limits of Newtonian natural philosophy

KEES DE PATER

Petrus van Musschenbroek (1692–1761) is often bracketed together with Willem Jacob ’s Gravesande (1688–1742) as the two great Dutch popularizers of the natural philosophy of Isaac Newton. Although each of them had his own individual approach, both men were experimental physicists who followed and defended Newton’s scientific method. They disseminated this approach in their teaching, which they improved drastically, in particular thanks to the often newly designed demonstration instruments.[1] A considerable number of students all over Europe learnt the first principles of physics from their textbooks or by attending their lectures.[2] Also in their academic orations both physicists often discussed Newton’s empirico-mathematical method and emphasised the reliability of its results. In the dissemination on the European Continent of Newton’s ideas, method and discoveries by means of teaching, textbooks and orations lies the enduring merit of both Dutch physicists.

However, Van Musschenbroek did more than just spread the word of this British genius. He also conducted research, in which he was guided by Newton’s methodology. In practice, Van Musschenbroek’s focus, however, was aimed particularly at the empirical aspect. This article, by focusing on the principles of research of Van Musschenbroek, aims to reveal some dilemmas raised by the limits of this empiricism. It could lead, as will be shown, to unfruitful observations and sometimes even to pointless speculations. This article will start with a survey of Van Musschenbroek’s life and career and the most important part of his scientific legacy: his textbook oeuvre. This will be followed by a discussion of Van Musschenbroek's methods of research: first his empirical studies and then his views on matter and forces.

Petrus Van Musschenbroek: Life and career

In 1726, when the third edition of Newton's *Principia* appeared, Petrus van Musschenbroek, at the time a 34–year-old professor of philosophy, mathematics and astronomy at the University of Utrecht, published a concise textbook entitled *Epitome elementorum physico-mathematicorum*. In the preface he mentions a number of luminaries in the rapidly expanding natural sciences. Newton is one of them, though Van Musschenbroek seems to believe that he surpasses them all. Newton is the only scientist who Van Musschenbroek praised in such transcendent terms as 'a man of extraordinary talent and divine acuteness in physics and mathematics'.[3] Such extravagant appreciation of the author of the *Principia* and the *Opticks* was, at that time, certainly not common on the European Continent.

Petrus (Pieter) van Musschenbroek was born in 1692 as the second son of the instrument maker Johan Joosten van Musschenbroek (1660–1707) and Margaretha van der Straeten (1659–1743). The Van Musschenbroeks were the most well-known family of instrument makers in the Dutch Republic in the period 1650–1750. In particular, Petrus' elder brother Jan gave the business a great reputation by producing air-pumps and other equipment for use in physical experiments. A unique collaboration existed between Jan van Musschenbroek (1687–1748) and the Leiden professor Willem Jacob 's Gravesande in the production of instruments for the demonstrations that enlivened the latter's lectures on experimental physics.[4] Contrary to his brother, Petrus chose an academic career. He studied medicine under Herman Boerhaave (1668–1738) in Leiden, and in 1715 he gained his doctorate under the renowned physician with a dissertation about air in bodily fluids.[5] His strongly empirical attitude was already apparent in this work.

The University of Leiden was surely the place where Van Musschenbroek became (better) acquainted with the ideas of Newton and other English investigators. A pirated edition of the second edition of the *Principia* (1713) produced in 1714 enabled many to become acquainted with Newton's main work.[6] In 1715 Boerhaave was one of the first who openly expressed his high esteem for Newton in an academic address (see Knoeff in this volume). All his life Van Musschenbroek was a faithful follower of Boerhaave.

In 1717, the same year that 's Gravesande became a professor at Leiden, Van Musschenbroek made a study trip to London, where he attended the lessons in experimental physics given by John Theophile Desaguliers (1683–1744), with whom he remained on friendly terms. He must have met other members of the Royal Society, but little is known about these contacts. We do know, from a letter dating from 1726 to which I will come back, that he had personally met with Newton. He only became a member of the Royal Society in 1734.

After his return from England Van Musschenbroek briefly attended 's Gravesande's lectures. In 1719 he was offered a professorship in mathematics and philosophy at Duisburg by King Wilhelm I of Prussia. On this occasion he was granted a doctorate *honoris causa* in philosophy. The degree certificate features the signatures of 's Gravesande and Wolferd Senguerd (1646–1724), who was also a member of the philosophical faculty of Leiden University. No work written by Van Musschenbroek appeared in print during the Duisburg period (1719–1723). Nothing is known about an inaugural lecture either. We do know, however, that after only six months he established an *'observatorium astronomicum'* on top of the Salvatorkirche. In the second year he was also appointed professor of medicine. He assumed this new function with a lecture on the possibility of linking medicine with natural philosophy.[7]

In 1723, at the age of 31, Van Musschenbroek became professor of philosophy and mathematics in Utrecht, where he introduced Newtonian natural philosophy. A professorship in astronomy was added in 1732, after the observatory on the Smeetoren (Smee Tower) had been very much improved. Van Musschenbroek assumed his duties in 1723 with an *Oratio de certa methodo philosophiae experimentalis*, in which he pleaded for Newton's empirico-mathematical method. A number of scientists were discussed, but Newton was the 'greatest of all mortals' or even an 'immortal light'. These were very novel views in Utrecht.[8] Late in the year 1739, Van Musschenbroek went back to Leiden. Formally he took over the chair of Jacobus Wittichius (1677–1739), but in practice he was known as successor to 's Gravesande (who died in 1742) as the figurehead of Leiden natural philosophy. Van Musschenbroek would stay in Leiden until his death in 1761.

The *Epitome*, a survey of the principles of physics mentioned above, was based on the physics lectures he delivered during the first three years of his Utrecht professorship. It seems he wanted Newton to know that he contributed to the dissemination of his theories, for he sent a

Fig. 1: Jan (standing) and Petrus van Musschenbroek, by Hieronimus van der Mij (1715). (Museum Boerhaave, Leiden, P00810)

copy to London, where the then 83–year old author of the *Principia* had been Master of the Mint for many years. Just like 's Gravesande, Van Musschenbroek displayed an almost diffident veneration for him:

> Being an admirer of your wisdom and philosophical teaching, of which I had experience while in Britain in familiar conversation with yourself, I thought it no error to follow in your footsteps (though far behind), in embracing and propagating the Newtonian philosophy. I began to do so in two universities, where the triflings of Cartesianism flourished, and met with success, so that there is hope that the Newtonian philosophy will be seen as true in the greater part of Holland, with praise of yourself. It would flourish even more but for the resistance of certain prejudiced and casuistical theologians.

> I have prepared a compendium for beginners with which, if it does not displease you greatly, I shall be well satisfied. I shall always endeavour to serve the wisest man to whom this Earth has as yet given birth. (Utrecht 23 February 1726)[9]

Quotations such as this one – to which several others could be added – might suggest that Van Musschenbroek was a slavish follower of Newton. Such a conclusion, however, would be premature. Just like 's Gravesande, Van Musschenbroek chose Leibniz's position in the so-called *vis viva* controversy – whether the 'force' of a moving body is proportional to mv (René Descartes, 1596–1650) or to mv^2 (Gottfried Leibniz, 1646–1716) – while most English Newtonians opted for Descartes' view.

Textbooks

Van Musschenbroek's textbooks are undoubtedly the most important part of his scientific legacy. The *Epitome* was the first of these. All subsequent publications can be viewed as adaptations and extensions of this book, even when the titles were different. In 1734 and 1741 the first and second editions appeared of the *Elementa physicae conscripta in usus academicos*, which was followed in 1748 by *Institutiones physicae conscripta in usus academicos*; and finally in 1762 Johan Lulofs (1711–1768) published posthumously a textbook that had been expanded and brought up to date by Van Musschenbroek himself, under the title *Introductio ad philosophiam naturalem*. In the same year an abridged version was made available for students, the *Compendium physicae experimentalis conscripta in usus academicos*, comparable in size to the *Epitome*. In addition, Van Musschenbroek published in 1736 the *Beginselen der natuurkunde, beschreven ten dienste der landgenooten*, the first modern physics textbook in Dutch, of which a new edition appeared only three years later (the first word of the title having been changed from 'Beginselen' to 'Beginsels'). This work closely resembled the Latin textbooks. In several European countries reprints appeared of the Latin textbooks, in particular of the *Elementa physicae* of 1741. There were also translations into French, German, English and Swedish. Contrary to present-day practice, these textbooks also contained the results of his own experiments.[10]

In line with his preference for empirical research (see the next section), Van Musschenbroek's textbooks are less mathematical in approach than the various editions of 's Gravesande's textbook. Petrus Camper (1722–1789), who gained his doctorate under Van Musschenbroek, advised new physics students to use the textbooks of his teacher because they contained less mathematics. Van Musschenbroek informed his readers extensively about the results of his experiments, even though he wasn't sure what to do with them. 's Gravesande usually included his measurements only if they could be processed mathematically and led to clear conclusions. In their academic addresses these different attitudes to mathematics were equally apparent: 's Gravesande paid special attention in one of his academic orations to the benefits of mathematics, while Van Musschenbroek gave an address on the proper experimental method.[11]

The content of 's Gravesande's *Physices elementa mathematica* has a stronger focus on Newton's work than Van Musschenbroek's textbooks. This is already apparent in the subtitle of 's Gravesande's work: *Introductio ad philosophiam Newtonianam*, which is lacking in the titles of Van Musschenbroek's textbooks. In this respect a comparison of the third edition of 's Gravesande's textbook (1742) with the second edition of Van Musschenbroek's *Elementa physicae* (1741), which appeared more or less simultaneously, is illuminating. The two physicists are entirely guided by Newton in the areas of gravitation, attractive forces, (celestial) mechanics, optics and the like, but Van Musschenbroek also pays attention to magnetism, electricity, heat, meteorology and the strength of materials, topics that are largely ignored by Newton and 's Gravesande. On the other hand, 's Gravesande discusses the Newtonian world system, which is not included in his textbooks by Van Musschenbroek. In the wake of Robert Boyle (1627–1691), Newton and Boerhaave, Van Musschenbroek pays attention to chemistry, which is ignored by 's Gravesande.

The limits of empiricism

Following a 'Newtonian' line of reasoning, Van Musschenbroek contended that reliable natural science can only be based on observation and experiment. From the evidence that has been obtained empirically, conclusions have to be drawn with the help of logic and mathematics and, if possible, laws have to be formulated that in their turn can be tested experimentally, so as to discover the causes of phenomena. In Van Musschenbroek's words:

> If a natural science is to be established and advanced, it will either be based on sensory perception and subsequently mathematical reasoning, or it will never come into being.[12]

and also:

> The Newtonians collect observations, and perform experiments, which they compare with each other, and from which they draw conclusions, which they again confirm with experiments, thus reasoning from facts, and attempting to discover the causes of phenomena from them.[13]

To be able to draw reliable conclusions and to give them a mathematical form, sufficiently reliable and varied factual evidence has to be available. This is strongly emphasized by Van Musschenbroek. In his *Introductio ad philosophiam naturalem* (1761) he writes: 'for only the observations, only the experiments constitute the true and solid foundations of natural philosophy'.[14] This emphasis on collecting evidence in itself was not introduced by Newton, but is characteristic of the Baconian tradition in natural philosophy. Around 1600 Francis Bacon (1561–1626) argued for the need of a 'natural history', a 'data bank' of reliable empirical evidence so as to construct a new natural science from the foundations.[15] Bacon's empiricism is a rational empiricism: the evidence that was collected would have to be ordered and processed by reason. In 1715 he was still mentioned in adulatory terms by Boerhaave.

There is also a certain element of Baconianism in Van Musschenbroek. Time and again we find in his publications lists, sometimes long lists, in which experimental results are assembled. In the *Introductio* there is a list of specific gravities that occupies no fewer than 26 pages. In his work we come across lists of substances that are attracted by magnets, lists of heights of fluid rise in capillaries, etc. His extensive meteorological investigations also reflect the Baconian tradition.[16] And yet, characterizing Van Musschenbroek purely as a Baconian doesn't do justice to his intentions. Just like his teacher and colleague 's Gravesande, he reiterated the need for processing the acquired evidence mathematically, if this was possible. In physics, empirical observation and mathematics cannot be separated, he argued. However, in fact he often published lists with a multiplicity of experimental results, which in future might be useful for the intended purpose, rather than jumping to conclusions and formulating mathematical relations on the basis of a few superficial observations.[17] At the same time he strongly emphasized the importance of finding forces and the laws they obey, an eminently Newtonian theme. Many of his investigations were devoted to such attempts in the areas of magnetism, capillarity, the strength of materials, and heat (expansion).

His unwillingness to make hasty generalizations is closely linked with the stringent demands he made on empirical research so as to produce reliable results. In an *éloge* devoted to Van Musschenbroek, Nicolas de Condorcet (1743–1794) drew attention to this point:

> One finds in his works a long series of well-performed experiments, the results of which have been exactly calculated; a large number of well-observed and precisely described facts, several experimental devices, either invented or improved by him, and above all an excellent method of philosophizing. When his investigations do not lead to general results, he contents himself with presenting his experiments baldly, and he rather runs the risk of being considered a physicist without vision, than producing systems instead of truths.[18]

A good example of Van Musschenbroek's empirical research are his studies on magnetism. In contrast to 's Gravesande, who only referred to it in passing, Van Musschenbroek occupied himself extensively with it. He published his study of this topic in *Dissertatio physica experimentalis de magnete*, as a part of a collection of treatises, which appeared in 1729. It was later reprinted separately in Vienna (1754).[19] In 1734 Emanuel Swedenborg (1688–1772) included large parts of the text in his *Examen principiorum rerum naturalium cum phaenomenis magneticis* (1734).[20] Van Musschenbroek's interest in magnetic phenomena is in part connected with its importance for navigation. Part of his work concerns this application. The Baconian element is abundantly present: there are many lists and tables in the book with observational data and results of measurement. He formulated the main purpose of the study of magnetism into two questions, viz. what link is there between the force and the distance of two attractive or repulsive magnets, and what is the essence, the true cause, of the phenomenon of magnetism?

Much earlier, in 1712, at the request of Newton, who had been president of the Royal Society since 1703, Francis Hauksbee (1660–1713) and Brook Taylor (1685–1731) had attempted to find a force law for magnetism by means of the deflection method: a magnetic needle placed in the meridian was deflected over a certain angle under the influence of a nearby magnet. By measuring the angle of deflection while the magnet was placed at different distances and calculating the force as a function of this angle, they tried to find a force law of the form $F \propto r^{-n}$, the exponent n to be derived from observations. They did not, however, manage to produce a satisfactory result. What is measured by this method, incidentally, is in fact the couple that makes the needle turn, and not the total magnetic force. Nevertheless, in the second edition of the *Principia* (1713), that is, after the experiments by Hauksbee and Taylor, Newton stated that a few rough measurements showed that the exponent n approximately equalled 3.[21]

Van Musschenbroek began his investigations in 1724.[22] He didn't use the deflection method but employed a balance. The force between a magnet suspended from one arm of the balance and a magnet attached to the table underneath was measured by placing a weight in the scale attached to the other arm that counterbalanced the force of the magnet. In his treatise of 1729 he published many observations, but was unable to derive a law. Van Musschenbroek continued his experiments for many years as is apparent from the repeatedly revised section on magnetism in his textbooks.

More than ten years later he formulated several laws of the form $F \propto r^{-n}$ for specific shapes of magnets or iron bodies and for a limited distance interval. They first appeared in a manuscript entitled *De viribus magneticis* (1740). There were four, where $n = 1$, $n = 1.5$, $n = 2.5$, and $n = 4$. As from the second edition of the *Elementa physicae* (1741) they were also included in the textbooks. The last case was already present in the second edition (1739) of the *Beginselen*. The notion of 'distance' (for example, between two globes) was now made more precise by taking the volume of the space between two bodies within an enveloping cylinder or cone, which involves a correction of the shortest distance. It should be pointed out that several contemporaries of the Dutch physicist concluded that there were general laws purely on the basis of a small number of observations. Van Musschenbroek never did that. His respect for the experimental results was too great for that.

In the 1740 manuscript he expressed already his disappointment about his experimental results:

> I am not entirely convinced that one and the same law applies to all magnets on earth, as I have used only three magnets in the investigation to be described below. However, if other magnets were to obey different laws, the investigators of nature would never see their wish [for a universally valid force law] fulfilled and would do better to give up their investigations and stop wasting their time.[23]

Drawing conclusions was hampered by the use of weak, often not very homogeneous natural magnets, and by the fact that there are two attractive and two repulsive forces if the magnetism is located in two points in a magnet. Apart from these problems, it is clear that the Baconian-heuristic method fails in this case. This approach implied that Van Musschenbroek was looking for a force law between two bodies as they are given in the experimental arrangement. In 1819, the Norwegian (geo) physicist Christopher Hansteen (1784–1873) pointed out that experiments like Van Musschenbroek's were not suited to finding a general law for magnetism, because the results also depended on the intensity distribution of the magnetism of the bodies that were used, while without a theory the concept of 'distance' was also problematic.[24]

Although Van Musschenbroek recognized these problems himself, he kept reiterating that an empirical approach was required: the magnet had to be subjected to a variety of experiments, without involving any hypotheses. It only became possible to find a law when Charles-Augustin de Coulomb (1736–1806) managed, with the help of a torsion balance, to measure the force between two point-poles. However, the inverse square law was only definitively accepted as the general law for the magnetic force when it was possible to perform experiments the results of which corresponded with the calculations made on the basis of the theory.[25]

Matter and forces

Van Musschenbroek was extremely negative about Descartes. In many places he denounced the dreaming up of general causes in order to construct a natural science deductively, without consulting nature itself. Cartesians know no better than piling hypothesis upon hypothesis, he said, so that natural science is debased to a 'science of guessing'. More than once he poured out the vials of his displeasure over the natural philosophers who in their studies devised chimaeras and 'inanities'. It is better to devote one's time to collecting observations than to building specious systems on an unsound foundation of imaginary principles.[26] In 's Gravesande's work this polemic is almost completely lacking, even though he was as disposed to hypotheses as Van Musschenbroek was. Only in the preface of his *Physices elementa mathematica* does he explicitly reject hypotheses.[27]

However, notwithstanding his warnings against using 'unsound imaginary principles', Van Musschenbroek himself could not prevent slipping into speculations about matter and forces, for instance in the discussion about the problem of the divisibility of matter. Van Musschenbroek addressed this issue following the British Newtonians and 's Gravesande. Contrary to 's Gravesande who viewed divisibility as a mathematical question, Van Musschenbroek distinguished between 'mathematical divisibility' and 'actual divisibility'. From the fact that the space taken up by a body can be shown to be infinitely divisible mathematically it cannot be concluded that the body itself is infinitely divisible. For that we have to rely on experiment. On the basis of arguments derived from experience, he was convinced of the existence of indivisible particles. Like Newton in the 'Queries' of the *Opticks*, he assumed that God had created these atoms in the beginning. He admitted that firm proofs were lacking, and he didn't want to impose this view upon others as an established fact.

The Newtonian John Keill (1671–1721) disputed the distinction between 'mathematical' and 'physical divisibility'. The divisibility of a physical body depends essentially only on its extension, a viewpoint that Descartes had adopted as a necessary consequence of his identification of matter and extension. Atoms created by God that are indivisible by the forces of nature cannot exist in Keill's view, as God is capable of dividing them. 's Gravesande shared this view, although he did not engage in a polemic against the atomists.[28]

Concerning the constitution of physical bodies Van Musschenbroek followed Newton. Atoms are the ultimate building blocks of all bodies. A small number of atoms forms a first-order particle; a number of these particles forms a second-order particle, and so on. Large bodies are composed of such agglomerates of different orders. Only homogeneous bodies are made up of particles of the same order. The real quantity of matter of a body remains unknown to us, as we don't know what the volume of the pores is. On the assumption that each particle of order n consists half of particles of order n–1 and half of empty space, the ratio of solid mass to empty space in a particle of order *n* equals $(2n-1) : 1$. Van Musschenbroek derived this calculation from Newton's *Opticks*.[29]

An important aspect of the Newtonian explanation of nature is the use of attractive and repulsive forces. In the *Principia* Newton had not only explained the motion of the planets with the help of the principle of general gravitation, which was highly praised by his followers, but he had also hinted at other attractive forces, stronger than gravitation and only active at short distances. In addition we also come across repulsive forces. In the preface of the *Principia* Newton had already expressed the conjecture: 'that all phenomena may depend on certain forces by which the particles of bodies, by causes not yet known, either are impelled toward one another and cohere in regular figures, or are repelled from one another and recede'.[30] Newton had given a hypothetical explanation of Boyle's law (pv = constant) by assuming a repulsive force between the particles of an elastic fluid, which was only active between adjacent particles and that was inversely proportional to the distance between them. And conversely he derived Boyle's law from this force.[31]

The success of Newton's theory of gravitation led to attempts by many investigators to discover the effects of forces in natural phenomena. In Van Musschenbroek's work forces play an important role, perhaps even more than in the work of other Newtonians in and before his time. In his textbooks he extensively discussed magnetism, electricity, capillarity and cohesion in solid bodies (strength of materials), while his most important scientific treatises (1729) were devoted to these phenomena.[32]

Van Musschenbroek usually assembles these natural phenomena, together with gravitation, under the heading of attractive (or repulsive) forces. By 'attraction' in the strict sense, however, he denotes the force that makes the smallest particles of bodies approach each other and adhere to each other. Gravity and this specific attraction are both invariable properties of matter, which God has implanted in physical bodies. That these are indeed two different forces is apparent from observation. The attraction between small particles is much stronger than the force of gravitation and diminishes so quickly that it is active only over very short distances while gravitation works over 'infinitely far distances'. Following Newton and the other Newtonians, he claims that a force law $F \propto r^{-n}$, where $n > 2$, must apply to this phenomenon.[33]

The examples that Van Musschenbroek adduces as proof for the existence of attraction are also to be found in Newton, Boerhaave, 's Gravesande and the English Newtonians. Amongst them are capillarity and cohesion in solid bodies, which he had investigated much more extensively than they had done. He calls cohesion between particles in solid bodies *cohaerentia*, or the 'strength, firmness or resistance of solid bodies'. He not only paid attention to this topic in his textbooks, in particularly in his *Introductio*, but with an eye to practical applications he had already in 1729 published an extensive study of the strength of wood, metal and other materials, which was one of the treatises I mentioned above.[34] From the large number of measurements he had derived a few formulae, one of them concerns a 'snap formula' for the force needed to break a vertical beam.[35]

Like Newton, Boerhaave and John Freind (1675–1728), Van Musschenbroek explains chemical action by attractive forces. If in a material that is made up of substances A and B the particles of a third substance C attract those of A more strongly, the C particles will oust the B particles. Precipitation reactions as well as dissolving of metals in acids have to be explained in this way. In addition, the shapes of the particles play a role in these processes. The sharper the particles of the acid in which a metal dissolves, the more easily these particles will 'cut' the metal particles to pieces.[36] These kind of speculative ideas were held not only by the adherents of Newton, but also by those of Descartes and Pierre Gassendi (1592–1655), for whom all phenomena had to be explained strictly mechanically, that is, exclusively on the basis of the shapes, sizes and arrangement of particles, and without what they viewed as 'occult' things like forces. Boerhaave also gives explanations that combine the action of forces with the shapes of the particles of a dissolving fluid. The better the particles of the one substance fit into the pores of those of the other, the more easily the mixture (solution) comes into being.

Both Van Musschenbroek's and Boerhaave's attitude is rather ambiguous from an empiricist point of view. On the one hand they warn against transgressing the bounds imposed by observation by introducing unverifiable hypotheses, but on the other hand they easily speak of sharp acid particles and globular water particles, although they certainly make no absolute statements about these shapes.

Because of the importance of gravitation the followers of Newton initially paid more attention to attraction than to repulsion. Only in

Fig. 2:
Pyrometer, an instrument invented by Van Musschenbroek to measure the rate of expansion of metal rods with the temperature. (Museum Boerhaave, Leiden, V09550)

the second half of the eighteenth century did repulsion and attraction become equivalent principles (magnetism, electricity). Van Musschenbroek discusses repulsion in his textbooks starting in 1748. In his *Introductio* he writes about the two forces:

> The attractive force is thus active at a distance from the bodies; its action is stronger in a smaller interval and weaker in a larger interval, strongest when there is direct contact, but its influence only extends over a short distance. [...] [W]here the attractive force leaves off, a repulsive force begins.[37]

Heating, fermenting and putrefaction of materials can produce vapours which, like air, consist of mutually repulsive particles. Following Newton and 's Gravesande, Van Musschenbroek derives from Boyle's law that this repulsive force is inversely proportional to the distance between the particles. He adds the comment that Boyle's law is not generally valid, as is shown by experiments. When a gas is compressed very strongly the law no longer applies as the particles will in the end touch one another.[38]

Optical phenomena like refraction, reflection and dispersion are also explained by Van Musschenbroek, following Newton and 's Gravesande, by attraction and repulsion. 's Gravesande does not assume that light is material, but he does see an analogy between the interaction of particles and the interaction between matter and light. Refraction is, according to Van Musschenbroek, the effect of attractive forces of the body on which the light falls and is refracted. Reflection is caused by repulsive forces acting outside the attractive sphere of the body. Newton himself explained the problem of why some light rays are refracted while others are reflected with his celebrated 'fits of easy transmission' and 'fits of easy reflexion'. Van Musschenbroek admitted he had no answer to this question. Like 's Gravesande he left Newton's 'fits' untouched.[39]

Conclusion

Despite all the efforts he put into gaining new insights in the workings of nature by his experiments, Van Musschenbroek (like 's Gravesande) became widely known mainly through his teaching and his textbooks. To be sure, he also lives on as the inventor of the pyrometer and the famous Leiden jar,[40] but Van Musschenbroek's contributions to the development of physics were limited and were forgotten rather soon. Time and again Van Musschenbroek propagated research according to 'Newtonian' principles. However, his reluctance to make 'premature' generalizations resulted in a strong bias on observations, which gave his studies a marked Baconian flavour.

Strictly Newtonian or not, Van Musschenbroek's research revealingly shows the limits of eighteenth-century empiricism. The seemingly endless accumulation of observations did not lead to natural laws concerning the behaviour of the weather or a force law for magnetism. Interestingly, Van Musschenbroek himself realized and admitted his failure in this respect. On the other hand, despite his professed aversion to 'hypotheses', Van Musschenbroek engaged in speculative (and fruitless) ideas about matter, forces and chemical reactions, which were hardly founded upon empirical evidence or mathematical proofs – the two pillars of Newton's methodology. The self-proclaimed Newtonian, Van Musschenbroek proved able only to a limited extent to bring into practice the kind of science that he disseminated in such a successful manner.

Notes

I would like to thank Bas Jongeling for correcting my English.

1 See the collection of devices designed and used by 's Gravesande and Van Musschenbroek in the Boerhaave Museum, Leiden.

2 An example is the French refugee, Jean-François de Boissy (1704–1754), who in 1746 – four years after the death of 's Gravesande – wrote to his brother that he attended Van Musschenbroek's physics lectures because they were fun, while he followed other courses only because they were obligatory. C.E. Engel, *Jean-François de Boissy (1704–1754), un réfugié français du XVIIIe siècle d'après sa correspondance* (Neuchâtel 1941), pp. 52–53: *'La physique sous M. Muschenbroek [sic], le premier homme du monde pour les expériences. C'est le seul collège qui me faisse plaisir; aux autres, je vais par devoir.'*

3 P. van Musschenbroek, *Epitome elementorum physico-mathematicorum, conscripta in usus academicos* (Leiden 1726), Praefatio.

4 P. de Clercq, *At the sign of the oriental lamp: the Musschenbroek workshop in Leiden, 1660–1750* (Rotterdam 1997), esp. 36–50, 73–102 and 134–149.

5 P. van Musschenbroek, *Disputatio medica inauguralis de aëris praesentia in humoribus animalibus, quam ... pro gradu doctoratus summisque in medicina honoribus ... ad diem 12. novembris 1715 ...* (Leiden 1715).

6 I. Newton, *Philosophiae naturalis principia mathematica* (London 1687); second edition (Cambridge 1713); pirated edition (Amsterdam 1714, 1723); third edition (London 1726), translated by I.B. Cohen and A. Whitman (eds), *The Principia: mathematical principles of natural philosophy with* 'A guide to Newton's *Principia*' by I.B. Cohen (Berkeley, Los Angeles 1999).

7 F.A. Meyer, 'Petrus van Musschenbroek: werden und Werk und seine Beziehungen zu Daniel Gabriel Fahrenheit', *Duisburger Forschungen* (1961), pp. 1–51, on 3–9; W. Ring, *Geschichte der Universität Duisburg* (Duisburg 1920), p. 187; C. de Pater, *Petrus van Musschenbroek (1692–1761), een Newtoniaans natuuronderzoeker* (PhD-thesis, Utrecht 1979), pp. 26 and 99 (fig. 9).

8 P. van Musschenbroek, *Oratio de certa methodo philosophiae experimentalis* (Utrecht 1723), pp. 22, 42; De Pater, *Musschenbroek* (note 7), pp. 26–28.

