

The Dutch Republic. Laboratory of the Scientific Revolution

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Historians agree about the significance of the Scientific Revolution for the development of modern society; there is little agreement, however, as to the nature and the causes of this major shift in our perception of the natural world. In this article, it is argued that we may profit from studying this problem in the context of the Dutch Republic during the seventeenth century, the Republic being in many ways a laboratory of modern life. In this article, three factors often mentioned as contributing to the new scientific themes are explored in the Dutch context. The first factor dealt with is the mingling of scholars and craftsmen; the second the role of the universities as centers of both teaching and research, and the third the congruence of scientific and mercantile values in the early modern Dutch trading communities.

Introduction

While the Scientific Revolution of the seventeenth century is widely acknowledged as one of the decisive transformations in world history, few historians of science would dare state this really was a *revolution*; or even that it was a revolution in *science*. The historical importance of the radical shift in our view of the natural world that occurred in the early modern period is not in dispute: but everything else is. The more we know about the Scientific Revolution, the less we feel sure that there really was a single movement in intellectual history that can be labelled as such.¹

The easiest way out would of be to stop using the term altogether. But this would not solve the problem: we would still face the need to analyse and explain the fundamental changes in the perception of the natural world in the early modern period. A better way to address the problem is to study these changes within a geographically restricted or ‘national’ context. Within the context of a specific cultural or political and institutional region, the ‘span of control’ is simply smaller than in Europe as a whole (assuming that the ‘Scientific Revolution’ was a European event). Knowledge is always produced



The scholars and cartographers Gerard Mercator (1512-1594) and Jodocus Hondius (1563-1612). Both made maps, celestial and world globes, as well as astronomical instruments.

Anonymous, around 1613.

Rijksmuseum, Amsterdam.

locally and initially bears the stamp of its place of origin. Then gradually, on travelling to other places, this knowledge is stripped of its local peculiarities and is transformed into something universally valid, as it becomes set in mathematical formulae or is otherwise formalized. So restricting a study into the causes and the nature of the Scientific Revolution to a specific region is in full accordance with the way knowledge is generated. This restricted area is then treated as if it were some sort of laboratory, where developments can be studied that would otherwise escape our attention or that otherwise are too complicated to approach directly. I would like to outline here why it would be helpful to look at the seventeenth century Dutch Republic as such a laboratory of science.²

Why the Dutch Republic? The Dutch contribution to modern science as it evolved in the seventeenth century has traditionally been underestimated. This was a time when the history of science was regarded as basically a series of successive theories about the natural world. The story about the unfolding of these theories, culminating in Isaac Newton's *Principia Mathematica*, could indeed be told without much reference to Dutch mathematicians and natural

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(Amsterdam 2007). For a recent survey of recent literature on early modern science: Pamela H. Smith, 'Science on the Move: Recent Trends in the History of Early Modern Science', *Renaissance Quarterly* 62 (2009) 345-375.

1 The literature on the concept of the Scientific Revolution is overwhelming. A helpful overview is provided by H. Floris Cohen, *The Scientific Revolution: A Historiographical Inquiry* (Chicago 1994). More recent discussions of the concept include: Steven Shapin, *The Scientific Revolution* (Chicago 1996); Peter Dear, *Revolutionizing the Sciences: European Knowledge and its Ambitions, 1500-1700* (Basingstoke 2001); Stephen Gaukroger, *The Emergence of a Scientific Culture: Science and the Shaping of Modernity, 1210-1685* (Oxford 2006); Katherine Park and Lorraine Daston (eds.), *Early Modern Science* (Cambridge 2006). In Dutch: H. Floris Cohen, *De herschepping van de wereld. Het ontstaan van de moderne wetenschap verklaard*

2 The idea of approaching the Scientific Revolution from a national perspective is not new. See Roy Porter and Mikulas Teich (eds.), *The Scientific Revolution in National Perspective* (Cambridge 1992), which includes an overview of the Dutch case by Hal Cook ('The New Philosophy in the Low Countries', 115-149). Cook underlines the many ways in which developments in the Netherlands illuminate the general trends in the Scientific Revolution. My approach will be different. By treating the Dutch Republic as a laboratory of science, I will concentrate on the differences with other countries. It is only by focusing on the differences that we can begin to grasp the relative significance of certain factors in the development of science.



Family of alchemists at work in a workshop, in a way the early modern equivalent of a laboratory. On the left, a man is melting metals on a stove, in the centre a fire is being stoked using bellows. On the right, a scholar at his books. Three children are escaping from the chaos; in the background, the parents are taking the children for treatment at a hospital.

Philips Galle, Pieter Brueghel (I), Hieronymus Cock,
 The Alchemist, 1553-1563.
 Rijksmuseum, Amsterdam.

philosophers.³ Mathematical practitioners and natural philosophers working in the footsteps of Simon Stevin were not so much occupied with articulating new theories, as with shaping new practices. Even Christiaan Huygens was above all a problem-solver rather than a natural philosopher with far-reaching ideas about the constitution of the natural world. However, now that science has come to be studied as a cultural activity – not just a set of theories, but also a set of practices – the Dutch tradition is no longer a sideshow phenomenon. Because the historian's traditional bias for theory against practice has more or less disappeared, science as practised in the Dutch Republic can reclaim its rightful place in the history of science. The words and deeds of Dutch craftsmen, engineers, mathematicians and medical doctors have become as relevant for understanding the changing interpretations of nature in the early modern period as those of representatives of other nations.

A new world

Two questions must be dealt with before discussing some of the major issues regarding the nature of the 'Scientific Revolution': what exactly is a laboratory and what kind of society was the Dutch Republic?

First of all, what do we mean by a laboratory? A laboratory is a place where experiments take place; a place where phenomena are studied under deliberately created and controlled circumstances. It is an artificial world that yields information about the real world: for instance, when the real world is too complicated to study directly or when this real world only produces phenomena under special circumstances. This specially designed environment may simply consist of an air pump, where something bordering on a vacuum is created, or it may be a complex set of machines and measuring instruments for the detection of elementary particles that remain hidden under normal circumstances. Sometimes, a laboratory is a place to test certain theories; sometimes a place simply to see what happens if special conditions are created. In general, a laboratory can serve different purposes, but a crucial element is generally its artificial nature. A laboratory is a world where things happen that never happen in normal life – or at least, should not happen.⁴

3 Another reason for underestimating the contribution of Dutch science was the language barrier. Most of the literature was written in Dutch, and thus inaccessible to the international community of historians of science. See however: Klaas van Berkel, Albert van Helden and Lodewijk Palm (eds.), *A History of Science in the Netherlands: Survey, Themes, and Reference* (Leiden 1999).

