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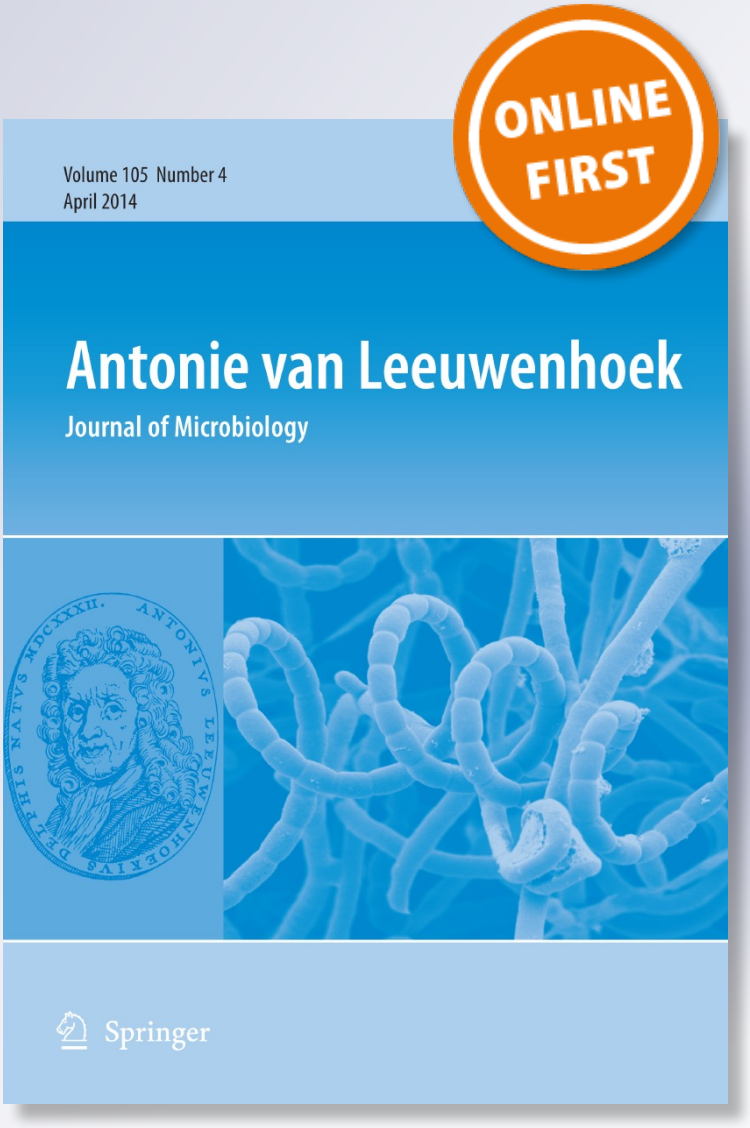
Antonie van Leeuwenhoek
Journal of Microbiology

ISSN 0003-6072

Antonie van Leeuwenhoek
DOI 10.1007/s10482-014-0152-1



Springer

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DOI 10.1007/s10482-014-0152-1

INVITED REVIEW

Antonie van Leeuwenhoek 80th Anniversary Issue

Still going strong: Leeuwenhoek at eighty

Douglas Anderson

Received: 7 January 2014 / Accepted: 10 March 2014

Abstract At age 80, Antony van Leeuwenhoek was a world-famous scientist who came from a prosperous Delft family with a heritage of public service. He continued that tradition by serving in paid municipal offices. Self-taught, he began his scientific career in his 40s, when he began making hundreds of tiny single-lens microscopes. Pioneering the use of now-common microscopic techniques, he was the first human to see microbes and microscopic structures in animals, plants, and minerals. Over 50 years, he wrote only letters, more than 300 of them, and published half of them himself. More than a hundred were published in translation in the Royal Society's *Philosophical Transactions*. Today, Leeuwenhoek is considered in the lesser rank of scientists and is not well known outside of his homeland. Recent archival research in Delft has contributed new information about his life that helps to contextualize his science, but much remains to be learned.

Keywords Antony van Leeuwenhoek · Heritage · Single-lens microscope · Microbes · Self-published letters · Science · Archives

Introduction

A few weeks after his 80th birthday in October 1712, Antony van Leeuwenhoek (see Note) addressed two letters to Dutch statesman Antony Heinsius, age 71 himself. A Delft native, Heinsius served as Grand Pensionary of Holland from 1689 until his death in 1720. He was the only person from Delft alive then whose international fame exceeded Leeuwenhoek's. They had known each other at least since 1670, when Heinsius, still in his 20s, became Delft's city secretary. Leeuwenhoek was then beginning his long civic career as a minor city official.

Four decades later, Leeuwenhoek's letters "to the noble and awful Lord" (*aan den wel edelen gestrengen Heere*) discussed whales (November 8, 1712) and various fish (December 17, 1712). No doubt the two old friends corresponded about mundane matters. However, the only letters that have survived are full of scientific observations. These two letters, it turned out, became the opening letters of *Send-Brieven*, the volume that Leeuwenhoek self-published in 1718 in Dutch and Latin translation. At 80, the old man was in

The spelling of Leeuwenhoek's first and last names in this article conforms to the spelling in Dobell's standard English biography. The reference to his family name without the "van" conforms to the biographies of Dobell and Schierbeek, both the original Dutch and the English translation, as well as the publications of many other writers in English, including Ford and Ruestow.

Electronic supplementary material The online version of this article (doi:10.1007/s10482-014-0152-1) contains supplementary material, which is available to authorized users.

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Published online: 30 March 2014

Fig. 1 Portrait of Leeuwenhoek in 1707 at age 75 by Jan Goeree, inset in frontispiece of *Send-Brieven* (Leeuwenhoek 1718)

full stride, beginning a major new publishing project. He had a long way to go yet, over 60 more letters, as it turned out.

Who was Antony van Leeuwenhoek at 80? Fig. 1, his final known portrait, shows him at age 75 with deep lines around thick lips. The little mustache evident in earlier portraits is gone. His cheeks have become jowly. The lines around his heavy-lidded eyes show the decades of intense concentration. His eyes, his most fragile and important tools, are strong and clear. A visitor not long after wrote that Leeuwenhoek was "a man of seventy-eight, hale and hearty, save that he cannot much use his feet. We were surprised to find him not at all shaky, and he still has almost incomparable eyesight, though he taxes his eyes greatly" (Dobell 1932, p 64).

Was Leeuwenhoek a proto-scientist of heroic accomplishment or a naïve, uneducated amateur who happened to be born at the right time and place? An innovator and visionary who was a 100 years ahead of his time or a clever burgher with good eyesight and a lot of proverbial Dutch stubbornness? His science has been discussed in depth, but his life has been given less attention due to lack of information. Clifford Dobell's *Antony van Leeuwenhoek and his "Little Animals"* (1932) and Abraham Shierbeek's *Measuring The Invisible World* (1959) remain the best biographies in English. Recent archival research coming available at LensOnLeeuwenhoek.net and highlighted in this article answers questions that fill in some of the details of his life and bring a richer context to his science.

His family and early life

What was his heritage?

1632 was a very good year. Dutch traders ruled the sea lanes. In India, construction began on the Taj Mahal. In Italy, Galileo's *Dialogue Concerning the Two Chief World Systems* was published in February. Closer to home, during June the tide turned for the Dutch against the mighty Spanish army in the 80 Years' War. In Amsterdam, Rembrandt finished one of his more famous paintings, *Anatomy Lesson of Dr. Nicolaes Tulp*.

In the late summer and fall, within fewer than 90 days, five births in only two countries brought into the world men whose work profoundly affects us today. John Locke (August 29) and Christopher Wren (October 20) were born in England. Across the North Sea, Johannes Vermeer (October 31) and Benedict de Spinoza (November 24) were born in the Netherlands. Between them, on October 24, Antony van Leeuwenhoek was born in Delft, the same city as Vermeer. Their baptisms are registered on the same page in the records of the Nieuwe Kerk (*Doopboek* 1624–1636).

Leeuwenhoek's mother, Margrietke Jacobs van den Berch, came from a wealthy family with a long history of public service. Her siblings, three sisters and two brothers, all married well and left Delft. Margrietke married a basket maker and moved from the city's wealthy west side to the working-class Oosteinde, close by the Oostpoort (Seters 1952).

Table 1 lists some of the milestone events in Leeuwenhoek's life, including his education (Seters 1982) and apprenticeship (Seters 1951). He grew up around industrious people working with their hands. His father, Philips Thonis Leeuwenhoek, came from a family of basket makers. Woven reed baskets were the chief packaging material for Delft's extensive world-wide trade in ceramics. The baskets were strong, but

Table 1 Timeline of important events in the life of Leeuwenhoek

1632	Born on the Oosteinde in Delft
1640–1648	Educated in Warmond and Benthuizen
1648–1654	Apprenticed with linen merchant in Amsterdam
1654	Married Barbara de Meij (died 1666)
1655–1660	Ran draper's shop from his home in Delft
1660	Appointed minor city official
1669	Certified as surveyor
1671	Married Cornelia Swalmius (died 1694)
1673–1723	Wrote letters about his microscopic observations and experiments
1676	Wrote letter about microbes that made him famous
1679	Appointed city wine gauger
1680	Elected a fellow of the Royal Society in London
1684–1718	Self-published 165 letters
1701	Had his 50th publication in *Philosophical Transactions*
1721	Had his 100th publication in *Philosophical Transactions*
1723	Died in his home on the Hippolytusbuurt in Delft

they were filled with goods and then put on ships that sailed to the far corners of the earth, creating constant demand for more baskets.

The size of the family's home in Fig. 2 (Mol 1924) indicates that they had a prosperous business that employed workers from outside the family. Bleyswick's Kaart Figuratief of 1678 labels the right-hand gate the Leeuwe Poort, or Lions Gate, from which Antony's grandfather took the family name (Houtzager 1995).

Throughout his life, Leeuwenhoek was surrounded by women. His father died when he was a child. He had four sisters, with whom he remained close. He had no surviving brothers or sons and he spent half of his adult life married. The summer before his only surviving daughter Maria turned ten, her infant brother and then her mother died within a month of each other. When Maria was 15, her father remarried. That marriage was childless. By the time Maria was 30, her father was a world-class scientist. Her stepmother died when she was 38.