9 A. Rupert Hall, 'Further Newton correspondence', *Notes and records of the Royal Society* 37 (1982), pp. 7–34, on 32.

10 For an extensive bibliography, see: De Pater, *Musschenbroek* (note 7), pp. 349–371.

11 Ibidem, pp. 80–81.

12 Van Musschenbroek, *Oratio* (note 8), p. 23; cf. De Pater, *Musschenbroek* (note 7), pp. 57–121.

13 P. van Musschenbroek, *Beginsels der natuurkunde, beschreeven ten dienste*

der landgenooten (Leiden 1739), p. 105; cf. De Pater, *Musschenbroek* (note 7), pp. 57–121.

14 P. van Musschenbroek, *Introductio ad philosophiam naturalem*, 2 vols (Leiden 1762), vol. 1, p. 391.

15 F. Bacon, *Historia naturalis et experimentalis ad condendam philosophiam, sive, phaenomena universi: quae est Instaurationis Magnae pars tertia* (London 1622), in: J. Spedding (ed.), *F. Bacon, Works,* 14 vols (London 1857–1874; rept Stuttgart/Bad Cannstatt 1963), vol. 2, pp. 13–16.

16 On Van Musschenbroek and Dutch meteorology: H.J. Zuidervaart, 'An eighteenth-century medical-meteorological society in the Netherlands', *The British journal for the history of science* 38 (2005), pp. 379–410 and 39 (2006), pp. 49–66.

17 P. van Musschenbroek, *Beginselen der natuurkunde, beschreven ten dienste der landgenooten* (Leiden 1736), Voorreden; Van Musschenbroek, *Beginsels* (note 13), Voorreden.

18 Nic. de Condorcet [A. Condorcet O'Connor, F. Arago (eds)], *Oeuvres*, vol. 2 (Paris 1847), 'Muschenbroek' [sic], pp. 125–127, on 125–126.

19 P. van Musschenbroek, *Dissertatio physica experimentalis de magnete* in: P. van Musschenbroek, *Physicae experimentales, et geometricae, de magnete, tuborum capillarium vitreorumque speculorum attractione, magnitudine terrae, cohaerentia corporum firmorum dissertationes: ut et ephemerides meteorologicae Ultrajectinae* (Leiden 1729), pp. 1–270; second edition (Wien 1754).

20 Cf. De Pater, *Musschenbroek* (note 7), pp. 352, 360.

21 B. Taylor, 'An account of an experiment … in order to discover the law of magnetical attraction', *Philosophical transactions* 29, 1714–1716 (London 1717; rept New York 1963), pp. 294–295; B. Taylor, 'Extract of a letter … giving an account of some experiments relating to magnetism', *Philosophical transactions* 31, 1720–1721 (London 1723; rept New York 1963), pp. 204–208; F. Hauksbee, 'An account of experiments, concerning the proportion of the power of the load-stone at different distances', *Philosophical transactions* 27, 1710–1712 (London 1712; rept New York 1963), pp. 506–511; Newton, *Principia* (note 6), bk. 3, prop. 6, theor. 6, cor. 5, in ed. Cohen and Whitman, p. 810.

22 For the paragraphs on magnetism, see: De Pater, *Musschenbroek* (note 7), pp. 122–226.

23 P. van Musschenbroek, *De magnete*, Leiden University Library, Western manuscripts, BPL 240, nr. 42, fol. 69r (my translation).

24 C. Hansteen, *Untersuchungen über den Magnetismus der Erde*, 2 vol. (Christiania [Oslo] 1819), vol1, pp. 279–281; cf. G. Crystal, 'Magnetism', in: *The Encyclopedia Britannica*, 9th ed., vol. 15 (Edinburgh 1883), pp. 219–276, on 234a.

25 C.A. Coulomb, 'Second mémoire sur l'électricité et le magnétisme, où l'on

détermine, suivant quelles loix le fluide magnétique, ainsi que le fluide électrique, agissent, soit par répulsion, soit par attraction', *Mémoires de mathématique et de physique de l'Académie des Sciences 1785* (Paris 1788), pp. 578–611; Hansteen, *Untersuchungen* (note 23), pp. 303–310.

26 Van Musschenbroek, *Epitome* (note 3), Praefatio; Van Musschenbroek, *Beginsels* (note 13), Voorreden and pp. 12 and 104–105; Van Musschenbroek, *Introductio* (note 13), vol. 1, pp. 92 and 108; P. van Musschenbroek, *Oratio de methodo instituendi experimenta physica*, in: P. van Musschenbroek, *Tentamina experimentorum naturalium captorum in Academia del Cimento sub auspiciis ... Leopoldi Magni Etruriae Ducis ... ex Italico ... conversa* (Leiden 1731), pp. i-xlviii, on xxxiv; De Pater, *Musschenbroek* (note 7), pp. 76–80.

27 G.J. 's Gravesande, *Physices elementa mathematica, experimentis confirmata. Sive Introductio ad philosophiam Newtonianam*, 3rd ed., 2 vols (Leiden 1742),vol1, pp. iii and x.

28 I. Newton, *Opticks: or a treatise of the reflections, refractions, inflections and colours of light* (London 1704, 4th ed. 1731); reprint 4th edition with 'Preface' by I.B. Cohen, 'Foreword' by A. Einstein, 'Introduction' by E.T. Whittaker, 'Analytical table of contents' by D.H.D. Roller (New York 1931, 1952), Query 31, pp. 400; J. Keill, *Introductio ad veram physicam* (Oxford 1701), quotations from J. Keill, *Introductiones ad veram physicam et veram astronomiam* (Leiden 1725), p. 26, 32–33 and 39; 's Gravesande, *Physices* (note 26), p. 7; de Pater, *Musschenbroek* (note 7), pp. 85–88.

29 Newton, *Opticks* (note 27), pp. 268–269 (book 2, prop. 8); Van Musschenbroek, *Beginsels* (note 13), p. 44; Van Musschenbroek, *Introductio* (note 13), vol. 1, p. 35 and 41–42; De Pater, *Musschenbroek* (note 7), p. 87.

30 Newton, *Principia* (note 6), Preface, in ed. Cohen and Whitman, pp. 382–383.

31 Ibidem, book 2, prop. 21–23, in ed. Cohen and Whitman, pp. 692–699.

32 Cf. Van Musschenbroek, *Physicae experimentales* (note 18); see also Van Musschenbroek, *Tentamina* (note 25), pars 2, pp. 12–57 ('Addidamentum' about the pyrometer).

33 Newton, *Principia* (note 6), book 1, section 13, prop. lxxxv-lxxxvi, in ed. Cohen and Whitman, pp. 382–383; Newton, *Opticks* (note 27), Query 31, pp. 388–389, 395; 's Gravesande, *Physices* (note 26), vol. 1, p. 18; Keill, *Introductio* (note 27), pp. 88–89; Van Musschenbroek, *Beginsels* (note 13), pp. 280–283; Van Musschenbroek, *Introductio* (note 14), vol. 1, pp. 348–353.

34 P. van Musschenbroek, *Introductio ad cohaerrentiam corporum firmorum*, in: Van Musschenbroek, *Physicae experimentales* (note 19), pp. 421–462.

35 Van Musschenbroek, *Physicae experimentales* (note 18), pp. 431 and 658–660; Van Musschenbroek, *Introductio* (note 13), vol. 1, pp. 390–476; J.H. Roetink, *Verhandeling over Pieter van Musschenbroeks onderzoek naar de sterkte van materialen* (TU Delft 1975, unpublished 'doctoraalscriptie').

36 J. Keill *Introductio* (note 27), pp. 623–636; J. Freind, *Praelectiones chymicae* (London 1709), in: J. Freind, *Opera omnia*, 3 vols (Leiden 1734), vol. 1, Dedicatio and pp. 3–5, 42–46 and 85–89; Boerhaave, *Sermo*, pp. 39–40; E. Kegel-Brinkgreve and A.M. Luyendijk-Elshout (eds), *Boerhaave's orations* (Leiden 1983), p. 212; H. Boerhaave, *Elementa chemiae,* 2 vols (Leiden 1732), vol. 1, pp. 683–684 and 688–689, 847–848; Van Musschenbroek, *Introductio* (note 13), vol. 1, p. 379; Van Musschenbroek, *Beginsels* (note 12), p. 346.

37 P. van Musschenbroek, *Institutiones physicae conscriptae in usus academicos* (Leiden 1748), pp. 259–260; Van Musschenbroek, *Introductio* (note 14), pp. 351–252.

38 's Gravesande, *Physices* (note 26), vol. 2, pp. 583–584; Van Musschenbroek, *Introductio* (note 14), vol. 1, p. 387; vol. 2, p. 862; Van Musschenbroek, *Beginsels* (note 14), pp. 690–691.

39 's Gravesande, *Physices* (note 26), vol. 2, pp. 583–584; Van Musschenbroek, *Introductio* (note 14), vol. 1, p. 387; vol. 2, p. 862; Van Musschenbroek, *Beginsels* (note 13), pp. 690–691.

40 For the 'pyrometer', see note 32; De Pater, *Musschenbroek* (note 7), pp. 33–40 (pyrometer), pp. 40–44 (Leiden jar).

Low Country Opticks

The optical pursuits of Lambert ten Kate and Daniel Fahrenheit in early Dutch 'Newtonianism'

FOKKO JAN DIJKSTERHUIS

With the publication of the second edition of the *Principia* (1713), a wave of Newtonophilia washed over the Low Countries. Within a decade Dutch Newtonianism had been codified in the works of 's Gravesande, Van Musschenbroek and Boerhaave. Newton's *Opticks* was also part of this codification. After the revised English edition of 1717, the first French translation was published in Amsterdam in 1720. *Opticks* had a different position and was read in a different way than *Principia*. This article discusses the early reception of Newton's optics in the Low Countries, focusing on the cases of Lambert ten Kate (1674–1731) and Daniel Fahrenheit (1686–1736). The polymath Ten Kate was a key figure in the pious circle that first brought Newton to the Dutch scene and a prominent writer on physico-theological themes. The Gdansk instrument maker Fahrenheit was welcomed in this circle of Newtonians and pioneered in the public teaching of experimental philosophy.

Ten Kate and Fahrenheit were particularly interested in optics and given the context one would expect that Newton's optics played a decisive role in their pursuits. However, their reading of the *Opticks* turns out to have been rather liberal. They picked out the things that were relevant to their interests, they often did not get the gist of Newton's accounts, and they largely ignored the central claims of the *Opticks*. From the viewpoint of the *Opticks* this would indicate some deficiency in their understanding of Newton, but from the perspective of its readers it needs not. The main question then is not how well men like Ten Kate and Fahrenheit read and understood the *Opticks*, but how they approached it from the context of their intellectual and cultural interests.

The label 'Newtonian' is customarily used for the experimental philosophy that developed in the Low Countries around 1720 in the circle of 's Gravesande, Van Musschenbroek and Boerhaave. Histographically such a label is fraught with difficulties. By following the rather catholic way in which Ten Kate and Fahrenheit read and used Newton, I will try and reassess the idea of 'Newtonianism' and of 'isms' in the history of science in general. A body of ideas like that of Newton can be read on various levels and from various perspectives, depending on the particular interests and agendas of the reader. Even in the case of one and the same person – viz. Ten Kate – the way Newton was taken up could vary from role model in natural philosophy to a sounding board in phenomenal inquiry. Drawing on the lessons from the cases of Ten Kate and Fahrenheit, at the end of this article I will discuss some problems inherent to the idea of 'Newtonianism'.

An experiment from the *Opticks*

Lambert ten Kate came from a wealthy family of Amsterdam merchants in the Baltic trade. Originally he participated in his family's trading company but around 1705 he left business and devoted his time to his intellectual interests. These were vast. He was a prominent connoisseur and collector in the arts and sciences and wrote on a wide range of topics: aesthetics, linguistics, philosophy, theology.[1] Decisive for his epistemic and aesthetic outlook was his particular cultural background. He belonged to the liberal Mennonite congregation in Amsterdam, to which many of the early Dutch Newtonians also had close links.[2]

On 29 October 1716 Ten Kate carried out an optical experiment following an experiment described in Newton's *Opticks*. He was accompanied by his nephew, Jan Willink. The report of the experiment was published forty years later in the *Transactions of the Holland Society of Sciences*, by Johannes Nettis (1707–1777) who had been a student at the Mennonite seminary in Amsterdam.[3] The title of the article ran: 'Experiment of the Separation of Colours, Found by a Prism in the Order of the Musical Tones, Following an Experiment in Newton's *Opticks*: At the Time Observed and Now Reported from the Inheritance of Lambert ten Kate Harmenszoon'.[4]

The article began with a reference to the third proposition of book

1, part 2 of *Opticks*.[5] In this proposition, substantiated by two experiments, Newton divided the spectrum on the basis of the division of tones in the octave, arriving at seven symmetrically ordered colours.[6] Newton had already introduced the harmonic division of the spectrum in his optical lectures in 1670 and in a paper read to the Royal Society in 1675.[7] In the *Opticks* he had used it to account for the vexing problem of ascertaining the regularity of the dispersion of colours for which he had not been able to find an alternative solution.[8] Ten Kate explained that the specific division of the octave Newton used was less than optimal – making twelve out of sixteen consonants false. He proposed an alternative division that had only six false consonants. Although Ten Kate ordinarily used the diatonic scale, in this case he used the ancient Dorian mode that Newton had used.[9] According to him the eye could not see the difference between his and Newton's division. Given the greater perfection of his alternative division of the octave, Ten Kate held it for the most real as 'the more the Works of Nature are known, the more perfect they are found'.[10]

This was not all, however: Ten Kate had found a new and better way of investigating the colours of the spectrum. A prism produced only one 'rainbow of colours' and thus only one octave. In contrast, Ten Kate's new method could produce up to five separate spectrums at once, displaying the colours in a clear and orderly manner. The method only required a bowl of rich suds and a wine glass: dip the glass in the bowl, hold it on its side and study the thin film of soap. Coloured spectrums appear from the top, starting to come down gradually, and disappearing at the bottom. These can be studied conveniently. Ten Kate continued by asking how this phenomenon may be understood. After all, prismatic colours only appear upon refraction but 'here now however [the colour making of the rainbow] is displayed by this film reflecting, so wonderful, clear, and in its supreme degree, rainbow after rainbow, octave after octave: of which the solution is utmost peculiar'.[11]

Ten Kate knew the solution: when the glass is held on its side, the particles of the film begin to come down because of their weight; thus the upper part of the film becomes thinner and the lower part thicker, 'from which a most noble prism-shaped film is born'.[12] Because of the glueyness of the suds this takes some time. Therefore, the colours only gradually appear. The colours are produced by consecutive refraction, reflection and refraction of the rays of light at the front and the back

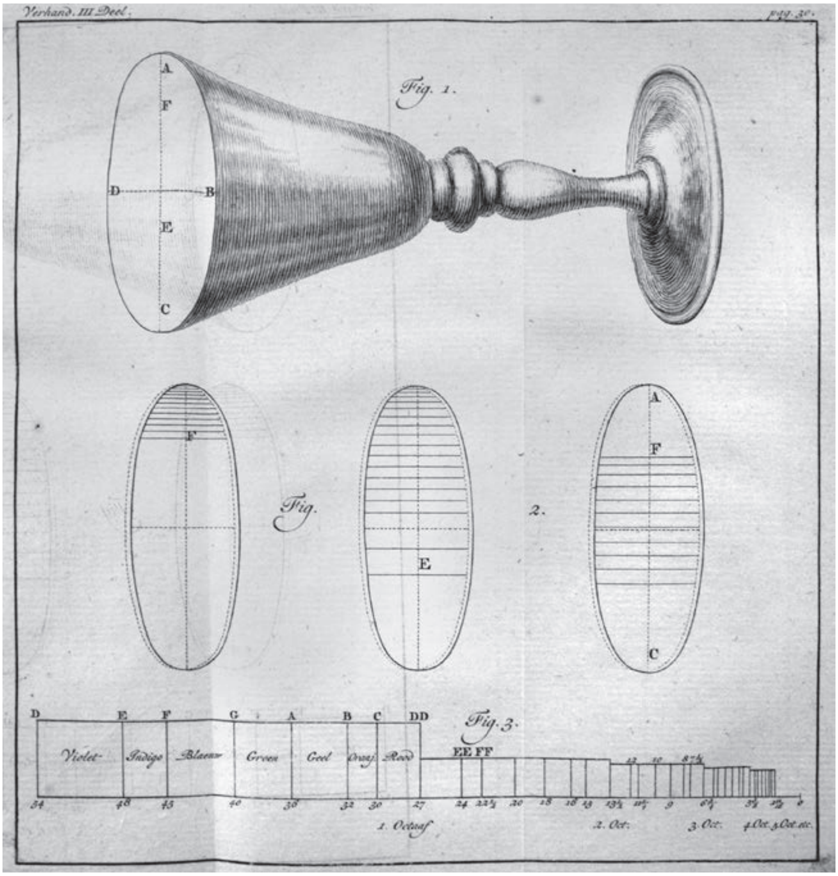


Fig. 1: Ten Kate's experiment on the separation of colours.

of the film. Ten Kate concluded by confirming that the colours are observed according to the harmonic order that he had introduced.

Ten Kate's account of the appearance of colours is interesting in the light of Newton's *Opticks*. According to him, the film of soap really produced 'rainbows of colours': the colours are produced in the same way as in drops of rain. In addition, he emphasized the *shape* of the film, arguing that it gradually acquired a prismatic cross-section. In this way he made clear that the spectrums in the soap film are truly prismatic colours. Newton, however, explained that the production of colours in thin films is different from that in prisms (or rain drops). In thin films some action of the rays affects the passage of rays of particular colours. This interference depends upon the length of the path of a ray through the film with respect to the position of the observer. In book 2 of the *Opticks* he had elaborately discussed the properties of the colours of thin films and showed the periodicity of the colours. Besides a quantitative phenomenological account, he also put forward a causal account in which the interaction between the ray and the surface of the medium produces 'fits of easy reflection and refraction' that enable or prohibit the passage of the ray at the other surface. Newton's theory of fits is notoriously obscure and was largely ignored by readers of the *Opticks*, so it is not a surprise that Ten Kate did not discuss it.[13] However, he took little notice of Newton's account of thin films altogether and apparently ignored the fundamental difference with prismatic colours.

The report of Ten Kate's experiment raises all kinds of questions. What inspired him to perform it? Why at this moment? Why did he want to correct Newton? How did he think his experiment added to Newton's doctrines? In order to make sense of the way Ten Kate responded to the *Opticks* we have to broaden our view a bit and see how Newton's optics was taken up in the circles around Ten Kate. This will also create an opportunity to discuss the reception of the *Opticks* more generally. In the history of early Dutch Newtonianism, the *Opticks* tends to have a secondary position in comparison to the *Principia*.

The *Opticks* in the Netherlands

Because Ten Kate gave a page number in his reference to the *Opticks*, it is clear that he referred to the 1706 Latin edition.[14] Whether he read *Optice* soon after its publication remains to be seen. In the summer of 1707 he began an extensive study of colour mixing together with his close acquaintance, the The Hague painter Hendrik van Limborch (1681–1759). Also involved in the research project was the painter and engraver Jacob Christoph Le Blon (1667–1741), who was working on what was to become the first method of colour printing.[15] The project lasted until 1713 and contained some inventive and original experimentation and conceptualization of colours and their properties.[16] Notably, no direct reference to Newton's optics was made in the course of the inquiry, not even to his doctrine of the heterogeneity of white light. The closest reference is in a letter of 3 February 1710, when Ten Kate mentioned 'mathematical experiments of the *prism*' to explain that blue is the weakest colour. Although the wording and the drift of the argument may suggest a reference to Newton, prism experiments as such were not exclusive to the *Opticks* and its author. Likewise, during the project no mention was made of Newton's account of colour mixing in the two propositions of *Opticks* following the harmonic division of the spectrum (to which Ten Kate responded with his '*proefondervinding*').[17] After Newton had proven how white light and shades of grey can be compounded of colours, he explained how the colours of paints are produced – by selective reflection – and how mixtures of paint produce compounded colours. Then he proposed a circle diagram to determine the position of a compound colour in the spectrum, based on the relative proportions of primary colours.[18] Despite Ten Kate's evident interest in optical themes directly related to the *Opticks* around 1710, he kept virtually silent on Newton at this time.

Ten Kate must have been, however, well aware of the existence and the content of the *Opticks* upon publication. His close acquaintance and early promotor of Newton, Jean Le Clerc (1657–1736) had favourably reviewed the *Opticks* in 1706. Le Clerc was professor at the Amsterdam Remonstrant College and published a learned journal discussing the latest developments in the Republic of Letters. The journal went through three series between the 1690s and the 1720s, *Bibliothèque universelle et historique*, *Bibliothèque choisie* and *Bibliothèque ancienne et moderne*. In the ninth issue of *Bibliothèque choisie*, Le Clerc presented the *Opticks* with a translation of large parts that ran over sixty pages.[19] He lauded Newton's experiments and discoveries, giving a faithful representation of the prism experiments and the doctrines of different refrangibility and the heterogeneity of white light. Equally interesting, however, is what Le Clerc left out. He skipped the mathematical and technical parts, referring his readers to the original. Newton's account of colours in thin films that comprised parts 1 and 2 of book 2 of the *Opticks* got only one paragraph in the review.

Le Clerc quickly moved on to the account of the colours of bodies that made up the rest of book 2. Propositions three to six, that contained Newton's harmonic division of the spectrum and his colour circle, he only mentioned without explaining the content. The whole idea of the colour circle thus did not become clear.[20] This predilection for Newton's doctrine of colours of bodies and disregard of his account of colours in thin films can also be seen with later Dutch Newtonians. 's Gravesande would do exactly the same in his *Physices elementa* (1720) and even integrated the doctrine of different refrangibility in the theory of colours of bodies.[21] In his review, Le Clerc discussed the queries at the end of the *Opticks* at some length and concluded with an exposition of what he regarded as Newton's exemplary method. Already at this point in 1706 the contours of the philosophical program of Dutch Newtonianism became visible.[22] Le Clerc stressed Newton's empirical bent and (thus) the purity of his philosophy as against Descartes', even at the level of the queries that Newton himself had presented as tentative speculations on the nature of things.

It is not clear when Ten Kate first went into the *Opticks* and neither can Le Blon's statement be substantiated that Ten Kate learned English with the purpose of reading the *Opticks*.[23] It might well be the case that Ten Kate only turned to the *Opticks*/*Optice* around 1716, ten years after its publication. In other words: on the wave of Newtonophilia that washed over the Dutch Republic from 1715. Part of the swelling Newtonianism was a publication of Ten Kate himself: *De Schepper en zyn bestier* (The Creator and His Rule, 1716). This physico-theological tract was a rendition of the *Philosophical Principles of Religion* (1715) by George Cheyne (1671–1743), an exposition of Newtonian natural philosophy. Ten Kate's edition was based on a summary by Le Clerc, to which he added extensive footnotes on mathematical issues, drawing on *Principia* and other mathematical works.[24] Although Cheyne had drawn substantially on the *Opticks*, Ten Kate's edition paid little attention to optics. He discussed the nature of light only with regard to the speed of light – and only by giving a reasoned value.[25] As regards colours he mentioned different refrangibility, listing seven original colours and suggesting the particle nature of light.[26]

Harmony in the senses

When in 1716 Ten Kate finally went into the subject matter of the *Opticks* seriously, he did not do so to preach the gospel of its master. On the contrary, his report was nothing more than a correction to Newton: first of the division of the spectrum, then of the experimental production of spectral colours. Ten Kate was not inexperienced in these matters. Far from that: in the preceding decades he had made profound study of both harmonics and colours. A manuscript from 1699 contains a study of the nature and production of sounds, in particular in human speech. Parts of this would be included in Ten Kate's *Aenleiding tot de kennisse van het verhevene deel der Nederduitsche sprake*, the groundbreaking study of linguistics he published in 1723. In this he also developed an account of musical harmony, thus providing the basis of his confident rebuttal of Newton. Then, in the late 1700s, he undertook the inquiry into colour mixing that was mentioned above. Ten Kate tried to develop a mathematical theory for the intensities of colours and developed a good deal of knowledge of the nature and proportionality of colours. So, he was no novice when critically assessing Newton's division of the spectrum. In this regard it is not surprising that he did not even mention the central claim of the *Opticks* about the heterogeneity of white light. It was not interesting for Ten Kate and besides, the idea that colours were not a modification of white light (and shadows) was not that new for artists and connoisseurs.[27] It was mainly interesting in the context of natural philosophy. In *Coloritto*, Le Blon in 1725 explicitly referred to Newton when he emphasized the difference with their accounts of colours: whereas he discussed material colours as they were used by painters, the *Opticks* concerned the 'impalpable' colours that mix into white.[28]

As it turns out, proposition 3 in book 1, part 2, of *Opticks* seized upon the very core of Ten Kate's interests. From a modern point of view these interests were quite disparate: linguistics, art theory, physico-theology, to name a few. As a result, the assessment of Ten Kate's contribution has been rather fragmented in historiography with historians of linguistics, art, science, philosophy each cutting out the relevant parts of his story. Only one or two have asked whether some kind of inner coherence in Ten Kate's work can be found.[29] Ten Kate was searching for harmony, in terms of regularity, beauty and piety. This was not, however, the classical Pythagorean harmony and its Renaissance renewal. First of all, Ten Kate combined the study of the classics with empirical and mathematical investigations of spoken languages, statues and drawings, and light and colours. Secondly, harmony for Ten Kate was not so much in the world – *in* Nature – as in the senses, in our perception of the world. This conviction was rooted in his aesthetical ideas that stressed the way in which art evoked religious experience.[30] This phenomenological conception of knowledge and emotive aesthetics was rooted in Ten Kate's liberal Mennonite milieu in which devotion was sought in the ordinary.[31]

Ten Kate's search for harmony and his particular epistemic outlook found expression in a broad spectrum of inquiries, starting in 1699 with a study of phonetics.[32] In the colour-mixing project with Hendrik van Limborch, it gave rise to a series of investigations of light and colours that is quite remarkable in the history of optics. They determined the relative clarity of colours by comparing gradations of colours with painted patterns of coloured and white/black lines, that from a distance are perceived as uniform colours. The number of lines then gave a measure of the power of a colour. This experimental set up was quite original and draws attention to a perceptual approach in optics that is largely ignored by historians of early modern optics.[33] Against this background of a particular research agenda and specific experiences in optics, Ten Kate responded to the *Opticks* in 1716. That is, he picked out a specific claim of Newton that he juxtaposed to his own convictions and experiences. A similar purposive reading of the *Opticks* is found in the work of the second protagonist of this story.

Fahrenheit

Not long after his experiment on the separation of colours, Ten Kate introduced a newcomer to the circle of Amsterdam amateurs: Daniel Gabriel Fahrenheit. Fahrenheit has acquired fame as a maker of instruments, thermometers in particular, and as a lecturer on experimental philosophy. In a letter to Le Clerc, Ten Kate wrote: 'there is here in Amsterdam a man named Fahrenheit who makes all kinds of barometers, thermometers, with far greater precision, for the use of physicists'.[34] Le Clerc published the letter in the issue of his *Bibliothèque* of that year, thus advertising the qualities of Fahrenheit and his instruments to a broader audience. The letter described in detail the instruments and the methods Fahrenheit used to assure their accuracy and reliability.

The emphasis of Ten Kate's letter was on an exotic phenomenon sometimes observed in the containers of vacuum pumps and barometers: a luminescence also called barometric light. In the early eighteenth century this phenomenon had become well known and was studied by savants all over Europe.[35] Barometric light was first observed by Jean Picard (1620–1682) in 1675: when mercury in a glass tube is shaken a band of light appears on the glass at the meniscus of the mercury.[36] The phenomenon requires very clean glass and very pure mercury and was difficult to reproduce until Johann Bernoulli (1667–1748) in Groningen invented an instrument to control it, Ten Kate explained.[37] Fahrenheit also made instruments called 'ethereal phosphors' and had improved the design. Ten Kate's account served on the one hand to demonstrate the high quality of Fahrenheit's instruments. On the other hand, Ten Kate appealed to the learnedness and interests of Le Clerc, pointing out that the editor of the *Bib-*

liothèque was familiar with the phenomenon and its history. Ten Kate concluded his letter by pointing out other instances of phosphorescence and the importance to find an explanation of the phenomenon. The emphasis on barometric glow did not only appeal to Le Clerc but also reflected the particular interests of Fahrenheit in chemical issues in natural inquiry.

Fahrenheit had recently arrived in Amsterdam, probably during the second half of 1717, but he was familiar with the city. Having been raised and orphaned in Gdansk, he had been brought to Amsterdam in 1702 to become an apprentice in the Van Beuningen house of merchants in the Baltic trade. As Ten Kate had also been a partner in a merchant house that traded with Gdansk and other Baltic towns, it is possible that he and Fahrenheit had made their acquaintance in those days. In 1707 Fahrenheit left business to pursue his interest in natural philosophy and embarked on a ten-year journey through the Scandinavian, Baltic and German lands. During this journey he visited Ole Rømer (1644–1710) in Copenhagen – who had developed a mercury thermometer – Gottfried Leibniz (1646–1716) in Hanover and Christian Wolff (1679–1754) in Halle. In 1717 he returned to Amsterdam, probably because the prospects for patronage in Germany had vanished. He established himself as an instrument maker and soon started to give lectures to paying attendants, which he would continue until his death.[38] These lectures are quite instructive as regards the way Newton's *Opticks* was presented to the circle of early Newtonians.