There are signs that the situation has improved significantly, at least for the early modern period: Paula Findlen, 'A Tulip for a Cup of Tea? Commerce and Nature in the Dutch Golden Age', *Annals of Science* 66 (2009) 267-276. For the history of Dutch technology, we can now refer to: Karel Davids, *The Rise and Decline of Dutch Technological Leadership: Economy and Culture in the Netherlands 1350-1800* (Leiden 2007).

Of course, the Dutch Republic was only a laboratory in a metaphorical sense. This young state was ‘a new world’, where things happened that happened nowhere else and where social, political and intellectual conditions existed that were unmatched by anything else in early modern Europe. It was a natural laboratory, designed by no one, but created by history. When, in the 1570s, noblemen, city magistrates and religious groups revolted against the absolutist ambitions of the King of Spain, Lord of the Netherlands, no one could foresee the outcome of this struggle. The Republic that in the end emerged from the conflict was as unintentional as a country can be.

In more than one respect, the Dutch Republic differed fundamentally from what was common in neighbouring countries.⁵ Politically, the Republic was completely out of step with the rest of Europe, where kings and courts were the norm. After the rebels had abjured the king (Philip II) in 1581, they first tried to find a new sovereign in England and France, but this search proved fruitless and by 1590 it was clear that no one would take Philip’s place. Consequently, there was no strong, central authority, as there was everywhere else (even in the Republic of Venice).⁶ The States General, directed by the Grand Pensionary or chief administrator of Holland, acted as the central government of the Republic but, in theory and in fact, the seven provinces that together made up the Republic were fully autonomous. The Republic was based on a treaty between these sovereign provinces that left ample space for provincial self-government. Much of the executive power within the provinces lay in the hands of a stadholder – formerly appointed by the king, now by the provinces – but his powers were restricted. Even though the stadholders were without exception chosen from the family of William of Orange and his nephew Willem Lodewijk – and even though these stadholders wielded some additional power as commander-in-chief of the army – their royal aspirations were always checked by the regents in the major cities, who painstakingly guarded their rights against the would-be king of the House of Orange. The stadholders could in no way be considered equal to the reigning monarchs in Spain, France or England; their households were also a far cry from the magnificent courts in Madrid, Paris and London. They had substantial

4 Essentially, the laboratory approach is closely related to the comparative method, since highlighting the characteristics of science in one country means implicitly comparing it to the situation in another. Cf. Jared Diamond and James Robinson (eds.), *Natural Experiments in History* (Cambridge, MA 2010).

5 There are a number of well-written books on the Dutch Republic: Jonathan I. Israel, *The Dutch Republic: Its Rise, Greatness, and Fall, 1477-1806*

(Oxford 1995); John Leslie Price, *Dutch Society, 1588-1713* (Harlow 2000); Willem Frijhoff and Marijke Spies, *1650: Hard-Won Unity* (Assen, Basingstoke 2004); Maarten Prak, *The Dutch Republic in the Seventeenth Century: The Golden Age* (Cambridge 2005).

6 The only exception is of course Switzerland, but a parallel study of scientific developments in Switzerland and the Netherlands has not yet been undertaken.

influence on the affairs in the Netherlands, but much of this influence was informal and indirect. Foreigners therefore often had difficulty figuring out who was really in charge in the Dutch Republic.

In religious affairs, the situation was at least as complicated. The Dutch Reformed church was not the state church, yet for many official positions adherence to the Reformed creed was essential. The Reformed church was regarded as the 'public church', protected and favoured by the state, but it had no monopoly. Unofficially, dissenting Protestants and even Catholics were allowed to practise their religion as long as they submitted to the secular authorities and did not give offence to the Reformed church. In Article 13 of the Union of Utrecht, a defensive treaty of some provinces and cities concluded in 1579 and gradually seen as the constitution of the Republic, stipulated that people in the Dutch Republic would have freedom of conscience. This did not imply freedom to practice each and every religion, although in everyday life minorities had substantial freedom to practice their beliefs. They may sometimes have had to bribe the local authorities in order to be allowed to continue their worship, but most of the time these same authorities turned a deaf ear to Reformed preachers who railed against Catholics, Jews, Socinians or 'atheists'. Dissenting voices were tolerated: not out of principle, but simply on the very pragmatic grounds that civil order was best guaranteed by a policy of bending and accommodating. Likewise, freedom of the press was considerable. The provincial assemblies or city councils might issue a ban on certain books or pamphlets, but in practice hardly any measures were then taken to ensure that the prohibited books were really taken out of circulation. Moreover, there were several ways in which authors and printers could get around a ban, as long as they made sure not to endanger the social order. They knew that, in the end, the regents were much more worried about preserving this social order (an essentially secular concept) than in maintaining any True Faith.

No less confusing, at least for foreigners, was the social fabric of the country. The Dutch Republic was first and foremost a burgher society, where wealthy merchants dominated politics and social life. Of course, the nobility, though reduced in size and political power owing to the Revolt, had not been marginalized, and retained substantial influence. In the inland provinces, they were sometimes even in the majority in the provincial assemblies, and even in Holland – where there was only one vote for the nobility as against 18 votes for the cities – the vote of the nobility counted for something, if only because protocol prescribed that the nobility should cast its vote first. Moreover, in the course of the seventeenth century, wealthy merchants and senior administrators began to imitate the lifestyle of the nobility. They bought seigniorial titles and rights, married off their sons to daughters of impoverished nobles and built elegant country houses. As early as 1620, Constantijn Huygens, secretary to stadholder Frederik Hendrik, famous poet and father of Christiaan Huygens, acquired the castle of Zuilichem along the river Waal, and from then on presented himself as Lord of Zuilichem.

Yet this bears no comparison with the social prestige of dukes, counts and other grandees in other countries. The Dutch Republic, and especially the province of Holland, was a highly urbanized society, where city life and burgher values pervaded even the lives of people not living in the cities. Trade and industry dominated economic life, whatever significance agriculture still may have had. Also, from the very start, the Dutch Republic was a much more egalitarian country than any of the other countries of Europe. Social differences were of course not absent. Honour and rank were as important as in other countries, and political power was restricted to a small elite in the cities. Yet, although excluded from narrowly defined political power, the middle classes did have a say in many of the affairs of their cities through guilds, neighbourhoods, associations and fraternities and church councils.⁷ In the first half of the century, social mobility was high and it was only in the second half of the century that the wealthiest merchants and regents started to close ranks against newcomers. And even then, they never completely repudiated the norms and values that had inspired their ilk in the early days of the Republic. Manual work was never denounced, as it was in more aristocratic societies, and ostentation was always something to be treated with caution. There is more than one story about foreigners who could not believe that a group of people dressed in simple black cloths and eating bread by the side of the road were actually the members of the States General, supposedly directing the affairs of this country.