Maria spent her life living in the house where she was born, taking care of her father and, along with the maid, doing all the shopping, cooking, cleaning, and washing. He seemed not always to welcome distractions, so Maria probably answered the door and fended off visitors, too. Maria outlived her father by 20 years, keeping his papers, his tools, and hundreds of his single-lens microscopes (Geesteranus 1745). Of all

Fig. 2 Photograph of Leeuwenhoek's boyhood home, still from 1924 film (Mol 1924)

that, fewer than a dozen microscopes have survived (Ford 1991).

How prominent was his family?

Other than archival records, the best single source for information about Delft in Leeuwenhoek's time is Reinier Boitet's *Beschryving der Stadt Delft*. In chapter III, Boitet provides almost a hundred pages of lists of people who had held public appointments.

These lists have over sixty-five hundred names, many repeated due to re-appointment. With rare exceptions, all of these functions were filled by volunteer members of the self-appointed regents. Since the middle of the thirteenth century, these wealthy families had taken responsibility for ensuring Delft's peace and safety. They paid most of the taxes and managed the city's government. Leeuwenhoek's mother's family, the van den Berchs and the Hogenhoucks, were regents. In his short biography of Leeuwenhoek, Boitet (1729, pp 765–770) calls her family "very respectable and honorable". Later biographers have concurred, without details.

Leeuwenhoek's father's family, however, came from one of the new families. Grandfather Thonis Philips had moved to Delft as a young man, perhaps from The Hague, as discussed in W.H. van Seters' thorough article on Leeuwenhoek's heritage and youth. Leeuwenhoek married into an even newer family. His first set of in-laws, the parents of Barbara de Meij, were from Norwich in England and Utrecht in the Dutch Republic. His second set, parents of Cornelia Swalmius, were also a mixed family. Cornelia's father and brothers were preachers. The Dutch Reformed Church called them to various cities during their careers. Cornelia's mother, however, was from the Uyttenbrouck family. It had a history of public service in Delft as deep though not as wide as the van den Berches and Hogenhoucks (Seters 1952).

Delft at its height in 1670 had around 25,000 residents (Israel 1995) within the one square kilometer (half a square mile) inside its walls. Whatever prominence Leeuwenhoek had in that small world came from the families of his maternal grandparents as well as his second wife's grandparents. As shown on Table 2, a handful of family names occur repeatedly on Boitet's lists.

These families had many members involved in city government. These members also tended to be appointed to multiple offices during their civic careers. Through marriage, Leeuwenhoek was related to most of the families on the list above. For example, great-grandmother Neeltje's brother Maerten Jans Hogenhouck (Fig. 3) married Catharijne Adriaens van der Dussen. Table 3 shows the number of terms in public office by

Table 2 Most active regent families in Delft up to 1729. Numbers of appointments, not numbers of people (from Boitet 1729; Leeuwenhoek's families in bold)

Number of appointments	Family
300–400	van der Dussen
	van Bleiswijk
200–300	**van den Berch**/Berg/Burch
	Meerman
	van der Meer
100–200	van Santen/Zanten
	van Groenewegen
	Graswinkel
	van Lodensteijn
	Hogenhouck

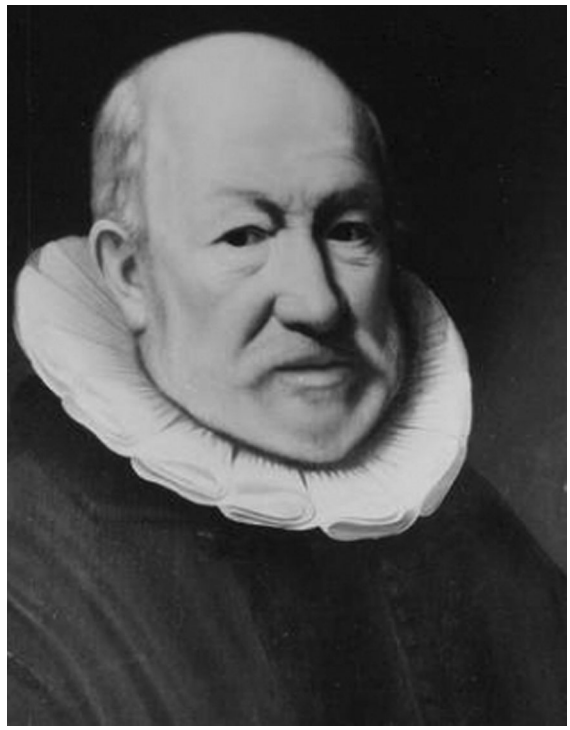


Fig. 3 Portrait of Leeuwenhoek's great great-uncle Maerten Jans Hogenhouck (1550–1613), artist unknown, private collection

Table 3 Leeuwenhoek's ancestors in municipal office (from Boitet 1729; Leeuwenhoek's families in bold)

Family	Relationship to Leeuwenhoek	Council of Forty (Veertigraad)	Annual terms as Mayor, Magistrate, or Treasurer
van den Berch	On mother Margriete's father's side		
Sebastiaan Cornelis	Great-grandfather	1579–1605	2
Jacob Sebastiaans	Grandfather	1608–1615	2
Maarten Sebastiaans	Great-uncle	1625–1626	
Pieter Sebastiaans [a]	Great-uncle		
Hogenhouck	On mother Margriete's father's side		
Jan Jacobs	Great–great-grandfather, Neeltje's father	1560–1586	11
Maerten Jans [b]	Great-grandmother Neeltje's brother	1586–1613	7
Adriaan Maertens	Neeltje's nephew	1613–1618	2
Jacob Maertens	Neeltje's nephew	1618–1638	3
Abraham Maertens	Neeltje's nephew	1638–1641	1
Cornelis Maertens	Neeltje's nephew	1641–1656	2
Pieter Abrahams	Neeltje's nephew's son	1643–1679	11
Jacob Cornelis	Neeltje's nephew's son	1656–1665	7
Maarten Pieters	Neeltje's nephew's son	1687–1720	15
Verburch	On mother Margriete's mother's side		
Claes Hendrikz	Great-grandfather's nephew	1575–1609	2
van der Eyck	On mother Margriete's mother's side		
Gerrit Jans	great-great-uncle on both branches of his mother's side of the family	1582–1620	15
Uyttenbrouck	On second wife Cornelia's mother's side		
Dirk Harperts	Cornelia's great great great-grandfather	?–1535	3
Jan Dircks	Cornelia's great great-grandfather	1536–1559	7
Dirck Jans	Cornelia's great grandfather	1560–1596	9

[a] Married Neeltje van Adrichem, whose father Jacob and brother Joost were four and seven times mayors plus most other offices

[b] Married into the van der Dussen family

Leeuwenhoek's ancestors, a record exceeded by very few families. In short, Leeuwenhoek's family on his mother's side was among the most prominent in Delft. He had a heritage of public service that he continued.

How prosperous was his family?

In the Dutch Republic, wealth was stored in two main instruments, real estate and cash. The cash was often invested in government bonds and personal loans. In the absence of savings banks, much of it remained in bags stored in bedroom chests.

Leeuwenhoek's Hogenhouck and van den Berch relatives owned property all over town but especially along the two oldest canals where most of the regent families lived. The daughters of those families married into other regent families, whose daughters married the Hogenhouck and van den Berch sons. Some of these other regent families were larger and much wealthier than Leeuwenhoek's. A comparison of the list of property owners to total number of residents shows that most people in Delft did not own property. Weeskamer (orphans' chamber) records of the resources of those who died with children confirm a large working class with few assets beyond their own labor (Registers 1618–1812).

Delft's spotty real estate records in the *Registers van Onroerende Goederen* show that the properties in Table 4 were owned at one time or another by people closely related to Leeuwenhoek, those marked with an asterisk by Antony himself. These addresses are the current street addresses. Most of the seventeenth century buildings on those properties are long gone.

Firmly rooted in Delft, Leeuwenhoek was surrounded by a prosperous, middle-class family in the first country in history to have such a class.

Table 4 Properties in Delft owned by people closely related to Leeuwenhoek (from *Registers van Onroerende Goederen* 1649; Leeuwenhoek's property marked with asterisks)

de Meij family first wife	de Molijn family mother and sister	Leeuwenhoek family father and uncle
Donkerstraat 51 A	Choorstraat 26	Brabanste Turfmarkt 71
Gasthuislaan 5	Choorstraat 33	Buitenwatersloot 121
Nieuwe Langendijk 84	Choorstraat 35	Buitenwatersloot 214
Oosteinde 248	Choorstraat 38	Buitenwatersloot 218
* Oosteinde 25	Doorniksteeg	Dr. Schaepmanstraat
	Verwersdijk 52 B	Gasthuislaan 181–203; Zuiderstraat 222–256; Kruisstraat 77
	Voldersgracht 4	* Hippolytusbuurt 1
	Voldersgracht 8	Kerkstraat 3
	Voorstraat 8	Koornmarkt 105
		Koornmarkt 65
		Kruisstraat 5 t/m 69
		Markt 17B
		Markt 25
		Markt 71
		* Nieuwstraat 18
		Oosteinde 56
		Oosteinde 58
		Oranje Plantage 79
		Oude Delft 97
		Peperstraat 7
		Pieterstraat 27
		Pynepoort 14
		Verwersdijk 97 A
		Voorstraat 19
		Zuiderstraat 256

His civic career

What was his role Delft's city government?

In 1660, Leeuwenhoek was given his first position of trust in city government. He was appointed an official (*kamerbewaarder*) of the city's magistrates court (*schepenenkamer)* (see Fig. 4) in the Stadhuis, city hall (*Resolutieboek* 1537–1740). His duties as specified in the oath of office in the *Registers van kleine ambten en officiën* (Registers 1650–1720) are not clear, and every city in the Republic had a unique bureaucracy. *Kamerbewaarder* is often translated as chamberlain (Dobell p 31), the duties described as janitorial, and the job deemed a sinecure. Considering the later duties Leeuwenhoek was given, most certainly not sinecures, it might be better to translate *kamerbewaarder* as city court official. By the mid-1670s, Leeuwenhoek had been nationally certified as a surveyor (Schierbeek 1930). He was also serving Delft as a curator of insolvent estates, an office held usually by notaries. He was curator for, among others, the tangled estate of the painter Johannes Vermeer's widow (*Kamerboek* 171 p 113).