Fahrenheit's lectures are quite well documented in a prospectus from 1721 and a collection of lecture notes.[39] The lectures consisted of two series on Wednesdays, one of fifteen meetings on hydrostatics from 3:00 to 5:00 in the afternoon, and one of sixteen meetings on optics from 5:30 to 7:30 in the evening. They were announced with the following words: 'The method to demonstrate natural sciences that are attached to mathematics by means of "experimenta" or tests is undeniably the best'.[40] Fahrenheit said he used 'the best French and Latin writers' and for hydrostatics he particularly named Boyle's *Paradoxa* and 's Gravesande's *Physices*. He did not mention Newton at this point. The series of lectures on optics started with a general exposition of the nature and properties of light and its rays, quickly moving on to refraction and lenses. Dioptrics and the design of refractors comprised nine lectures, followed by five lectures on catoptrics. It is clear that Fahrenheit's principal interest in optics concerned instruments.

The lecture notes start with four unnumbered folios headed 'Introduction' that appear to have been inserted separately, considering the size of the leaves and the style of writing. This introduction described some experiments with coloured fluids, including observations through a prism, and the 'ethereal phosphors'.[41] The actual lectures on hydrostatics and optics are on numbered pages and the latter starts with an exposition on the nature of light in which the 'ethereal phosphors' return again. Fahrenheit took a non-committal stance regarding discussions about the nature of light, although in the course of his lectures he expressed sympathy for Descartes several times. His main goal, however, was to explain the properties of light and his principal interest was the design of instruments and chemical phenomena. He offered an experimental discourse in which propositions (like the law of refraction) were proven by experiments. Fahrenheit was particularly interested in the colours of bodies and the way these could be investigated by prisms. In this regard, he referred approvingly to Newton. He stressed the specialist nature of the *Opticks*, explaining that it demanded a considerable knowledge of optics.[42] He explicitly left out mathematical analyses, referring his audience to the dioptrics of Nicolaas Hartsoeker (1656–1725). This is interesting because Hartsoeker was professedly anti-Newton and had written a critical letter in response to Le Clerc's lauding review of Cheyne.[43] Colours in soap films are mentioned as well, with a brief explanation of the effect, but the account is too brief to establish a link with Ten Kate.[44]

Fahrenheit discussed all kinds of optical instruments, practical as well as entertaining. In the last lecture on catoptrics, he discussed instruments with mirrors. Here Newton finally got centre stage. Fahrenheit first explained how a refracting telescope could be shortened by use of plane mirrors, before coming to Newton's invention of a telescope with a concave mirror objective. In his view the main advantage of Newton's reflector was the shortening of telescopes. In the course of the seventeenth century, refracting telescopes had gradually become too long to handle, reaching lengths of ten metres and more. Fahrenheit did not mention chromatic aberration, which had been Newton's principal goal of designing the instrument. He was well aware of chromatic aberration, having explained that the reddish appearance of telescope images was caused by the shorter focal distance for blue rays. In an earlier lecture he had discussed chromatic aberration in greater detail. In a rather lengthy exposition on refracting telescopes,

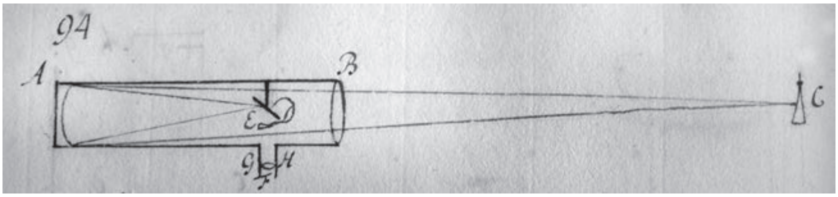


Fig. 2: Fahrenheit's sketch of a Newton reflector. (Source: Leiden University Library, BPL 772, fol. 51v)

he had explained that Newton in his *Opticks* had proven with accurate experiments that colours are differently refrangible and argued that this was the reason of the poor performance of telescopes. However, Fahrenheit surprisingly added, Newton only aimed at Galilean telescopes (consisting of a convex objective and a concave ocular), thus implying that the effect was less relevant in the Keplerian telescopes (consisting of convex objectives and oculars) that were common in astronomy.[45]

Fahrenheit closed the lecture by discussing a reflecting telescope and microscope of his own design. According to the notes he had said the following:

> After I had read Newton's *Opticks* about nine years ago, the composition of the preceding telescope pleased me so much that I looked for an opportunity to make one mechanically. And as Newton complains about the metal as well as the glass, I chose about six years ago a hardened steel for the objective mirror of six-inch focal distance, Rhineland measure. And as it seemed to me to be a bit awkward in use to look into the mirror from the side, I made a round hole in the middle of the mirror and furthermore I placed a small convex mirror on such a distance from the objective mirror, so that the rays of objects that were reflected by the large mirror bounced off for a second time to the hole in the large mirror, where the rays were thus gathered into an image.[46]

There is no diagram to this description, but it is clear how Fahrenheit had taken up the *Opticks*. Not as a foundational exposition on the nature and properties of light and colours and not as a primer on the design of optical instruments, but as a challenge to his instrument-making skills. Reading about Newton's reflector, he immediately considered ways of improving the material properties of mirrors and configuring mirrors and lenses to make telescopes more convenient to use.

The challenge had presented itself a couple of years earlier, most probably when Fahrenheit was staying in the German countries. If the lectures took place from 1721 on, his statement that he worked on mirrors six years prior accords pretty well with a letter he wrote to Leibniz on 1 July 1716 in which he said he had just built his first reflector.[47] This would imply that he first read the *Opticks* around 1713. Probably it was not before 1714, after he had arrived in the German countries from Copenhagen. His biographers suggest that Fahrenheit did not start to work on mirrors prior to his stay in Berlin, Halle, Leipzig and Dresden from 1714–1716.[48] Fahrenheit had gone to these German towns to improve his skills in glass-working for the purpose of making thermometers. His plan paid off, for he became one of the best blowers of capillary tubes.

Circumstantial evidence may shed some more light on the development of Fahrenheit's interests and his involvement in mirrors in particular. From the 1690s Ehrenfried Walter von Tschirnhaus (1651–1708), a nobleman in the patronage of the Saxon Elector, had made substantial efforts to improve and modernize the Saxon glass industries.[49] Besides promoting the economic interests of Saxony, Tschirnhaus was particularly interested in developing technologies for making high-quality burning mirrors. Burning mirrors had been central to his interests since his extended sojourns in the savant circles of the Dutch Republic, Paris and London between 1668 and 1682.[50] He had experimented with mirrors, considered the physics of light, and developed the mathematical theory of caustics, on which he corresponded extensively with men like Christiaan Huygens and Gottfried Leibniz. After the death of Tschirnhaus his mirrors remained in the Dresden Kunstkammer and the optical manufacturing techniques were further developed in the Saxon glass huts.[51] We may surmise that Fahrenheit encountered this legacy on his visit to Dresden. A direct link does not exist, but there are several indirect links between Fahrenheit and Tschirnhaus such as the latter's Dutch network and of course Leibniz. Such circumstantial evidence suggests that Fahrenheit's interest and expertise in reflectors was spawned by Saxon mirror-work.

These speculations aside — but I do feign hypotheses — the biography of Fahrenheit offers an important lesson regarding the influence of Newton. The formative years of Fahrenheit's experimental method and his instrumental proficiency took place in the vicinity of men like Rømer, Leibniz and Wolff. Skilled and learned, he arrived in Amsterdam in 1717, finding a natural place among the Amsterdam 'Newtonians'. In this development, Newton's *Opticks* was a source of inspiration, but not at all the cornerstone of Fahrenheit's optical pursuits. Some of it was relevant to him, but the natural philosophy hardly interested him. The same goes for Ten Kate; he too read the *Opticks* from his own particular points of view. They were well-versed in optics and picked out the parts that were relevant to their interests – the harmony of colours, the perfection of instruments. What does this all mean for Ten Kate's and Fahrenheit's alleged 'Newtonianism'?

Not all roads lead from London

The optical pursuits of Ten Kate and Fahrenheit can easily be read as examples of deficient reading of the *Opticks*, containing many misunderstanding, ignoring the gist of Newton's argument, and so on. This would imply that something like Newtonian optics existed and that it was a principal point of reference for the early Dutch Newtonians. The cases of Ten Kate and Fahrenheit raise some fundamental difficulties with such an interpretation. Theirs are not stories of the reception of some coherent body of knowledge, but of purposeful appropriation of particular elements within a broader spectrum of ideas and practices. The cases of Ten Kate and Fahrenheit bear upon the early stages of so-called Dutch Newtonianism and have, I believe, historiographical implications for the very idea of 'Newtonianism'. In the historiography of eighteenth-century science terms like 'Newtonian' and 'Newtonianism' are rather common and often used in an uncritical way. Ten Kate's linguistics is generally characterized as 'Newtonian', as are the pursuits of many Dutch savants of the period. In my view, however, the use of such a designation is not enlightening and often misleading in terms of historical understanding. In the final part of this article I want to seize the opportunity and discuss some problematic aspects of the idea 'Newtonianism'.[52]

Until quite recently the term 'Newtonianism' was used in a wide range of meanings, ranging from a physical theory, to a methodology and a philosophical system.[53] The free use of the label suggests some coherent system of knowledge. In early modern conceptions this would be a system of natural philosophy, comprising ontology, epistemology, cosmology and metaphysics.[54] In many cases, however, such systems have been narrowed down to physical theories and methodological positions, neglecting the broad scope of natural philosophy in both philosophy and subject matter.[55] Efforts have been made to precisely define such a system, resulting in a collection of brands of 'Newtonianism'.[56] Apart from the question to what extent it is historiographically legitimate to characterize 'Newtonianisms' in terms of physical theories, such exercises leave open the question to what extent a 'Newtonianism' has agency.[57] First of all, no 'school' of natural philosophy came into being before the late eighteenth century. Second, a *system* of natural philosophy rarely if ever was a main point of reference for natural inquirers. Ten Kate and Fahrenheit provide cases in point. They adopted elements of Newton's teachings – a physical explanation, an experimental find, an inventive artefact, a metaphysical idea – but were largely indifferent to his system of natural philosophy as a whole. Not all praise for or critique of Newton should be understood on the level of natural philosophical systems. Often inquirers had a different agenda that concerned specific empirical, mathematical or technical issues.[58] 'Newtonianism' does not seem a very fruitful category for doing history of science.[59]

A second problem in the use of 'Newtonianism' is the tendency to focus exclusively on Newton when interpreting early-eighteenth-century science, neglecting other big names like Boyle, Leibniz and Wolff. However, Newton was not the prime mover of eighteenth-century experimental philosophy. The Republic of Letters offered a broad spectrum of ideas, convictions, examples and things to the natural inquirer who created assemblages fitted to his needs. Schofield has argued that the spectrum of references was much broader for the Dutch, and that Newton was relatively secondary for the Swiss and French. In his taxonomy he effectively deconstructs the 'Newtonian' nature of most of the Newtonian brands.[60] The experimental philosophy that is labelled 'Newtonian' had been taking shape well before Newton entered the scene. Wiesenfeldt has shown how at Leiden University an experimental physics was established in the 1670s, primarily in response to the ongoing debates about the status of philosophy.[61] His discussion of De Volder shows that later 'Cartesianism' was quite empirical, which is confirmed by 'post-Cartesians' like Rohault.[62] Likewise, at Halle Wolff continued a tradition of experimental teaching that had begun by Johann Christoph Sturm (1635–1703) at the University of Altdorf. Not coincidentally, Halle was one of Fahrenheit's stopovers in the German states. Taking contexts like these will seriously yield a much richer historical picture.

The term 'Newtonianism' is often used in terms of *reception* of Newton's doctrines, suggesting a one-way traffic from a given set of doctrines to an attentive audience. Closer inspection of early Dutch 'Newtonianism' makes clear that the process was far from unidirectional. It was largely a joint venture of Desaguliers and 's Gravesande in their to-and-fro between England and the Dutch Republic, linking receptive circles in both places. The second edition of the *Principia* was pivotal, but it was also a creative appropriation of Newton's original mechanics, including the 'Newtonianization' of Newton himself by his English circle of devotees. Rienk Vermij has shown in a brilliant article how a particular group of pious but freethinking Amsterdam amateurs adopted Newton around 1715 as the banner for their philosophical and theological convictions.[63] In this process the term 'Newtonian' acquires actual historical significance and was indeed an actor's category. Yet it was used for a specific purpose, as a label to distinguish a particular conception of natural philosophy, and to its theological aspects in particular. 'Newtonianism' as used by early Dutch Newtonians was the physico-theological program that mobilized the pious response to the allegedly atheist implications of Descartes' and Spinoza's mechanistic philosophies.[64] In other words, 'Newtonianism' is a theological/philosophical concept that should be carefully distinguished from astronomical, physical or chemical theories. If the label 'Newtonianism' has any historiographical value, it is as the ideological label in the way the Dutch Newtonians used it.

The rhetoric used to separate the new philosophy from the Cartesian (and Spinozist) threats of atheism was loud and persuasive. At the same time it obscured the ideas and practices they had developed on their own, as well as the other sources of inspiration and justification like Rohault, Huygens, De Volder and Wolff. Central to the Newton-rhetoric was the requirement to deduce propositions from the phenomena, as contrasted to the rationalist speculations of Cartesians. Significantly, in their rhetoric they used the name of Boyle almost as often as Newton to mark off the despicable Descartes. Boyle fitted the physico-theological ideology of the 'Newtonians' perfectly, but he also provides a much earlier source than Newton and a direct link with the previous pursuits of De Volder. Moreover, the reference to Boyle points to the conspicuous interest in chemistry among the Dutch 'Newtonians'. An example of this is the particular attention Ten Kate gave Fahrenheit's 'ethereal phosphors' when introducing him to the Amsterdam circles. Likewise, in the *Opticks* Ten Kate and other 'Newtonians' singled out Newton's theory of the colours of bodies in particular. This chemical context was quite significant from 1700 and should be taken into account when considering the development of 'Newtonianism'. Early modern chemistry has a history of its own that sheds new light to the development of experimental physics and the role of Newton.[65]

In optics too, the Dutch 'Newtonians' had different sources of inspiration prior to Newton. In its early days, Vermij's circle of Amsterdam amateurs had been a principal promoter of Tschirnhaus. Le Clerc and Ameldonk Blok (fl. 1687) saw to the publication of Tschirnhaus' 'Medicinae' and their prompt translations. They had a particular interest in his optical projects, advertising and circulation burning mirrors and lenses of his. The connection I hypothesized between Fahrenheit and Tschirnhaus was probably not coincidental. Finally, the same circle had been instrumental in promoting the optical works of Hartsoeker in the 1690s. Despite the fact that Hartsoeker turned against Newton in 1712, to the audience of his lectures Fahrenheit recommended him in optics. However, in the 'Newtonian' rhetoric of the 1710s and 1720s such diverse sources of inspiration largely disappeared from view.

Ten Kate would vehemently advocate Newton against Descartes for it in *De Schepper en zyn bestier*. Still, he did not need Newton to become an empiricist. He already was long before Newton came to his attention. Ten Kate had developed his empirical approach to linguistics from the late 1690s onwards.[66] The label 'Newtonian' fitted his empiricism – proposing and proving properties from phenomena – but with respect to Newton's account of the nature and properties of light, he was rather liberal. His phenomenological approach to nature did not quite fit Newton's analytical optics and the ontology of his theory of sound was entirely at odds with Newton's doctrines. These did not disappear after 1716. Very few Dutch Newtonians were orthodox in any sense of the word. 's Gravesande and Van Musschenbroek explicitly used hypotheses; in a circumspect manner but still introducing speculative elements in experimental philosophy.[67] 'Newtonian physics' had many features that were rather non-Newtonian, like the predilection for pumps and hydrology 's Gravesande and Van Musschenbroek shared with Desaguliers, and a focus on chemistry. In optics too, the Dutch 'Newtonians' put emphasis on specific themes – the colours of bodies, the nature of light – that transformed Newtonian optics into a new entity. Newtonian about their philosophy was mostly the ontology of particles and forces. Compared to Ten Kate and Fahrenheit, 's Gravesande and Van Musschenbroek were more occupied with building a system of natural philosophy, but this was primarily because they wrote textbooks.

Newtonian *Opticks*

If there was something like Dutch 'Newtonianism', it was primarily linked to the second edition of the *Principia* and the ideology of pious natural philosophy. In the history of Dutch 'Newtonianism', the *Opticks* is relatively overshadowed by the *Principia*. My account of the reading of the *Opticks* somewhat shifts the perspective from philosophical systems and worldviews to ingenuity and materials. In optics natural philosophical issues of God and Nature were less prominent. Although I have confined my discussion to the intellectual aspects of 'Dutch Newtonianism', it can be questioned whether this can be approached as a set of ideas at all. Interpreting early Dutch Newtonianism – and Ten Kate's and Fahrenheit's pursuits in particular – as material culture may be historically illuminating.[68] Yet even from an intellectual perspective it is clear that the 'recipients' of Newton's optical doctrines actively appropriated their readings to their own causes. They possessed considerable expertise in matters of optics and this shaped the way they took up the *Opticks*. 'Newton's optics' was not ready-made to be exported; it was read and thus made, in the Low Countries too.

Despite the enthusiasm for Newton's optics and despite the large amount of publications in Dutch on experimental philosophy, *Opticks* was never translated into Dutch. By the time the second, enlarged edition of *Opticks* appeared in 1717, the Low Countries had been flooded by the tsunami of Newtonophilia. This new edition was 'Newtonianized' in a similar way as the second edition of *Principia*, emphasizing its epistemological and ontological outlook.[69] In 1720 the first French translation was published in Amsterdam. It was followed by a second edition in Paris, to which Newton himself exerted his authority by making its 'Newtonian' message unmistakable. Eventually, *Opticks* made it to the Dutch language via a considerable detour. In 1753 the Amsterdam printer Isaak Tirion (1705–1765) published a Dutch translation of Robert Smith's *Compleat System of Opticks*. This was a carefully structured textbook on optics, in which the *Opticks* was the foundation of the physical part. But Smith, too, appropriated Newton's doctrines to his own didactic interests.[70] A direct Dutch translation of *Opticks* was never made and so a *Gezigtkunde* never saw the light.

Notes

1 L. ten Kate, *Gemeenschap tussen de Gottische spraeke en de Nederduytsche* (Amsterdam 1710); L. ten Kate, *Den schepper en zyn bestier te kennen in Zyne schepselen, volgens het licht der reden en wiskonst* (Amsterdam 1716); L. ten Kate, *Aenleiding tot de kennisse van het verhevene deel der Nederduitsche sprake* (Amsterdam 1723); L. ten Kate, *The beau ideal, by the late ingenious and learned Hollander Lambert Hermanson ten Kate, translated from the original French by James Christopher Le Blon, author of the* Coloritto (London 1732). Ten Kate wrote a manuscript treatise on phonetics in 1699, parts of which appeared in the *Aenleiding* of 1723, his major publication on linguistics. A transcript of the manuscript by Cornelis Ploos van Amstel is in the library of the University of Amsterdam: L. ten Kate, 'Verhandeling over de klankkunde', Library University of Amsterdam, 63 U.B. I.C. 21. The manuscript is discussed in A. van der Hoeven, *Lambert ten Kate: De 'Gemeenschap tussen de Gottische spraeke en de Nederduytsche' en zijne onuitgegeven geschriften over klankkunde en versbouw* ('s Gravenhage 1896).

2 Principal sources for Ten Kate's biography are: C.L. ten Cate, *Lambert ten Kate Hermansz. (1674–1731). taalgeleerde en konstminnaar* (Utrecht 1987); J. Noordegraaf and M. van der Wal, 'Lambert ten Kate (1674–1731) and linguistics', introduction to L. ten Kate Harmensz., *Aenleiding tot de kennisse van het verhevene deel der Nederduitse sprake* (Alphen aan den Rijn 2001), pp. 2–32; R. Vermij, 'The formation of the Newtonian philosophy: the case of the Amsterdam mathematical amateurs', *British journal for the history of science* 36 (2003), pp. 183–200; H.J. Zuidervaart, *Van 'Konstgenoten' en hemelse fenomenen. Nederlandse sterrenkunde in de achttiende eeuw* (Rotterdam, 1999), p. 450. On the Mennonite context, see in particular: H.Th. van Veen, 'Devotie en esthetiek bij Lambert ten Kate', *Doopsgezinde bijdragen* 21 (1995), pp. 63–96.

3 Nettis became minister in Middelburg and practiced as eye doctor. In Middelburg he was a central figure in the local scientific culture, see: Zuidervaart, *'Konstgenoten'* (note 2), p. 392 (in particular note 247, p. 535).

4 L. ten Kate, 'Proef-ondervinding over de scheyding der coleuren, bevonden, door een prisma, in de volgende orde der muzyk-toonen; in navolging eener Proef-ondervinding in *Newtons gezigtkunde*: eertyds waargenomen, en nu uit de nalatenschap van *Lamb. ten Katen, Hz.* medegedeeld door den voorgem: *Joh: Nettis*', *Verhandelingen uitgegeeven door de Hollandse Maatschappy der Weetenschappen, te Haarlem*, part 3 (Haarlem 1757), pp. 17–30.

5 Ten Kate, 'Scheyding' (note 4), pp. 17–18. 'Newton berigt in zyn Boek over de *gezigt-kunde* (Boek I. Afdeel. II. *III. Deel.* Voorstel III. Proef VII.) pag. 104, ...'.

6 This is probably one of the weakest spots in the *Opticks* because Newton did not really substantiate – theoretically or empirically – this statement. The musical division of the spectrum was in fact the weak bid after Newton had failed to find a law of dispersion that met his standards. With hindsight this is exactly where his project of turning the science of colours mathematical foundered. For a complete account, see: A.E. Shapiro, 'Newton's "Achromatic" dispersion law: theoretical background and experimental evidence', *Archive for history of exact sciences* 21 (1979), pp. 91–128.

7 A.E. Shapiro (ed.), *The optical papers of Isaac Newton*, Vol. 1, *The Optical Lectures, 1670–1672* (Cambridge 1984), pp. 537–549; I. Newton, 'An hypothesis explaining the properties of light discoursed of in my several papers', in: Th. Birch, *The history of the Royal Society of London, for Improving of Natural Knowledge, from its first rise*, 4 vols (London 1756–1757), vol. 3, pp. 247–305.

8 Shapiro, 'Achromatic' (note 6), pp. 105–113.

9 P. Gouk, 'The harmonic roots of Newtonian science', in: J. Fauvel et al. (eds), *Let Newton be!* (Oxford 1988), pp. 101–126; H. Miedema, *Denkbeeldig schoon. Lambert ten Kates opvattingen over beeldende kunst,* 2 vols (Leiden 2006), vol. 2, p. 35. See Ten Kate's letters in this edition, vol. 1, p. 177, p. 197 and p. 202.

10 '*De Scheijding der Koleuren met de Prisma vloeijt zo teder ondereen, dat geen oog dit verschil tussen de omstaende Newtons deeling en de myne vermerken kan; waarom ik, vermits de Werken der Natuer, hoe meer ze gekent, hoe volmaeckter dat ze gevonden worden, de myne voor de egtste houde*.' Kate, 'Scheyding' (note 4), p. 21.

11 '*Hier nu egter vertoont ze [de Straelscheijding of Regenboogsche Coleurmaking] zig by dit Vlies reflecterende, zoo heerlyk, duijdelyk, en in haer oppersten graed, met Regenboog op Regenboog, en Octaef op Octaef: waervan de Oplossing ten uitersten merkwaerdig is*.' Ten Kate, 'Scheyding' (note 4), p. 25.

12 '... *waaruit een alleredelst Prisma-vormig Vlies geboren word:*'. Ten Kate, 'Scheyding' (note 4), p. 26.

13 A.E. Shapiro, *Fits, passions, and paroxysms. physics, method, and chemistry and Newton's theories of colored bodies and fits of easy reflection* (Cambridge 1993), pp. 199–207.
14 He gives page number 104. Book 1, part 2, Proposition III, Experiment VII is on pp. 91–93 in the original English edition of *Opticks* of 1704. In *Optice* of 1706 it is on pp. 103–106.
15 O.M. Lilien, *Jacob Christoph Le Blon 1667–1741: inventor of three- and four colour printing* (Stuttgart 1985).
16 F.J. Dijksterhuis, '"Will the eye be the sole judge?" "Science" and "Art" in the optical inquiries of Lambert ten Kate and Hendrik van Limborch around 1710', in E. Jorink and B. Ramakers (eds), *Art and science in the early modern Low Countries,* Netherlands Yearbook for History of Art/ Nederlands Kunsthistorisch Jaarboek 61 (Zwolle 2011) 308–331.
17 I. Newton, *Opticks* (London 1704), pp. 110–117 (Book I, Part II, Prop. V, Theorem IV, Exp. XV; and Prop. VI, Problem II).
18 The colors of the spectrum are represented by arcs on the circumference of the circle, whose lengths are based on the harmonic division of the spectrum. The portion of each color in the mixture is represented by a weight and the common center of gravity can then be determined. The radius through this point gives the position of the compound color on the circumference of the circle, and thus its position in the spectrum.
19 J. Le Clerc, 'Article VII. Optics (sic), ... A Londres 1604. in 4. pagg. 356', *Bibliothèque Choisie* 9 (1706), pp. 245–319.
20 J. Le Clerc, 'Optics' (note 19), pp. 278–281. Newton's account of the rainbow again received ample attention.
21 F.J. Dijksterhuis, 'Reading up on the upticks. Refashioning Newton's theories of light and colors in eighteenth-century textbooks', *Perspectives on science* 16 (2008), pp. 309–327. Likewise Desaguliers, who also ignored Newton's account of colours in thin films.
22 J. Le Clerc, 'Optics' (note 19), pp. 304–319.
23 Ten Kate, *Beau ideal* (note 1), preface i.
24 J. Le Clerc, 'Article II. Livres Anglois. Pour trouver la vérité de la religion naturelle, par des raisons philosophiques', *Bibliotheque ancienne & moderne* 3–1 (1715), pp. 41–158; Ten Kate, *Schepper* (note 1).
25 Ten Kate, *Schepper* (note 1), pp. 48–49.
26 Ibidem, p. 121.
27 See also J. Gage, *Colour and culture: practice and meaning from antiquity to abstraction* (London 1993), pp. 168–171.
28 J.C. Le Blon, *Coloritto, or the harmony of coloring in painting: reduced to mechanical practice under easy precepts and infallible rules, together with some colour'd figures in order to render the said precepts and rules intelligible not only to painters but even to all lovers of painting* (London [1725]), p. 6.

29 Van Veen, 'Devotie' (note 2); Miedema, *Denkbeeldig schoon* (note 9), vol. 2, pp. 39–42.
30 Van Veen, 'Devotie' (note 2), pp. 79–95.
31 In particular, Ibidem, pp. 71–77.
32 Ten Kate, 'Klankkunde' (note 1). See also Van der Hoeven, *Onuitgegeven geschriften* (note 1).
33 I discuss the project and elaborate my argument about its significance for the historiography of optics in Dijksterhuis, 'Will the eye' (note 16).
34 L. ten Kate, (L.t.K.H.), 'Article VII. Lettre écrite à l'auteur de la B.A.&M.', *Bibliothèque ancienne & moderne* 8 (1717), 1st part, pp. 223–231. Citation on p. 223: *'je vous communicai qu'il y avoit ici, à Amsterdam, un Mr. Farenheit, qui fait plusieurs sortes de* Barometres *& de* Thermometres*, avec beaucoup plus d'exactitude, pour l'usage des Physiciens, que j'en aye trouvé jusqu'à présent'.*
35 Ten Kate did not refer to the publications of Hauksbee. For the history of barometric light, see E.N. Harvey, *A history of luminescence from the earliest times until 1900* (Philadelphia 1957), in particular pp. 271–277; D.W. Corson, 'Pierre Poliniere, Francis Hauksbee, and electroluminescence: a case of simultaneous discovery', *Isis* 59 (1968), pp. 402–413.
36 J. Picard, 'Experience fait à l'observatoire sur la barometre simple touchant un nouveau phenomene qu'on y a découvert', *Journal des sçavans* (25 May 1676), p. 112 (Paris edition); p. 126 (Amsterdam edition).
37 J. Bernoulli, 'Nouvelle maniere de rendre les baromètres lumineux', *Mémoires de l'Académie Royale des Sciences de Paris* 2 (1703), pp. 178–190; J. Bernoulli, 'Noveau phosphore', *Mémoires de l'Académie Royale des Sciences de Paris* 2 (1704), pp. 1–9; J. Bernoulli, 'Lettre de M. Bernoulli Professor à Groningue, touchant son noveau phosphore', *Mémoires de l'Académie Royale des Sciences de Paris* 2 (1704), pp. 135–146.
38 P. van der Star (ed. and trans.), *Fahrenheit's letters to Leibniz and Boerhaave* (Amsterdam 1983), pp. 1–18.
39 'Natuurkundige Lessen van Daniel Gabriel Fahrenheit', Leiden University Library, BPL 772. See Zuidervaart, *Konstgenoten* (note 2), p. 445 n.70. H. Snelders, 'De beoefening van de natuurkunde door de gegoede burgerij uit de achttiende eeuw', *Documentatieblad werkgroep achttiende eeuw* 31–32 (1976), pp. 3–24. The notes were made by Jacob Ploos van Amstel (1693–1758). His son Cornelis Ploos van Amstel (1726–1798) was an avid collector of art and instruments. He acquired large parts of Ten Kate's collection and copied a substantial part of his manuscript writings. The manuscript copies are in the library of the University of Amsterdam, 63 U.B.I.C. 21–24. See Miedema, *Denkbeeldig schoon* (note 9), vol. 1, pp. 14–15; Th. Laurentius et al. (eds), *Cornelis Ploos van Amstel (1726–1798). kunstverzamelaar en prentuitgever* (Assen 1980), pp. 97–99.
40 D. Fahrenheit, 'Berigt', transcribed in E. Cohen and W.A.T. Cohen-de

Meester, 'Daniel Gabriel Fahrenheit (geb. te Danzig 24 Mei 1686, overl. te 's-Gravenhage 16 Sept. 1736)', *Chemisch weekblad* 33 (1936), pp. 374–393 (separate copy: pp. 19–27). *'De Methode om Natuurkundige Wetenschappen, die met de Wiskonst verknogt zyn, door Experimenta of Proeven te demonstreeren, is onwederspreeklyk de beste.'*

41 In 1722 Fahrenheit had a letter published on ethereal phosphors, emphasizing the proof of quality these provided for barometers: D.G. Fahrenheit, 'Brief van den heere D.G. Fahrenheit aan Willem van Ranouw over de lichtende barometers, en over de kentekenen van een goeden barometer', *Kabinet der natuurlyke historien, wetenschappen, konsten en handwerken* 7 (1722), pp. 21–63.