The role of craft knowledge

What questions can we then profitably ask about the nature of the Scientific Revolution in the seventeenth century, in the context of the Dutch laboratory? Firstly, I will discuss the role of craft knowledge in the development of the new sciences. I will then outline the contribution of the universities to the new science, before finally tackling the impact of commercial values on the habits of mind of early modern ‘scientists’.

The historiography of the Scientific Revolution is traditionally dominated by two diametrically opposed interpretations. The first, and the older of the two, sees the rise of modern science as a great intellectual revolution, in which new ideas about the mathematical structure of the world overturned the older, more organic worldview embodied by Aristotle. Alexander Koyré’s seminal work on Galileo and Descartes, written shortly

7 See the contribution of Maarten Prak elsewhere in this volume.

before the Second World War, is usually seen as the ‘locus classicus’ of this line of thought. The other tradition sees the new science as emerging from the empirical work of artisans and from the interaction between craftsmen and scholars. In the 1940s, Edgar Zilsel was the first to formulate this view in a coherent way and later on Paolo Rossi did much to give this interpretation credibility. According to Zilsel, social barriers had separated intellectuals and craftsmen in the Middle Ages, until the rise of capitalism and the decline of the guilds enabled some of the craftsmen to enter the world of the middle class and graft their hands-on knowledge of materials onto the theoretical knowledge of the academically trained scholars. The union of hand and mind resulted in the empirical and experimental methodology that formed the core of the new science of the seventeenth century. Rossi identified a so-called ‘artisanal epistemology’, in which the manual work in the workshop is conceived as a form of cognition. If knowledge is regarded as construction and man is said to know best what he can make himself, the door is open to the formulation of the mechanical worldview, so Rossi speculated.⁸

Until a few decades ago, the Koyré view of things was clearly dominant.⁹ Indeed, it was hard to disregard the forceful criticism formulated by the British historian A. Rupert Hall in his famous article on the scholar and the craftsman. The success of craft empiricism, so Hall reasoned, was nothing new in the Middle Ages and the early modern period, and if scholars in the early modern period became conscious of this – which certainly was the case – this was because these scholars had changed their minds, and not because of some putative rise of a new class of superior craftsmen.¹⁰ Earlier, Koyré had already shown that in ballistics, the introduction of new mathematical and physical principles was not the work of the craftsmen, but of outsiders who applied their knowledge to this military art: ‘The new ballistics was not made by artificers and gunners, but against them’. Furthermore, both Zilsel and Rossi were criticized for being unable to come up with detailed studies of craftsmen actually contributing to the formulation and refinement of the mechanical philosophy of nature. These authors highlighted the parallels between the artisanal epistemology and the epistemology of the new science, but had failed to show exactly where and when the one led to the other.

8 A. Koyré, *Etudes galiléennes* (Paris 1939); E. Zilsel, *Die sozialen Ursprünge der neuzeitlichen Wissenschaft*, W. Krohn (ed.) (Frankfurt am Main 1976); Paolo Rossi, *Philosophy, Technology, and the Arts in the Early Modern Era* (New York 1970).

9 In the Netherlands, the Koyré approach was exemplified by E.J. Dijksterhuis, whose *Mechanization of the World Picture* (Oxford 1961) remains one of the classics in the history of science.

10 A. Rupert Hall, ‘The Scholar and the Craftsman in the Scientific Revolution’, in: M. Clagett (ed.), *Critical Problems in the History of Science* (Madison, Wisc. 1959); A. Rupert Hall, *Ballistics in the Seventeenth Century: A Study of the Relations of Science and War, With Reference Particularly to England* (Cambridge 1952); A. Koyré, ‘Galileo and Plato’, in: A. Koyré, *Metaphysics and Measurement: Essays in the Scientific Revolution* (London 1968) 17.

In this respect, the situation in the Dutch Republic offers itself as an excellent testing ground for this debate, whereby it can be shown that the situation in the Netherlands confirms the Zilsel-Rossi thesis. Dutch science has always been typified by its practical orientation and its large number of practitioners with a background in the mechanical arts. Artisans in the Netherlands are also believed to have shown an assertiveness and self-consciousness that was not to be found in many other parts of Europe, while manual labour did not seem to carry the same stigma as elsewhere. This can be inferred, for instance, from the large percentage of regents, merchants, doctors, and even landed gentlemen who applied for patents in the seventeenth century. Although artisans formed the largest group (53 percent of the patents applied for between 1580 and 1640 originated with artisans), merchants were responsible for 13 percent and urban regents for almost 7 percent.¹¹ The social distance between craftsmen and scholars here was smaller than anywhere else. If modern science is the fruit of both the mind and the hand, and if we are looking for the missing link between the implicit craftsman's epistemology and the explicit values of the new science, there is no better place to look than the Dutch Republic.

One such attempt has been made by Pamela Smith in *The Body of the Artisan: Art and Experience in the Scientific Revolution*.¹² She reiterates the view that the new science – interpreted mainly as experimental science – was partially created by people who in former times had played no role whatsoever in our picture of the knowledge-making process; that is craftsmen and artisans such as painters, goldsmiths and pottery makers. In their work, these practitioners crossed the line between nature and art all the time and along the way developed an implicit 'artisanal epistemology' which, once articulated as the experimental method, would define the new science. The bodily process of making art, Smith argues, is a form of cognition and results in a better understanding of nature. She substantiates her version of the Zilsel thesis with a detailed analysis of the actual work of a painter such as Albrecht Dürer, a goldsmith such as Wenzel Jamnitzer and a potter such as Bernard Palissy. In the course of her book, the geographical focus of her treatment of the artisanal epistemology gradually shifts to the Low Countries and the book culminates in a discussion of the views of the Dutch alchemist Johann Rudolph Glauber and the Leiden professor of medicine Franciscus dele Boë Sylvius.