Leeuwenhoek's appointment as an official of the court when he was not yet 30 made him one of the more highly paid city employees. He received an additional sum to keep the room clean and the fire lit, which may well have been done by someone Leeuwenhoek hired. He held the post until 1699 and continued to draw the salary until his death (Hoppesteijn van Leeuwen 1720, 1722). Abraham Schierbeek, Leeuwenhoek's Dutch biographer, wrote: "It is extremely difficult to form a good notion of the functions of a camerbewaarder" (1950 p 20). This item in the city's archives appointing Leeuwenhoek lists his responsibilities (*Resolutieboek* 16.3 p 365; my paragraphing and emphasis):

> On March 26, 1660 was Antony Leeuwenhoek, in place of Jan Strick, appointed as Camerbewaarder, at the same wages, benefits and emoluments. Their Worships the Burgomasters and Magistrates of the Town of Delft have appointed and do hereby charge Antony Leeuwenhoek to look after the Chamber wherein the Chief Judge, the Sheriffs, and the Law Officers of this Town do assemble [in order] to open and to shut the foresaid Chamber at both ordinary and extraordinary assemblies of the foresaid Gentlemen in such wise as shall be required and needful to show towards these Gentlemen all respect, honour, and reverence and **diligently to perform and faithfully to execute all charges which may be laid upon him** and to keep to himself whatever he may overhear in the Chamber
> to clean the foresaid Chamber properly and to keep it neat and tidy
> to lay the fire at such times as it may be required and at his own convenience and carefully to preserve for his own profit what coals may

Fig. 4 Photograph of magistrates' room in Delft's city hall, photograph by the author, 2011

remain unconsumed and see to it that no mischance befall thereby nor from the light of the candles.
He shall furthermore do **all that is required of and that pertaineth to a good and trusty Chamberlain**.
For the which service the foresaid Antony Leeuwenhoek shall enjoy such wages, benefits and emoluments as the foresaid lamented Jan Strick his predecessor in office did enjoy and shall enter into his duties upon the morning of the twenty fourth of January 1660 and his wages shall be paid upon the same terms as those whereon the foresaid Jan Strick's were paid.
Ordered by all the Burgomasters in Council assembled this twenty sixth day of March 1660 and signed by J. Camerling, Pensionary.

The extract in Fig. 5 comes from the *Resolutions of the Council of State of Holland and West Friesland*, dated 1723, the year Leeuwenhoek died (Resolutions 1723). It lists the fees that their *kamerbewaarders* could charge for various services in addition to their salary. Some of them had to do with debtors. Others, including the payments, were for:

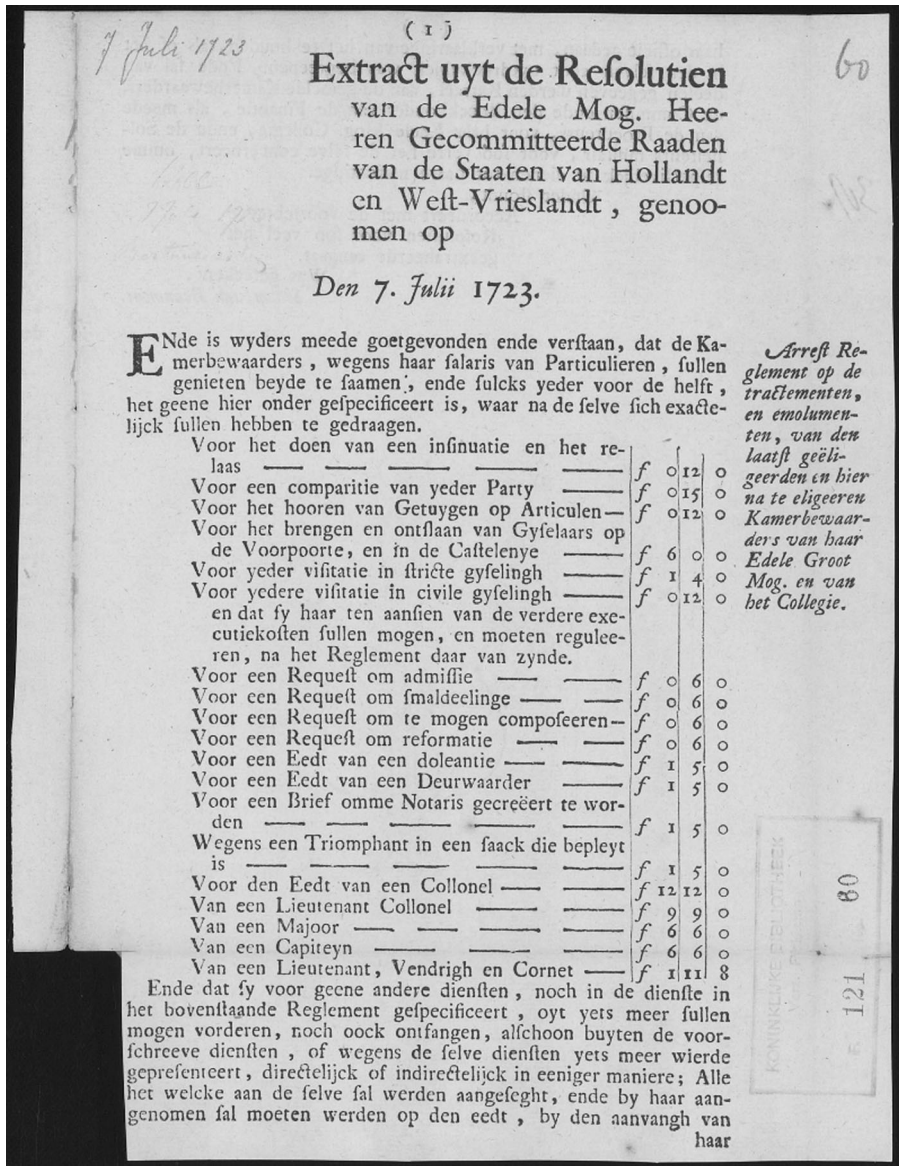
- executing a summons or warrant, 12 stuivers
- hearing a witness, 12 stuivers
- administering an oath of office to a process server, 1 guilder, 5 stuivers

While this was not Leeuwenhoek's job, it suggests that a *kamerbewaarder* could do far more than keep the room open, warm, and tidy. It also suggests that Leeuwenhoek could have received payments in addition to his official salary.

What did he do for Delft's excise tax collection?

In 1679, Leeuwenhoek was appointed to the office of city wine gauger (*wijnroeier*) and held it for the rest of his life. He used his surveying skills to measure the contents of irregularly shaped barrels of wine and other liquids being imported into and exported from Delft. The arithmetic for measuring the volume of curved spaces was not difficult, but the computational skills were not common, either. The city had several gaugers (*peijlders*) of liquids like wine, beer, brandy, and oils as well as grain. They worked in the Waag, the city's weighing house on the canal right behind City Hall and not a hundred yards from Leeuwenhoek's house farther along the same canal.

The gaugers were trusted to standardize within a city's economy. After the wine gauger measured something, it could then be fairly taxed and



(1)

7 Julii 1723

60

Extract uyt de Reſolutien van de Edele Mog. Heeren Gecommitteerde Raaden van de Staaten van Hollandt en Weſt-Vrieslandt, genoomen op

Den 7. Julii 1723.

ENde is wyders meede goetgevonden ende verſtaan, dat de Kamerbewaarders, wegens haar ſalaris van Particulieren, ſullen genieten beyde te ſaamen, ende ſulcks yeder voor de helft, het geene hier onder geſpecificeert is, waar na de ſelve ſich exactelijck ſullen hebben te gedraagen.

Arreſt Reglement op de tractementen, en emolumenten, van den laatſt geëligeerden en hiernaa te eligeeren Kamerbewaarders van haar Edele Groot Mog. en van het Collegie.

Voor het doen van een inſinuatie en het relaas	f	0 12	0
Voor een comparitie van yeder Party	f	0 15	0
Voor het hooren van Getuygen op Articulen	f	0 12	0
Voor het brengen en ontſlaan van Gyſelaars op de Voorpoorte, en in de Caſtelenye	f	6 0	0
Voor yeder viſitatie in ſtricte gyſelingh	f	1 4	0
Voor yedere viſitatie in civile gyſelingh	f	0 12	0
en dat ſy haar ten aanſien van de verdere executiekoſten ſullen mogen, en moeten reguleeren, na het Reglement daar van zynde.			
Voor een Requeſt om admiſſie	f	0 6	0
Voor een Requeſt om ſmaldeelinge	f	0 6	0
Voor een Requeſt om te mogen compoſeeren	f	0 6	0
Voor een Requeſt om reformatie	f	0 6	0
Voor een Eedt van een doleantie	f	1 5	0
Voor een Eedt van een Deurwaarder	f	1 5	0
Voor een Brief omme Notaris gecreëert te worden	f	1 5	0
Wegens een Triomphant in een ſaack die bepleyt is	f	1 5	0
Voor den Eedt van een Collonel	f	12 12	0
Van een Lieutenant Collonel	f	9 9	0
Van een Majoor	f	6 6	0
Van een Capiteyn	f	6 6	0
Van een Lieutenant, Vendrigh en Cornet	f	1 11	8

Ende dat ſy voor geene andere dienſten, noch in de dienſte in het bovenſtaande Reglement geſpecificeert, oyt yets meer ſullen mogen vorderen, noch oock ontfangen, alſchoon buyten de voorſchreeve dienſten, of wegens de ſelve dienſten yets meer wierde gepreſenteert, directelijck of indirectelijck in eeniger maniere; Alle het welcke aan de ſelve ſal werden aangeſeght, ende by haar aangenomen ſal moeten werden op den eedt, by den aanvangh van haar

Fig. 5 Extract showing *kamerbewaarder*'s fees (*Resolutions* 1723)

confidently subdivided, combined, bought, and sold, at the time of measuring and in the future. Each city in the Republic organized this task differently and gave the functions different names and compensated it differently. According to the Delft city bylaws, the wine gaugers swore to this oath (*6de Keurboek der stad Delft* 1614–1739):

> I promise and swear, that I, as gauger for wines and other commodities that will offer themselves for me to gauge, truly and with my best learning in accordance with the art of wine gauging will gauge and measure … and that I moreover in everything will do what a sincere wine gauger is obliged to do.
>
> Likewise, all barrels to be filled with the City, from eight to forty stoups, will for the first time out of the cellar need to be made watertight and after that branded with the letter D by the gauger in person, without his being permitted to use anyone else for that purpose.

Were his city jobs sinecures?

Most twentieth century biographers follow Dobell (1932, p 33) and treat Leeuwenhoek's civic jobs as

sinecures. The magistrates needed a glorified janitor, someone to keep the fire going and the room tidy. They paid Leeuwenhoek a good sum plus enough to hire someone else to actually do the work. Other biographers, notably Schierbeek (1950, p 19), argue otherwise.