42 'Natuurkundige Lessen' (note 39), f. 11r.

43 N. Hartsoeker, 'Lettre de Mr. Hartsoeker, sur quelques endroits des ouvrages de Mrs. Cheyne & Derham', *Bibliotheque ancienne & moderne* 8 (1712), pp. 303–350. See also C. Berkvens-Stevelinck, 'Nicolas Hartsoeker contre Isaac Newton ou pourquoi les planètes se meuvent-elles?', *Lias* 2 (1975), pp. 313–328.

44 'Natuurkundige lessen (note 39) f. 8r.

45 Ibidem, f. 34v.

46 Ibidem, ff. 52r-52v. *'Zijn eigen woorden luiden aldus. Nadat ik voor omtrent 9 jaren de Optique van den heere Newton gelezen had, beviel mij de Compositie van de voorbeschreven Verrekijker zo wel, dat ik maar naar gelegenheid haakte om een diergelijke werkstellig te maken, en vermits den heer Newton zo wel over het Metaal, als over het Glas in zijn werk klaagt, verkoos ik voor omtrent 6 Jaren een zeer hart gemaakt Staal tot de voorwerp Spiegel van Ses duim brandpunt, Rhijnlandse maat; en nadermaal het mij in 't gebruik wat ongemaklijk scheen om van ter zijden in de spiegel te kijken, zo maakte ik in 't midden van die Spiegel een rond gat, voorts stelde ik een klein bultig spiegeltje op zodanigen afstand van de Voorwerp Spiegel, dat de stralen der Voorwerpen (die van de groote spiegel gereflecteert wierden) voor de tweedemaal afkaatsten naar de Opening, die in de groote Voorwerp Spiegel gemaakt was, bij welke opening de Stralen tot een beeltnis verzameld wierden.'*

47 Van der Star, *Letters* (note 38), pp. 66–71.

48 Cohen and Cohen-de Meester, 'Fahrenheit' (note 40), pp. 9–15; Van der Star, *Letters* (note 38), pp. 5–8.

49 G. Haase, 'Tschirnhaus und die sächsischen Glashütten in Pretzsch, Dresden und Glücksburg', in: W. Dolz and P. Plaßmeyer (eds), *Experimente mit dem Sonnenfeuer: Ehrenfried Walther von Tschirnhaus (1651–1708). Sonderausstellung im Mathematisch-Physikalischen Salon im Dresdner Zwinger vom 11 April bis 29 Juli 2001* (Dresden 2001), pp. 55–67.

50 He had been a nodal point to a circle of heterodox thinkers in the Dutch Republic. R.H. Vermij, 'De Nederlandse vriendenkring van E.W. von

Tschirnhaus', *Tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 11 (1988), pp. 153–178.

51 K. Schillinger, 'Herstellung und Anwendung von Brennspiegeln und Brennlinsen durch Ehrenfried Walther von Tschirnhaus', in: Dolz and Plaßmeyer (eds), *Experimente* (note 49), pp. 43–54.

52 This is by no means a novel issue; it has been discussed from at least the 1970s (see the references in the notes). Nevertheless, the label 'Newtonianism' is still frequently used and often in a rather careless manner. I therefore find it appropriate to go into the matter again. Moreover, the reception of *Opticks* offers some additional perspectives on the matter.

53 See, for example, E. Ruestow, *Physics at seventeenth- and eighteenth-century Leiden: philosophy and the new science in the university* (The Hague 1973). In the history of science nuances may have developed, but the generic term 'Newtonianism' endures.

54 J. Schuster, 'The scientific revolution', in: R.C. Olby et al. (eds), *Companion to the history of modern science* (London 1990), pp. 217–242; R. Iliffe, 'Philosophy of science', in: R. Porter (ed.), *The Cambridge history of science,* Vol. 4*, eighteenth-century science* (Cambridge 2003), pp. 267–284.

55 This is even in the case in the quite lucid accounts of Heilbron and Hakfoort: J.L. Heilbron, *Electricity in the 17th and 18th centuries: a study of early modern physics* (Berkeley 1979); C. Hakfoort, 'Christian Wolff tussen Cartesianen en Newtonianen', *Tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 5 (1982), pp. 27–38.

56 C. de Pater, *Petrus van Musschenbroek (1692–1761), een Newtoniaans natuuronderzoeker* (PhD-thesis, Utrecht 1979); R.E. Schofield, 'An evolutionary taxonomy of eighteenth-century Newtonianisms', *Studies in eighteenth-century culture* 7 (1978), pp. 175–192.

57 J. Gascoigne, 'Ideas of nature: natural philosophy', in: Porter, *Cambridge history* (note 54), pp. 285–304.

58 A case in question is Huygens' response in 1672 to Newton's 'New theory of white light and colours', that was not motivated by his different ideas of the ontology of light but by his material and intellectual expertise in telescope making. See F.J. Dijksterhuis, *Lenses and waves: Christiaan Huygens (1629–1695) and the mathematical science of optics in the seventeenth century* (Dordrecht 2004), pp. 83–92.

59 Coincidentally, in a response to Hakfoort and a defense of the use of categories like 'Newtonianism', Van Berkel explained that the criterion for historical concepts is not empirical correctness but narrative fruitfulness. K. van Berkel, 'Wat is er mis met het isme? Kanttekeningen bij een themanummer', *Tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 5 (1982), pp. 118–125, on 124. The focus on natural philosophical systems probably is a product of twenti-

eth-century conceptions of natural science in which foundational theories are central. Projecting this in history presupposes paradigms to be the cornerstone of natural inquiry. Less orthodox dealings with systems is then often called 'eclectic', a term that explains little to nothing. In my view, one will look hard for a 'hard core' with 'Newtonians' or other 'ians'.

60 Schofield, 'Taxonomy' (note 56).

61 G. Wiesenfeldt, *Leeres Raum in Minervas Haus. Experimentelle naturlehre an der Universität Leiden, 1675–1715* (Amsterdam 2002), pp. 54–58.

62 D.M. Clark, *Occult powers and hypotheses: Cartesian philosophy under Louis XIV* (Oxford 1989).

63 Vermij, 'Formation' (note 2).

64 M. Evers, 'Pro Newtone et religione: de receptie van Newton en de Engelse fysicotheologen in de *Bibliotheqe Ancienne et Moderne* (1714–1727), *Documentatieblad achttiende eeuw* 20 (1988), pp. 247–267; E. Jorink, 'Honouring Sir Isaac, or, exorcising the ghost of Spinoza: some remarks on the success of Newton in the Dutch Republic', in: S. Ducheyne (ed.), *Future perspectives on Newton scholarship and the Newtonian legacy in eighteenth-century science and philosophy,* Verhandelingen van de Koninklijke Vlaamse Academie van België voor Wetenschappen en Kunsten (Brussel 2009), pp. 21–32, on pp. 26–31.

65 L.M. Principe, 'A revolution nobody noticed? Changes in early eighteenth-century chymistry', in: L.M. Principe (ed.), *New narratives in eighteenth-century chemistry: contributions from the first Francis Bacon workshop, 21–23 April 2005* (Dordrecht 2007), pp. 1–22.

66 R. Salverda, 'Newtonian linguistics', in: M.C. Davies, J.L. Floord, and D.N. Yeandle (eds), *'Proper words in proper places': studies in lexicology and lexicography in honour of William Jervies Jones* (Stuttgart 2001), pp. 115–132; Noordegraaf and Van der Wal, 'Lambert ten Kate and linguistics' (note 2), pp. 10–12. Jorink offers a more balanced interpretation, although he does not elaborate very much upon the roots of Dutch experimentalism: Jorink, 'Honouring Sir Isaac' (note 64), pp. 21–32.

67 Dijksterhuis, 'Reading up' (note 21).

68 L.L. Roberts, 'Going Dutch: situating science in the Dutch Enlightenment', in: W. Clark, J. Golinski and S. Schaffer (eds), *The sciences in Enlightened Europe* (Chicago 1999), pp. 350–388.

69 J.-F. Baillon, 'Two eighteenth-century translators of Newton's *Opticks*: Pierre Coste and Jean-Paul Marat', *Enlightenment and dissent* 25 (2009), pp. 1–28

70 Dijksterhuis, 'Reading up' (note 21).

Defining the Supernatural

The Dutch Newtonians, the Bible and the Laws of Nature

RIENK VERMIJ

'Newtonianism' is, as we all know, a problematic term.[1] Newton's ideas were appropriated by different people in different ways and for different purposes, and not all concepts which came to be sold under Newton's name actually stemmed from him. It is of little use to try to define a concept like 'Newtonianism' *a priori*, or based on our own preconceptions of the 'real' content or significance of Newton's ideas. The study of Newtonianism should be a study of how far and why people at the time admired Newton, and what they felt his ideas meant, or should mean.

We can tackle the subject in both its wide and narrow senses. Newtonianism in a narrow sense can be equalled to the contemporary use of this or a similar term. 'Newtonian philosophy' was a term used by people at the time, so we may ask what exactly they meant by it. On the other hand, we can wonder why such concepts were attractive at all. If people invoked Newton, that was because his name came to be associated with a more general view of the world. Such a view would consist of many (in our view often disparate) elements, certainly not all of them directly originating with Newton, even if associated with his name. This Newtonianism in a wide sense is more difficult to define. Its identity is not fixed in a scientific or philosophical content, but is continuously reshaped by historical dynamics. In this essay, I will limit myself to the situation in the Dutch Republic, although some glances at the general European context will be found useful.

There appears to be by and large consensus about the main factors which in the Netherlands shaped 'Newtonianism' in its wide sense.

Newtonianism was on the one hand an answer to the confessional strife of the seventeenth century. It was hoped that Newton's ideas, or 'correct' scientific ideas generally, would serve as a rational foundation for both philosophical and religious truth, and thereby overcome doctrinal and confessional strife. On the other hand, it was an answer to, and an alternative for, the Cartesian philosophy which had dominated the second half of the seventeenth century. This Cartesianism was no longer acceptable for several reasons. Some of these were scientific, but for the large majority of people, the religious aspects of natural philosophy would weigh heavier. At the end of the seventeenth century, philosophical developments were upsetting established beliefs. Benedictus Spinoza (1632–1676) came forward with a philosophy which threatened the whole of religion. Newtonian philosophy made headway because it was seen as offering a decisive blow to the Spinozistic threat.[2]

In earlier work, I discussed the social dimensions of early Dutch Newtonianism, how it served as a way to obtain social and religious peace.[3] In this essay, though largely based on earlier research, I will concentrate on its more purely intellectual dimensions. It should be said from the outset that as a philosophy, Newtonianism is highly problematic. It consisted of various elements which appeared to cohere, but were not necessarily coherent. I will try to throw some light upon this complex by putting it in the context of contemporary debates. The formulation of a Newtonian philosophy cannot be explained just by the impact of Newton's writings, nor even as a reaction to René Descartes (1596–1650) and Spinoza. The relevance of Newton's work imposed itself only after 1713, when the second edition of the *Principia* was published. Spinoza's work had been around since 1670 and 1677. The Newtonian alternative was therefore formulated rather late. Indeed, there had been several earlier (failed) attempts to bring natural philosophy in agreement with the demands of religion. The Newtonians were well aware of these and the outcome of the earlier debates influenced their ideas as much as the specific things Newton had to say. In the end, the issue that mattered most was the authority of the Bible. Purely philosophical problems were secondary.

Dutch Newtonians: People and ideas

First of all, let us have a short view on the people who, under our wide definition, we might label 'Newtonians'. This will also give us some idea of the various reasons why people admired Newton. Among the first propagators of 'Newtonianism' were the scientific amateurs in the circle of Adriaan Verwer (c.1655–1717) in Amsterdam in the 1710s. Members included Lambert ten Kate (1674–1731) and Bernard Nieuwentijt (1654–1717). These people had been worried by Spinozism for a long time. Under the influence of some of Newton's friends, like David Gregory (1659–1708), they became aware of the apologetic potential of Newton's work and seized upon it as an orthodox form of natural philosophy to counter the Spinozistic threat. Their use of Newton's theories was selective and, from the point of view of modern science, defective. (On Ten Kate for instance, see the contribution by Dijksterhuis in this volume.) Newton had to fit in with their preconceived ideas. Bernard Nieuwentijt, the most influential member of the group, appears also the most lukewarm about Newton's theory of universal gravitation.[4]

Also in contact with Verwer and his friends was the journalist Jean Le Clerc (1657–1736), who discussed Newtonian ideas in his journals. A francophone who edited a French journal, he moved in different circles and he had his own contacts with England (he even read English). Le Clerc's aims as a journalist may have been slightly different from those of the Amsterdam amateurs, but his worries appear very similar. He presented Newton as a new philosopher who would counter the atheistic tendencies of his time. His extract of George Cheyne's *Principles of natural religion* (1715), which he presented as a specimen of Newton's philosophy, was later translated into Dutch by Ten Kate and published separately. Le Clerc again commended this edition in his journal. It appeared like a kind of systematic campaign.[5]

Probably the most prominent or conspicuous Dutch 'Newtonians' were the academic teachers who expressly claimed to be propagating Newton's theories in their lectures and textbooks. Among the first generation of Newtonian professors, the most influential were Willem Jacob 's Gravesande (1688–1742), who obtained a chair at Leiden in 1717, and Petrus van Musschenbroek (1687–1747), who in succession was a professor at Duisburg (1719), Utrecht (1723) and Leiden (1739).[6] The professors' main aim was to explain natural philosophy to students, not to practice religious apologetics, but that is not to say that the latter was completely off their minds. The modern strict division between scientific, philosophical and religious knowledge did not exist at the time. 's Gravesande and Van Musschenbroek had been introduced to Newton's theories by English scientists, during trips to

England, but there was also common ground with the above mentioned amateurs. 's Gravesande and Nieuwentijt maintained contacts well before the former went to England or became a professor. In 1715, Nieuwentijt referred to 's Gravesande when discussing an apologetical argument by John Arbuthnot (1667–1735) and presented 's Gravesande with a copy of the book wherein it was published. This book then was reviewed at great length in the *Journal littéraire de La Haye*, of which 's Gravesande was an editor.[7]

Somewhat different is the case of Jacob Odé (b. 1698), who in 1723 became a professor at Utrecht along with Van Musschenbroek. Odé had not been so privileged as to get first-hand knowledge of the new theories from English scientists. Whereas 's Gravesande and Van Musschenbroek aimed to completely restructure natural philosophy on the foundation of Newton's theories, Odé was more cautious in this respect. His use of Newton's theories remained more piecemeal, trying to harmonize old and new ideas. Still, he too saw good use for Newton's ideas and in the course of his career these gradually became more prominent in his writings. His recognition of their apologetical potential appears to have been an important stimulus.[8]

Even if all of these people had their own purposes and referred to different aspects of Newton's writings, they could still regard each other as participants in a common project. Broadly speaking, this project was defining the relation between God and nature in a way which answered both scientific and religious demands. Still, this 'project' did not comprehend a systematic or coherent philosophy. Rather, it was a complex of ideas which consisted of heterogeneous elements. Some ideas came from Newton's work, others were borrowed from the early English 'Newtonians', who of course were just as heterogeneous a group. Moreover, different people emphasised various elements more than others. We can list the most important of these elements.

The most obvious 'Newtonian' element is the inference from Newton's theory of universal gravitation that there are decidedly non-mechanical forces at work in the universe; and hence, that mechanical principles cannot explain everything. The argument was proposed first by Roger Cotes (1612–1716) in the preface to the second edition of Newton's *Principia* and much used abroad. In the Dutch Republic, the argument was particularly advanced by Le Clerc. We find an echo in Odé's textbook of 1727, where he defines gravity as a quality added to matter, impressed by the supreme Creator with the purpose that bodies will strive towards the centre of the celestial bodies or be moved around them. This gravity is not natural but effected by the Divine will.[9]

Another important element is the argument from design, the idea that the world cannot have its origin in mere mechanical causes, but can only be explained by the actions of an all-wise, powerful and benevolent Creator. This is of course much older than Newton, but was reformulated by English apologists close to Newton. It became one of the most popular apologetic arguments of the eighteenth century and gave rise to a whole genre of apologetic literature, called physico-theology. In the Netherlands, Bernard Nieuwentijt was the most important representative. Lambert ten Kate also was among the pioneers with his translation of Cheyne. But the physico-theological argument was also looked upon favourably by professors, as Van Musschenbroek and Johannes Lulofs (1711–1768), a student of Van Musschenbroek and 's Gravesande's successor at Leiden.[10]

A third element is experimental philosophy, used to refute not only Cartesian speculations, but also Spinoza's geometrical way of reasoning. This idea too is older than Newtonianism. It can be claimed that it owes as much to Robert Boyle (1627–1691) as to Isaac Newton, though it nevertheless became part and parcel in the Newtonian argument. Experimental philosophy pervaded the eighteenth century. It not just propagated experimentation, but also denounced speculative philosophy. As such, it was not just a scientific method, but also a social strategy for defending orthodoxy and dealing with dissent. It was an essential element of the academic teaching of philosophy, in particular in the courses of 's Gravesande and Van Musschenbroek. But it was also used for apologetics. Here again, Nieuwentijt was the most important early propagator in the Dutch Republic.[11]

Finally, we should point to a (from our point of view) more purely philosophical element, the emphasis on theological voluntarism.[12] This in itself was no new stance. The question concerned is the relation between God and His creation. Voluntarists maintain that the world depends on God's will. That is, God could have created things differently, had He wanted so, and still may intervene at any moment. This position opposes the view that God wills only the best (which is *a priori* given) and is limited by his own decisions (which are eternal). Newton emphatically defended God's absolute freedom of action, in his 'General Scholium' and in the controversy with Gottfried Leibniz (1646–1716) which his follower Samuel Clarke (1675–1729) had fought in his name. Voluntarism was much favoured in the eighteenth century as it countered the unwelcome consequences of Cartesian and mechanical philosophy and refuted the claims of materialistic philosophers. The philosopher who had most radically limited God's freedom in this way was, again, Spinoza. The Dutch Newtonians were well aware of his work and of the need to refute it, as will become clear in the next section.

Newtonianism as an answer to philosophical problems

The novelty of 'Newtonianism' laid not so much in the disparate elements, many of which had been familiar for long, but in the cocktail. Newton's unique authority as scientist and mathematician was used to promote an apologetic, anti-mechanistic and anti-Cartesian worldview. But of course this would not have happened had the philosophical constellation not favoured it. The old Cartesian philosophy, which so far had offered the main legitimation for scientific research, had run into trouble, in particular because of Spinoza's work. Eighteenth-century 'Newtonianism' was in large part an attempt to create a viable philosophy of nature that on the one hand would account for all the scientific discoveries of the previous century, but on the other would avoid the problems of the mechanical philosophy.

The main problem concerned the relation between God and nature. Descartes had claimed that God acted by immutable and universal laws of nature. As a new and upsetting concept, these laws demanded a philosophical and theological justification. As John Henry has argued, this was the main reason for the emergence of what Amos Funkenstein described as 'secular theology', the seventeenth century field which discussed the relation between God and nature. This thinking referred to medieval scholastic tradition, but its lynchpin was Descartes' explanation of his laws. Descartes explained that the laws of nature were the direct expression of God's will. As God was eternal and immutable, so were the laws of nature. Any change in the universe had to be explained by laws which were immutable themselves.[13]

The problem with this idea was that Descartes' identification of the laws of nature with God's eternal will made it difficult to maintain that God could still sidestep the laws of nature. Spinoza drew the utmost conclusion and identified God and nature altogether. Hence, the laws of nature were strictly necessary. God, or nature, acted in an eternally unchanging way. Miracles and special providence had no place, neither in the order of nature, nor even in the divine order. As Edgar

Zilsel stated, 'Spinoza is the first author combining general metaphysical determinism with the modern concept of natural law'.[14] Spinoza thereby did away with the traditional concept of God as a transcendent governor of the world who cared for his creation, and he did so following the leading thoughts of Cartesian philosophy.

Descartes' interpretation of the laws of nature therefore led to consequences which were deemed unacceptable. This discredited the field of 'secular theology'. The project attempting to metaphysically bolster the laws of nature was therefore abandoned – one of the reasons, it would seem, for the turn to experimental philosophy. Eighteenth-century proponents of natural philosophy had to find other ways to justify their undertaking. Newtonian authors still regarded the laws of nature as a cornerstone of natural philosophy, but would no longer see them as a consequence of God's immutability. They would claim that the laws of nature were free, and by no means necessary, dispositions of God. The examples of British authors emphasizing this point (Newton, Cotes, etc.) are too familiar to be repeated here. This interpretation tallied nicely with the new emphasis on experimental philosophy, theological voluntarism and the argument from design.

Newtonian philosophy was embraced as a way to maintain an active Divine presence in a world which was increasingly seen in scientific terms. A definition of the laws of nature which left room for divine miracles was one of the major requirements. This is also true for the early Dutch Newtonians. Laws of nature play a very prominent role in the work of Nieuwentijt. The 27th chapter in his book *Het regt gebruik* bears the title: 'On some laws of nature'. As if that were not enough, the 28th is called: 'On some chemical laws of nature'. Taken together, these two chapters make up over a hundred pages.[15] In these chapters, Nieuwentijt aims to demonstrate that God 'acts not only rationally, not only incomprehensibly, but also according to his pleasure, not forced by any necessity, and freely'.[16] This latter argument is one of the main themes, not just of these two chapters, but of the book as a whole. Time and time again Nieuwentijt rejects the Spinozistic opinion that everything in nature is dependent upon necessary laws. If the laws of nature were necessary, he argues, they should always produce the same effects. The abundant variation of nature therefore argues for an all-powerful Creator.

Nieuwentijt gave many examples, be it not all of them convincing to a modern reader. The fact that fishes live under water shows that

> a God and adorable wise and intelligent Being manifests itself in their formation; Who, having for other animals made the air so indispensable that without it they can hardly a minute survive, now, in creating these water animals, has demonstrated irrefutably that one can deduce their origin and nature only from a wisdom which arranges everything according to his pleasure, and not from any laws of nature which are necessary and therefore always operate in the same way.[17]

In the formation of the dragonfly, God

> thought fit to make the eyes thereof immovable, which in bigger Creatures can be turned to all sides; showing thereby that he does everything according to his good pleasure, and will be bound to no Laws. An Atheist, who feels that everything happens by an unwitting necessity, should learn from this [...] that he who has made the eyes of animals is not limited to one and the same way in accomplishing something, but that this diversity in works shows not unclearly that his wisdom, making the very laws, has power to arrange things according to his good pleasure.[18]

Dutch academic textbooks also pay due attention to the character of the laws of nature. 's Gravesande introduced the laws of nature in a way which is clearly reminiscent of Descartes. However, the immutability of the laws of nature is no longer explained from God's majesty, which makes Him to work always in the same way, as earlier philosophers would have it. According to 's Gravesande, the immutability is a result of God's goodness. If the laws of nature were variable, human life would not be predictable. The food that was safe yesterday, might be dangerous today. It is only because of the fact that God has established fixed laws that man can exist in safety. By means of these laws, humans can draw conclusions about the world from analogy.[19] In other words, the laws of nature are the result of design. They are fixed because they thus serve better the purposes of the all-wise Architect; but God could change the laws any time if this would fit His purpose better.

Petrus van Musschenbroek in his textbook simply followed 's Gravesande. He expressly disavowed any speculation on the origin of the laws of nature, but stresses their voluntaristic character: 'God, according to his omnipotence, could have established other laws as the ones we find now. True, we do not see the reasons, why he has chosen and established the like, because of the limits of our small understanding. But it should satisfy us to see that everything has been made and ordained very wisely'.[20]

The Bible in the new science

The rise of Newtonianism can be described as a philosophical answer to philosophical problems. Still, this cannot be the whole story. For why would people be so worried about maintaining an idea of divine miracles? The idea of a passive, mechanical nature had become popular exactly because it reduced comets, earthquakes, monsters, and so on, which had often been explained as divine signs and warnings, to the status of mere natural phenomena without any special meaning. People had become wary of vitalistic or occult principles, sympathies or antipathies, omens and prodigies; they no longer saw the sphere of the magical or the divine to interpenetrate that of the natural, everyday world.

In the eighteenth century, this attitude would not change very much. The Newtonians were as little inclined as their Cartesian predecessors to regard comets or monsters as special Divine providences. They might have felt more free to speculate on the purposes God might have had in designing such phenomena (most often, they claimed they served the well-being of mankind), but the phenomena themselves should be explained from the known universal laws which governed the whole of nature. If this was so, one might well wonder why natural philosophers were so upset about Spinoza's dismission of miracles. Many seventeenth-century protestant theologians held that the age of miracles was over anyway.

That miracles were a sensitive topic was not because the miraculous still played a role in people's daily lives, but because miracles were mentioned quite prominently in the Bible. Denying the reality of miracles amounted to denying the truth of the biblical story and hence, it was felt, to undermining all religion. Actually, this was what made Spinoza's rejection of miracles so outrageous. His arguments seemed not much different from those of many other seventeenth-century philosophers. But whereas those philosophers had only spoken in terms of natural philosophy and had carefully left religion alone, Spinoza expressly applied his principles to the miracles in the Bible. For the great majority of his contemporaries, this was definitely a bridge too far. People accepted gladly that their day-to-day world was 'disenchanted' and devoid of miracles. But at the same time they emphatically defended that the biblical miracles had been real.[21]

The debate on miracles and the laws of nature, which was a central question in the rise of 'Newtonianism', was really a debate about the authority of the Bible. This debate on biblical authority affected the formulation or defence of many other ideas as well. It is easy to regard physico-theology, experimental philosophy, and other elements of 'Newtonianism', as purely philosophical or intellectual positions, but in reality, such positions almost always served the purpose of salvaging a traditional interpretation of the Bible. Nieuwentijt is definite about this. About half of his book is devoted to defending a literal reading of the Bible. Experimental philosophy is for him not just an argument against philosophical speculation, but also for Biblical truth. The Bible is a book of facts and observations, written by an all-wise Author. According to experimental principles, one therefore has to accept its sayings at face value.[22]

In defending biblical truth, authors joined a long-standing debate. The rise of the new philosophy in the Dutch Republic had from the beginning been accompanied by fierce polemics on the religious consequences. Although these debates touched on all kinds of subjects, the authority of the Bible had been the crucial point. By 1656, a huge pamphlet war had erupted over the Copernican system, on the question whether the Earth moves or not. Cartesian theologians accepted the findings of modern philosophy and astronomy and maintained that the sentences of the Bible which appeared to state or imply the opposite, should be interpreted in a different way. In philosophical or cosmological matters, the Bible should be taken as representing the world as things appear to us, not as how they really are in a philosophical sense. Their traditionalist opponents, on the other hand, led by the Utrecht professor of theology Gisbertus Voetius (1589–1676), held that the Bible was the one and only source of real truth and regarded it as irreligious to modify its interpretation according to the secular sciences. Other debates of the period also came down to the question of biblical authority. The question whether animals are machines was initially waged in terms of the interpretation of biblical sentences.[23]

The debates of the 1650s and later ended in a stalemate, with an important part of the theologians accepting the accommodating Bible interpretations, and another part denouncing it. It should be stressed that both parties kept to the Bible as a source of divine truth. Most theologians who defended accommodation were in theological matters followers of Johannes Cocceius (1603–1669), who gave the Bible a very central place in belief and spiritual life. The uneasy balance would not last, however. A principled attack on the sole authority of the Bible came in 1666 with Lodewijk Meyer's book *Philosophia S. Scripturae interpres*, wherein he argued that theology was subordinated to philosophy – biblical exegesis should direct itself to truth as established by sane reason. In 1670 was published Spinoza's *Tractatus theologico-politicus* with the infamous chapter 'On miracles'. These authors made clear that the stakes were much higher and casted doubt upon the earlier strategies which tried to defend the new philosophy while at the same time upholding the authority of the Bible.[24]

Consequently, it would be wrong to regard the debate about the principles of natural philosophy as one on purely philosophical questions. If there was a problem with the legitimation of Cartesian philosophy and the laws of nature, this was because there was a problem with accommodating these insights to the Bible.