The book makes a convincing case for the thesis that the crafts should be seen as a process of both making and knowing. Even in the most bodily operations of the craftsmen, theoretical knowledge was produced. Craft

11 Davids, *The Rise and Decline*, 421.

12 Pamela H. Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago 2004).

knowledge was, as Smith summarizes in a more recent article, investigative, experimental, collaborative, public and flexible; characteristics it shares, to a surprising degree, with the experimental philosophy of the late seventeenth century.¹³ Yet one could argue that Smith still fails to do what critics have repeatedly asked Zinsel and Rossi to do: that is, to show exactly where the craftsmen and the scholars met, where the link between their epistemology and the new science that emerged in the seventeenth century was actually forged, and what elements of the new science really did result from the bodily labour of the goldsmiths and the potters. Smith indeed establishes a link between artisanal knowledge and the experimental method in science, but is it not special pleading to define the new science in such a way that it is almost self-evident that the artisans contributed decisively to it? Is the new science mainly concerned with experimental research, or is experimental research just part of it? How is Kepler's new astronomy related to artisanal knowledge, where does Huygens' mathematical treatment of light fit in, how is Descartes' mechanical philosophy related to the work of artisans, and in what sense do Newton's *Principia* depend on the contribution of mechanics and shipwrights? Franciscus de Boë Sylvius was an iatrochemist, a follower (with many reservations) of Paracelsus. But he was not a major figure in the Scientific Revolution and his career cannot stand for the new science as a whole. The Zinsel-Rossi-Smith thesis would gain credibility if we were able to show how the link between craftsmanship and mathematical sciences was established.

That this link did indeed exist can be demonstrated from the history of science in the Dutch Republic. As early as the years around 1600, the still somewhat isolated figure of Simon Stevin bridged the gap between, on the one hand, engineering and practical mathematics and, on the other, pure mathematics, astronomy and hydrostatics. Stevin is especially interesting because he transcends the distinction between craftsmen and scholars. He was neither a simple craftsman nor a university educated scholar. He belonged to a middle-group of engineers, surveyors and teachers of mathematics who go by the name of mathematical practitioners; people who were instrumental in bringing the results of practical exercises to the attention of scholars. People like Stevin were go-betweens, mingling with the millwrights and carpenters as well as chatting with the burgomasters and university professors.¹⁴ An even

13 Pamela H. Smith, 'In a Sixteenth-Century Goldsmith's Workshop', in: Lissa Roberts, Simon Schaffer and Peter Dear (eds.), *The Mindful Hand: Inquiry and Invention from the Renaissance to Early Industrialization* (Amsterdam 2007) 33-57.

14 There still is a tendency to picture Stevin as a brilliant but isolated mathematician: Jozef T. Devreese and Guido Vanden Berghe, 'Wonder en is gheen wonder'. *De geniale wereld van Simon*

Stevin 1548-1620 (Leuven 2003). Although this book contains information that was not available half a century ago, the approach is not much different from: E.J. Dijksterhuis, *Simon Stevin: Science in the Netherlands Around 1600* (The Hague 1970). For the concept of go-betweens: Simon Schaffer et al. (eds.), *The Brokered World: Go-betweens and Global Intelligence 1770-1820* (Sagamore Beach, MA 2009).

more convincing case is provided by the natural philosopher Isaac Beeckman. Beeckman was the son of an immigrant candle-maker, and was in the business himself for several years. He also made a living by constructing and repairing water systems in breweries: an activity from which he gained an expert working knowledge of hydraulics. Yet Beeckman also studied theology and mathematics at Leiden University, rounding off his education with a medical degree from the University of Caen in northern France, and going on to become a highly respected headmaster of the Latin school in Dordrecht – the finest school in Holland. In the early decades of the seventeenth century, he took full advantage of the opportunities for social mobility that characterized the early Republic. If ever there was someone who bridged the gap between the world of the artisan and the world of the scholar, it surely was Beeckman. Apart from this, another consideration that makes him so special is the fact that he kept a detailed diary, in which he reported both his dealings with water systems and his speculations concerning the corpuscular structure of the world. On reading Beeckman's *Journal*, we cannot help but be struck by the way in which the most abstract questions of natural philosophy alternate with discussions of highly practical matters such as the manufacture of candles, the dredging of harbours and the grinding of lenses. Beeckman's mind seems to have been running – simultaneously, so it seems – on at least two tracks: that of the artisan and that of the natural philosopher, and there are several paragraphs that actually show how criteria taken from the world of the crafts shaped his natural philosophical thinking and stimulated him in formulating crucial principles underlying the new mechanical philosophy, such as the new concept of inertia. Beeckman influenced Descartes considerably, and in this way his artisanal knowledge directly impacted the development of the new science.¹⁵

Far be it from me to say that what is true for Beeckman is also true for all the other craftsmen who worked at the interface of the crafts and the sciences. Yet a closer look at the situation in the Dutch Republic confirms that artisanal knowledge was indeed instrumental in bringing forth key developments in the Scientific Revolution. The Zilsel-Rossi-Smith thesis withstands the test in the Dutch laboratory.¹⁶

15 Klaas van Berkel, *Mechanical Philosophy in the Making: Isaac Beeckman 1588-1637* (in press).

16 Nautical science offers itself as another testing ground for the Zilsel-Rossi-Smith thesis: C.A. Davids, *Zeewezen en wetenschap. De wetenschap en de ontwikkeling van de navigatietechniek in Nederland tussen 1585 en 1815* (Amsterdam 1986).

The infrastructure of knowledge

For a long time, universities were seen as the bulwark of old-fashioned Aristotelianism and regarded as a stumbling block on the road to the new science. In many universities, it was indeed decreed that teaching should be restricted to the philosophy of Aristotle and there was, officially at least, little room for the introduction of new ideas and practices. Furthermore, many seventeenth century champions of scientific innovation actively propagated the image of universities as intellectual backwaters, outdated in their teaching and unwilling to provide the kind of knowledge demanded by the new age. Francis Bacon, among others, demanded that new institutions should take the place of the universities and indeed there was a strong tendency in England to replace the universities by new centres of teaching and research (Gresham College being one example). It has however been shown that the situation was not as clear-cut as all that. To begin with, we should not forget that, although many of the leading exponents of the Scientific Revolution worked outside the universities, others were university professors, at least for part of their careers. Galileo was a successful professor at Pisa and Padua; Isaac Newton developed his new mathematical physics while teaching at Cambridge. Officially, a university might stick to old-fashioned Aristotelianism and refuse to take the new sciences on board, but unofficially much more openness was practised. Private teachers who taught the principles of the new science attracted significant numbers of students, and even the professors themselves might give private courses in which up-to-date information regarding the new sciences would be given: much more so in any event than was officially acknowledged. Mordechai Feingold has demonstrated the openness of the English university to the mathematical sciences and Geert Vanpaemel has analysed the diffusion of Copernicanism and the mechanical worldview in one of the most traditional universities of Europe, the University of Louvain in the Spanish Netherlands.¹⁷ So the question arises of how important the universities really were to the Scientific Revolution.