The sinecure idea came from Haaxman's biography (1875, p 21). He stated that he got it from Delft archivist Soutendam (my translation):

> The little job was also (always according to Mr. Soutendam), not less honorable than that of the Kamerheer of the Hof (Chamberman of the Court), "mutatis mutandis" (changing only those things that need to be changed); of course, Leeuwenhoek will have to supervise the dirty work.

The city archives point to several problems with Soutendam's interpretation.

Plausibility

Why would the city fathers grant such a large sinecure to a 28-year-old linen merchant, succeeding Jan Strick, who went on to own a tavern? Leeuwenhoek was not yet doing the research for which he became famous. He was not the ne'er-do-well son of a beloved city father. If he were only supervising someone keeping the room open, warm, and tidy, what do these items in his 1660 commission refer to?

- "diligently to perform and faithfully to execute all charges which may be laid upon him"
- "do all that is required of and that pertaineth to a good and trusty Camerbewaarder"

According to the *Woordenboek der Nederlandsche Taal* (1882–1998), supported by the fee schedule in Fig. 5, a *kamerbewaarder* also actively participated in the workings of the court.

When Leeuwenhoek was appointed a curator of estates, he was one of the very few men in that position who were not notaries. As recorded in the *Register van de Curateelen*, where the notaries' pages have "Nots." after their name, Leeuwenhoek's has "Camerbewaarder" (Fig. 6). Being a curator of insolvent estates was one of those charges that the magistrates laid upon him. His most noteworthy case among the six that we know about was the estate of Catherine Bolnes, widow of painter Johannes Vermeer.

Precedent

What evidence is there of other sinecures? The Delft *Registers van kleine ambten en officiën*, Registers of minor offices, lists about two hundred minor officials who were appointed by the burgemeesters. The regents were rich and made all the big decisions. These minor officials implemented the decisions and made the system work.

Taken together, the two hundred job titles paint a picture of a small group of what we would now call civil servants. For most, salaries are noted along with those who had to take an oath of office. Very few of the citizens holding these positions had the family names of regent families, so they probably needed the salary. The *Register* gives no evidence that any of the minor offices was a sinecure and makes no special distinction for Leeuwenhoek's. Both of Leeuwenhoek's civic appointments, *kamerbewaarder* and *wijnroeier*, are listed. He had to take an oath for both offices and his salary was among the highest.

Practicality

Because most of the minor civil and criminal problems in Delft were dealt with among the parties and often a notary, only the most heinous, egregious, and intractable reached the magistrates (Rozemond 1991).

- On Mondays, the magistrates met in their chamber with other Heren van de Weth (Gentlemen of the Law): the mayors, sheriff, city lawyer, and city secretary.
- On Tuesdays, they met by themselves in their chamber.
- On Wednesdays and Saturdays, they convened in the Burgerzaal (citizen's hall) as the Vierschaar, the public court of justice.

These magistrates had clerks to organize the documents and write down their proceedings. That was a desk job. The closest other civil servants were the court messengers and summons officers (*gerechtsboden* and *deurwaarders*). In a time before local post offices, their jobs involved going to private homes and businesses to take information to and from the court.

Whose duties involved dealing with those who gathered at City Hall with a claim on the attention of the magistrates? On Tuesdays, there would be

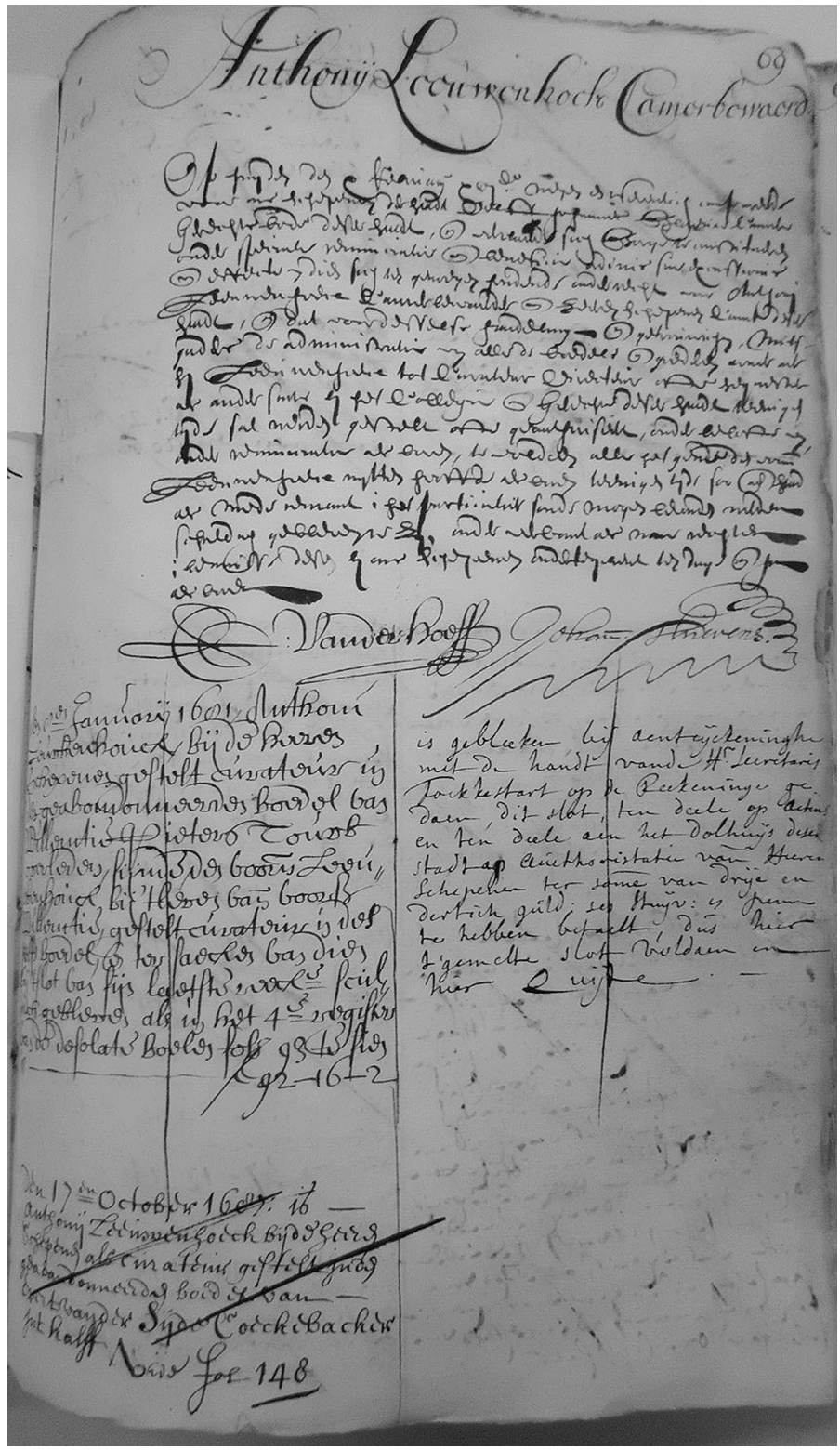


Fig. 6 Leeuwenhoek's page in the 5e Register van de Curateelen (1675–1719) Oud-Rechterlijk Archief 318

Table 5 Financial instruments in estate of Maria Thonis van Leeuwenhoek (from Geesteranus 1745)

Type of instrument	Issued by (bought from)	Amount	Interest rate (Fritschy 2009)	Annual interest
Seven life annuities (*lijfrenten*)	republic, province, city	9,132	9 %, 10 %	843
Two annuities (*losrenten*)	province	2,300	5 %, 8.3 %	125
Five bonds (*obligaties*)	republic	8,000	4 %	320
Eight bonds	province's Hague office	17,900	4 %, 5 %	770
25 bonds	province's Delft office	27,382	4 %, 5 %	1,162
Three bonds	Weeshuijs (orphanage)	3,100	3 %	93
Eight bonds	private individuals	3,900	3 %, 3.5 %, 4 %	119
11 lottery bonds (*prijsobligaties*)	republic (4), province (7)	2,300	4 %	92
One bond	VOC (East India Company)	500	?	?
		74,514		3,524

attorneys and witnesses, plaintiffs and victims, notaries and their clerks. For many contracts between private parties to be enforceable, the document had to be witnessed and signed by two magistrates. On Wednesdays and Saturdays, add the families and the public crowded into the Burgerzaal.

Who kept order in this court? Who organized it? Who managed the flow of people around the proceedings, the principals, the attorneys, the witnesses, the public? If it was the court official known as the *kamerbewaarder*, then nothing that took up that much time and effort can be considered a sinecure.

How prosperous was he?

When Leeuwenhoek died, he bequeathed a good quantity of bonds to his heirs. We do not have an inventory of his estate. When his daughter Maria died in 1745, notary Joris Geesteranus made an inventory of her estate and filed it in The Hague (Geesteranus 1645). In addition to three properties and a large collection of gold, silver, and diamond jewelry, she had almost ten thousand guilders in cash in sacks in her upstairs front room and bedroom.

As shown in Table 5, she also had seventy financial instruments worth almost 75,000 guilders paying her over 3,500 guilders per year. While she added to this investment portfolio, the bulk of it was accumulated while her father was still alive.

These financial instruments had been only recently introduced, one of the set of financial and economic innovations that give the Dutch Republic in the eyes of many historians the reputation as the world's first modern economy. They enabled Maria van Leeuwenhoek, without close male relatives, to live out her life in comfort. They also make it clear that Leeuwenhoek did not have to work as long as he did. He apparently retired from his city jobs around the turn of the century, leaving him with enough time at age 80 to begin a fresh set of observations and letters.

His scientific career

What did he discover in his 80s?

In his 80th year, Leeuwenhoek began a new set of observations and a new publishing project. Between 1712 and 1717, he wrote 46 letters to a variety of people, many of them public figures, politicians and academics. He addressed about a fifth of them to the Royal Society in spite of the fact that *Philosophical Transactions* editor Edmond Halley was showing not the slightest interest in publishing them. In 1718, Leeuwenhoek collected these letters, titled them *Send-Brieven* (Epistles), numbered them with Roman numerals I through XLVI, and published them himself in Dutch as the fourth and final volume of his 165 collected letters, his *Brieven*.