The interpretation of the Bible at the end of the seventeenth century

The question of how the Bible should be read in the light of the new philosophical and scientific insights was a heavily debated one in the last years of the seventeenth century, well before the rise of Newtonianism. This was not so much a debate between Spinozistic free-thinkers and the defenders of orthodoxy, although this opposition was heavily looming in the background. Nor was it a debate between Voetian literalists and Cartesian (or Cocceian) accommodators, although these parties still existed. Rather, it was a debate of accommodating and scientifically-minded theologians and philosophers among themselves. This implies that the first Dutch 'Newtonians' were not just reacting to Spinoza. They were aware of others who had tried to solve the problems raised by Spinoza in one way or another. And if they succeeded in finding a solution acceptable to most of their contemporaries, this was partly because during the earlier debates a consensus had formed upon which they could build.

In the Dutch Republic, the focal point for debates on the Bible and the new philosophy about 1700 was the work of the Dutch Reformed minister, Balthasar Bekker (1634–1698). In his book *De betoverde weereld* (The World Bewitched), Bekker denied that the devil had any power in the physical world. He argued his case with both theological and philosophical arguments, but his main source of inspiration appears to have been Cartesian philosophy. To Bekker, the world was a material whole, governed by the laws of nature. Spiritual substances, either good or bad, simply had no place in this world.

The book caused an enormous outcry, not so much because Bekker denied the existence of witches or ghosts, which most educated people by this time had come to dismiss anyway, but because he denied as well that the Bible spoke of them. The Bible could not possibly teach things that were not true or not possible. So, Bekker felt that the passages wherein the Bible speaks of demonic possessions, angels, etc., could not be taken literally. Such passages had been accommodated to the understanding of the common people. The debate on the book was therefore largely a debate on the interpretation of the Bible.[25]

Bekker was not a Spinozist or atheist but a sincere Calvinist, who, however, took seriously the new view of nature and the world which had emerged in the preceding decades. His aim was not to undermine the Bible as God's word, but to salvage it. He used the same accommodating exegesis which had earlier been applied by Cartesian theologians to account for the motion of the Earth. In this case, however, his contemporaries did not swallow it – not just the conservative Voetians, who defended a strict literalism, rejected his position, but also the Cocceians, who supported an accommodationist reading of the Bible in the case of the motion of the Earth. Bekker's views were nearly universally rejected and would regain some credit among mainstream theologians only in the second half of the eighteenth century.[26]

The campaign against Bekker's work played an important role in shaping the views on the proper relation between the Bible and science. A consensus emerged that the truth of the biblical narrative could not be measured by the yardstick of science or philosophy. Laws and miracles each had their proper sphere. The Newtonian authors obviously cannot have missed this major debate, which directly touched upon their main concerns. It is therefore striking that they remain almost completely silent upon the issue. Still, on a closer look, they do show awareness of the underlying problems. In his book *Gronden van zekerheid* (Foundations of certitude), Bernard Nieuwentijt, having refuted Spinoza's metaphysics at length, discussed the possibility of an 'experimental metaphysics', a metaphysics based upon 'spiritual experiences'. Here, he left open the possibility of appearances. The true scientific method demanded that one should accept reports from trustworthy witnesses about spirits and appearances. Rejecting such testimonies showed just philosophical prejudice. Although Nieuwentijt does not mention Bekker's name, his argument speaks directly against his tenets.[27]

In the Dutch Republic, the debate on Bekker's book absorbed most of the energy spent on this kind of questions, but it was not the only debate of its kind. Another example is the book by the Haarlem physician Antoni van Dale (1638–1708) on the ancient pagan oracles. Van Dale claimed that all of these oracles had been the result of clever deceit by priests. This book too caused a furious response. Van Dale's readers were particularly offended by his 'debunking' of a particular biblical oracle, the story of the witch of Endor in 1 Samuel 28, who, on behalf of King Saul, conjured up the spirit of the dead prophet Samuel. This gave rise to a vehement dispute, again largely on the question how to read the Bible. Unavoidably, the issue was read often in the light of Bekker's book.[28]

Another debate concerned the book of the English cleric Thomas Burnet (c. 1635 – 1715), *Telluris theoria sacra* (The Sacred Theory of the Earth, 1681–1689). Herein, Burnet, among other things, gave a natural explanation of the biblical Flood. Whereas the Bekker debate dominated the Dutch intellectual scene at the end of the seventeenth century, it can be said that Burnet's book was the focus of very similar debates in England. In the Dutch Republic, Burnet's book was known and did play a role in the formation of a new consensus, but it was something of a side show. Still, it may be of interest to look into its role somewhat deeper. First of all, it indicates that the questions on natural science and the Bible were not just a local Dutch interest. The specifics were determined by local circumstances, but the underlying questions were more universal. Moreover, the debate is of interest as it put the question of laws of nature centre stage.

Basically, Burnet tried to bring the interpretation of the Bible into agreement with recent philosophical ideas (especially as propagated by Descartes) that the origin and constitution of the Earth, just as everything else in the universe, could be explained from the laws of nature. He gave a detailed account how the Earth had come into being 'according to the Laws established in Nature by the Divine Power and

Wisdom'.[29] But whereas Descartes left the creation story alone, Burnet wanted explicitly to harmonize his views with the Genesis narrative. The biblical Deluge had a special place in his story, as it explained the Earth's tilted axis and uneven surface. The original Earth had been smooth and even, but at a certain point, the Earth's crust had collapsed, unlashing the waters below and thus causing the Flood. This therefore had not been a special act of God, who had changed the course of nature in a supernatural way: it was the outcome of a chain of natural events, inevitable by the very constitution of the Earth. According to Burnet, most other planets too had undergone a similar deluge. [30]

Here again, Burnet's aim was not to undermine belief in divine providence, but to find a way to integrate sacred history into natural philosophy. What he envisions is a 'general system of Divine Providence'. For one thing, there is the traditional notion of Providence, which Burnet calls theological Providence, by which God directs the affairs of man: souls, religion, morals and the state of humankind. However, another part of the general system is natural Providence, by which God governs, by his fixed laws, the order of nature: 'the motions of Nature are indeed no less than human affairs subjugated to the care of Divine power'.[31] Burnet emphasizes that the two went hand in hand: the natural world was arranged so as to support the moral world. So, it is by this natural Providence that the Deluge, though the outcome of natural causes, happened at a time that it was most needed for moral purposes.[32] Burnet acknowledged that God can and does act outside the laws of nature, but that such miracles are a last resort: 'We must observe and consider, that The Course of Nature is truly the Will of God; and as I may say, his first Will; from which we are not to recede, but upon clear evidence and necessity'.[33]

Burnet's work was known among the philosophical and scientific amateurs at Amsterdam. The Amsterdam author Willem Goeree (1635–1711) used Burnet's theory extensively in his *Voor-bereidselen tot de bybelsche wysheid* of 1690.[34] In 1695–1696, a Dutch translation of Burnet's *Telluris theoria sacra*, as well as his later *Archaeologia philosophica*, was published. The translator is not mentioned but was in all probability the Amsterdam merchant Ameldonk Blok. Blok was an admirer of Spinoza and a friend of the German philosopher Ehrenfried Walter von Tschirnhaus (1651–1708). Tschirnhaus was much impressed by Burnet's book and it was he, it seems, who encouraged Blok to translate it. Blok undertook the work as a member of the literary society *Nil Volentibus Arduum* and he read several chapters in its meetings, according to the minutes.[35] Burnet found a few other defenders. Apart from Goeree, who in 1705 defended him against the charge of Spinozism, one could mention the naturalist Simon Schijnvoet (1652–1727). It is probably no coincidence that both Goeree and Schijnvoet counted among the few advocates of Bekker as well.[36]

It would seem that the book found admirers mainly among the radical fringe. The authors who after 1714 propagated a Newtonian philosophy decidedly rejected it. Nieuwentijt would abstain from open polemics and referred to Burnet's work only for geographical information. But he did criticize his ideas. One of the more conspicuous elements of Burnet's thought was his view of mountains as ugly and useless deformities, which therefore could not have been part of God's original creation. In his view, God had created the world as a perfectly round sphere and only the upheavals of the Deluge had brought mountains and oceans into being. Nieuwentijt on the other hand emphasized that mountains play an important part in water circulation around the globe, causing the clouds to bring rain, and thereby show the wisdom of the Creator's original design. Consequently, he refuted atheist philosophers who defended their materialist view on the hypothesis

> that so many and such amazing great Bodies as the Mountains, are of no use at all; and who, if they had had the fashioning of the Globe of the Earth, according to their own Humours, they would have made it without them, and would have given it a perfect round Figure, without the least Inequalities.[37]

Some later authors expressly referred to Burnet. Jacob Odé refuted Burnet's work in his textbook on natural philosophy. He protested that Burnet's interpretation of the Flood went against the Bible.[38] A few years later, Johannes Lulofs, the later Leiden professor, defended a thesis under Odé wherein he referred to Nieuwentijt's explanation of the use of mountains in a disputation which had a decidedly physico-theological character. He expressly mentioned Burnet as the author to be refuted.[39] In general, eighteenth-century theories of the Earth would prefer to take the Genesis account literally, even if they would often describe it in scientific language. A major work in this respect was *Physica sacra* by the Swiss scientist Johann Jacob Scheuchzer (1672–1733), a monumental overview of physical elements in the Bible. The lavishly illustrated, multi-volume work became quite popular and saw a Dutch translation as well.[40]

One might easily overlook the relevance of the earlier debates for the Newtonian position, as these were largely (and deliberately) ignored by the Newtonians themselves. The Newtonians claimed that their stance was the simple and logical outcome of the true scientific method. Experimental philosophy demanded that one would not indulge in theological or metaphysical subtleties. So, they made it appear as if there only was this debate between reasonable belief and atheistic folly. To them, this was the only thing that really mattered. Still, a closer look at the earlier debates may help us to understand their position. Nieuwentijt offers a case in point. In his books, he waged a campaign against 'atheism' (read Spinozism), which he tried as far as possible to dissociate from existing philosophical and theological debates. He made it a principle not to engage in debate with other mainstream Christians. He carefully refrained (unlike many Voetian theologians) from calling Cartesianism irreligious. Still, there is no doubt that Nieuwentijt rejected the claims of Cartesian philosophy, and that this partly shaped his ideas. Likewise, it appears obvious that the Dutch Newtonians followed the consensus which had formed over the interpretation of the Bible, that the Bible described supernatural events which could not be measured by the yardstick of natural philosophy, and that their apologetics was partly intended to give this a scientific basis.

Conclusion

It has long been recognized that the eighteenth century saw a major effort to harmonize the new science with traditional religious insights. The new scientific worldview which had imposed itself in the seventeenth century was powerful and enticing. Still, people were not ready to reject all aspects of the old worldview. Uneasiness emerged where the new view of the world appeared to be contradicting vital elements of the old. Spinoza was such a disturbing character exactly because he pointed out such inconsistencies with unrelenting logic. What people wanted was a science which respected the traditional elements of religion they still valued.

Historians have so far mostly studied the more philosophical aspects of this harmonizing efforts, like the argument from design or the question of materialism. But to contemporaries, the status of the Bible probably even mattered more. The Bible was the central element in Protestant religion and therewith a vital support of the social and moral order. For eighteenth-century philosophers, the Bible was a perfectly legitimate subject. Academic disputations discussed such 'physical' topics as the earthquake and darkness during the death of Christ, the manna in the desert, and so on. This was perfectly legitimate as long as the philosophers respected the biblical mysteries and by their use of scientific language legitimized the miraculous, rather than refuted it. Protests arose when science or philosophy tried to incorporate the sphere of the religious altogether. It was felt that there was a domain where the standards of the natural sciences could not be admitted. The Bible was no longer a book about the real world, but a guarantee for the existence of a realm beyond the world.

But, paradoxically, it was science which was used to define the boundaries of this supernatural realm. It was with scientific arguments that the wisdom of the Creator was demonstrated. It was Newton's science that taught that the world could not be explained from mere mechanical causes, but needed the design of a divine intelligence. A miracle was now foremost something that could not be explained scientifically, as occurring outside the laws of nature. This strict separation between a scientific and a religious sphere was a result of the new philosophy of the seventeenth century. In earlier times, the border between the natural and the supernatural had often been rather blurred.[41] In the eighteenth century, nature was explained in a strictly natural way, whereas religion was felt to be present only where such natural explanations did not hold. An unexpected consequence was that in the eighteenth century miracles and the miraculous, although (or rather, because) they were no longer deemed to play any part in actual life, played an increasingly important role in Christian apologetics.[42]

Apparently, the 'disenchantment of the world' concerned not so much the disappearance of the mystery altogether, but rather its restriction to its own separate domain. This domain was well separated from day-to-day existence, but considered real nevertheless. Cartesian philosophy had created a new view of nature. It remained up to the Newtonians to establish a corresponding idea of the supernatural.

Notes

The author thanks Cornelia Lambert for linguistic improvements.

1 For 'Newtonianism' in a European context, see J. Gascoigne, 'Ideas of nature: natural philosophy', in: R. Porter (ed.), *The Cambridge history of science*, Vol. IV, *Eighteenth-century science* (Cambridge 2003), pp. 285–304; M. Feingold, *The Newtonian moment. Isaac Newton and the making of modern culture* (New York, Oxford 2004); J. Israel, *Enlightenment contested: philosophy, modernity, and the emancipation of man, 1670–1752* (Oxford 2006), pp. 201–222; B.J.T. Dobbs and M.C. Jacob, *Newton and the culture of Newtonianism* (Atlantic Highlands, NJ 1995). A new volume on 'the reception of Isaac Newton in Europe' is presently being prepared by Helmut Pulte and Scott Mandelbrote.

2 E. Jorink, 'Honoring Sir Isaac, or, excorcising the ghost of Spinoza: some remarks on the success of Newton in the Dutch Republic', in: S. Ducheyne (ed.), *Future perspectives on Newton scholarship and the Newtonian legacy in eighteenth-century science and philosophy* (Brussel 2009), pp. 22–34; E.G.E. van der Wall, 'Newtonianism and religion in the Netherlands', *Studies in history and philosophy of science* 35 (2004), pp. 493–514, a contribution to a special issue on Newtonianism. Similar factors were at work elsewhere. For England, see in particular J. Gascoigne, 'From Bentley to the Victorians: the rise and fall of British Newtonian natural philosophy', *Science in context* 2 (1988), pp. 219–256.

3 R.H. Vermij, *Secularisering en natuurwetenschap in de zeventiende en achttiende eeuw: Bernard Nieuwentijt* (Amsterdam 1991).

4 R.H. Vermij, 'At the formation of the Newtonian philosophy: the case of the Amsterdam mathematical amateurs', *British journal for the history of science* 36 (2003), pp. 183–200.

5 Ibidem, pp. 197–199. M. Evers, 'Pro Newtone et religione: de receptie van Newton en de Engelse fysicotheologen in de *Bibliothèque Ancienne et Moderne* (1714–1727)', *Documentatieblad werkgroep achttiende eeuw* 20 (1988), pp. 247–267.

6 On the tradition of Newtonianism at Dutch universities, see Henri Krop, this volume. Further: C. de Pater, *Petrus van Musschenbroek (1692–1761), een newtoniaans natuuronderzoeker* (PhD thesis, Utrecht 1979); Willem Jacob 's Gravesande, *Welzijn, wijsbegeerte en wetenschap*, ed. C. de Pater (Baarn 1988); Ad Maas, this volume; R.H. Vermij, *The Calvinist Copernicans: the reception of the new astronomy in the Dutch Republic, 1575–1750* (Amsterdam 2002), pp. 335–341.

7 Vermij, *Secularisering en natuurwetenschap* (note 3), pp. 115–120. H. Bots, J.J.V.M. de Vet, 'De fysico-theologie in het Journal Littéraire. Haagse journalisten ten strijde tegen het ongeloof', *Documentatieblad werkgroep*

achttiende eeuw 18 (1986), pp. 213–226.

8 Vermij, *Calvinist Copernicans* (note 6), pp. 344–347; R.H. Vermij, 'Johannes Lulofs als vertegenwoordiger van het newtonianisme in de Republiek', *Gewina* 22 (1999), pp. 136–150, on 140–141.

9 The classical study on this argument is H. Metzger, *Attraction universelle et religion naturelle chez quelques commentateurs anglais de Newton,* 3 vols (Paris 1938). For Le Clerc, see the literature mentioned in footnote 5. Jacob Odé, *Principia philosophia naturalis in usum scholarum privatarum conscripta, et captui studiosae juventutis accomodata* I (Utrecht 1727), p. 61.

10 On Dutch physico-theology, see in particular R.H. Vermij, *Secularisering en natuurwetenschap* (note 3); J. Bots, *Tussen Descartes en Darwin. Geloof en natuurwetenschap in de achttiende eeuw in Nederland* (Assen 1972). The connection between physico-theology and Newtonian philosophy in England has been emphasized in N.C. Gillespie, 'Natural history, natural theology and social order: John Ray and the "Newtonian ideology"', *Journal for the history of biology* 20 (1987), pp. 1–49.

11 Vermij, *Secularisering en natuurwetenschap* (note 3).

12 On the question of voluntarism and science, see especially J. Henry, 'Voluntarist theology at the origins of modern science: a response to Peter Harrison', *History of science* 47 (2009), pp. 79–113. See also P. Harrison, 'Voluntarism and the origin of modern science: a reply to John Henry', *History of science* 47 (2009), pp. 223–231.

13 J. Henry, 'Metaphysics and the origins of modern science: Descartes and the importance of laws of nature', *Early science and medicine* 9 (2004), pp. 73–114; esp. pp. 96–97. The article also conveniently summarizes the earlier historiography on the laws of nature. See also L. Daston and M. Stolleis (eds), *Natural law and laws of nature in early modern Europe: jurisprudence, theology, moral and natural philosophy* (Aldershot 2008); R.H. Vermij, 'Een nieuw concept: de wetten der natuur', in: F. Egmond, E. Jorink and R.H. Vermij (eds), *Kometen, monsters, muilezels. het veranderende natuurbeeld en de natuurwetenschap in de zeventiende eeuw* (Haarlem 1999), pp. 105–120; F. Steinle, 'The amalgamation of a concept – laws of nature in the new sciences', in: F. Weinert (ed.), *Laws of nature: essays on the philosophical, scientific and historical dimensions* (Berlin, New York 1995), pp. 316–368; L. Daston, 'Wunder, Naturgesetze und die wissenschaftliche Revolution des 17. Jahrhunderts', *Jahrbuch der Akademie der Wissenschaften in Göttingen* (1991), pp. 99–122.

14 E. Zilsel, 'The genesis of the concept of physical law', in: D. Raven and W. Krohn (eds), *The social origins of modern science* (Dordrecht, Boston, London 2000), pp. 96–122, on 116.

15 B. Nieuwentijt, *Het regt gebruik der wereltbeschouwingen, ter overtuiginge van ongodisten en ongelovigen* (Amsterdam 1715), pp. 752–826 and 827–854. In John Chamberlayne's (abridged) translation, *The religious philos-*

opher, or, the right use of contemplating the works of the Creator (London 1718), these are the 26th and 27th chapters, pp. 471–533 and 533–548 respectively.

16 Nieuwentijt, *Regt gebruik* (note 15), p. 777. My translation, as not included in Chamberlayne's (note 15); cf. pp. 486–487.

17 Nieuwentijt, *Regt gebruik* (note 15), p. 549. My translation, as not included in Chamberlayne's (note 15); cf. p. 658.

18 Nieuwentijt, *Regt gebruik* (note 15), p. 563. Partly translated in idem, *Religious philosopher* (note 15), p. 679.

19 See 's Gravesande, *Welzijn, wijsbegeerte en wetenschap* (note 6), pp. 41–42.

20 P. van Musschenbroek, *Beginselen der natuurkunde beschreven ten dienste der landgenooten* (Leiden 1736), p. 7 (my translation).

21 J. Israel, *Radical Enlightenment: philosophy and the making of modernity, 1650–1750* (Oxford 2001), pp. 218–229 and 242–246.

22 See also R.H. Vermij, 'Nature in defence of Scripture: physico-theology and experimental philosophy in the work of Bernard Nieuwentijt', in: K. van Berkel and A. Vanderjagt (eds), *The book of nature in early modern and modern history* (Leuven etc. 2006), pp. 83–96.

23 Vermij, *Calvinist Copernicans* (note 6), pp. 239–331. W. van Bunge, *From Stevin to Spinoza: an essay on philosophy in the seventeenth-century Dutch Republic* (Leiden 2001), pp. 74–93. See also R. Vermij, 'The debate on the motion of the Earth in the Dutch Republic in the 1650s', in: J.M. van der Meer and S. Mandelbrot (eds), *Nature and Scripture in the Abrahamic religions: up to 1700*, 2 vols (Leiden, Boston 2008), vol. 2, pp. 605–625. On the place of the theory of the animal-machine in the debate, see R. Vermij, 'Dieren als machines: een stok om de hond te slaan', *Groniek* 126 (September 1994), pp. 50–63.

24 Israel, *Radical Enlightenment* (note 21), pp. 197–217; Van Bunge, *From Stevin to Spinoza* (note 23), pp. 94–122.

25 W. van Bunge, 'Balthasar Bekker's Cartesian hermeneutics and the challenge of Spinozism', *British journal for the history of philosophy* 1 (1993), pp. 55–79; Israel, *Radical Enlightenment* (note 21), 375– 405; J. Israel, 'The Bekker controversies as a turning point in the history of Dutch culture and thought', *Dutch crossing* 20–21 (winter 1996), pp. 5–21; G.J. Stronks, 'De betekenis van "De betoverde weereld" van Balthasar Bekker', in: M. Gijswijt-Hofstra and W. Frijhoff (eds), *Nederland betoverd. toverij en hekserij van de veertiende tot in de twintigste eeuw* (Amsterdam 1987), pp. 207–211.

26 J.W. Buisman, 'Bekkers wraak. Balthasar Bekker (1634–1698), de accomodatietheorie en Nederlandse protestantse theologen 1750–1800', *Documentatieblad werkgroep achttiende eeuw* 30 (1998), pp. 97–111.

27 B. Nieuwentijt, *Gronden van zekerheid* (Amsterdam 1720), pp. 403–405. Cf. Vermij, *Secularisering en natuurwetenschap* (note 3), p. 122.

28 M. Evers, 'Die "Orakel" von Antonius van Dale (1638–1708): eine Streitschrift', *Lias* 8 (1981), pp. 225–267. For the witch of Endor, see pp. 229–233. Van Dale was here influenced by Reginald Scott. On the witch of Endor in biblical exegesis, see also F. Laplanche, 'Dieu ou diable? Nécromancie et théologie, de Calvin à Dom Calmet', in: G. Demerson and B. Dompnier (eds), *Les signes de Dieu aux XVIe et XVIIe siècles* (Clermont-Ferrand 1993), pp. 57–63. On the disputes over Van Dale's book, see Israel, *Radical Enlightenment* (note 21), pp. 359–374.

29 Th. Burnet, *The sacred theory of the Earth*, ed. B. Willey (London-Fontwell 1965), p. 54. Willey follows the second English edition (1690–1691). The English version is Burnet's own, but he has reworked it from the Latin original.

30 K. Magruder, 'Thomas Burnet, Biblical idiom and seventeenth-century theories of the Earth', in: Van der Meer and Mandelbrote, *Nature and Scripture* (note 23), pp. 451–490; S. Mandelbrote, 'Isaac Newton and Thomas Burnet: biblical criticism and the crisis of late seventeenth-century England', in: J.E. Force and R.H. Popkin (eds), *The books of nature and Scripture* (Dordrecht etc. 1994), pp. 149–178; R.H. Vermij, 'The Flood and the scientific revolution: Thomas Burnet's system of natural providence', in: F. García Martínez and G.P. Luttikhuizen (eds), *Interpretations of the Flood* (Leiden etc. 1998), pp. 150–166.

31 Th. Burnet, *Telluris theoria sacra originem et mutationes generales orbis nostri [...] complectens* (Amsterdam 1694), p. 247.

32 Ibidem, p. 31 and Burnet, *Sacred theory of the Earth* (note 29), p. 89.

33 Burnet, *Sacred theory of the Earth* (note 29), p. 221.

34 [W. Goeree], *Voor-bereidselen tot de bybelsche wysheid, en gebruik der heilige en kerkelijke historien,* 2 vols (Amsterdam 1690), vol. 2, passim.

35 R.H. Vermij, 'Le spinozisme en Hollande: le cercle de Tschirnhaus', *Cahiers Spinoza* 6 (1991), pp. 145–168, on 161.

36 G.M. van de Roemer, *De geschikte natuur. Theorieën over natuur en kunst in de verzameling van zeldzaamheden van Simon Schijnvoet (1652–1727)* (PhD thesis, University of Amsterdam 2005), pp. 147–150.

37 Nieuwentijt, *Regt gebruik* (note 15), p. 415 (Beschouwing 20, section 44). Chamberlayne's translation (note 15), vol. 1, p. 495.

38 Odé, *Principia philosophia naturalis* (note 9), vol. 2, pp. 39–42. See also the long discussion of Descartes' cosmogony, ibidem, vol. 1, pp. 13–18.

39 J. Lulofs, auctor and respondens, *Disputatio philosophica de causis, propter quas zona torrida est habitabilis* (disp. Utrecht, 1729 Nov. 9), p. 18 (par. 10).

40 M. Kempe, *Wissenschaft, Theologie, Aufklärung. Johann Jakob Scheuchzer (1672–1733) und die Sintfluttheorie* (Epfendorf 2003); I. Müsch, *Geheiligte Naturwissenschaft. Die Kupferbibel des Johann Jakob Scheuchzer* (Göttingen 2000).

41 S. Clark, 'The scientific status of demonology', in: B. Vickers (ed.), *Occult and scientific mentalities in the Renaissance* (Cambridge 1984), pp. 351–374.

42 R.M. Burns, *The great debate on miracles: from Joseph Glanvill to David Hume* (Lewisburgh 1981).

Anti-Newtonianism and Radical Enlightenment

JORDY GEERLINGS

In July 1745, a self-declared natural philosopher using the pseudonym 'Chevalier Veridicus Nassaviensis' was arrested in The Hague for publishing a blasphemous treatise called *La découverte de la vérité, et le monde détrompé a l'égard de la philosophie et de la religion.* It was arguably the most ferocious attack on Newtonian philosophy and organized religion to be published in the Dutch Republic during the eighteenth century. The author, who had also presented himself as Johann Konrad Franz von Hatzfeld (1685–after 1751), had taken the risk of personally presenting prominent men in the city with copies of this work and was therefore soon caught. All copies of the book that could be found were seized, although the archives are silent about the consignment that was to be taken across the German border.[1] Hatzfeld was taken to the Voorpoorte prison in The Hague, where he was subjected to questioning. Despite Hatzfeld's protests, the book was then found to be blasphemous by an assembly of theologians, and the *procureur generaal* (magistrate) thereupon sought to have Hatzfeld 'confined for life'. This was an unusually harsh punishment in the Dutch Republic, even for heterodox writers, and it was only when the already aged Hatzfeld started to display very believable signs of delusion that the authorities took pity on him and downgraded his sentence to a permanent banishment from the provinces of Holland, Zeeland and West Friesland.[2] On 24 January 1746, Hatzfeld was forced to witness the public burning of his books, and let go afterwards.[3]

The prosecution of Hatzfeld was more than simply the end point of a fascinating footnote in the history of anti-Newtonian thought.

On the contrary, his book caused a scandal within the Republic and internationally, even implicating the Halle-based theologian Christian Wolff (1679–1754), whose approbation of the work was prominently but uninvitedly displayed on the title page. Thus, the case of Hatzfeld raises questions about the significance of international connections between radicals who in varying degrees were opposed to Newtonianism, which may have been stronger than is usually supposed. The development of Hatzfeld's ideas within the context of these connections is equally of interest because it sheds more light on what drove the acceptance of Radical Enlightenment thought for individual intellectuals.

In the following, I will investigate how Hatzfeld built a Radical Enlightenment worldview on the rejection of Newtonian thought, while taking into account the role played by social factors, such as dissatisfaction with a lowly social standing, the difficulties of making one's way in networks of patronage and contact with specific intellectual circles. All of these factors contributed to what I would like to call 'radicalization', the intellectual growth process towards radical thought which as such has rarely been described with such social factors in mind. Also, I will examine how some of these same factors limited the influence of Hatzfeld's treatise on the discussion of Newtonian ideas in the Dutch Republic. Finally, instead of repeating the criticisms directed at Jonathan Israel for his excessive emphasis on the doctrinal unity of the Radical Enlightenment and his tendency to divorce intellectual history from its social context, I will attempt to take a methodological middle ground that takes seriously Israel's plea for an integrated history[4] based on the understanding that Enlightenment thought evolved in a more or less dialectical fashion with social and political factors.

The London period, 1723–1725

Little is known about Hatzfeld's early life, other than that he came from a Lutheran background and that he trained as a court servant.[5] Some time during the early 1720s, Hatzfeld moved to London, having served as a *valet de chambre* in various noble households. During his time in England he was not yet the radical critic of religion and political power he would later become. Instead, his ambition was to become a respected, indeed revered, 'natural philosopher'. Although we can't be sure if he continued to be a court servant during this time, it is clear that he had sufficient leisure to instruct himself in the sciences. An important element of his learning process consisted of the experiments conducted by Elias Bessler (1680–1745), who claimed to have succeeded in building a machine capable of perpetual motion without external assistance, but had remained controversial in spite of the support of the Lord of Hesse Cassel. Hatzfeld believed he could outdo Bessler by building his own version of the machine, which was to be his first major scientific project, and in his opinion a ticket to an international reputation as a scientist.