17 M. Feingold, *The Mathematician's Apprenticeship: Science, University, and Society in England, 1560-1640* (Cambridge 1984); Geert Vanpaemel, *Echo's van de Wetenschappelijke Revolutie. De mechanistische natuurwetenschap aan de Leuvense Artes-faculteit (1650-1797)* (Brussel 1986).

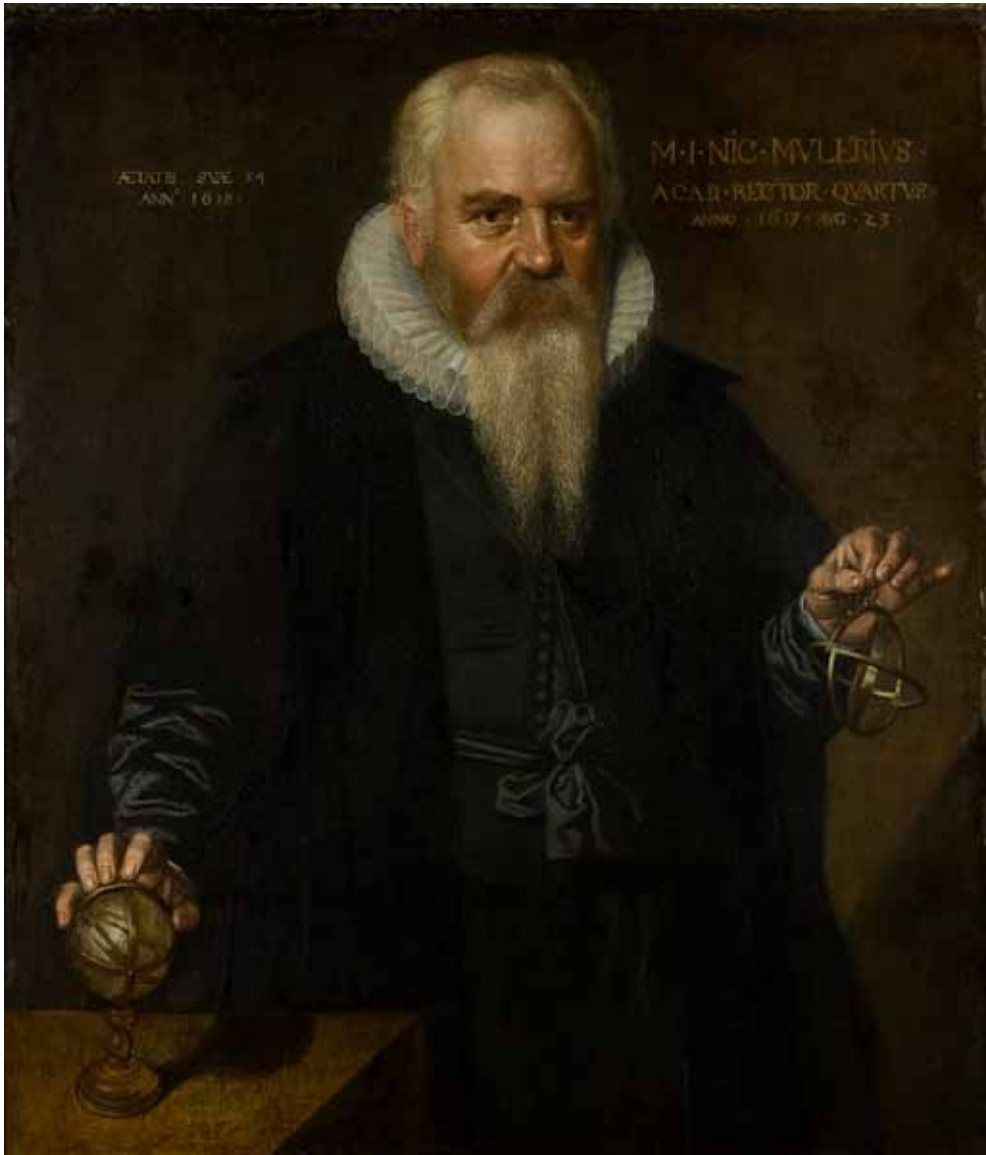


By 1650, the Dutch Republic had a well-developed university system. All of these universities, however, were young and surprisingly modern. The University of Leiden was only founded in 1575, and the province of Friesland founded its own university in the city of Franeker in 1585. Before the middle of the seventeenth century, a whole range of other institutions were established by local and provincial governments. Groningen became a university town in 1614, Utrecht followed in 1636 and Harderwijk, in the province of Gelderland, got its university in 1648. Alongside these universities, there were several ‘Illustrious Schools’: city institutions where an academic education was provided but no academic degrees could be conferred on the students. The founding of a university was the privilege of the sovereign and since the abjuration of the Spanish king, the individual provinces were sovereign. Once a university has been founded in one of the provinces, there was no room for a second one: Amsterdam therefore had to be content with just an Illustrious School. Yet these Illustrious Schools in Amsterdam, Breda, Deventer and elsewhere provided quality education and were an integral and often quite innovative part of the system of higher education in the Dutch Republic.¹⁸

Dutch universities attracted large numbers of foreign students. In part, this was due to the disastrous state of affairs in Central Europe. The Thirty Years War in Germany and the prosecution of the Protestant minorities in a country like Poland led to a remarkable influx of students from Central Europe to the universities in the Protestant Dutch Republic. Yet the influx of foreign students also reflected the high quality of academic teaching in the Republic and the excellent reputation the universities had abroad. Leiden University in particular had done its utmost to attract internationally renowned scholars in order to boost its reputation: and met with remarkable success. With scholars such as Justus Lipsius and Joseph Scaliger, Leiden University gained distinction as the foremost university of north-western Europe, and names such as Rembertus Dodonaeus and Carolus Clusius had the same effect in the field of botany. Other universities also boasted scholars with an international reputation. In Franeker, for instance, the Hebrew scholars Drusius and Ames ranked among the top in their field.

◀ The conferring of a degree at the University of Leiden: the young doctor emerges from the gate of the university building between two professors in a procession, preceded by two Bedels. In the foreground, onlookers and children playing. Hendrick van der Burgh, *The conferring of a degree at the University of Leiden, around 1650*. Rijksmuseum, Amsterdam.

¹⁸ For a survey: W.Th.M. Frijhoff, *La société néerlandaise et ses gradués, 1575-1814* (Amsterdam 1981).