Half of the *Send-Brieven* letters had figures, Leeuwenhoek's own version of the cabinets of wonders so popular in his day. They were copperplates made from drawings, most commonly of red chalk. They were drawn by a hand other than Leeuwenhoek's, probably that of Thomas and Willem van der Wilt (Boitet 1729). His eyesight was not as sharp as it

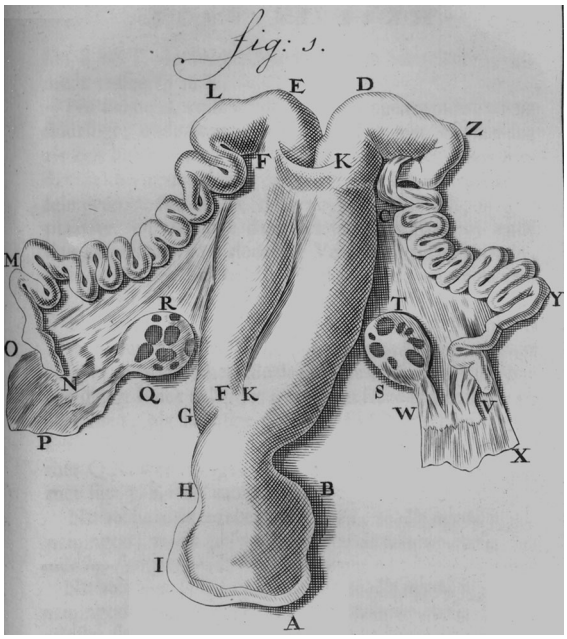


Fig. 7 Figure 1 accompanying Leeuwenhoek's letter of November 17, 1716 (*Send-Brieven* XXX) to Gottfried Leibniz

once had been. As a young man, he had been amazed to see protozoa and bacteria in everyday waters and red blood cells moving from artery to vein. He had performed countless micro-dissections and found sperm in every male animal he put under his knife. In his 80s, his observations were not quite as close but remained as catholic as ever, ranging over these plants, animals, and minerals:

- grain meals
- fruit seeds
- coconuts
- sheep—reproductive organs (see Fig. 7)
- fish—muscles and scales
- cows and pigs—nervous system
- various animals—hair, skin, muscles and tendons
- salts

He wrote the last of these letters in November 1717, when he was 85. Halley was still editor of *Philosophical Transactions*, so Leeuwenhoek must have thought his career was over. However, in November 1719, physician James Jurin replaced Halley and Leeuwenhoek's contributions were again welcome. Six weeks later, in January 1720, Leeuwenhoek wrote a letter to Jurin that was published in *Philosophical Transactions*, his first since 1714. Fourteen more letters followed, all published, ending in the two dictated from his deathbed in August 1723. It had been 50 years since he sent his first one.

What tools did he use?

The archives have so far yielded little about how much time his civic jobs took or when Leeuwenhoek was able to close his draper's shop. Cornelia Swalmius, his second wife, came from a family of Dutch Reformed clergy. Their 1671 marriage was childless. She died 23 years later and was buried near Barbara under the floor of the Oude Kerk. Some biographers, following Schierbeek (1950 p 24) have assumed that her family's social circle brought Leeuwenhoek into contact with a group of university-educated professionals who may have encouraged his lens-grinding and careful observations. There is no documentary evidence to support this inference of causality. The couple lived in the same neighborhood for two decades before their marriage, so it is equally plausible that they knew each other for years before marrying.

All the separate tool-making skills that Leeuwenhoek needed were commonly practiced in Delft, specifically heating and shaping of metal and using lathes to turn metal rods to make screws and grind glass to make lenses. As a cloth merchant, Leeuwenhoek knew the usefulness of low-power magnifying glasses to count threads. As a surveyor, he knew the usefulness of low-power telescopes to see distant landmarks. His daughter Maria's estate inventory has tools for all of these activities (Geesteranus 1745).

The metallurgy and especially the grinding and polishing of such small glass pieces were skills that would have taken years to develop. Early in his career, Leeuwenhoek settled on a "good enough" design for brass and silver devices to hold his tiny lenses. It solved these problems:

- *visibility* how to illuminate the specimen
- *magnification and resolution* how to bring the specimen into focus
- *utility* how to hold both dry specimens and liquids

Over his 50 year career, he made over five hundred microscopes, a rate of almost one per month. By the time he came to writing the *Send-Brieven*, he was still using the same design. Dozens of letters meant dozens of specimens, which meant dozens of lenses to grind and mount, with three positioning screws for each. As

Harting noted (1850, p 41), the two dozen he bequeathed to the Royal Society all had specimens still attached.

Lenses

The smaller the lens, the greater the magnification and thus the closer the focal length, that is, the distance from the lens where the object will be in perfect focus. The focal length of a convex lens is just a little more than its radius. For Leeuwenhoek's strongest surviving lens, less than 2 mm in diameter, magnifying around 266 times, with a measured resolution of 1.35 μm, the specimen had to be 0.9 mm, less than four hundredths of an inch, away from the lens (Zuylen 1981). However, for most observations, Leeuwenhoek did not need lenses that strong.

Leeuwenhoek used three methods to make lenses.

- Robert Hooke's method of drawing out a thread to make a spherical drop (see below)
- blowing to make a plano-convex lens
- grinding and polishing the old-fashioned way, his preferred method, to make a double-convex lens

Devices

Leeuwenhoek was often observing three-dimensional objects that either were moving or could be rotated on an axis. He needed, more than anything, something that would keep lens and the specimen at a constant but adjustable distance. It made more sense to keep the lens fixed and to move the specimen. Once he finally got focus, he did not want to lose it. There was no need for a tube that would change the relative position of multiple lenses. Instead, Leeuwenhoek focussed by moving the specimen.

When he made his devices, he used the single-lens microscope, really a palm-sized magnifying glass, according to the design Hooke described in the Preface to *Micrographia* (1665).

> The fewer the Refractions are, the more bright and clear the Object appears. And therefore 'tis not to be doubted, but could we make a Microscope to have one only refraction, it would, cæteris paribus, far excel any other that had a greater number.
>
> And hence it is, that if you take a very clear piece of a broken Venice Glass, and in a Lamp draw it out into very small hairs or threads, then holding the ends of these threads in the flame, till they melt and run into a small round Globul, or drop, which will hang at the end of the thread;
> and if further you stick several of these upon the end of a stick with a little sealing Wax, so as that the threads stand upwards, and then on a Whetstone first grind off a good part of them, and afterward on a smooth Metal plate, with a little Tripoly, rub them till they come to be very smooth;
> if one of these be fixt with a little soft Wax against a small needle hole, prick'd through a thin Plate of Brass, Lead, Pewter, or any other Metal, and an Object, plac'd very near, be look'd at through it, it will both magnifie and make some Objects more distinct then any of the great Microscopes. …
> These, though exceeding easily made, are yet very troublesome to be us'd, because of their smallness, and the nearness of the Object.

That nearness created Leeuwenhoek's final design problem: how to light the specimens enough to make his simple microscope useful. Hooke had discussed this problem later in *Micrographia*, and we can only assume that Leeuwenhoek tried some of these methods, too.

In 1699, he wrote: "But to mount such small glasses well, requires a far greater judgment, than to make them" (*Collected Letters* 200). Two decades later, just turned 80, he was still trying new techniques to increase visibility. In a letter written in 1714, he describes using saffron to stain cows' muscles yellow so that he could better distinguish fat cows from lean cows (*Send-Brieven* XI).

Almost all of Leeuwenhoek's lenses were mounted singly, according to the design in Fig. 8. The widest of the surviving plates is 28 mm or 1.1 inches, and the longest is 47 mm or 1.9 inches (Baker 1739; Ford 1991). The matching plates, riveted together, had matching holes slightly smaller than the lens that they held.

Martin Folkes (1722) describes them in detail. Behind the plates was a pin on a block controlled by three screws, one for each dimension. The pin itself could be swiveled by the little handle to rotate the

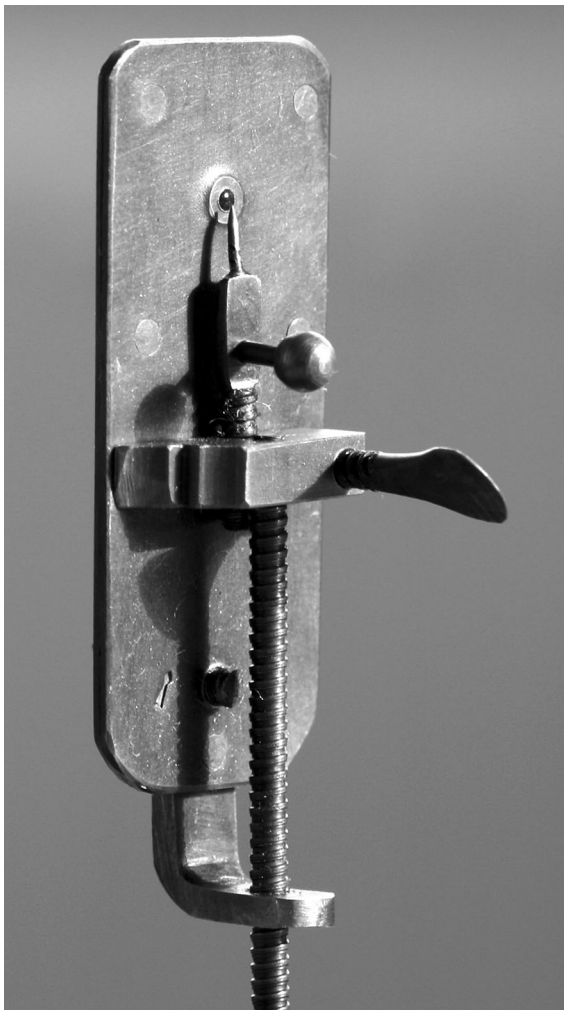


Fig. 8 Photograph of the most common design of Leeuwenhoek's single-lens microscopes

specimen around its vertical axis. These parts are not interchangeable. Leeuwenhoek made them all by hand out of brass, copper, silver, and even gold. The metal was soft so that after use, the screw threads would wear. This may be one reason that Leeuwenhoek made hundreds of these tiny magnifying glasses. After he developed this design and adjusted to the trade-offs inherent in its differences with Hooke's design, he stayed with it for 50 years. He put his energy into improving the lenses.

According to the description of the lot of hundreds of microscopes sold after the death of Leeuwenhoek's daughter Maria, a few of the microscopes were wider and had two or three single lenses mounted side by

Fig. 9 Detail of portrait of Leeuwenhoek showing three lenses on one microscope, Jan Verkolje, mezzotint, 1686

side. One of these, with three lenses, is clearly visible in the 1686 portrait by Jan Verkolje (Fig. 9). It looks as though it has only one specimen pin. Perhaps it was for wide specimens.