By 1724, Hatzfeld had worked out plans for his wheel of perpetual motion and felt sufficiently confident to show them to the public. Desiring the presence of authoritative witnesses, he directed his attention to the Royal Society, where he intended to demonstrate the results he had achieved with his machine. To this end, he sent at least three letters to the society's secretary, along with technical drawings and explanations of how his wheel could sustain its independent movement.[6] Yet in spite of his repeated efforts, Hatzfeld was never allowed to present his plans at the society. His letters show the bitterness he felt after having been rejected. He complained furiously about the society's unwillingness to recognize the evident merits of his plans for the machine. Adding to his bitterness was the fact that he had also been rejected by Newton, who had refused to receive him when he turned up at his doorstep. Hatzfeld fired off an angry letter to Newton, whose intellectual merits he doubted profoundly, in which he boasted to have already seen 'more light in these matters' than Newton had ever done.[7] He later claimed that he had defeated Newton several times by confronting him in person with his errors concerning the nature of light and matter.[8] This claim remains unsubstantiated; Newton was perhaps predictably unwilling to engage Hatzfeld in conversation.

As far as the rejection by the Royal Society is concerned, it is not possible to draw a conclusive explanation from existing evidence, but the fact that the prevailing opinion within the society rejected even the theoretical possibility of a *perpetuum mobile* certainly worked against Hatzfeld. An article in the *Philosophical Transactions* by Royal Society member John Theophilus Desaguliers (1683–1744) on the subject denied perpetual motion was possible and explained how the idea of it was based on false principles, while casting doubt on the veracity of Elias Bessler's claims about his wheel,[9] and he was by no means the only one to state such views. Newton moreover presided over the session of the Royal Society which considered and rejected one of Hatzfeld's letters,[10] raising the possibility that Newton personally played a part in blocking Hatzfeld's attempts at intellectual recognition by the society. The ageing Newton was becoming weary of Hatzfeld and other quarrelsome continental philosophers. He confided in his correspondence that he wished to see the end of these speculations.[11] Thus, by the time Hatzfeld took up the project of Bessler, many key London scientists considered it outdated, even fantastical, making any recognition for the perpetual motion machine virtually impossible.

***The Case of the Learned* (1724)**

The construction of a perpetual motion machine was not the only scientific pursuit in which Hatzfeld engaged during his time in London. He was also developing his own theory of the physical world, complete with metaphysical and religious underpinnings. In 1724, Hatzfeld went on the attack by publishing a treatise, in which he defended his *perpetuum mobile* project and offered his own worldview. Essentially, his treatise was a comprehensive rejection of Newtonian science and its implications in the fields of theology and metaphysics. Although most of his criticism was directed at Newton himself, Hatzfeld also attacked key Newtonians William Whiston (1667–1752) and Samuel Clarke (1675–1725), as well as writers who, he believed, had published similarly objectionable theories, such as the well-known doctor George Cheyne (1671–1743).

The foremost objection Hatzfeld formulated against Newtonian philosophy was that it constituted a metaphysical degradation to God and man alike, by making the natural world dependent on constant divine intervention in order to keep it working. Although Newton had been characteristically reserved about expressing himself about the role of God in his natural philosophy, and usually left it to others to spell out the metaphysical consequences of his theories, he had claimed that the preservation of motion in the universe and the maintenance of natural law and order depended constantly on the divine will.[12] In doing so, Hatzfeld believed, Newton and his supporters had reduced God to a lowly engineer, condemned to perpetually patch up an imperfectly constructed machine.[13] Also, since Newton's God would only have created a natural world dependent on his constant control because this gave him pleasure, he would have been even more pleased to create and control the spiritual world, which would be an even greater demonstration of divine power. Thus, Hatzfeld believed, the Newtonian God must logically extend his control of the natural world to the control of souls. Hatzfeld decried this thinking as 'predestinism' because it deprived mankind of its ability to act freely, making it impossible for humans to wilfully act for good or evil.[14]

The core of Hatzfeld's criticisms is clearly reminiscent of Gottfried Leibniz (1646–1716), and specifically of Leibniz's correspondence with Samuel Clarke, which had been in circulation since 1715, and had been available in a French-English edition since 1717.[15] For Hatzfeld, reading this debate was a formative experience, from which he derived categories of thought that would continue to guide him for the rest of his life. It informed him about the central problems concerning the metaphysical implications of natural science, and provided principles with which he could support his own worldview. Inspired by his reading, Hatzfeld included a chapter in his treatise which defended Leibniz against Clarke's charge that his idea of a metaphysically independent natural universe removed providence from the world, because it eliminated all divine influence on it. Hatzfeld, repeating Leibniz's own defence against the charge, attempted to explain that providence should be interpreted as God's ability to foresee what would be required for the maintenance of order in the world, and prearrange it accordingly. God had endowed matter and nature with all the necessary properties and laws for his creation to function without his intervention, according to his 'concept of pre-established order'.[16]

Hatzfeld's alternative view of nature was designed to counter the difficulties of Newtonianism by offering a comprehensively different account for everything Newton had attempted to explain. First of all, Hatzfeld believed that attraction and repulsion were inherent to matter, which necessarily existed in a plenum. He abhorred the supposition that a vacuum was possible in nature because it implied action at a distance between particles, which seemed to support the idea of direct divine intervention in the world. In this sense, Newtonian theory should be considered contrary to the Bible, which clearly said that God had created the world in six days, while Newton's belief in constant divine intervention seemed to imply that God had not completely finished his creation.[17] Newton's aether, too, was a concept to be rejected. There was no evidence to prove its existence, and any substance of this kind would create resistance to the movement of the planets. However subtle it might be, aether would eventually cause enough resistance to stop the movement of the planets. Yet, as the length of the years on Earth was showing no signs of decreasing, the planets had to be moving at the same speed they had always done, thus disproving the existence of the aetherial medium, or requiring the unacceptable supposition of another act of divine intervention.[18]

Regarding the motion of planets, Newton had erred in other ways as well. A solar system working according to the Newtonian notion of gravity, Hatzfeld thought, would necessarily collapse: if the sun's attractive force were greater than the resisting force of the planets, it would draw them into its centre and consume them. Newton and his followers, as well as George Cheyne with his *Philosophical Principles of Religion* (1715), had tried to counter this difficulty by positing that this was precisely one of the points at which divine intervention manifested itself.[19] This, of course, was unacceptable to Hatzfeld, who believed that any configuration of gravitational force would produce a planetary disaster dishonourable to God.[20]

Hatzfeld's alternative explanation for the motion of planets depended on the principle of fermentation, which by 'violently agitating' matter in the sun caused the sun to heat up, producing light but also agitating the 'particles' of the nearby planets in such a way as to provoke the contraction and extension of matter in the planets.[21] This would cause them to exhale vapours which acted on the air, producing motion. For Hatzfeld, the fact that the planets closest to the sun moved faster than the others confirmed this thesis.[22] The solar system clearly subsisted because of a constant exchange of matter driven by fermentation. How the planets could stay in orbit through fermentation remained unclear, however.

Fermentation as an account of movement in matter was nevertheless the centre point of Hatzfeld's physical worldview. Contrary to Newtonian physics, it allowed for an independent natural world that worked in perfect harmony, revealing the foresight of its creator. Newton, on the contrary, was a disaster for science as well as religion. His many mistaken presuppositions regarding the 'machine of the world' had hampered his experiments, leading to contradictory explanations of what these experiments proved, and dangerous ideas about how divine power influenced the workings of nature. Hatzfeld believed he had provided a powerful counterargument, and fully expected that it would bring down the Newtonian scientific edifice, along with its metaphysical implications.

Newton and his followers, however, appear to have ignored Hatzfeld's treatise entirely. In fact, *The Case of the Learned* seems to have gone largely unnoticed in contemporary scientific discussions, even though various London book auction catalogues carried the title from the 1720s until as late as 1791,[23] indicating that the book had found its way into a fair number of English libraries. My research has thus far discovered only one published response to it. This one response came not from the well-known circle of Newtonians, but from James Sedgwick, an apothecary operating from Stratford-le-Bow to the east of London, who knew of Hatzfeld's work and even engaged with it in his own writing. In 1725, Sedgwick referred to Hatzfeld in his *A New Treatise on Liquors,*[24] which was intended mainly to describe the effects of alcoholic and other liquids on the human body, as well as to advise on the treatment of the resulting problems. Hatzfeld and Sedgwick shared a tendency to combine the chemical language of fermentation, spirits and vapours with the traditional humoral analysis of the human body. For both of them, fermentation was the main principle on which the operation of living bodies, including human beings, depended. By fermenting victuals in the stomach, and through the fermentability of the blood, living beings were able to maintain their existence.[25]

On Liquors in fact appropriated many of the ideas found in *The Case of the Learned*, sometimes without acknowledging its debt to Hatzfeld. This connection with Sedgwick and his use of humours as a tool to analyze the functioning of the human body indicate that the description of Hatzfeld as a *'Freidenker englisher Prägung, in der der Deismus entwickelt wurde'*[26] needs to be augmented by emphasizing Hatzfeld's connections to humoral theory, chemistry and, to some extent, materialism as described in Ann Thompson's work on the development of eighteenth-century materialism outside of the gentlemanly Royal Society.[27] Many of the natural philosophers Thompson describes, such as Thomas Willis (1621–1675), employed evolving types of humoral analysis, fermentation theory and chemical accounts of matter to explain the physical world as well as the nature of the soul and its connection to the human body. Hatzfeld's vague ideas about this connection, which described the soul as different from and above the body, but still susceptible to the influence of humours and fermentation,[28] were not unprecedented in contemporary English thought, especially insofar as it mixed the increasingly outdated humoralism with mechanist and materialist accounts of the human body.[29]

Hatzfeld, then, may have been a vague, incoherent thinker, but he had read widely to stake out a modestly deist worldview which rejected direct divine intervention in the pre-established harmony of the physical world and the soul, but simultaneously upheld the veracity of revealed religion. He did not engage in the critiques of religion such as those offered by John Toland (1670–1722) or Anthony Collins (1676–1729), and as far as his views on the physical world were concerned, he bore a much closer resemblance to the moderate English materialists and Leibnizianism than to any form of early-eighteenth-century radical thought in England. Yet, in spite of his relatively moderate stance in religious matters, it is clear that Hatzfeld's intellectual agenda was singularly incompatible with that of the Royal Society or any other part of respectable mainstream academia in early-eighteenth-century London. His support of Leibniz after the conclusion of the calculus conflict, his espousal of the controversial perpetual motion project and his comprehensive rejection of Newtonianism along with its metaphysical underpinnings drove him to the fringes of contemporary scientific discourse in London. His ideas were similarly at odds with influential Latitudinarian positions, which relied on a synthesis of natural religion buttressed by a Newtonian universe, built on the constant agency of God as a guarantor of order and as a moral standard for a stable society.[30] In addition to his problematic intellectual identity, Hatzfeld's bid for fame was frustrated by his impatience with the 'gentlemanly' conventions according to which London's learned society functioned, as his repeated outbursts of anger showed.[31] There would be no breakthrough for him in London, but Hatzfeld was nevertheless solidly convinced of his own merits as a scholar, and the experience of rejection, which bitterly resounded in his letters and his treatise, set him on the path towards ever more extreme convictions.

Radicalization and the anti-Newtonian miscalculation, 1741–1746

If little is known about his London period, the next stage of Hatzfeld's life is a mystery. At some point, he left London for the Continent, but it is not clear exactly when he did so, or why. Jonathan Israel claims that Hatzfeld left in 1725, after having been accused of espionage, and court papers in The Hague confirm that Hatzfeld took mass at the Walloon Church in The Hague in 1726.[32] It was not until 1741 that Hatzfeld turned up again. He was now in Berlin to seek an audience with King Frederick of Prussia, but was apparently denied access to the royal court. We can only speculate as to the circumstances of this refusal, but the stay in Berlin was not a complete disaster. Hatzfeld was able to obtain letters of recommendation to the well-known theologian Christian Wolff (1679–1754), who was to play a crucial part in the development of Hatzfeld's second, more radical work. Wolff himself had only recently returned to his post at Halle after an accusation of 'atheism' in 1721. His return to Halle in 1740 had largely been due to Frederick the Great's arrival to power,[33] which permitted a greater amount of latitude to reform-minded philosophers. However, in spite of royal backing and his accession to the rectorate at his university, Wolff was still engaged in a long-standing conflict with powerful Pietist factions, and even the charges of heterodoxy and atheism had not abated.

In fact, in cities like Halle, Leipzig, Gotha and Berlin, the term 'Wolffianism' had come to include a variety of heterodox views on religion and society. Students were thought to be especially susceptible to these views, and many prospective academics were asked to first explain their views on Wolffianism. The fears of Wolffian heterodoxy were not entirely baseless, as research by Günter Mühlpfordt and, more recently, Martin Mulsow has shown. According to Mühlpfordt, the 1740s saw the development of a *'radikaler Wolffianismus'*, or 'left Wolffianism', which tended towards deism, the critique of religious traditions and even social reform.[34] Mulsow, in his research of learned networks in eighteenth-century Germany, has drawn on Mühlpfordt's work and located radical Wolffianism primarily among student groups, especially in Leipzig, Halle and Gotha, where Theodor Ludwig Lau, Johann Hein, Carl August Gebhardi and Christlob Mylius were among the most prominent and active radicals.

Some of these radicals gravitated around the Aletophilenkreis, founded by Wolffians Ernst Christoph Graf von Mantteuffel (1676–1749) and Johann Gustav Reinbeck (1683–1741) in Berlin during 1736. This circle, the hub of which seems to have been Johann Christoph Gottsched (1700–1766), tended towards a liberal Wolffian worldview, claiming to love truth (*aletophilia*) as a polemical stance against orthodox theology, but without presenting a clear-cut alternative worldview. Thus, the Aletophilenkreis included many conservative thinkers, while also becoming a meeting place for radical Wolffians, many of whom were university students. With Wolffian rationalist philosophy as their starting point, these radicals criticized superstition, supernaturalism, revealed religion and the veracity of the Bible, usually adopting deist positions in the process.[35] Needless to say, they opposed Pietism as well as Lutheran orthodoxy, often publishing scandalous deist works such as *Der Vernünftige Freygeist* and *Betrachtungen über die Majestät Gottes* (both from 1743). It may therefore be said that Leipzig, where Gottsched was based, was a significant centre of Enlightenment critique of religion at the middle of the eighteenth century.[36] Hatzfeld was heading straight for this city and the surrounding region, and I submit that his subsequent encounter with important figures in the Aletophilenkreis was a key stage in the radicalization of his thought.

Although Hatzfeld seems to have had some success in finding support for his new book in Leipzig, he initially struggled in Halle, where he was repulsed by the Pietist and anti-Wolffian theologian Joachim Lange (1670–1744), who wished to have nothing to do with his work.[37] Hatzfeld also claimed to have been rejected in Berlin, for example by, amongst others, Leonhard Euler (1707–1783), who had insisted that Newton's ideas were *'pas touché'* by his plan for the new text.[38]

It was not until 1742 that Hatzfeld truly achieved his breakthrough in Halle. In that year, Hatzfeld finally met Christian Wolff in that city, after having travelled there from Berlin carrying a letter of recommendation from as yet unknown sources. With surprising ease, Hatzfeld obtained Wolff's 'excellente Protection'[39] for the new book as well as some measure of access to Wolff's learned network. In fact, a recent dissertation by Johannes Bronisch has found fascinating evidence which proves that between 1742 and 1744, Hatzfeld stayed at the Leipzig residence of Von Manteuffel,[40] whose salon had become a meeting place for the city's intellectuals.

While no recommendation from Wolff has been found, Bronisch suspects that it is because of Wolff's connection to Manteuffel that Hatzfeld was able to gain this protection. Bronisch has interpreted Wolff's actions in favour of Hatzfeld as an attempt to create a 'flanking movement' in support of his own work against the metaphysical implications of Cartesianism and Newtonianism,[41] which, owing to the language barrier, had not yet gained a foothold in the French-speaking world. Accepting Hatzfeld's proposal for a new book would have been a strategic choice by Wolff, engaging a highly ambitious supporter to say what he himself could not and gaining an ally in the continuing *Monadenstreit* against prominent supporters of Newtonian philosophy at the royal academy in Berlin, like Leonhard Euler. For Hatzfeld, Wolff brought the advantages of intellectual protection and even material support. Through Wolff, he could finally rise to fame and recognition, as well as defeat the philosophy of his enemy Newton.

These hopes were soon dashed, however, when it became clear that Hatzfeld was not the ideal ally against Newtonian philosophy. Manteuffel had to ask Hatzfeld repeatedly to rework his harsh criticisms of Newton in a more ordered, systematic manner, but was proving unsuccessful in his attempts to moderate Hatzfeld's characteristic zeal.[42] In 1744, Manteuffel even complained to Wolff that Hatzfeld was 'incorrigible'.[43] By this time, Manteuffel's support for Hatzfeld was faltering, and he was relieved to see Hatzfeld leave on foot for The Hague with the intention of proceeding to London, after having spent a brief period at court in Gotha.[44] It is not clear what personally motivated Hatzfeld to return to London, but it is possible that the tensions with Manteuffel brought about his departure. Hatzfeld does not seem to have severed his ties to Wolff, nor had he abandoned the project of reworking and expanding his treatise of natural philosophy. He had resolved to once again publish his ideas on these issues, this time together with his newly acquired views on government and religion.

Placing the radical Hatzfeld

In 1745, having reached The Hague, and having ostensibly been prevented by illness and bad weather from moving on to London, Hatzfeld decided to publish his treatise in The Hague.[45] The documentary evidence in The Hague does not allow a careful reconstruction of how much time he spent in the city, or where exactly he lived, but the records do show that Hatzfeld had considerable difficulties in finding a printer and bookseller willing to publish the treatise. In the end, Pierre d'Hondt, a bookseller who later claimed to not to read French, agreed to Hatzfeld's request. However, he did so only after he had been assured that the text did not violate any civil or religious laws, and that Hatzfeld would take full responsibility for his text. The treatise, moreover, was to be published at Hatzfeld's own expense, presumably paid out of his earnings from Leipzig.

Interestingly, the proofs were read by professor of mathematics and fortifications Pierre Antoine de Saint-Hilaire (dates unknown) in The Hague, who was connected with local Freemasons, and later became prominent in the Loge de Juste.[46] This would suggest that Hatzfeld himself had connections with Masonic circles in The Hague, some of which have been identified as centres of radical thought,[47] and could thus have given their support to the publication process. Men like Jean Rousset de Missy (1686–1762) and others involved in the posthumous publication of Spinoza's works immediately spring to mind as likely contacts in The Hague. The idea that Hatzfeld made such connections is made more likely by the fact that Hatzfeld mentioned Lambert Ignace Douxfils, a Commissioner of the Post in Brussels and important colporteur of books for the pre-Masonic group called the Knights of Jubilation, on his list of subscribers for *La découverte.*[48] However, the evidence is too scarce to establish anything more than the likelihood that Hatzfeld did meet with freemasons and radicals in The Hague, possibly even as early as 1726 upon his return from London.

La découverte, conversely, is a more solid basis on which to identify Hatzfeld as a radical, because the persecution of the book was due to its highly unorthodox views on religion, the Church and the princely governments of Europe. Hatzfeld now challenged the historical veracity of the Bible, denounced the oppressive superstition imposed by the priests, denied the holiness of Christ and the existence of devils, and rejected the possibility of miracles. Clearly, Hatzfeld's ideas, which must have originated in Leipzig, had begun to resemble those of the radical Spinozists in the Dutch Republic who continued to worry religious authorities. However, in spite of this ideological convergence, Hatzfeld never abandoned his staunchly deist belief in a God metaphysically distinct from and above Creation and continued to abhor any worldview that confused the immaterial divine with nature.[49]

The text also included a meritocratic political agenda with a strongly republican thrust. Even though this did not prevent him from seeking princely support whenever he could, Hatzfeld found that the princes of Europe and their selfish lackeys were responsible for misgovernment and that they had prevented the rise to influence of more meritorious men, as Hatzfeld believed himself to be. Moreover, governments must not only be more meritocratic, but must also act in the interest of the people from which any government derives its mandate. England and the Dutch Republic were examples of states that embraced political liberty, but they too were in danger if they did not contain the threat of priestly deception and the abuse of secular authority.[50]

La découverte, therefore, contained many radical views against which the authorities in The Hague would necessarily take offense. However, the treatise also conveyed other messages. The pseudonym Hatzfeld employed, for example, offers some interesting clues as to his ideological motivations, the self-styling strategies he employed and even his social background. In calling himself the 'Chevalier Veridicus Nassaviensis', he referred to his Nassau origins, but it seems unlikely that he was simultaneously displaying further political loyalties to such parties as the House of Orange, about which he would very likely have been quite vocal. Similarly, the use of the word 'chevalier' would suggest that Hatzfeld was of noble descent, but the hearings conducted at the Voorpoorte prison revealed that Hatzfeld was in fact of common descent, and that his real name was 'Harsveld'.

Clearly, Hatzfeld had changed his surname and added his middle names,[51] quite possibly to associate himself with the famous and powerful aristocratic family of Hatzfeld, in an effort to give himself a more noble appearance. His native Dillenburg was home to a branch of this family, and there was a tendency there to change the surnames of family branches that no longer had noble status by giving them a slightly different spelling.[52] 'Hatzfeld' could thus easily become 'Harsfeld', making it likely that Hatzfeld attempted to cover up his real name in order to claim this status, even though there may well have been no family connection based on which he could legitimately do so. Nevertheless, the use of the name Hatzfeld seems to have worked a number of times throughout his life, and some of the later commentators of *La découverte* still believed Hatzfeld to be a 'noble Saxon'.[53]

In using this pseudonym, Hatzfeld was clearly also claiming association with the Aletophilen, who described themselves with great emphasis as 'lovers of truth'. The title of his treatise, his pseudonym 'Veridicus' and his insistence on his 'love of truth' to the authorities in The Hague[54] all suggest that he counted himself among the *Aletophilen*, and that this group must have exercised a considerable measure of influence on Hatzfeld's intellectual development towards radicalism. This would explain how Hatzfeld acquired the ideas that permitted him to form his radical critique of the European clergy, the veracity of the Bible and the existence of the devil, none of which naturally derived from the moderate deist natural philosophy of the London period which still underpinned *La découverte.* However, the journalists and theologians who commented on Hatzfeld's book generally ignored the deeper implications of its title, limiting their coverage of it to its 'blasphemous' content and the claimed connection with Christian Wolff, whose approbation of *La découverte* appeared on its title page, no doubt to the surprise of many.

In Halle, Wolff was shocked to find his name associated with such a scandalous treatise. He quickly denied any support for Hatzfeld's ideas, explaining that Hatzfeld had come to him seeking subscriptions for a book on Cartesian and Newtonian philosophy.[55] Wolff claimed to have supported these plans only out of his desire to suppress controversy, implying that Hatzfeld had lied about his intentions.[56] Several other publications by Wolff in the *Bibliothèque germanique,* the *Acta eruditorum,* and the *Bibliothèque raisonnée* repeated these claims. Wolff was very much concerned about his own reputation, quoting extensively from his own published work to prove his philosophical orthodoxy and dissociate his views from Hatzfeld's.

Johannes Bronisch describes how Wolff activated his network of correspondents to receive information on Hatzfeld's book, which he had not seen himself, and to disseminate his rejection of it.[57] Von Manteuffel seems to have been most prominent in the effort to control the damage of what Bronisch has aptly called the 'anti-Newtonian miscalculation',[58] but others aided in these efforts as well. Samuel Koenig (1712–1757), a prominent mathematician at the academy in Berlin, who had experienced a personal confrontation with Hatzfeld there, helped Wolff publish a French text against Hatzfeld in the *Bibliothèque raisonnée*,[59] which had already published a damning review of the book, albeit without judging Wolff's involvement.[60] Also, Pierre Moreau de Maupertuis included Wolff's self-defence from the *Acta eruditorum* in his *Bibliothèque germanique.* [61] In the next few years, the indignation at Hatzfeld's book extended as far from The Hague as Florence.[62] It also became known in Poland, whereas Jan Poszakowski (1684–1757), a Jesuit abbot from Nieswicz closely allied to the influential Zaluski noble family, announced a full refutation of Hatzfeld's text, which also claimed *'le livre de M Hatzfeld est aussi ecrit en allemand'*.[63] However, no translation has been found, and Poszakowski's announced refutation has appeared only in a nineteenth-century bibliography of Jesuit writings and has not been seen since.[64]

From the many theological responses to his book it is clear that Hatzfeld quickly acquired international infamy as a 'deist', *'freygeist'* (freethinker) and even a *'cerveau brûlé'* (hothead). Contemporary commentators were especially indignant about the Hatzfeld's blasphemous ideas on religion, which in their perception completely overshadowed his metaphysical and physical arguments. Although the *Bibliothèque raisonnée* believed he had been *'quelquefois assez* *sage avec Wolff and Leibniz'*,[65] all other comments on the book were scathing. In the eyes of Johann Georg Meusel (1743–1820), Hatzfeld had joined the ranks of Simon Tissot de Patot, Pierre Bayle, Georg Schade and Carl August Gebhardi, who had been branded as 'deists',[66] and the German theologian Johann von Mosheim (1693–1755) mentioned him in the same breath with Voltaire and Lieutenant La Serre,[67] the free-thinker who was hanged for espionage during the siege of Maastricht in 1748. Especially for German-speaking intellectuals, Hatzfeld had become one of the most outrageous examples of irreligiosity in recent times.

The scandalous nature of his treatise also put Hatzfeld well beyond the intellectual agenda of moderate Dutch thinkers critical of Newtonianism and its theological implications. The attempt to enlist the support of Willem Jacob 's Gravesande (1688–1742),[68] who became increasingly critical of Newtonian physico-theology towards the end of his life, had been unsuccessful. Even the conflicts with the Royal Society about the *vis viva* and the Leibniz-Newton controversy – in which, according to Jonathan Israel, Dutch intellectuals like 's Gravesande and Petrus van Musschenbroek (1692–1761) crucially diverged from Newtonianism on such issues as the externality of motion to

Fig. 1: Book burning, probably of Hatzfeld's book.

matter[69] – did not create sufficient conditions for an ideological convergence between Hatzfeld and Dutch anti-Newtonians. Moreover, as Michiel Wielema has demonstrated, the influence of Leibnizian-Wolffian philosophy on Dutch thought did not begin to take effect untill the later decades of the eighteenth century, as a result of Dutch translations of Leibniz and Wolff's works.[70] Ideologically speaking, therefore, Hatzfeld seems to have been very much distinct and separate from any segment of the Dutch intellectual landscape, in spite of his likely connections with radical thinkers in The Hague. No overt support was forthcoming, and Hatzfeld disappeared into obscurity.

Conclusion: The origins of radicalism

As it evolved, Hatzfeld's worldview intersected with a number of contemporary intellectual developments, including the Leibnizian-Wolffian struggle against Newtonianism and the complex varieties of Wolffian deism it generated,[71] as well as replacement of humoral accounts of the human body with theories drawn from chemistry and materialist philosophy. Out of contemporary ideas, Hatzfeld created a highly peculiar amalgam of Leibnizian metaphysics, mechanist materialism, fermentation theory and deism, which although already heterodox, did not reveal any necessary tendency towards radicalism on the level of political and religious convictions. Rather than his relatively modest natural philosophy, it was his frustrated ambition, his status anxiety and his contacts with German freethinking circles and perhaps even his impatience with contemporary academic mores that were the driving forces behind his movement towards the radical critique of Christianity and absolutist government in Europe.

The case of Hatzfeld thus shows how strongly social factors could impact on the persuasive force of Radical Enlightenment ideas on individual readers. The communication of Radical Enlightenment ideas was successful not merely because of the transmission of radical texts or the semantic strength of radical positions in Enlightenment debates: concerns about status, ambitions, frustrations and contact with freethinking groups must have contributed in a highly significant way to the acceptance of these ideas. Radicals criticized the institutions of the *ancien régime* for personal as well as intellectual reasons, and analyzed its imperfections according to their perception of their own dreams and interests. Examining radicalization as it occurred at the individual level may therefore be a useful contribution to our understanding of how the radical strain of the Enlightenment spread, and how those drawn to these ideas shaped their intellectual identities within a complex of social pressures, fears and hopes. Intellectual history should also be a history of intellectuals.