The Groningen Professor of Medicine and Mathematics
Nicolaus Mulerius (1564-1630).
Anonymous, Nicolaus Mulerius, 1618.
University Museum, Groningen.

The openness of the Dutch universities towards the new science can be demonstrated by an impressive number of examples. In 1609, a year after the invention of the telescope (in the Dutch city of Middelburg), the Leiden professor of mathematics Rudolph Snellius was already demonstrating the new instrument to students who took his course on optics (one of them, David Fabritius, took the instrument with him to his native East-Friesland and pointed the telescope at the sky, at the same time as Galileo was doing so in Padua). The son of Rudolph Snellius, Willebrord Snellius, who is remembered as the discoverer of the law of refraction, managed to find a dignified place for modern mathematics at a university that was still dominated by philologists such as Lipsius and Scaliger.¹⁹

In Groningen, the professor of mathematics, Mulerius, in his own way made mathematics a fashionable topic by publishing a revised third edition of Copernicus' *De revolutionibus orbium coelestium*, even though he was aware of the many objections to the Copernican system and did not himself believe in its physical reality. He published the book in 1617, one year after the Catholic church had put the book on the Index of forbidden books, and although Mulerius must have taken the decision to publish the book long before the news about the decision of the Inquisition had reached the Netherlands, the coincidence is remarkable.²⁰ Somewhat later, Descartes acquired his first following at the Dutch universities, with professors of natural philosophy such as Henri Reneri and Henricus Regius at Utrecht University being among his first followers. According to Descartes, Utrecht was an excellent university precisely because, as he said in 1638, it was founded only recently 'and therefore did not have the time to be corrupted'. At this time, Descartes was so fed up with the criticism his *Discourse on Method* (1637) had met in France, he was consciously trying to get his ideas accepted at the Dutch universities: 'If the French are unjust to me, I shall turn to the Gentiles', he wrote to one of his correspondents.²¹ Apparently, he considered the Dutch universities to be the perfect testing ground for his new philosophy. In this respect Descartes was right, although he did not expect to be as severely criticized by theologians as he in fact was: in Utrecht by Gisbertus Voetius and in Leiden by Jacob Trigland. The vehement attacks on Descartes by Voetius and other defenders of traditional philosophy should not however be seen as a proof of the backwardness of the universities, but on the contrary as a

19 Liesbeth de Wreede, 'Willebrord Snellius (1580-1626): A Humanist Reshaping the Mathematical Sciences' (PhD dissertation, Utrecht University 2007).

20 D.H. van Netten, 'Koopman in kennis. Willem Jansz. Blaeu als uitgever' (PhD dissertation, University of Groningen 2010).

21 Descartes to Mersenne, *Oeuvres complètes de Descartes*, II, 334.

sign that the universities were surprisingly open to new ideas. Voetius had indeed to take extreme measures to try and kill off the Cartesian movement, because he would otherwise have lost the battle completely.²² Furthermore, we should not forget that the debate was about the official courses and disputations, not about the education provided by the private teachers, who were complementing the official courses with new perspectives and new ideas.

Universities were important for the new science in several ways. In the first place, they offered employment for practitioners of the new science. In other countries, the royal court might offer such opportunities to aspiring mathematicians and other exponents of the new science. In the Dutch Republic however, this option did not exist. A university job was thus even more welcome to researchers than elsewhere. Furthermore, universities offered the systematic education even practitioners of the new science could not do without. Descartes could not have devised his new mechanical philosophy without his serious training in mathematics at the Jesuit College at La Flèche, and Isaac Newton only learned what intellectual discipline was when he studied Aristotelian natural philosophy as an undergraduate at Cambridge. The importance of university training becomes obvious as soon as one meets a scientist without such a background. The fact that Antoni van Leeuwenhoek was 'uneducated' may for instance have prevented him using his tiny microscope in a more systematic and fruitful way. It certainly hindered him seriously in his relations with fellow researchers who had studied at university.²³ Finally, the university was important because, at a time when boundaries between disciplines were shifting, universities offered at least some kind of intellectual stability. This provided the exponents of the new science with a background against which their revolutionary new approaches made sense. For a long time, the universities defined what scientific disciplines really were, and it was only gradually that the new science acquired a stability of its own, mainly through the new textbooks and exemplary monographs written during the second half of the seventeenth century. We know for instance that Isaac Newton became acquainted with Cartesian mathematics not by reading Descartes' *Géométrie*, but by studying the 1654 Latin translation and revision by Frans van Schooten jr.: a close ally of Descartes, but also a university professor at Leiden University.²⁴

- 22 Theo Verbeek, *Descartes and the Dutch: Early Reactions to Cartesian Philosophy, 1637-1650* (Carbondale 1992).
- 23 K. van Berkel, 'Intellectuals against Leeuwenhoek', in: L.C. Palm and H.A.M. Snelders (eds.), *Antoni van Leeuwenhoek, 1632-1723* (Amsterdam 1982) 187-209.

- 24 Van Schooten counted famous mathematicians such as Christiaan Huygens and Johannes Hudde among his pupils. Cf. J.A. van Maanen, *Facets of Seventeenth-Century Mathematics in the Netherlands* (Utrecht 1987).

It is only during the second half of the seventeenth century that the fruitful interaction between the universities and the new science became less intense. In Leiden, this trend is partly disguised by the fact that, in 1675, the professor of mathematics Burchardus de Volder was allowed to teach experimental philosophy in his newly constructed laboratory. A few decades later, professor of medicine Hermann Boerhaave and his colleague in philosophy and mathematics Willem Jacob 's Gravesande acquired an international reputation for their efforts to disseminate Newtonian science all over Europe. Elsewhere in the Netherlands, however, practically nothing was done that deserves our attention, and even at Leiden involvement with the latest developments in science was mainly pedagogical, whereas in the first half of the century pedagogy and research had been more interwoven. This relative decline in scientific endeavour – if it is permissible to phrase it this way – partly reflects the general downward trend in the Dutch universities, at least as far as the enrolment of foreign students is concerned (which in itself was caused by the new stability in the countries of Central Europe). It also reflects – and this may be more significant – the rise of a new alternative for the universities as centres of scientific research – the scientific society. Soon after the establishment of the Royal Society in London (1662) and the Académie des Sciences in Paris (1666), these societies became the focal points of the new science. The Royal Society mainly exercised this influence through Henri Oldenburg's *Philosophical Transactions*; the Académie des Sciences by its 'pensions', awarded to top scientists, both French and foreign. Antoni van Leeuwenhoek became a reputed microscopist first and foremost because of his letters to the Royal Society and Christiaan Huygens was one of the beneficiaries of the Académie des Sciences. Intimate relations with the universities were of course maintained. When Huygens looked for colleagues to entrust his posthumous writings to, he chose two university professors: De Volder at Leiden and Bernard Fullenius, jr., at Franeker. But with regard to active research, the universities receded into the background.