Leeuwenhoek's showcase for visitors was the eel viewer (*aalkijker*) (Fig. 10). It provided a demonstration of the blood circulating through the capillaries in the tail of an eel. The eel had to be living if the blood were to circulate and a living eel would not stay still on the edge of a pin.

For the curious who came to visit, including Tsar Peter the Great in 1698, this observation was easy to explain. Finally proving Harvey's famous conjectures about the systemic circulation of blood in the cardiovascular system, it was an important observation. It could be easily seen with a relatively low-powered lens without the patience and rigor needed for viewing protozoa. Visitors could relate it to their own bodies without having to accept anything either too unusual or too numerous. The long letter explaining it, dated September 7, 1688 (*Collected Letters* 110), he had printed separately, in Dutch only, under the title *Den Waaragtigen Omloop des Bloeds*, On the True Circulation of the Blood. Visitors could take a copy with them as a souvenir.

What techniques and methods did he use?

Biographies include much speculation about Leeuwenhoek's techniques, especially secret techniques.

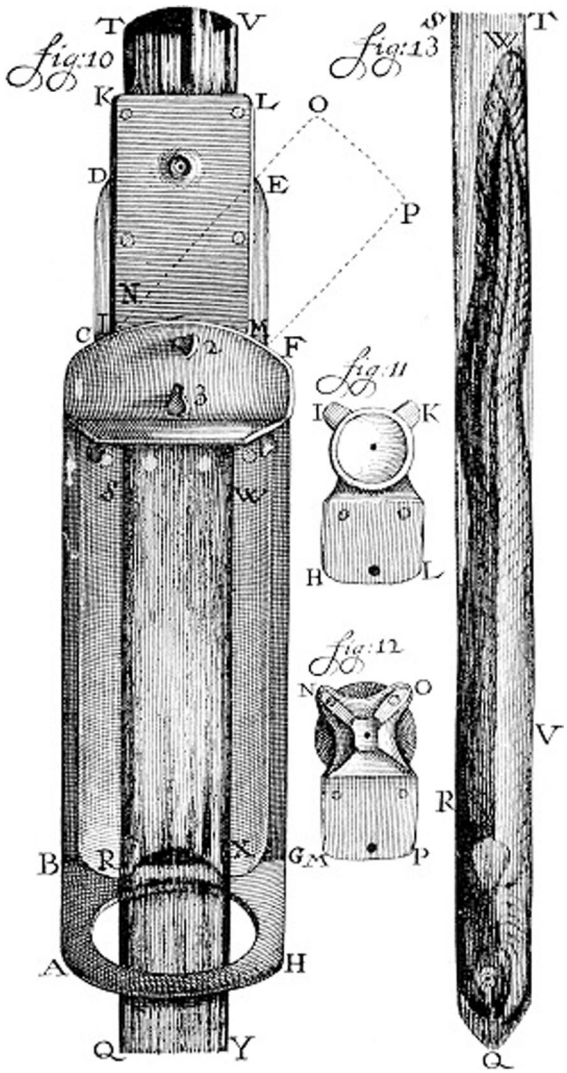


Fig. 10 Figures 10–13 accompanying Leeuwenhoek's letter of January 12, 1689 (*Collected letters* 113) of an eel viewer,a cupped lens holder and an eel in a glass tube

Early in his career, on October 9th, 1676 (*Collected Letters* 26), he wrote to the Royal Society (my translation):

> My method for seeing the very smallest little animals and minute eels, I do not impart to others; nor how to see very many little animals at one time. That I keep for myself alone.

Visitors such as Thomas Molyneux in 1685 noted (Birch 1756, IV p 384):

> Such were the microscopes, which I saw, and these are they that he shews to the curious that come and visit him: but besides these, he told me that he had another sort, which no man living had looked through setting aside himself; these he reserves for his own private observations wholly, and he assured me they performed far beyond any, that he had shewed me yet, but would not allow me a sight of them.

Dobell gives these secret methods several pages of guarded speculation (1932, pp 330–332). Many short biographies of Leeuwenhoek seem to mention the "secrets" as a dash of romantic flair or to portray him as a hopeless amateur too intimidated to communicate with real scientists.

The microscopes themselves were not secret. He showed them to people all the time. To grind his lenses, he did what any other lens grinder did, only smaller. The other lens-making methods were no secret; Hooke's *Micrographia*, detailing the method of making lenses from drops of molten glass, was one of the best selling books of the time. The construction of the device itself was transparent; it had no inner parts hidden from view.

Perhaps some of his techniques were hard to explain and harder to demonstrate. The pin was fine for dry or sliced specimens, but not for liquids. Leeuwenhoek drew liquids into a thin glass tube, what we now call a capillary tube. It had to be held or clamped directly behind the lens, or broken into a small section and fixed to the pin, sometimes with his own saliva. In addition, his letters suggest other techniques:

- *dark field microscopy* to increase visibility - letter of January 22, 1675 (*Collected Letters* 20; Dobell 1932 p 331)
- *water lenses* to increase magnification - described in Gray (1696)
- *mica sheets* (Muscovy glass) to fix specimens, functioning as today's glass slides - letter of February 21, 1679 (*Collected Letters* 42)
- *sections* to let light through - letter of June 1, 1674 (*Collected Letters* 8) and many times thereafter.

Several of the items from his daughter Maria's estate inventory—mirrors, glasses, and prisms—suggest methods Leeuwenhoek might have used to illuminate his specimens. The short focal length meant that the specimen had to be too close to the lens to illuminate easily. Using a replica of one of his devices

soon convinces the researcher that Leeuwenhoek did not hold them by hand for the length of time he needed to make his observations, often while taking notes. How did his draftsmen keep their hands free for drawing with red chalk? He must have had a clamp of some sort, probably adjustable. Swivel arms were common enough, if only from Hooke's drawings in *Micrographia* or the low-power microscopes that Johannes van Musschenbroek made in Leiden.

In 1692, when as it turns out Leeuwenhoek was not halfway through his long career, Robert Hooke delivered a lecture about the history and future of both the telescope and microscope. He called Leeuwenhoek the microscope's "single votary, … besides whom none make any other use of that instrument" (Hooke 1726).

A decade later, in his 80s, Leeuwenhoek wrote to Leibniz (*Send-Brieven* XVII; Dobell 1932 p 325):

> To train young people to grind lenses, and to found a sort of school for this purpose, I can't see there'd be much use :… most students go there to make money out of science, or to get a reputation in the learned world. But in lens-grinding, and discovering things hidden from our sight, these count for nought. And I'm satisfied too that not one man in a thousand is capable of such study, because it needs much time, and spending much money; and you must always keep on thinking about these things, if you are to get any results. And over and above all, most men are not curious to know: nay, some even make no bones about saying. What does it matter whether we know this or not?

Two years later, he wrote to Abraham van Bleyswijk (*Send-Brieven* XXXII; my translation):

> I know well that my writings will not be accepted by some, judging that such discoveries are impossible to make. But I am not offended by such objections. Among the ignorant, they still say about me that I'm a conjuror, and that I show people what does not exist. But they're to be forgiven, they do not know better.

Leeuwenhoek's devices were hard to use and some of his techniques even harder to explain. To the outsider, it might seem as though he kept secrets like a magician or alchemist. To Leeuwenhoek, it might simply have been not worth the effort to show visitors, however important they thought themselves, the elaborate techniques that took more subtlety and patience.

Table 6 Leeuwenhoek as scientist

Characteristics of modern science	Leeuwenhoek's activities that exemplify them
Tools to collect objective data	His little lenses extended human senses, in this case sight.
Tools to analyze data	He quantified and measured. His surveyor's mathematics let him solve for unknowns in simple equations.
Experiments	His curiosity and logical mind led him to what we now call controlled experiments.
Records of observations	Many of his letters were write-ups of his lab and field notes; most include illustrations.
Peer review	His observations were validated by others working independently, most famously by Hooke replicating Leeuwenhoek's first systematic, controlled observations of microbes in the letter of October 9, 1676.
Open publication	His letters were published and translated. Given his international reputation, they were widely disseminated within the Republic of Letters.
Social context	Leeuwenhoek frequently made observations at the request or suggestion of his correspondents.

Was he a scientist?

Looking back, we want answers to questions that Leeuwenhoek himself never asked. Was he a scientist or just a clever burgher? Dobell's "Father of Protozoology and Bacteriology" or Baas Becking's "Immortal Dilettante" (1924)? An amateur scientist or a scientific amateur?

In its current meaning, the term scientist was not common in English until the mid-nineteenth century. In the seventeenth century, people like Leeuwenhoek and Robert Hooke referred to themselves as philosophers, as in the journal *Philosophical Transactions*, sometimes as natural philosophers, as in Newton's *Mathematical Principles of Natural Philosophy*.

To what extent do Leeuwenhoek's values and methods resemble those of scientists today? His daughter's estate inventory (Geesteranus 1745) shows

the tools and instruments to support the conclusion that he had wide-ranging scientific interests and activities, summarized in Table 6.

To many, Leeuwenhoek is not considered among the first rank of scientists because he was a generalist who looked at everything he could get behind his lenses. He did not specialize nor did he have the synthesizing mind of a theoretician like Newton. Neither did anyone else at the time have a mind like Newton's. Newton himself was an alchemist, the kind of distraction that never seemed to cross Leeuwenhoek's literal, commonsensical mind. Leeuwenhoek openly published everything, yet no one else was able to look at his voluminous observations and synthesize the evidence into a profound theory. He died when Linnaeus was still a teenager in Sweden, so he had no terminology or taxonomy. In the century after his death, everything he saw was re-discovered before similar observations were synthesized and theorized into threatening germs in the wake of the discoveries of Louis Pasteur, Joseph Lister, and Robert Koch. Today, a dozen different scientific disciplines claim Leeuwenhoek as a "father". Was this pioneer supposed to have had the foresight to create all of those disciplines himself? His activities were bottom-up, driven by his tools and his methods, not top-down, driven by the traditions and expectations of a discipline.

Leeuwenhoek was as much a scientist as anyone of his time. He held and practiced the values of empiricism, objectivity, and openness. He willingly participated in the validation of his claims. He changed his ideas based on new evidence. He was for half a century an important participant in what we now call the Scientific Revolution and the Enlightenment.

His publications

What did he write?

Leeuwenhoek wrote only letters, though he collected half of them, unedited, into bound volumes. *Alle de Brieven/The Collected Letters*, begun in 1939 and not yet finished, will end up with around three hundred fifty letters, a few of them known only by reference in others letters. Over 50 years, that's an average of seven per year.