Notes

1 Algemeen Rijksarchief, Hof van Holland, MS 5863 'Sententie 24 januari 1746'.
2 Algemeen Rijksarchief, Hof van Holland, MS 5454, 'Eysch van den Avocaat Ficaal en Procureur', 24 januari 1746.
3 Ibidem.
4 Jonathan Israel, *Enlightenment contested: philosophy, modernity and the emancipation of man, 1670–1752* (Oxford 2006), p. 23.
5 Algemeen Rijksarchief, Hof van Holland, MS 5454.
6 Royal Society Archives, ELH H3 124–126.
7 H.W. Turnbull, A. R. Hall and L. Tilling (eds), *The correspondence of Isaac Newton*, 7 vols. (Cambridge 1959–1977), vol 7, nr. 1418.
8 J.C.F. von Hatzfeld, *The case of the learned, represented according to the merit of the ill progress hithereto made in the arts and sciences, chiefly in philosophy, of which the author gives an entirely new system* (London 1724), pp. 82–83.
9 *Philosophical transactions, giving some account of the present undertaking, studies and labours of the ingenious in many considerable parts of the world* (1720–1721), vol. 31, pp. 234–239, esp. p. 234.
10 R. Westfall, *Never at rest: a biography of sir Isaac Newton* (Cambridge 1980), p. 811.
11 Ibidem, p. 811.
12 B.J. Teeter Dobbs and M.C. Jacob, *Newton and the culture of Newtonianism* (New York 1995), p. 14.
13 Hatzfeld, *Case of the learned* (note 8), p. 25.
14 Ibidem, p. 20.
15 *A collection of papers which passed between the late learned Mr Leibnitz and Dr Clarke in the years 1715 and 1716 relating to the principles of philosophy and religion* (London 1717), pp. 1–46.
16 Hatzfeld, *Case of the learned* (note 8), p. 31.
17 Ibidem, p. 39.
18 Ibidem, p. 111.
19 G. Cheyne, *Philosophical principles of religion* (London 1715), p. 187.
20 Hatzfeld, *Case of the learned* (note 8) p. 107.
21 Ibidem, p. 125.
22 Ibidem, p. 127.

23 *A catalogue of books, comprehending many libraries, particularly that of Robert Butler Esq, and a general officer, lately deceased, also the valuable articles at the Pinelli Sale, intended for abroad* (London 1791), p. 264. An ECCO search yields thirteen catalogues mentioning *The case of the learned.*
24 James Sedgwick, *A new treatise on liquors: wherein the use and abuse of wine, malt-drinks and water, &c. are particularly consider'd, in many diseases, constitutions and ages* (London 1725).
25 Ibidem, p. 160.
26 E. Tortarolo, 'Ein Opfer der Zensur in Den Haag: Johann Conrad von Hatzfeld,' in: U.J. Schneider (ed.), *Kultur der Kommunikation* (Wiesbaden 2005), pp. 229–240, on 239.
27 A. Thompson, *Bodies of thought: science, religion, and the soul in the early Enlightenment* (Oxford 2008).
28 Hatzfeld, *Case of the learned* (note 6), p. 134.
29 N. Arikha, *Bodies and tempers: a history of the humours* (London 2007), pp. 173–199.
30 M.C. Jacob, *The Newtonians and the English Revolution, 1689–1720* (Ithaca, London 1976).
31 S. Shapin, *A social history of truth: civility and science in seventeenth-century England* (Chicago 1994).
32 Algemeen Rijksarchief, Hof van Holland, MS 5454, 'Eysch van den Avocaat Ficaal en Procureur', 24 januari 1746.
33 J. Israel, *Radical Enlightenment: philosophy and the making of modernity* (Oxford 2001), p. 557.
34 G. Mühlpfordt, 'Radikaler Wolffianismus: Zur Differenzierung und Wirkung der Wolffschen Schule ab 1735', in: W. Schneiders (ed.), *Christian Wolff 1679–1754: Interpretationen zu seiner Philosophie und deren Wirkung* (Hamburg 1979), pp. 237–253, on 242.
35 M. Mulsow, *Freigeister im Gottsched-Kreis: Wolffianismus, studentische Aktivitäten und Religionskritiek in Leipzig 1740–1745* (Berlin 2007), p. 38.
36 Ibidem, p. 11.
37 J. Bronisch, *Der Mäzen der Aufklärung: Ernst Christoph von Manteuffel und das Netzwerk des Wolffianismus* (Berlin 2010), pp. 325–326.
38 J.C.F. Hatzfeld, *La découverte de la verité et le monde détrompé a l'égard de la philosophie et de la réligion,* (The Hague 1745), p. 15.
39 Ibidem, p. 50.
40 Bronisch, *Der Mäzen der Aufklärung* (note 37), p. 327.
41 Ibidem, p. 326.
42 Ibidem, p. 328.
43 Ibidem, p. 330.
44 Ibidem, p. 333.
45 Hatzfeld, *La découverte* (note 38), p. lxvi.

46 M. Davies, 'The Grand Lodge of Adoption, La Loge de Juste 1751, a short-lived experiment in mixed Freemasonry or a victim of elegant exploitation?', in: A. Heidle and J. Snoek, (eds), *Women's agency and rituals in mixed and female masonic orders* (Leiden 2008), pp. 51–76, on 54.
47 See M.C. Jacob, *The radical Enlightenment: pantheists, freemasons and republicans* (London 1981).
48 Ibidem, p. 172; Hatzfeld, *La découverte* (note 38), p. cxi.
49 Hatzfeld, *La découverte* (note 38), pp. 91 and 167–168.
50 For more on Hatzfeld's political views, see Israel, *Enlightenment contested* (note 4), pp. 338–340.
51 *Nederlandsch gedenkboek of Europische Mercurius* 57 (1746), pp. 114–116. This periodical was aware of the proceedings of Hatzfeld's trial and the manner in which Hatzfeld had answered the questions put to him by his interrogators. See also Algemeen Rijksarchief, Hof van Holland MS 5454/13/1.
52 L. Hatzfeld, 'G. Hatzfeld von Dillenburg: Genesis einer nassauischen Beamtenfamilie', *Nassauische Annalen* 101 (1990), pp 59–89, on 81.
53 H. de Gregoire, *Histoire des sectes religieuses* (Paris 1845), p. 266.
54 Algemeen Rijksarchief, Hof van Holland MS 5454.1; Israel, *Enlightenment contested* (note 4), p. 338.
55 *Nova acta eruditorum, mensis novembris* (Leipzig 1746), pp. 669–672, on 670.
56 *Acta Historico-Ecclesiastica, oder gesammlete Nachrichten von den neuesten Kirchengeschichten* 73 (Weimar 1749), pp. 447–448.
57 Bronisch, *Der Mäzen der Aufklärung* (note 37), p. 319.
58 Ibidem, p. 325.
59 *Bibliothèque raisonnée, des ouvrages des savans de l'Europe* 38–1 (1747), pp. 235–239.
60 Ibidem, 36 (1746), pp. 368–397.
61 *Nouvelle bibliothèque germanique ou histoire littéraire* (July-September 1746), pp. 189–201.
62 *Novelle letterarie pubblicate in Firenze* 7 (1747), pp. 731–733.
63 *Bibliothèque anuelle et universelle* 3 (1753), pp. 177–178.
64 P. Augustin and L. de Backer, *Bibliothèque des écrivains de la Compagnie de Jesus,* 4 vols (Liège 1858), vol. 4, p. 596. The title of Poszakowski's refutation is *Censura libri ab Hatzfeldo perversae homine hoc titolo divulgati* La decouverte de la verité et le monde detrompé a l'égard de la philosophie et de la réligion (place and date of publication unknown).
65 *Bibliothèque raisonnée des ouvrages des sçavans de l'Europe* 36 (1746), pp. 368–397, on 369.
66 J.G. Meusel, *Historische Literatur für das Jahr 1784* (Erlangen 1784), pp. 293 and 296.
67 J.L. von Mosheim and G. Winkler, *Vorlesungen über den Beweis der*

Wahrheit und Göttlichkeit der christlichen Religion: Vorlesungen über den zweiter Theil (Dresden 1784), pp. 334–336.

68 Israel, *Enlightenment contested* (note 4), p. 214.

69 Ibidem, p. 220.

70 M. Wielema, *Ketters en verlichters: de invloed van het Spinozisme en Wolffianisme op de Verlichting in gereformeerd Nederland* (Amsterdam 1999), pp. 121–131.

71 Israel, *Radical Enlightenment* (note 33), pp. 552–558.

Newtonianism at the Dutch Universities during the Enlightenment

The teaching of 'philosophy' from 's Gravesande to Van Swinden

HENRI KROP

Introduction

In 1779 Jean Henri van Swinden (1747–1825), a leading late-eighteenth-century Dutch scientist and the rector of the Frisian University at Franeker, on laying down his office delivered an address on Newtonian philosophy.[1] The argument of this huge text, which runs to more than eighty pages, illustrates the fact that during the eighteenth century Newtonianism at the Dutch universities had developed into a full-fledged philosophical system, which at that time philosophers and scientists put on a par with the preceding Cartesianism and its contemporary rival system, Wolffianism. From the 1720s onwards 'Newtonianism' was generally taught at the universities of the Republic as an integrated and comprehensive philosophical system, which besides natural philosophy also included logic and metaphysics. Obviously, 'Newtonianism' is a problematic term and in this article no attempts will be made to identify a general meaning, but merely the 'Newtonianism' taught by Willem Jacob 's Gravesande (1666–1742) and his followers at the Dutch universities will be dealt with.[2]

In his *Philosophie der Aufklärung,* E. Cassirer was one of the first historians to give Newtonianism a significant place in the philosophy of the Enlightenment, and his example was adopted by the famous historian of Dutch philosophy, F. Sassen, albeit hesitantly.[3] The development of such an academic Newtonianism in the United Provinces seems to be unique and is, for example, clearly opposed to the situation in Germany, where during the first half of the eighteenth century Newtonianism was taken to be a set of merely mathematical and physical doctrines. For example, Zedler's *Universallexicon* in its entry 'Newtonische philosophie'[4] listed contemporary debates on questions in these fields at random.[5]

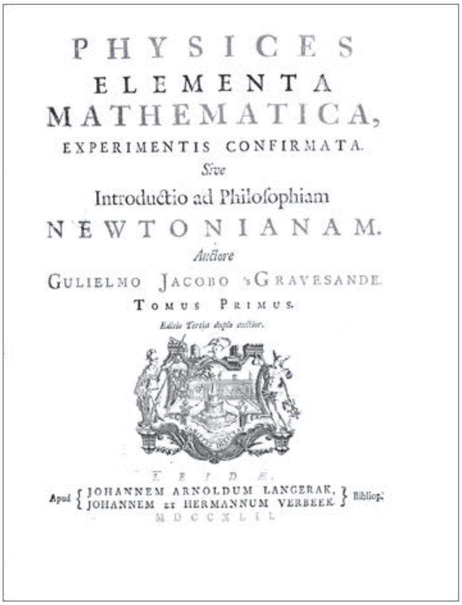
In the Dutch Republic the philosophical Newtonianism supported by the universities has to be distinguished from a more popular Newtonianism of a markedly religious nature, which had the societies of enlightened burghers as its institutional background.[6] Apparently this Newtonianism for some decades outlived the academic one and survived well into the nineteenth century. It is marked by its close alliance with physico-theology and its openness to other philosophical ideas. This popular Newtonianism even adopted Leibnizian themes.[7] The apparent split between two diverse forms of Newtonianism, a popular and an academic one, confirms M. Jacob's recent observation: 'In the course of the eighteenth century, Newtonianism took a multitude of forms'.[8] This plurality of Newtonianisms was already recognized by d'Alembert (1717–1783), who in his article 'Newtonianisme, ou philosophie Newtonienne' distinguished no less than five meanings of the term.[9]

The creator of academic Newtonianism in the Netherlands was the Leiden professor Willem Jacob 's Gravesande.[10] In his many university addresses, the preface to his manual of physics, *Physices elementa mathematica, experimentis confirmata, sive introductio ad philosophiam Newtonianam* (1720–1721),[11] and his manual of philosophy, the *Introductio ad philosophiam* (1736), 's Gravesande developed an open Newtonianism which was spread by his pupils to most other universities of the Republic: Utrecht – Petrus van Musschenbroek (1692–1761),[12] appointed in 1723; Franeker – Johannes Oosterdijk Schacht (1704–1792), appointed in 1727; and Harderwijk – Johan Hendrik van Lom (1704–1763),[13] appointed in 1734. Nearly everywhere it replaced Cartesianism as the framework for the teaching of philosophy. In the Netherlands the University of Groningen was an exception in that it resisted the general eighteenth-century Dutch tendency towards Newtonianism by adopting Wolffianism together with the university's German hinterland.[14] The academic Newtonianism of the four other universities in the United Provinces was open as well, because 's Gravesande categorically rejected a slavish imitation of the British scientist.[15]

Moreover, the particular nature of Dutch academic Newtonianism appears from its attitude towards physico-theology. With good reason Jonathan Israel observed that contrary to the Newtonians outside the universities, 's Gravesande ignored physico-theology, which attempted to prove God's existence and His attributes from the order of nature, observed by the senses.[16] With the exception of Van Musschenbroek in his address *De sapientia divina* (1744), none of the major academic Newtonians ever dealt with this hybrid of experimental physics and theology.[17] 's Gravesande and his school realized that the empirical knowledge of God and the divine attributes is pointless when trying to prove the reliability of the senses and the viability of the empirical sciences and of the laws of nature. The justification of Newtonian physics in such a manner is a vicious circle and would have been a fallacy without any philosophical significance. Hence, 's Gravesande and his Newtonian school attempted to supply such a justification of physics by means of the a priori science of metaphysics.

The argument of this article is that Newtonianism at the Dutch universities, or 'Newtonian philosophy', the term current in the eighteenth century, was primarily conceived as a philosophical system. It does not rely on the use of the word 'philosophy' in contemporary sources. In the juxtaposition of disciplines in the teaching assignment of Van Swinden, philosophy is apparently not to be taken in the traditional sense of a master discipline covering all things divine and human.[18] The word is here obviously used in the more specific meaning of physics. At that time this specific meaning of philosophy was rather current and as late as the first half of the nineteenth century it remained usual in the Netherlands to use the word in the sense of physics. In an 1828 essay on the deplorable state of philosophy at the university, after the split of the faculty of philosophy into a faculty of physics and mathematics on the one hand and a faculty of humanities on the other, Jacob Nieuwenhuis (1777–1857), the Leiden professor of speculative philosophy, drew attention to the fact that it was not the new faculty of the humanities that inherited the name philosophy, but the new faculty of mathematics and physics which popularly continued to be called the faculty of philosophy.[19] However, although the word philosophy in the eighteenth-century phrase *philosophia Newtoniana* may well mean physics, the fact remains that Van Swinden at Franeker and the other Newtonian professors had to teach the whole of philosophy and were forced to place their scientific activities within the context of a full-fledged philosophical system. Therefore, at the Dutch universities Newtonianism had been more than a method of physics.[20]

In the outline of this academic Newtonianism, I will be mainly guid-



PHYSICES
ELEMENTA
MATHEMATICA,
EXPERIMENTIS CONFIRMATA.
Sive
Introductio ad Philosophiam
NEWTONIANAM.
Auctore
GULIELMO JACOBO 'S GRAVESANDE.
TOMUS PRIMUS.
Editio Tertia duplo auctior.

LEIDAE,
Apud { JOHANNEM ARNOLDUM LANGERAK, JOHANNEM ET HERMANNUM VERBEEK. } Bibliop.
MDCCXLII.

Fig. 1:
Title page of 's Gravensande's manual

ed by the texts of Van Swinden's academic addresses and his manual of philosophy. Although in his philosophical writings he took no new course, he more than other Newtonians tended to call all parts of his philosophy 'Newtonian'. Hence, his writings may be safely used to deal with the particular nature of the Newtonian philosophical system taught at the Dutch universities, which like other eighteenth-century philosophical systems consisted of interrelated notions of method, epistemology and metaphysics. The first section will present an outline of Van Swinden's intellectual biography. Such an overview will facilitate our understanding of the social and institutional background of Dutch academic Newtonianism. Van Swinden's rectorial address, the *Oratio de philosophia Newtoniana*, typifies the notions of philosophical method (second section). The third second section will deal with the epistemology at the basis of it. The fourth section will discuss the Newtonian metaphysics that justifies this epistemology. The final section will contain some remarks on the intellectual and institutional context of this form of Newtonianism.

Life and works of Van Swinden (1746–1823)

Van Swinden was born in 1746 at The Hague.[21] In 1763 he matriculated as a law student at Leiden University, but also attended the philosophy lectures of 's Gravesande's successor J.N.S. Allamand (1713–1787) and the mathematical lessons of Johann Friedrich Hennert (1733–1813), a pupil of Euler at Berlin, who ran a mathematical school at Leiden and in 1764 was appointed professor of philosophy, mathematics and astronomy at Utrecht University. On 12 June 1766 Van Swinden took his philosophical degree by discussing the typical Newtonian topic of the force of attraction. The first three of the theses appended to his dissertation summarize the basic principles of 's Gravesande's philosophy: the metaphysical proof of God (thesis 1), the notion of moral necessity of the will (thesis 2), and the dualistic epistemology (thesis 3).[22] A year later Van Swinden accepted a chair in Franeker, which covered philosophy, logic and metaphysics. The philosophical interests Van Swinden cultivated at Franeker, besides his many scientific pursuits, are apparent from his Franeker inaugural address of 1767, which dealt with the causes of error in philosophy.

For eighteen years, until 1785, Van Swinden remained a professor at Franeker. His years spent there were a period of much original work in the fields of electricity, magnetism, meteorology and the northern lights. His strength lay in his internationally acclaimed observational and experimental work. An impressive part of his activities is the series of meteorological observations made during the years 1771–1784, which in the first six years were done on an hourly basis. The results of these observations were published in the journals of several scientific academies, sometimes in Latin and Dutch, but mostly in French. In 1777 he together with Ch.A. Coulomb (1736–1806) received a gold medal awarded by the Paris Academy of the Sciences for his prize essay on magnetic needles. His teaching of physics resulted in a manual entitled *Positiones physicae* and several disputations, dealing for example with the elasticity of water and of air, the nature of fire, electricity and the Leyden jar.

Van Swinden, however, taught philosophy as well. From 1767 till 1775, the year a budget cut of the university precluded their continuation, eight disputations were published, which by their continuous pagination were meant to form a manual of philosophy with the title *Cogitationes de variis philosophiae capitibus* (Thoughts about Various Chapters of Philosophy).

In 1785 the Amsterdam magistrate offered Van Swinden a professorship at the Amsterdam Illustrious School. This chair not only covered mathematics, physics and astronomy, but also metaphysics. Although the Amsterdam Illustrious School (Athenaeum Illustre) was no university, Van Swinden accepted, since he would earn a salary that was double his Franeker wages. His inaugural address, *De hypothesibus physicis quomodo sint e mente Newtoni intelligendae,* which referred to Newton in the title, had no less than 111 pages in its printed form, but it dealt with a special topic of Newtonian method already touched upon in the Franeker rectorial address: the concept of hypothesis. Here he advanced his conviction that Newton never denied the need for hypotheses in physics. During his Amsterdam years Van Swinden did not publish on philosophy again. Apparently at the Amsterdam Athenaeum, which, being no university, in principle did not produce theologians, physicians or lawyers, there was no longer a need to deal with the philosophical presuppositions of the sciences. In this respect he anticipated the emancipation of the sciences from philosophy at the Dutch universities. After the 1795 Batavian revolution Van Swinden briefly became a minister in the Batavian government. In 1808 he became president of the Mathematical and Physical Department of the first Dutch national Academy of Sciences, established by King Louis Napoleon. After the Napoleonic era he was appointed councillor of state by King William I. He died in 1823. The next year his library was sold. His collection gives evidence of the wide range of the philosophical interests he entertained besides his scientific endeavours. Van Swinden possessed books by Spinoza, Wolff, Kant – in Latin and the original German – and the Dutch Kantians, P. van Hemert (1757–1825) and J. Kinker (1764–1845).[23] Apparently Van Swinden did not buy philosophical books published after the first years of the nineteenth century.

The philosophical method

Basic to every philosophy are its notions on scientific method and epistemology (dealt with in the next section). Van Swinden dealt with his notions on method in his 1779 rectorial address on Newtonian philosophy in Franeker. He began by observing that after the renaissance of the sciences in the sixteenth century many philosophers and scholars flourished.[24] Although many deserve our praise and admiration on account of their teaching, ingenuity of mind and their art of discovering new things, no man has to be extolled more than Isaac Newton, Van Swinden concludes after two pages of academic rhetoric.[25] In order to confirm this view he quotes a verse taken from Edmund Halley's commendatory poem in the *Principia* ('no mortal may approach nearer to the gods') and Herman Boerhaave's lavish laudation of Newton as 'a man in whom Nature has revealed the acme of human perspicacity'.[26] The religious overtone in the Halley verse is no literary device, for as Van Swinden underlined it was the 'Supreme Maker and Ruler' who aimed at man's blessedness by removing the darkness and obscurity brought forth by scholasticism, which veiled the face of nature, by sending Newton to restore natural philosophy.[27] God elected Newton to accomplish the task which his predecessors had begun. According to Van Swinden, Newton represented a crucial moment in the history of God's relations with mankind: 'in order to complete this work the divine providence generated Newton'.[28] In this view it was Newton who created the highway of philosophy by combining the two previous roads taken by mankind. Some scholars followed in the footsteps of Descartes and practised the mathematical sciences (page 11), other scholars, such as Galileo, Toricelli, Boyle and Mariotte, joined forces and created a complete 'catalogue of the phenomena' (page 12). Through this dichotomy Van Swinden transforms Newtonianism into a synthesis of all preceding thought by observing that Newton combined the mathematics of the Cartesian tradition with an empirical approach in natural philosophy. Hence, according to Van Swinden, Newton's greatness is due to the powers granted him by God to transcend the limitations of rationalism and empiricism by establishing a new method in philosophy.[29] Newton's successors all followed in his footsteps and combined mathematics and observation, reason and experience, in the practise of natural philosophy. In the second part of his address Van Swinden dealt with Newton's scientific achievements. However, in his argument he wanted to ignore these accomplishments, together with Newton's research in the fields of chronometry, metaphysics and theology, since Newtonianism in his view was primarily to be seen as a method, which complemented the Wolffian notions on method (pages 39–40). Van Swinden reminded his audience that exactly thirty years earlier his predecessor Samuel Koenig (1712–1752) had held his inaugural address by dealing with the harmony between the Newtonian and Wolffian methods of philosophizing. However, Van Swinden's predecessor only dealt with the Wolffian method and a second oration dealing with Newtonianism remained an unfulfilled promise till Van Swinden undertook this task (page 41).

According to Van Swinden – and many others – Newton described his method in a nutshell in query 28, observing: 'the main business of natural philosophy is to argue from phenomena without feigning hypotheses and to deduce causes from effects till we come to the very first cause'.[30] This observation implied three principles:

1. In natural things only claims are to be admitted which are substantiated by empirical observation.
2. Most hypotheses are to be rejected; some, however, are to be examined and applied.
3. It is all-important, after investigating the degrees of certainty of all our knowledge, to keep certain and uncertain things apart.

The truth of the first methodological principle is obvious. If we ignore this principle, Van Swinden states, then just like Descartes we arrive at studying a factious universe instead of the universe created by God.[31] However, we are unable to investigate many things by means of the senses and these have to be examined by reason alone. The implication of this conclusion is that Newton – and Newtonianism – did not attempt to reduce the whole of philosophy to mere experimental philosophy. Experimental and rational philosophy should be combined and a real marriage of experience and reason is to be aimed at.[32] The same programme was formulated by Van Swinden's Wolffian predecessor thirty years earlier and exemplifies the tendency of Dutch philosophy during the eighteenth century to link the new experimental sciences to a more general philosophical context of non-empirical sciences. The consequence of the need felt both in the Newtonian and Wolffian method to link empirical and intellectual knowledge is that according to Van Swinden, Newton did admit hypotheses. The famous '*hypotheses non fingo*' of the *General scholium,* therefore, only refers to false or metaphysical hypotheses (page 48). Van Swinden's *bête noir* is in this respect Descartes who in the *Principles of Philosophy* I, 24, advocated an utterly false method – *verae scientiae adversa* – by observing that, as God is the cause of all things, it would be wise in philosophy to attempt to explain natural phenomena by means of our knowledge of God. The nefarious effect of this intermingling of metaphysics and the empirical sciences had been that the French philosopher, by severing the necessary link with experience and observation, led the sciences into the field of fiction and error. In order to distinguish false 'Cartesian' from sensible 'Newtonian' hypotheses, Van Swinden once more refers to the Queries (I quote from the English original, although as in the previous quotation the Latin not exactly renders Newton's words):

> in natural philosophy the investigation of difficult things by the method of analysis ought ever to precede the method of composition. This method of analysis consists in making experiments and observations and in drawing general conclusions from them by induction and admitting of no objections against the conclusions but such are as taken from experiments or other certain truths.

Van Swinden's reading of Newton is one of the better examples of creative hermeneutics, since the next (not quoted) sentence in Newton's text runs: 'for hypotheses are not to be regarded in experimental philosophy'.[33]

The last principle of the Newtonian method exhorts the philosopher to respect the order of the sciences, which precludes the deduction of physics from metaphysics. Leibniz readily but erroneously inferred from final causes and the general principles of metaphysics how things in sensory reality should be. God's wisdom, for example, led him to deny the existence of the void (page 56), while Wolff argued for the universality of mechanical explanations on account of God's power (page 60). Such arguments are pointless if they are not corroborated by the phenomena. We may sum up Van Swinden's argument as follows: Newtonianism is a method which first of all presupposes the epistemological need to link reason and observation, and which follows from the metaphysical dualism of bodies and minds (dealt with in the following sections).

Newtonian epistemology: *Oratio inauguralis de causis errorum*

The new Franeker professor began his discourse by laying down the two basic metaphysical principles of Dutch Newtonianism. Van Swinden established the first principle, namely of nature's order, by observing that all human knowledge is based on Cartesian introspection.[34] By contemplating our mind we become clearly and distinctly aware that we are endowed with the powers to know the ultimate Truth and the means to attain our happiness.[35] Moreover, we know that in us a 'natural instinct' exists aiming at our good and a reason enabling us to know that good, although vice disturbs this natural order and installs itself by false education and the imitation of false examples. They cause immoderate appetites in our minds for honour and greed, through unnatural passions.[36] Hence, just as philosophers had done from Plato and Aristotle onwards, Van Swinden believes that the science of nature intrinsically possesses a moral significance. Moreover, we acknowledge the all-embracing order in the universe. This metaphysical notion of order constitutes the metaphysical base of the epistemology of Dutch Newtonianism and forms part of the natural law tradition.

The second metaphysical principle advanced by Van Swinden is a Cartesian dualism between mind and body. By contemplating ourselves we know that on the one hand there are spiritual substances existing eternally, unchangingly and acting freely, while on the hand there are bodies, which are changeable, existing in time and determined by necessary causes.[37]

From this metaphysical dualism Van Swinden in a natural manner deduces two general epistemological notions. One is a basic epistemological dualism. The material universe we know by observation and the intelligible world by reason. The truth of our ideas of immaterial entities we assess in a Cartesian reflective manner by considering their intrinsic attributes of clearness and distinctness alone. Hence in the sciences dealing with immaterial substances, such as metaphysics and mathematics, we can rely on arguments which use the geometrical method.[38] These rational sciences, therefore, are in principle exempt from error and dispute. Contrary to the physicists, mathematicians readily accept each other's inferences, and between the mathematics of the ancients and the moderns there is a substantial agreement. On the other hand, the knowledge of the bodily world begins with the observation of phenomena. Only by using our senses do we ascertain the truth of our ideas about bodies and their properties. The sole application of the a priori method of geometry in the empirical science of physics resulted in 'the monstrous doctrines of Spinoza's *Ethics*'.[39] Other examples of philosophers who ignored this epistemological dualism are Leibniz with his doctrine of monads (page 18) and Descartes with his laws of motion (page 33), which are deduced in an a priori manner from God's attributes without consulting the senses and without seeking confirmation by observation.

The second epistemological inference from his metaphysical dualism is a limited 'scepticism', that is to say, the need to accept the limits of human knowledge. Of certain phenomena we have mere empirical or factual knowledge, and we are unable to acquire full insight in their causes.[40] Our knowledge of the material world is basically of an a posteriori nature and does not transcend the limits of the senses. By contemplating ourselves we know that we consist of a mind and a body, two distinct beings. At the same time experience teaches us that although body and mind interact, how this interaction is produced we do not know.[41] Since Van Swinden hardly comments on this scepticism, I turn to 's Gravesande's teachings. In the eighteenth century this metaphysical theory of mind-body relation went by the name of *influxus physicus* and it was generally opposed to the doctrines of Cartesian occasionalism and Leibnizian pre-established harmony. Although the theory of bodily interaction rests on experience, it is inconsistent with arguments that 's Gravesande tends to consider irrefutable. 'How can a thing which is by no means material resist the action of a body?'[42]

More in general: we know bodies by the effects they produce on our senses, that is to say the phenomena, but of their substantial nature we have only a partial understanding.[43] This scepticism in Van Swinden's epistemology may be derived from Locke.[44] The British philosopher in his famous *Essay Concerning Human Understanding* denied our having any knowledge of the real essences of substances. Of substances we can have no certain but only probable knowledge, or in Locke's words, opinion or belief. In the case of substances, Locke prefers the 'historical, plain method' to the geometrical method (*Essay* 1,2), but 's Gravesande and Van Swinden did not share Locke's preference.