We can therefore conclude that a study of the universities in the Dutch Republic confirms that universities played a major role in the development of the new science, at least during the first phase of the Scientific Revolution. Dutch universities differed in some respects from universities elsewhere. Their remarkable openness to new developments, the importance given to mathematics and natural philosophy and the unequalled freedom of expression, characteristic of Dutch society in general, turned the Dutch universities into small laboratories of the new science.

The elusive 'mercator sapiens'

A third topic of debate nowadays is the role of commerce in the emergence of modern science. In what way did the development of trade and commerce facilitate, stimulate or direct the development of modern science? Is there a connection between the rise of capitalism and global trade in the sixteenth and seventeenth centuries on the one hand and the emergence of a truly scientific culture on the other? At a basic level, this connection is of course evident. Science needs some sort of material support, minimum amounts of wealth and spare time. An economy that is booming is much more likely to fulfil these conditions than an economy that is stagnant or declining. Science also depends on communication and information networks, and in this sense of course the rise of global trade will also have been favourable for the circulation of knowledge.

More interesting questions arise however as soon as we attempt to establish how exactly science and commerce are related. Did commerce favour particular scientific concepts, or did it generate a particular way of thinking that encouraged some sort of research while making other means of inquiry less attractive? There is indeed a long tradition in the historiography of early modern science that claims that commerce and industry were instrumental in producing the kind of science we associate with the Scientific Revolution. As early as the 1930s, Soviet historian of science Boris Hessen shocked his colleagues by stating that the mathematical physics of Newton's *Principia* was a direct reflection of the capitalist mentality of the British ruling classes.²⁵ Not much credit was given to this claim, and nor was this the case with other variations on this crude historical materialism. Yet the idea that somehow the mentality of the commercial elite in early modern Europe shaped the basic outlook of the protagonists of the new science of the seventeenth century has proven too attractive to dismiss completely. Shifting the attention to the experimental method as the hallmark of modern science, Paolo Rossi and Pamela Smith have therefore, each in their own way, tried to connect commerce to science.²⁶

Recently, in Harold Cook's *Matters of Exchange*, this basic idea is again explored, this time with detailed attention to the Dutch Republic. 'The intellectual activities we call science', so Cook claims, 'emerged from the ways of knowing valued most highly by the merchant-rulers of urban Europe'.²⁷ Merchants in the large cities of southern and western Europe

25 B. Hessen, 'The Social and Economic Roots of Newton's *Principia*', in: *Science at the Crossroads* (London 1938; second edition 1972) 150-212.

26 Pamela H. Smith and Paula Findlen (eds.), *Merchants and Marvels: Commerce, Science, and*

Art in Early Modern Europe (New York 2002).

27 H.J. Cook, *Matters of Exchange: Commerce, Medicine, and Science in the Dutch Golden Age* (New Haven 2007). See also: Findlen, 'A Tulip for a Cup of Tea?.'

were not only facilitating the new science, he argues, but also shaped its direction, differentiating it from the traditional knowledge that still dominated the universities. Commercial firms and companies that traded with the East and West Indies served as clearing houses for an enormous amount of new information regarding the natural world of far away places. This is a connection that is hard to deny. Commerce not only thrives on capital, but also on information; on knowledge that is at once reliable and useful. This information as such is not yet science, but it certainly is an important ingredient of this, and in disciplines such as botany and geography, information counted for much more than theories or hypotheses. Furthermore, merchants – and certainly those engaged in overseas trade with the East and West Indies – attached great importance to the accurate description and identification of the commodities they traded in. What exactly were they buying, what was it worth and what was it made of? Whereas in court culture, making a big splash was sometimes more important than actually proving a case, in a commercial setting all that mattered was factual information which was accurate and trustworthy. This was exactly what mattered to botanists, physicians, apothecaries and other practitioners of natural history (and even some of the natural philosophers). Their main concern was to know about individual plants, animals and objects, rather than understand the first principles on which the world is based. For them, science was first and foremost a matter of knowing facts, rather than causes. The new science, so Cook claims, was chiefly descriptive, rather than analytical; it was based on experience, accurate descriptions and broad observations: precisely the intellectual values that flourished in merchant circles and among those connected with their world, and even among court officials and kings who strove to promote the material welfare of their countries.

The affinity between the worlds of trade and science went even further. The vast supply of new and fascinating objects from all over the world fuelled certain passions that previously had had an inferior, or even dubious, status. In the new world of constantly novel commodities, curiosity and the desire for collecting things acquired a positive value, thereby elevating the passions in general to a status they had formerly lacked. Commerce taught that people were not driven by reason, but by passion, and the same applied to science. Reasoning as such was insufficient for learning about the world; knowledge also relied on passion and desire: for instance the desire to collect and to possess. This gave the new science an inherently materialistic – or at least non-metaphysical – quality.

If the link between commerce and science is going to be evident anywhere then, it will have to be in the Dutch Republic. World trade flourished here on an unprecedented scale and those who controlled trade to the East and West Indies also commanded the ship of state. And indeed, the history of science in the Dutch Republic offers substantial evidence to support the claim that the intellectual values of merchants ran parallel to those of the

practitioners of the new science. Cook's book contains detailed descriptions of the work of minor figures Jacob Bontius and Nicolaas Tulp, but also of some of the luminaries of the new science in the Dutch Republic, such as the botanist and Leiden professor Carolus Clusius and again the philosopher Descartes (whose philosophy includes a rehabilitation of the passions). This is not the kind of science that one comes across in the older textbooks on the Scientific Revolution. There, the mathematical disciplines are usually put at the forefront – mathematics itself, astronomy, optics and mechanics. Yet in Cook's book, the disciplines that really count are medicine, botany and other branches of natural history. According to him, these were indeed the disciplines that really mattered in the seventeenth century. Mathematics and physics were much more peripheral to early seventeenth century culture than we are inclined to think.