The letters fall into seven periods according to who was editor of *Philosophical Transactions*. As shown on Table 7, Leeuwenhoek addressed a little over two hundred letters to the Royal Society, either to officers by name or to the membership as a whole. Excerpts of about a half of them, often missing only the opening and closing formalities and administrative concerns, were published in *Philosophical Transactions*.

Beginning in the mid-1680s, Leeuwenhoek pursued a steady schedule of translations and self-publishing for the rest of his career. Of all the letters he wrote, he self-published 165 of them, about half of the total, in the original Dutch and in Latin translations over three decades, from 1684 to 1718. He included almost half of the letters also published in *Philosophical Transactions* and also over a hundred letters that were never translated and published in English until the twentieth century. Several dozen, including the *Send-Brieven*, remain unpublished in English translation as of 2014. In none of the self-published letters did Leeuwenhoek change or edit anything from the original versions.

According to Dobell (1932 p 388), who provides more details about various editions, the self-published letters include:

Table 7 Summary of Leeuwenhoek's letters, those addressed to the Royal Society, those published in *Philosophical Transactions*, and those that were self-published

PT Volume	Years	Editor	Letters	Royal Soc	Phil Trans	Self-pub
Vol 8–12	1673–1677	Oldenburg	36	30	13	0
Vol 12	1678–1682	Grew (and Hooke)	33	25	10	0
Vol 13–15	1683–1685	Plot and Musgrave	19	11	10	13
Vol 16, 17	1686–1692	Halley and Waller	37	30	0	27
Vol 18–28	1693–1712	Sloane	163	91	69	79
Vol 29, 30	1713–1719	Halley	44	13	2	46
Vol 31, 32	1720–1723	Jurin	15	15	15	0
Total	1673–1723		347	215	119	165

Table 8 Summary of Leeuwenhoek's self-published letters

Year	Part	Collected volumes	Number of letters
1685	1	9 pamphlets	25
1689	2	Vervolg–Vierde	31
1696	3	Vijfde–Sevende	63
1718	4	Send-Brieven	46
Total			165

- 9 *pamphlets* in the mid-1680s
- 8 *quarto volumes* every couple of years from 1687 to 1702 with a final volume in 1718
- 4 parts of the *Brieven*, the final edition of all 165 letters.

The eight quarto volumes exclude all the letters in the pamphlets. The printer for most of them was Henrik van Krooneveld. His shop on the corner of the Hippolytusbuurt and the Nieuwestraat was next door to Leeuwenhoek's house, so the old man did not have to go far to supervise the printing. As shown on Table 8, the four-part *Brieven* collected all the letters through 1718. It turned out he would write fifteen more.

To whom did he write?

From 1673 to 1723, Leeuwenhoek addressed over a hundred letters to specifically named officers of the Royal Society. Most of them are listed in the leftmost column of Table 9. Over a slightly shorter period, from 1680 to 1717, he addressed almost a hundred letters to the Royal Society without naming a specific member. In the five years 1696 to 1700, he addressed eleven letters to no one and two to people otherwise unknown: Luca Giamberti and Johan Arnoldi. The rest of his correspondents are listed: those in Delft, those elsewhere in the Dutch Republic, and those elsewhere in Europe. The boldfaced names have letters in *Send-Brieven* addressed to them.

Most of them were friends in Delft, who would not have had any special interest in the specimens or the observations. What would they do with the letters? In his 80s, at the end of his long career, Leeuwenhoek seemed to be addressing letters as a way of recognizing his friends and supporters.

Why are there gaps in his publication record?

Leeuwenhoek is the most published author, by far, in the almost four centuries of *Philosophical Transactions*. Of the 165 self-published letters, about a quarter of them also appeared in *Philosophical Transactions*, though not always first. Nevertheless, even though Leeuwenhoek addressed about a quarter of the *Send-Brieven* to members of the Royal Society, collectively,

Table 9 Leeuwenhoek's correspondents (*Send-Brieven* correspondents in bold)

In London	In Delft	In the Republic	In Europe
Christopher Wren	**Abraham Cornelis van Bleyswyck**	Angelus van Wikhuysen	Antonio Magliabechi
Francis Aston	**Adriaan Johannes Swalmius**	Christiaan Huygens	**Antony Cinck**
Hans Sloane	**Adriaen van Assendelft**	Constantijn Huygens	Daniël Papenbroek
Henry Oldenburg	**Antony Heinsius**	**Frederik Adriaan van Reede van Renswoude**	Francesco Corner
James Jurin	**Cornelis Spiering**	Govert Bidloo	**Gottfried Leibniz**
John Chamberlayne	**Ewout van Bleiswijk**	Harmen van Zoelen	James II, King of England
John Somers	**Gerard van Loon**	**Herman Boerhaave**	Johann Wilhelm von Pfalz-Neuburg, Elector Palatine
Nehemiah Grew	Hendrik van Bleyswijk	**Jan Gerard Kerkherdere**	Karl von Hessen-Kassel
Richard Waller	**Hubert Kornelis Poot**	Jan van Leeuwen	Mary, Queen of Great Britain
Robert Boyle	**Jan Meerman**	Lambert van Velthuysen	Melchisedec Thevenot
Robert Hooke	Nicolaes Boogaert van Belois	Maarten Etienne van Velden	Pieter Rabus
Thomas Gale	Directors, Delft VOC	Nicolaas Witsen	
William Brouncker	Mayors and managers of Delft	Petrus Valckenier	
Members of the Royal Society			

Table 10 Summary of Leeuwenhoek's letters published in *Philosophical Transactions* and those that were self-published

Of the letters Leeuwenhoek wrote between…	# In his self-published Brieven	# In Philosophical Transactions
1673–1679	5	15
1680–Apr 1702	114	11
Apr 1702–June 1712	None	67
Nov 1712–1719	46	2
1720–1722	None	15

none of them was published in *Philosophical Transactions*.

The pattern shown on Table 10 is clear. When Leeuwenhoek was not getting published in London in *Philosophical Transactions*, he published himself in Delft. For two periods, the astronomer Edmond Halley was editor, for volume 16 in the mid-1680s and volumes 29 and 30 twenty years later. During those years, Leeuwenhoek addressed dozens of letters to the Royal Society. None of them was published. Why?

The Society had trouble keeping Halley as editor. In 1812, Thomas Thomson published *The Royal Society, From Its Institution to the End of the Eighteenth Century* (1812). He recounts the travails of *Philosophical Transactions'* editor's position (p 7):

> It appears, from the registers of the Society, that Dr. Edmund Halley, who had been appointed Clerk to the Society in 1686, offered, on condition that the publication should he renewed, to furnish one-fourth of the whole out of his own private stock.

The article titles in Volume 16 of *Philosophical Transactions* (1686–1692) show that most of the articles were about astronomy, chemistry, and mechanics, including a dozen of Halley's own articles. Only a handful of articles were about biology, botany, or medicine. None was about microbiology.

Halley's not publishing Leeuwenhoek was a matter of stated policy. In the first number of volume 16, he began his tenure as editor with what he called an "Advertisement", what today we might call an editorial or editor's note. It begins below the table of contents and goes on to the next full page. In it, Halley wrote (my emphasis):

> The Royal Society have therefore thought it fit to order, that Care be taken for the future, that such Accounts shall be published in these Transactions Monthly, as may answer their expectations: Wherein will be contained not only several Experiments, Invented and tryed by divers of their own Body, but also such other useful Discourses or Relations concerning **Physical, Mathematical, and Mechanical** Theories or Observations as shall be communicated by their Correspondants for that Intent.

Physical obviously meant astronomy, too, but not biology or botany.

How do the patterns in the letters relate to events in his life?

Archival research has much to contribute here. One example brings together two events in Leeuwenhoek's life. On October 9, 1676, Leeuwenhoek addressed a letter (*Collected Letters* 26) to the Royal Society's secretary Henry Oldenburg about microorganisms in various waters and spice infusions, the relationship of their shape to taste, and whether there were microorganisms in the air. This is Leeuwenhoek's most famous letter, the one that made his name known world-wide. The bulk of Dobell's "Little Animals" is devoted to its translation and annotation. The heart of the letter is 145 observations of 19 different series of liquids, about half of them infused with various spices.

Other than the observation from the previous September, they were all conducted from mid-April to the end of September 1676. Some of the observations were one-time only. Many series lasted for a month or two. The longest spanned 18 weeks. The series suddenly stop at the end of September. Why? The observations were not all completed.

On the 30th of that month, Leeuwenhoek was appointed curator of the Vermeer estate (*Kamerboek* 1674–1681). Knowing both how tangled it was and the personality of Vermeer's mother-in-law, Maria Thins, perhaps Leeuwenhoek felt he should send that letter to the Royal Society before he became too busy. The letter that he sent over his signature was written in a hand other than his, perhaps from his notes.

His legacy

Leeuwenhoek continued working his city jobs until he approached 70 and continued receiving payments until his death, more a pension than a sinecure. His estate amounted to almost sixty thousand guilders (Geesteranus 1746) much of it in government bonds. At 80, he was financially secure. He died on August 26, 1723, not quite 91, and was buried 5 days later in the Oude Kerk. Before his daughter Maria died in 1745, she provided for the memorial that still marks his grave. Two years later, hundreds of his magnifying glasses were auctioned (Rees 1747).

The subtitle of Dobell's 1632 biography is "Being Some Account of the Father of Protozoology and Bacteriology". These microbial studies were only a small portion of his life's work. Journal articles and books since then have added to a long list of scientific disciplines and sub-disciplines, everything from histology to ecology, that can find their origins in Leeuwenhoek's observations. His ongoing concerns include the transport of fluids in plants and animals, reproduction of plants and animals, and the structure of crystals.

In the Netherlands today, many streets are named after Leeuwenhoek, along with the major cancer hospital. Medals, prizes, and even this microbiology journal commemorate and celebrate his accomplishments.

How famous was he?

After 1680 when he was elected a member of the Royal Society, Leeuwenhoek was the most internationally famous living person in Delft. He remained so until well after his death 40 years later.

In several letters during the years around his 80th birthday, Leeuwenhoek mentioned being overwhelmed and distracted by visitors. As Dobell notes (1932, p 78, 79), in 1710 and 1711 leading up to his 80th birthday, he addressed this topic in several letters that will be forthcoming in volume 16 of the *Collected Letters* (my translation):

> But if I should receive everyone who comes to my house, or tries to come, I should have no freedom at all, but be quite a slave.
> We send off everyone who tries to visit me, unless they have some sort of introduction.
> No less than 26 people came to see me within four days, all of them with introductions (except a Duke and a Count, with their Tutor): which made me so tired, that I broke out in a sweat all over.