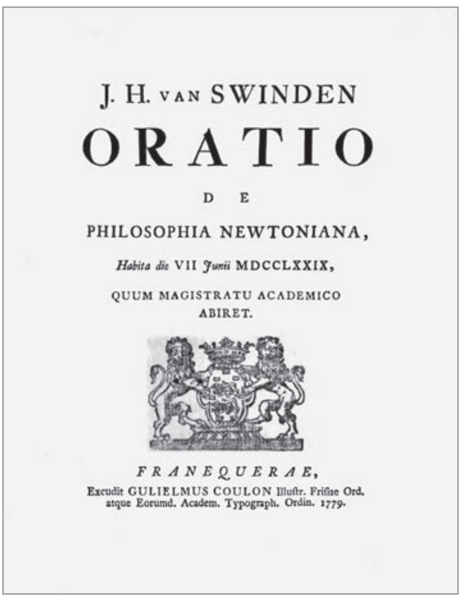
What is more, Van Swinden's scepticism resulted in the notion of a discontinuity between metaphysics and physics, which undermined the Cartesian belief that philosophy or the encyclopaedia of the sciences may be compared to a tree, the roots being metaphysics, the trunk physics and the other sciences its branches.[45] According to Van Swinden, metaphysical principles applied in physics are regulative ideas, if I may use this Kantian notion here anachronistically. The so-called law of continuity, which states that natural phenomena give evidence of a continuous sequence and which apparently directly follows from the metaphysical notion of the order of nature, for example, the metaphysical law of continuity seems to preclude the existence of perfectly solid bodies, which suddenly lose their velocity (page 33). Such an abrupt change would mean an infraction of this metaphysical principle. Hence, if we observe phenomena that apparently contradict this law, we have to call into question the accuracy of the empirical data. However, the adoption of metaphysical principles in empirical science often leads to error. An example given by Van Swinden is the Jesuit mathematician and philosopher R.G. Boscovitsch (1711–1787), who used this principle to argue for the hypothesis that a body consists of a series of mathematical points kept together by the force of attraction (page 34). According to Van Swinden, such a theory is false and its falsity is caused by the reckless use of principles which in themselves are true. On the other hand, the metaphysical law of simplicity was used with good reason by Leibniz and Descartes to elucidate the laws of light's refraction by arguing that nature chooses the shortest way in the shortest time and by P.L. de Maupertuis (1698–1759) in his attempts to prove that the amount of action involved in all motion remains constant (page 35). Such hypotheses agree with all physical truths known to us. Van Swinden, therefore, accepts the heuristic value of metaphysical principles, but in general the physicist should refrain from using final causes to discover the laws of nature. According to the Calvinist Van Swinden, the metaphysical order remains to a large extent unknown to our limited intellect.[46] However, we do know what is useful and required to attain our end in this life.

Cogitationes de variis philosophiae capitibus

The eight dissertations from Van Swinden's Franeker period that made up the *Cogitationes de variis philosophiae capitibus* develop the principles that Van Swinden outlined in his inaugural address. It should be noted that of the seven students who presented these disputations compiled in a manual of the professor and published under his name, as was usual at the premodern Dutch universities, four studied theology, two were medical students and only one is recorded as a student of 'humanities and philosophy'.[47] This fact reminds us of the propedeutic character of the teaching of philosophy and physics at the universities during the Enlightenment. Nearly all students ended their educational career not as philosophers or scientists, but as lawyers, ministers or physicians. The basis of Van Swinden's manual is 's Gravesande's popular *Introductio ad philosophiam,* widely read in its eight contemporary editions and its French and Dutch versions, which, however, was modified at several points.[48] For example, although both philosophers began their manual with metaphysics, the Leiden philosopher started with ontology, observing that metaphysics is useful because it acquaints us with abstract ideas and so enables the mind to be effective in the study of truth.[49] However, Van Swinden began with natural theology and the teleological order in the universe, a topic that 's Gravesande only touched upon in the second logical part where he dealt with the evidence of the senses.[50] In the first dissertation (submitted by G. Coopmans, who in 1770 presented a physical thesis on the winds, and afterwards became a professor of medicine), Van Swinden observed that from ideas immediately present in our mind we necessarily and a priori deduce the existence of an infinite and perfect Being.[51] Hence, according to metaphysics, every being possesses its proper goal and as part of the whole of nature partakes in its common end. In order to reach this common end the relations between the parts have to be fixed: the same causes should always have the same effects, as Newton with good reason, Van Swinden observed, recorded in his second rule.[52] From this metaphysical premise, Van Swinden infers the invariability of the laws of nature.[53] However, due to the limitations of our intellect, our knowledge of this metaphysical order is only fragmentary.[54] For example, we know that both in the material and in the intelligible world all things happen in accordance with the eternal decrees of God. Yet we are also certain that a will acting in accordance with its own laws is free. How both certainties are to be reconciled is a mystery.[55] The same applies to the material world. Bodies are apparently inert: without an external cause setting them in motion they do not move. However, as far as we know attraction is neither caused by an external cause, nor is an inner property of a body. The first disputation ends by observing that miracles as such (that is, with respect to God) are impossible. However, with respect to man, in possession of a limited intellect only, they obviously occur.[56] To quote Van Swinden's own example, the making of ice is a miracle to an African, unless the natural laws, which are used in the production of ice, are explained to him (page 18). Moreover, the common people often consider miraculous natural phenomena, which the scientist fully understands, thanks to his insight into the inflexible rules God uses to govern the world. The limits of our understanding force us to accept the fact that for us the universe will always be of miraculous nature. It is this scepticism, which prevents Van Swinden from adopting a full-fledged Spinozistic determinism. The universe is ruled by invariable laws of nature determined by God, who by His unchanging nature precluded the existence of miracles. However, our knowledge of God's nature is limited. Hence, Van Swinden did not adopt Nieuwentijt's and 's Gravesande's voluntaristic view of natural laws.

The second disputation in Van Swinden's manual was presented by F.N. de Villepoix, a student of theology, and deals with logic. It focuses on the distinction between ideas 's Gravesande made in chapters 6 and 13 of the second book of his *Introductio*. On the one hand, we know ideas originating in the mind itself. Such ideas concern the determinations of our will, our memory, the operations of our intellect, and our passions. We may have an idea of a pain without knowing its cause in our body.[57] Our judgements consisting of such ideas are certain, because the mind immediately perceives the relation between the ideas involved. This direct evidence, according to Van Swinden and 's Gravesande, results in mathematical certainty. On the other hand there are ideas produced in the mind by means of the senses. Such ideas denote an object in the material world outside the mind. Judgements passed by means of such ideas possess moral certainty, which may equal the certainty of mathematically evident judgements but is indirect.[58] The mind perceives the link between the combined ideas by using the senses – in observation or experiment, in analogy or the testimony of others (page 28). 's Gravesande's distinction of these three means was adopted by Van Swinden, but he noted that in fact all three amounted to experience.[59] Hence he summarizes his logic by stating that reason and experience are the two sources of our knowledge. Their relation was a basic theme that had engaged the minds of Dutch philosophers since the final phase of Dutch Cartesianism.[60] Moreover, Dutch Newtonians underlined the fact that both forms of knowledge were of a scientific nature. Although empirical knowledge is often merely probable, something in between perfect science and ignorance, with the help of mathematics we can determine the precise degree of probability of a judgement. Instead of the two short chapters in 's Gravesande's *Introductio*, Van Swinden elaborates for some eighty pages on mathematical probability. He stresses that the *ars conjecturandi*, the art of guessing, is a science as well, based on two metaphysical principles: first, that the whole of the universe is governed by unchanging laws, and second, the Leibnizian principle of sufficient reason.[61] From this point in the argument onwards, which continues by dealing with error, method and syllogism, Van Swinden does not follow the *Introductio* any longer.

He next discusses the order of the sciences and their epistemological principles. 's Gravesande had dealt with this important topic not in his *Introductio* but in the address he had delivered in 1724 when resigning as rector of Leiden University. Applying the distinction between moral and mathematical evidence to the sciences, he sets those sciences that are based upon rational ideas and use the geometrical method apart from the empirical sciences. The first group consists of mathematics, both pure and applied, logic, ontology, natural theology and the universal principles of moral philosophy. The second group consists of physics, history, Christian theology and social morality. The ideas of these sciences denote objects in the material world existing outside the mind and are therefore of an empirical nature. Van Swinden replaces 's Gravesande's clear-cut dichotomy with an encyclopaedia of the sciences containing many gradations. On the one hand there is mathematics, the only rational and a priori science both with respect to method and ideas; on the other hand there are the historical sciences, which are empirical both with respect to method and ideas. In this scheme the other sciences are placed in between. Metaphysics, for example, is not a pure science, since its ideas of substance, mode, being and cause are learned by experience and only afterwards abstracted by the intellect.[62] Moreover, if metaphysics is to be of any use it must be applied to and checked against the phenom-


J. H. VAN SWINDEN

ORATIO

DE

PHILOSOPHIA NEWTONIANA,

Habita die VII *Junii* MDCCLXXIX,

QUUM MAGISTRATU ACADEMICO
ABIRET.

FRANEQUERAE,

Excudit GULIELMUS COULON Illustr. Frisiae Ord.
atque Eorumd. Academ. Typograph. Ordin. 1779.

Fig. 2:
The title page of Van Swinden's address.

ena observed by the senses. So this part of Van Swinden's argument restricts the significance of the rational sciences. On the other hand Van Swinden seems to underline the rational element in the empirical sciences by arguing for the use of mathematics in all natural sciences, even in chemistry and biology. In conclusion, it might be observed that the *Cogitationes philosophicae* does not contain substantially new notions, but only develops the philosophical principles of the academic addresses.

The university context

At the end of this article outlining Dutch academic Newtonianism as adopted by 's Gravesande and his successors, some remarks will be made in order to explain why Dutch Newtonians were not only scientists but also philosophers. In the first place, Dutch scientists were academics, working at a faculty of philosophy. The first scientific society, the Hollandsche Maatschappij der Wetenschappen (Dutch Society of Sciences) at Haarlem, was only established in 1752. The teaching in the faculty of philosophy was general and propedeutic, most students completing their education in the higher faculties, which gave access to certain learned professions.[63] Where in the modern universities the teaching aims at the training of experts in a particular branch of learning, pre-modern universities continued to provide a general education. This institutional context forced the professors of philosophy, who in general had a broad teaching assignment not restricted to physics, astronomy or mathematics, to include logic and metaphysics in their teaching.

My second remark concerns the reading public of Dutch Newtonian texts. The readers of scientific and philosophical texts produced at the universities were either students or members of the so-called 'learned class' who thanks to their education could read Latin. Latin remained the official language of instruction at the Dutch universities well into the nineteenth century.[64] However, at the end of the eighteenth century more and more scholarly literature was becoming available in Dutch translations. Manuals, academic addresses and even disputations were often translated into Dutch. However, the reading public basically remained the class of citizens with a broad cultural and social interest, instead of experts who more naturally found their way to the specialist dissertations and journals published by the learned societies. This appears, for example, from the translation of Van Swinden's manual of physics written during his Franeker period, the *Positiones physicae* and published in 1792. In the preface Van Swinden observed that the translation aimed at young people eager to acquire 'true learning'. Such learning had to be encyclopaedic, consisting of *belles-lettres*, history, logic and the philosophical and mathematical disciplines.[65] Philosophy included the knowledge of God, of ourselves and of nature.[66] Physics, however, he observed, was seldom studied by those who aimed at a specialised and intimate knowledge of some particular subjects, but Van Swinden wrote for those not professionally interested in physics.[67] Such writing called for an overview of the general principles of a particular science and an orderly treatment of the subject matter.[68] Hence even in his non-academic writing the scientist Van Swinden had to be a philosopher as well. Apparently this dual function of the professors of philosophy at the Dutch universities during the eighteenth century stimulated Dutch academic Newtonians to develop a Newtonianism, which was both a scientific theory and a philosophical system.

Notes

1 J.H. van Swinden, *Oratio de philosophia Newtoniana, habita die VII Junii MDCCLXXIX, quum magistratu academico abiret* (Franeker 1779) [22], 82, [13] pages.

2 Cf Vermij's contribution to this volume.

3 F. Sassen, *Geschiedenis van de wijsbegeerte in Nederland* (Amsterdam 1959), pp. 218–222. Sassen preferred the designation 'experimental philosophy' or 'empiricism', which, however, in his view on account of its eclecticism lacked all philosophical depth. Cf my 'Die niederländische Newtonianismus', in: H. Holzhey and V. Mudroch (eds), *Grundriss der Geschichte der Philosophie: die Philosophie des 18. Jahrhunderts,* Vol. 2, *Grossbritannien und Nordamerika, Niederlande* (Basel 2004), pp. 1094–1112.

4 J.H. Zedler, *Grosses vollständiges Universal Lexicon aller Wissenschaften und Künste, welche bißhero durch menschlichen Verstand und Witz erfunden und verbessert worden* (Halle and Leipzig 1731–1751), vol. 24, coll. 413–416, 414: *'so haben sich doch unter den Ausländer nicht wenige gefunden welche den herrn Newton zwar für einen unstreitig großen Mathematicum von ersten Rang, aber nur für einen mittelmäßigen Philosophen gehalten haben'.*

5 Th. Ahnhert, 'Newtonianism in early Enlightenment Germany, c. 1720 to

1750: metaphysics and the critique of dogmatic philosophy', *Studies in history and philosophy of science* 35 (2004), special issue on Newton and Newtonianism (ed. S. Mandelbrote), pp. 471–491, on p. 482.

6 E. van der Wall, 'Newtonianism and religion in the Netherlands', *Studies in history and philosophy of science* 35 (2004), special issue on Newton and Newtonianism (ed. S. Mandelbrote) (note 5), pp. 493–514.

7 Ibidem, p. 494.

8 M. Jacob, 'Introduction', in: J.E. Force and S. Hutton (eds), *Newton and Newtonianism: new studies* (Dordrecht 2004), pp. ix-xvii, on p. xi.

9 D. Diderot and J. le Rond d'Alembert (eds), *Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des métiers* (Paris 1751–1780), vol. 11, p. 1222; see I. Bernard Cohen, *Franklin and Newton* (Philadelphia 1956), pp. 179–183, and the 'Introduction' in: I. Bernard Cohen and G.E. Smith (eds), *The Cambridge companion to Newton* (Cambridge 2002), pp. 29–31. See also R.E. Schofield, 'An evolutionary taxonomy of eighteenth-century Newtonianisms', *Studies in eighteenth-century culture* 7 (1978), pp. 175–194.

10 Still the most basic study of his thought is G. Gori, *La fondazione dell'esperienza in 's Gravesande,* pubblicazioni del Centro di studi del pensiero filosofico del cinquecento e del seicento in relazione ai problemi della scienza del Consiglo Nazionale delle ricerche Studi 2, Serie I (Florence 1972).

11 The title in the contemporary English translation by Desaguliers ran *Mathematical elements of natural philosophy, confirmed by experiments or an introduction to Sir Isaac Newton's philosophy* (London 1720–1721). See the contribution by Jorink and Zuidervaart in this volume.

12 C. de Pater, *Petrus van Musschenbroek (1692–1761), een newtoniaans natuuronderzoeker* (PhD-thesis, Utrecht 1979).

13 H.A. Krop. 'Tussen wetenschap en levensleer. de beoefening van de wijsbegeerte aan de universiteit te Harderwijk', in: J.A.H. Bots et al. (ed.), *Het Gelders Athene: bijdragen tot de geschiedenis van de Gelderse Universiteit in Harderwijk (1648–1811)* (Hilversum 2000), pp. 133–162, on 145–157.

14 M.J. Petry and M.R. Wielema, 'Antonius Brugmans (1732–1789), bruggenbouwer in de filosofie' and M.R. Wielema, 'Nicolaus Engelhard (1696–1765), de leibniz-wolffiaanse metafysica te Groningen', in: H.A. Krop, J.A. van Ruler and A.J. Vanderjagt (eds), *Zeer kundige professoren: beoefening van de filosofie in Groningen van 1614 tot 1996* (Hilversum 1997), pp. 135–147 and 149–161.

15 W.J. 's Gravesande, 'Monitum ad lectorem', *Physices elementa mathematica* 2 vols (Leiden 1725), vol. 1, p. v. English version 'To the reader', *Mathematical elements of natural philosophy*, 2 vols (London 1737), vol. 1, p. xi: 'He only who in Physics reasons from the phaenomena, rejecting all feign'd hypotheses, and pursues this method inviolably to the best of his

power, endeavours to follow the steps of Sir Isaac Newton, and very justly declares that he is a Newtonian philosopher; and not he who implicitly follows the opinion of any particular person.'

16 J. Israel, *Enlightenment contested: philosophy, modernity and the emancipation of man (1670–1752)* (Oxford 2008), pp. 216–218.

17 De Pater, *Musschenbroek* (note 12), pp. 318–324.

18 Zedler, *Universal Lexicon* (note 4) vol 27, p. 2014, and Diderot and d'Alembert (eds), *Encyclopédie, ou dictionnaire raisonné* (note 9), vol. 12, p. 512 s.v. 'philosophie'.

19 J. Nieuwenhuis, *Gedachten over het akademisch onderwijs der bespiegelende wijsbegeerte in het Koningrijk der Nederlanden* (Leiden 1828), p. 27: *'bij de wis- en natuurkundige faculteit, die zij [philosophy] heeft moeten verlaten, heeft zij haren naam als erftitel achtergelaten'*.

20 E.G. Ruestow, *Physics at seventeenth- and eighteenth-century Leiden. philosophy and the new science in the university* (The Hague 1973), p. 121, who to that end quotes from 's Gravesande's *Philosophiae Newtonianae institutiones*: 'we justifiably call Newtonian that philosophy in which hypotheses having been rejected, conclusions are deduced from phenomena. No one before Newton followed that method unremittingly.' See also De Pater, *Petrus van Musschenbroek* (note 12), ch. 3.

21 His biography in S.H.M. Galama, *Het wijsgerig onderwijs aan de Hogeschool te Franeker (1585–1811)* (Franeker 1954), pp. 177–181; M. van Hoorn, 'Jan Hendrik van Swinden (1746–1823), een gemeenebestgezind geleerde', in: J.H. van Swinden, *Beschrijving van het Eijsinga-planetarium te Franeker* (fotomechanische herdruk van het oorspronkelijke werk uit 1851; Franeker 1994), pp. ix-xxv; M. van Hoorn, 'De gemeenebestgezindheid van Jan Hendrik van Swinden (1746–1823)', in: E.O.G. Haitsma Mulier et al. (eds), *Athenaeum Illustre, elf studies over de Amsterdamse Doorluchtige School (1632–1877)* (Amsterdam 1999), pp. 227–231. About his views on educational politics: B. Theunissen *'Nut en nog eens nut', wetenschapsbeelden van Nederlandse natuuronderzoekers (1800–1900)* (Hilversum 2000), pp. 13–36.

22 J.H. van Swinden, *Dissertatio philosophica inauguralis, de attractione* (Leiden 1766), p. 76 (between brackets the source in the writings of 's Gravesande). The theses are: *'Causarum effectuumque series infinata dari non potest'* (cf. J.N.S. Allamand (ed.) *Oeuvres philosophiques et mathématiques de Mr. G.J. 's Gravesande*, 2 vols (Amsterdam 1774), vol. 2, p. 1. 'Essai de métaphysique' 2, II, pp. 176–180) and *'Actiones hominis liberae pendent ab voluntate, voluntas ab judicio, judicium ab ideis'* (cf. G.J 's Gravesande, *Introduction à la philosophie* (Leiden 1737), part 1, ch. 12) and 'Ideas seu notiones omnes sensuum ac reflexionum acquirimus' (*Introduction à la philosophie*, part 2, ch. 19).

23 *Catalogue des livres de la bibliothèque de feu Mr. Jean Henri van Swinden*

(Amsterdam 1823). It is interesting to note that in the title of this catalogue and in the *avertissement,* 'philosophy' is used unambiguously in the modern sense, opposing it to the '*sciences exactes*', '*théologie*', '*histoire naturelle*', '*chemie*', '*belles lettres*' and '*histoire naturelle*'.

24 Van Swinden, *Oratio de philosophia Newtoniana* (note 1), p. 3: *'a renatis scientiis haud pauci floruerint philosophi, viri doctrina et ingenio eminentes, et de republica litteraria optime meriti [...] novas veritatem inveniendi atque demonstrandi aperuerunt vias'*.

25 Ibidem, p. 4: *'nullus [...] honoribus dignior quam Isaacus Newton'*.

26 Ibidem, p. 8: *'natura ultimam posuisse videtur perspicientiae humanae metam'* (a note refers to the *Orat. de Chemia suos errores expurgente*, in fine, in: *Boerhaave's orations,* trans. with introd. and notes by E. Kegel-Brinkgreve and A.M. Luyendijk-Elshout (Leiden 1983), p. 212, and: *'Nec fas est proprius mortali adtingere divos.'*

27 Ibidem, *Oratio de philosophia Newtoniana,* p. 9: *'Artifex et Gubernator Deus'*.

28 Ibidem, p. 14: [Newton] *'ad hoc opus perficiendum Divina providentia suscitatum arbitror'*.

29 Ibidem, p. 14: *'nova et inaudita methodo'*.

30 Ibidem, p. 43: *'in rerum sc. proprietates diligenter inquirere, has experimentis stabilire e phaenomenis vero arguere et ab effectis ratiocinatione progredi ad causas donec ad causam omnium primam perveniamus'*. Van Swinden more or less conflates two sentences of Newton. One taken from query 28 and the other from a Latin version of *Philosophical Transactions,* nr. 85, p. 5014.

31 Ibidem, p. 45: *'fictitium condere mundum in animo [...] non veram quem Supremus rerum artifex creavit'*.

32 Ibidem, p. 47: *'multa denique quae scire interest ratione tantum intelligi possunt'*. Hence 'by no means should we either forgo the rational sciences, or pay them hardly any attention. We also do not take pride in the title of empiricists', but *'ubivis experimentalis et rationalis philosophiae connubium'*. For the theme of the *'connubium'*, see my 'Het moeizame einde van een huwelijk (1687–1781), filosofen in de rol van een echtscheidingsadvocaat', *Gewina* 30 (1987), pp. 230–246, with an English summary.

33 Van Swinden, *Oratio de philosophia Newtoniana* (note 1), p. 54: *'methodum analyticam, tamquam primum omnium nostrarum investigationum partem commendat, jubet ut ex institutis experimentis observatis phaenomenis conclusiones inductione inferamus'*. He inaccurately quotes the last query from the Latin version (published at Lausanne and Genève 1740, p. 329).

34 J.H. van Swinden, *Oratio inauguralis De causis errorum in rebus philosophicis* (Franeker 1767), p. 3: *'si quis mentis humanae attente perpendat'*.

35 Ibidem, p. 4–5: *'homines ad imaginem Dei esse confectos [...] eximias mentis faculates iis ad veritatem et felicitatem consequendum datas [...] instinc-*

tu naturali Creatore optimo hominis indito'.

36 Ibidem, p. 6: *'ex mentis facultatibus percipiendi, cogitandi, volendi, agendi [...] patet, nil corporei ad mentis essentiam concurrere'*.

37 Ibidem, p. 3: *'homines partim suapte natura in pejus versa, partim prava educatione partim aliorum exempla inducti. Hinc innumeri in vita instituendi errores, hinc indominati animi affectus, hinc pleraque vitia, hinc omnes pravae hominum actiones'*.

38 Ibidem, p. 13: *'ideae perfectae [...] ab omni parte sunt clarae, distinctae, adequatae [...] Hinc nullae inter mathematicos disputationes nullae pugnae, sed maxima potius stupenda fere inter veterum et recentiorum mathematicorum placita concordia, egegrius inter ea consensus'*.

39 Ibidem, p. 12: *'Spinosae ethicam, quae licet mathematica methodo sic satis concinne digesta, ideo tamen quod falsis notionum substantiae et attributi definitionibus monstra dogmata produxit'*. See also Vermij's contribution in this volume.

40 Ibidem, p. 13: *'limita est mentis vis [...] vix posse ut homines ab errore semper stent immunes'*.

41 's Gravesande, *Introduction à la philosophie* (note 22), vol. 1, ch. 17, p. 36: *'l'expérience est l'unique fondament de cette opinion.'*

42 Ibidem, vol. 1, ch. 17, p. 37: *'Mais ce qui n'est point materiel, peut-il résister au Corps? Qui oserait advancer une pareille proposition?'*

43 Ibidem, vol. 1, ch. 2, p. 4: '*Les substances sont connues que par le moyen de leurs attributes*' and more clearly in the preface of the *Mathematical elements* (note 15), p. xi: 'what substances are, is one of the things hidden from us. We know, for instance, some of the properties of matter, but we are absolutely ignorant, what subject they are inherent in.'

44 P. Schuurman, *Ideas, mental faculties and method: the logic of ideas of Descartes and Locke and its reception in the Dutch Republic (1630–1750)* (Leiden 2004), pp. 137–148.

45 Van Swinden, *Oratio inauguralis* (note 34), p. 33: *'omnia quae ex applicatione metaphysicae ad physicam redundant errores'*.

46 Ibidem, p. 38: *'nimium arcti sunt mentis limites quam ut semper ad scopum Dei in hoc illove phaenomeno producendo assequari queamus'*.

47 J.H. van Swinden, *Cogitationes de variis philosophiae capitibus, quas [...] praeside Johann. Henr. van Swinden [...] publico examini submittit G. Coopmans* [et al.] (Franeker 1767–1775).

48 Gori, *La fondazione dell'esperienza* (note 10), pp. 134–154.

49 Allamand (ed.), *Oeuvres philosophiques* (note 22), vol. 2, p. 1.

50 Van Swinden, *Cogitationes* (note 47), p. 1: *'Deus [...] entia creavit varia determinatas partes agentia ad communem finem.'*

51 Ibidem, p. 5: *'Haec propositio ex ideis immediate menti praesentibus a priori deducta, necessario vera est.'* The order of nature may be deduced a priori from God's wisdom, Van Swinden continues, but it is difficult to

reconcile the doctrine of nature's order a posteriori with 'both moral and physical evil'. This observation implies the pointlessness of physico-theology. Experience might establish the order of nature at most imperfectly.

52 Ibidem, p. 12: *'Quae itaque effectus edunt prorsus eosdem, easdem quoque habent causas, eandem habent naturam. [...] Haec regula eximia veroque philosopho digna a summo Newtono fuit prolata.'*

53 Ibidem, p. 16: *'natura secundum constantes et determinatas agit leges'*. Cf. Vermij's contribution to this volume.

54 Ibidem, p. 3: *'mentis vis limitibus angustissimis circumscribitur'*. Hence: *'omnia probe cognoscere et perfecta habere nullius est aut hominis aut aetatis'*.

55 Ibidem, p. 7: *'hujusmodi repugnantiae apparentes a sola mentis imbecillitate oriundae non solum in mundo intellectuali occurunt, sed et in Physico'*.

56 Ibidem, p. 20: *'miracula nobis philosophis duplice sunt consideranda modo, vel in relatione ad totam rerum in hoc universo existentium seriem et creationis fines i.e. respectu Dei, vel in relatione ad illam seriei istius partem quam cogniscomus et ad nosmet ipsos'*.

57 Ibidem, p. 25: *'alquando similis dolor adest, licet nullus acus nos pugnat. Dolores sentimus, licet nullius causae externae actionem percipiamus'*.

58 Ibidem, p. 30: *'persuasionem aeque validam quam evidentia mathematica'*.

59 Ibidem, p. 30: *'reducantur ad unicum principium'*.

60 Ibidem, p. 32: *'rationem et experientiam esse sola omnium nostrarum cognitionum fundamenta'*.

61 Ibidem, p. 60: *'universum constantibus legibus regi – nil fieri absque ratione sufficiente'. Cf. p. 184: 'haec conjectandi ars immensi est usus'*.

62 Ibidem, p. 189: *'ejus principia esse debent constituta ut absque errore singulis entibus applicari possint'*.

63 L. Roberts, 'Going Dutch, situating science in the Dutch Enlightenment', in W. Clark, J. Golinkski and S. Schaffer (eds), *The sciences in Enlightened Europe* (Chicago 1999), pp. 363–367; G. Wiesenfeldt, *Leerer Raum in Minervas Haus: experimentelle Naturlehre an der Universität Leiden, (1675–1715)* (Amsterdam 2002), ch. 5. Of the students who held disputations under the Leiden professors B. de Volder (1643–1709) and W. Senguerd (1646–1724), as far as facts about their career could be established, the majority were theologians, who afterwards became ministers, while the rest consisted equally of future physicians on the one hand and lawyers and government officials on the other. He sums up (p. 253): *'Von allen Fächern, die an den Universitäten gelehrt wurden, war Philosophie dasjenige, welches am wenigsten in Hinsicht auf eine zukünftige Berufstätigkeit studiert werden konnte.'*

64 This fact made the Republic an exception, as Van Swinden realized, and restricted the usefulness of Dutch academic writing. J.H. van Swinden,

'Voorrede van den schrijver', *Natuurkundige stellingen* (Harderwijk 1792), p. xi: *'het aanhoudend gebruik van de oude schryveren' and p. ix: 'En eindelijk dat op buitenlandsche Akademien, het gebruik om alle wetenschappen, zelfs de zodanige die rechtstreeks Latijnsche en Grieksche litteratuur betreffen in de landstael te behandelen zo sterk was toegenomen, dat [...] de tael alleen waer in dit werk geschreven is, het gebruik van het zelve zoude beletten'.*

65 Ibidem, p. vii: *'fraeie letteren, de geschiedenissen, de oordeelkunde [...] wiskundige en wijsgeerige wetenschappen'.*

66 Ibidem, p. xii: *'kennis van God en van ons zelven en van de natuur'.*

67 Ibidem, p. xv: *'zelden natuurkunde beoefenen om beroepshalven natuurkundige te worden, maar alleen op een wijze, die alle geletterden past'.*

68 Ibidem, p. xiv: *'om de beginselen der Physische wetenschappen en konsten te verstaen'.*

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