We should adopt a cautious approach, nonetheless. Cook amply documents the ways of knowing of the practitioners of the new science, but remains silent on the ways of thinking of the merchants who are supposed to have provided the scientists with new values. The merchant that Cook presents is at best an ideal representative of his class; a sociological reconstruction of how a merchant must have done business in order to obtain maximum profit from his enterprise. But what do we know about real-life merchants, how they thought and how they evaluated their own ways of going on? Cook presents us with the famous inaugural address delivered by Caspar Barlaeus to the Amsterdam Illustrious School in 1632, 'Mercator sapiens': but this is not really a sound source for the mentality of the Amsterdam merchants. The oration sketches an ideal type, seen through the eyes of a classical scholar, with little knowledge of what exactly went on in the offices and warehouses where these merchants operated.²⁸ So the question remains: what did they really think and does this really correspond to the means of enquiry practised by the representatives of the new science?

In my opinion, the case is therefore still undecided. The Dutch Republic offers ample opportunity for studying the relationship between commerce and science. Not all merchants were interested in science, but even those who did not share this passion for new knowledge certainly contributed to it, simply by keeping the flow of information coming, albeit indirectly. And then there were the merchants who did indeed have a genuine interest in science and scholarship. The name of the ambitious Nicolaes Witsen immediately springs to mind, burgomaster of Amsterdam and one of the directors of the East India Company. If ever there was a regent with

28 For a more detailed discussion of Barlaeus' oration: Klaas van Berkel, 'Rediscovering Clusius. How Dutch Commerce Contributed to the

Emergence of Modern Science', *Bijdragen en Mededelingen betreffende de Geschiedenis der Nederlanden/The Low Countries Historical Review* 123:2 (2008) 227-236.

an interest in science and scholarship, it was he – although the science this merchant was interested in would nowadays hardly be considered new or modern in any sense of the word (at the end of the seventeenth century Witsen was still searching for the enigmatic unicorn).²⁹ But there were others too, such as Johannes Hudde and Johan de Witt, two of the more gifted pupils of the Leiden mathematician Frans van Schooten.³⁰ Or father and son Joan Huydecoper van Maarsseveen, directors – as was Witsen – of the VOC and owners of a famous cabinet of curiosities.³¹ Dutch material corroborates Cook's thesis regarding the link between commerce and science, but more research needs to be undertaken before we can fully grasp what these connections really were.

Conclusion

Is there a common lesson to be learned from these three different cases? Does studying the development of modern science in the laboratory that was created in the Dutch Republic point in a specific direction? Perhaps it does. It is the lack – or at least the lowering – of barriers that seems to have stimulated modern science the most. I am thinking of barriers first of all in the political sense. The Dutch Republic was characterized by the absence of borders that could interrupt the free flow of information and people from one province to another, as well as in and out of the country. Knowledge travels not only through books and letters, but it is also (still) essential that people themselves travel. Travel to and within the Dutch Republic was remarkably easy and safe. Ideas were therefore exchanged freely, also owing to the lack of serious censorship. It was virtually impossible to stifle new ideas, even if anyone should want to do such a thing.

29 On Witsen: Igor Wladimiroff, *De kaart van een verzwegen vriendschap. Nicolaas Witsen en Andrej Winius en de Nederlandse cartografie van Rusland* (Groningen 2008) and Marion Peters, *De wijze koopman. Het wereldwijde onderzoek van Nicolaas Witsen (1641-1717), burgemeester en VOC-bewindhebber van Amsterdam* (Amsterdam 2010).

30 See note 24.

31 The history of collecting became a fashionable topic of study in the Netherlands with the exhibition 'The wereld binnen handbereik' in the Amsterdam Historical Museum in 1992. See the collection of essays and the catalogue accompanying this exhibition: Ellinoor

Bergvelt and Renée Kistemaker (eds.), *De wereld binnen handbereik. Nederlandse kunst- en rariteitenverzamelingen, 1585-1735* (Amsterdam, Zwolle 1992). Collecting, commerce and botanical knowledge were intimately connected during the 'tulip craze' in the 1630s: Anne Goldgar, *Tulipmania: Money, Honor, and Knowledge in the Dutch Golden Age* (Chicago 2007). For a recent addition to the literature on commerce and collecting: Daniel Margocsy, 'Commercial Visions: Trading with Representations of Nature in Early Modern Netherlands' (PhD dissertation, Department of the History of Science, Harvard University 2009).



The tulip was imported into the Netherlands from Turkey in the sixteenth century. During the course of the seventeenth century, the Netherlands was gripped by a veritable rage: the tulip craze or tulip mania, which gave rise to an incredible wave of financial speculation on tulip bulbs: the bulbs were sold (on) before they had been received by the trader and an exclusive bulb could

fetch as much as a canal-side house in Amsterdam. After 1637 the tulip trade collapsed, seriously harming many buyers and sellers. Tulips remained popular, however, and even went on to become a national symbol of the Netherlands. Jacob Marrel, *Two Tulips, a Shell, a Butterfly and a Dragonfly*, 1639. Rijksmuseum, Amsterdam.

Secondly, I mean barriers in the social sense. The Dutch Republic was unique for the absence of the chasm that separated those who worked with their hands (the craftsmen) from those who worked with their minds (the scholars). In medieval Europe, these two groups possessed vastly different social status and maintained separate educational structures. The former could liken themselves to the aristocracy, the latter were usually seen as not much more than simple technicians. In Holland, however, this social divide had never been particularly prominent. Guilds were a relatively new phenomenon in the Dutch Republic, and certainly did not have the same power as in other countries. Therefore the Dutch Republic around 1600 was a perfect place for groups to mingle and learn from each other. Elsewhere, the new capitalist economy was breaking through the old divides just as well; almost everywhere in Western Europe, the society of orders was beginning to fragment under the pressure of new concepts of status and new forms of wealth. Yet the Dutch Republic was far ahead of the pack, and therefore offered an especially fertile ground for groups in between the scholars and the craftsmen, who disregarded the boundaries set by the old established groups.

Finally, I believe that the Dutch case is characterized by a lack of intellectual barriers. The institutional setting of the Scientific Revolution in the Dutch Republic was far from rigid. The university attracted students from many different countries and from surprisingly different social backgrounds. Furthermore, in addition to the universities, there were other educational institutions – from the engineering school attached to Leiden University to the anatomical theatres of the guilds – where knowledge was disseminated to a wider public, both in Latin and in Dutch. As a result of the Reformation and of the Dutch Revolt – but perhaps also as a continuation of a social make-up that went back to the time of the first colonization of marshy regions in the western part of the country – the Dutch Republic, at least in the beginning of the seventeenth century, was moving towards an egalitarian society in which preconceived ideas about what was appropriate and what was not were being questioned or simply swept aside.³² This unforeseen combination of special conditions created a situation that was definitively favourable to the new science. ◀

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32 See Bas van Bavel's contribution elsewhere in this volume.