He did not give away or sell his glasses, so the curious had to come to him. Some of them, however, were distinguished enough that he welcomed them and either addressed letters to them or referred to their visits with pride. Among the most distinguished were Tsar Peter the Great of Russia and Mary, Queen of Great Britain.

How did Leeuwenhoek's fame fare outside of his homeland after his death? The Google Books Ngram in Online Supplementary Fig. 1 compares mentions of him in print in English to those of his contemporary Johannes Vermeer. After World War II, their relative fame reversed.

What about their online presence? A Google search in late 2013 gives a sense of the Leeuwenhoek's current popularity, a few orders of magnitude less than Vermeer's.

- Vermeer—15.3 million results
- "van Leeuwenhoek"—0.9 million results
- Leeuwenhoek—0.7 million results

Leeuwenhoek had few competitors as a microscopist. Jan Swammerdam and Nicholas Hartsoeker were the only Dutch rivals. Both had contentious relationships with Leeuwenhoek. Marcello Malpighi in Italy and Robert Hooke and Nehemiah Grew in England were the only others who published microscopic observations comparable to Leeuwenhoek's. Early in his career, Leeuwenhoek and Grew exchanged published critiques of each other's observations. How have the reputations of these men compared since then? The Google Books Ngram in Online Supplementary Fig. 2 compares mentions of them in print in English.

Grew was clearly the more prominent throughout the twentieth century. The spikes for Leeuwenhoek are first, 1932, the tricentennial of Leeuwenhoek's birth and the publication of Dobell's biography and second, in the late 1950s, the reviews upon publication of Schierbeek's biography in English translation, Dobell's biography in Dover paperback, and volumes 4 and 5 of the *Collected Letters*.

Where are the archives incomplete?

While Leeuwenhoek seems to have been a fixture at City Hall and the weighing house, his name appears on very few surviving documents, either legal or personal. His research, of course, is thoroughly documented in his letters. However, the few facts of his life and those of his friends and relatives are locked in seventeenth century handwritten documents, now slowly being digitized. Some information, however, we will never have.

- few portraits of Leeuwenhoek, his ancestors, or his contemporaries
- incomplete baptism, marriage, and burial records
- few estate inventories that list cash, bonds, and property items
- largely incomplete records of property transactions
- incomplete, unclear, and ambiguous city records, especially those related to Leeuwenhoek's jobs of court official and wine gauger and his finances

For example, Leeuwenhoek surely wrote more letters than the three hundred and fifty that will be in the nineteen-volume *Collected Letters*. They would probably tell us less about his science but much more about the rest of his life. His own papers are lost, and none of the Delftenaars with whom he was in daily contact have left anything about him.

Where is there potential for more archival research?

Both of Leeuwenhoek's twentieth century biographers, Dobell and Schierbeek, concentrated on his research, as did Ruestow's *The Microscope in the Dutch Republic* (1996); they devoted few pages to his life. Dobell spent only two weeks in Delft and never visited the city archives. The secondary literature about Leeuwenhoek, largely in English, also concentrates on his research. Like Dobell, these writers are scientists, not historians. The research into the extra-scientific events in Leeuwenhoek's life has been short, focused, and written almost entirely in Dutch.

Three recent developments in Leeuwenhoek studies offer promise for the next wave of historical research.

Digitized records

Most importantly, the archivists in Delft are slowly digitizing their records. The notary records at the Digital Arena < http://digitalearenadelft.nl > web site of the Delft City Archive are a small portion of the whole. As of early 2014, only a quarter of the notaries active during Leeuwenhoek's lifetime have their records even partially digitized. These records will reveal more about his friends and relatives.

It is safe to say that everyone in Delft knew of him. But who were his friends? There are few surviving records of direct connections, so we are left with a game of degrees of separation. In addition to the people Leeuwenhoek addressed letters to, he mentioned some contemporaries in his letters. Others are names that appear with his on surviving documents. A short list for archival searching might include:

- Adriaan Beman, printer
- Arnold Ramp, city official
- Cornelis Isaaks 's Gravesande, medical doctor and anatomist
- Dirck Arrisz, wine gauger
- Frederik Ruysch, botanist and anatomist
- Henrik van Krooneveld, printer and next-door neighbor
- Jacob Spoors, surveyor and notary
- Jan Strick, court official and tavern owner
- Johannes Verkolje, portrait painter
- Johannes Vermeer, painter
- Maria Duyst van Voorhout, neighbor and philanthropist
- Paulus Durven, notary
- Theodorus Craanen, academic
- Thomas and Willem van der Wilt, illustrators

Searchable letters

The first fifteen volumes of *The Collected Letters*, under the steadfast guidance of Lodewijk Palm since volume 10, are now online as searchable text at the Digitale Bibliotheek voor de Nederlandse Letteren. The four remaining volumes will join them several years after publication (Palm 1939–1999).

Leeuwenhoek had his 165 self-published letters translated into Latin. They are online and searchable at ECHO—European Cultural Heritage Online

(Leeuwenhoek 1679–1718). They contain the same images as the Dutch editions, often producing cleaner scans.

Completion of the *Collected Letters* will also complete the publication of the approximately eleven hundred numbered figures that accompany the letters. Most of them exist in three variants:

- the originals, usually in red chalk, some in ink, in possession of the Royal Society.
- the reverse-image figures published in *Philosophical Transactions* from plates engraved by someone who never looked through a Leeuwenhoek lens.
- the figures in the self-published volumes.

This corpus of searchable text in three languages and the accompanying figures will be a rich source for the pattern searching known as text mining.

Online presence

Finally, the new web site Lens on Leeuwenhoek < http://LensOnLeeuwenhoek.net > (Anderson 2013) is a growing repository of documentary evidence and short articles about the life and times of Leeuwenhoek. It has additional information about every topic discussed in the present article as well as the most comprehensive bibliography of the secondary literature.

Conclusion: who was he?

Just after the turn of this century, a Dutch news organization ran a poll for people to vote for the greatest Dutch person of all time. Leeuwenhoek came in 4th, ahead of Anne Frank, Rembrandt, and van Gogh in places 8, 9, and 10 (*Grootste Nederlander* 2012). Those results say more about today's Dutch, of course, but whatever Leeuwenhoek represents today, the man has been lost. Who was he before he become *Van Leeuwenhoek*?

In terms of the standard facts of a biography, we have very little documentary evidence about Leeuwenhoek's daily activities. Fortunately, the enduring popularity of both the Golden Age and Jan Vermeer have made daily life in Leeuwenhoek's Holland and Delft the topic of countless publications. The genre painters made the Dutch Republic the most visually documented society in history up to the invention of the camera 200 years later. They let us fill in the general picture. But what about the man himself?

To Maria Duyst, the 10-year-old girl living across the canal in 1672, he's Antonij Leeuwenhoek, the stocky guy who works in City Hall, lives across from the fish market and has quiet passions. What do Maria and the neighbors make of Antonij's lens grinding, metal working, and surveying? He has a spring-pole lathe and an anvil for hammering bronze. He spends time alone trying to make something very small. Given how few people could replicate his results, his tool-making must be difficult to learn and distinguished by repeated failure, especially the lens grinding and polishing. There is no prospect of monetary payoff. He has no clue where it will all lead. But he wants to look for himself at what Hooke drew in *Micrographia*. Was Antonij a madman or a conjuror? Or just obsessively curious?

Forty years later, when Antonij was 80, Maria Duyst van Voorhout van Reede van Renswoude van Emmickhuysen en Bornewal was a wealthy member of the intelligentsia in The Hague. Antonij from across the canal was world famous. When he visited her estate near Utrecht (Leeuwenhoek 1696), who was he then? His letters show his admiration for the natural world and give us a view of his daily life. He almost never mentions his family or neighbors, but we know about his work area, his garden, his horse and his parrot, and his alcohol consumption. As a cure, he drank a lot of tea and he was particular in taking care of his teeth. In addition, his specimens taken as a whole tell us about the things in his daily life, from the food he had for dinner to his bowel movements and tooth scrapings. He suffered from diarrhea, especially when he ate fat meat.

By the time he was 80, Leeuwenhoek's study was full of the most advanced scientific instruments of the time. His daughter Maria's estate inventory in 1745 shows that she kept some of her father's tools after his death. Most of them were made of copper, wood, or glass.

- a table bellows for heating metal and glass, a lathe for making screws and grinding glass, tools for polishing glass
- burning mirrors, low-power magnifying glasses, prisms, a fire glass (*brandglas*)
- a telescope, barometers, globes, a magic lantern

- a surveyor's chain, an astrolabe, compasses, a pantograph, half-circle protractors, a quadrant, rulers, a sundial and calendar, triangles (set squares)
- copper sheets to engrave for printing
- gauges for measuring liquids in barrels

He had instruments for measuring and counting, for lens making and metal smithing, and for sciences other than his own, especially astronomy and optics. He had training in surveying and may have done more surveying than we have written evidence of. For his civil service job, his gauges (*peylstokken*) to measure liquids in barrels were the finest, made from ebony with silver knobs and bands.

Leeuwenhoek's direct, often discursive writing style reveals his personality. He did not write stuffy academese, which was yet to be invented. Almost everything he saw, he was the first human ever to see. He was like Adam in a microscopic garden where nothing had a name. He wrote about it in common often ungrammatical Dutch, a personal voice that gives us a record of his thoughts in the language as it was spoken. If he had today's technology, he would be a blogger.

That is the Leeuwenhoek the archives will continue to reveal, the curious observer whom Maria Duyst grew to admire. In her will, she established three schools to train poor but promising young men, just like her life-long friend from across the canal. He was not a Newton or Linnaeus or Darwin or Pasteur, all of whom have a Big Idea inseparable from their names. Online Supplementary Fig. 3 is another Google Ngram display that gives a rough comparison of their relative influence in the twentieth century. In print in English, Leeuwenhoek is invisible, unknown.

What did Leeuwenhoek do? He used a dead-end microscope design to reveal microbes and structures that had always been there, everywhere. How did he do it? He had the best tools and much patience.

Is not this the genius of the Dutch Republic, the result of the values it nurtured? In the seventeenth century, nowhere else on Earth could a curious, stubborn, methodical burgher with no higher education, no patron, and no institutional affiliation have so astonished the world simply by being curious and persistent. His challenge to us: *Wat doe je als je dingen ziet dat niemand ooit heeft gezien?* What do you do when you see things that no one else has ever seen before?

Acknowledgments I would like to thank the archivists of Delft City Archive and especially Dr. Lesley Robertson of Delft University of Technology for their assistance.

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