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CRITICAL FOCUS

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Leeuwenhoek Microscopes: Mystery and Mischief

The emergence of three more possible Leeuwenhoek microscopes calls for new protocols to determine the authenticity of antique scientific instruments.

So, unknown Leeuwenhoek microscopes still exist? The remarkable revelation that three new examples have emerged has surprised many — none more than me. I was astonished in 1981, when I discovered that Leeuwenhoek's original specimens still lay hidden among his letters in London, yet nobody expected more of his microscopes to emerge. These are dramatic developments, and the curious tales of double-dealing that surround them are remarkable. Each Leeuwenhoek microscope is unique and tells a fascinating tale. They are valuable, too; the single example that was recently sold on the open market cost half a million dollars.

My interest began with a casual comment at school. It was an autumn evening; the chestnut trees were beginning to turn and linden leaves were drifting lazily past the window. My tutor A.G. Lowndes was an eminent biologist and the man who introduced me to Antony van Leeuwenhoek and his works. As the session trundled towards closing time, I asked him again about the Dutchman. I didn't understand how anyone could observe microbes with a single lens. Nor did Lowndes. Then he said something prophetic, even though neither of us knew it at the time:

"There are still some of his microscopes locked away in museums, but none is in England," he averred. "One set of them went to the Royal Society but they have since gone missing." That caught my juvenile attention.

"Missing? Lost? Well, they must be somewhere," I said.

Lowndes grinned. "Then that is another project. You'll just have to find them."

"One day I might," I said, and wandered home, lost in thought about microbes and tiny microscopes.

Many scholars have speculated on the fate of Leeuwenhoek's microscopes. A summary is soon to be published by Douglas Anderson in *Annals of Science* (72:4, in press), which is a timely review of the sources and includes the inventory of the possessions left by Leeuwenhoek's daughter Maria, who outlived her father by 20 years. She continued to dwell for the rest of her life in the house in Delft, where she had been born (it was named Het Gulden Hoofd, the Golden Head, in the Hippolytusbuurt district) and where Leeuwenhoek worked. The house remained in use until 1928, when it was torn down to make way for a shopping center. In 1933, an archivist in Delft, Petra Beydals, had transcribed the inventory and was planning to publish it, but nothing was done until Anderson included the information in his paper.

The inventory included three microscopes made from gold, 143 from silver and 125 from copper, together with 23 microscopes attached to test tubes for examining fish, plus four boxes of various microscopes,

some of them without lenses. Two local notaries, Willem van Assendelft and Willem van der Lely, commissioned an auctioneer named Adriaan Rees to organize a public sale of effects, and on May 29, 1747, everything was sold. All the items were bought by local Delft residents. Once the contents of the four boxes had been included, 531 microscopes were listed. Leeuwenhoek had given a few others to distinguished visitors, plus the 26 he had bequeathed to the Royal Society in London, so we now know that he must have made at least 560 microscopes in a career spanning 50 years. Yet, after such a prodigious output, little remains. There are a few lenses and viewers for pond water associated with his name, which need further investigation; his original specimens, which I discovered in 1981; and his standard rectangular instruments claimed by scholars. These are the famous Leeuwenhoek microscopes, of which nine genuine examples were believed to exist. It is easy to understand how the rest could have been lost or thrown away. A descendant of Dirck Haaxman, a member of Leeuwenhoek's family, was an apothecary named Pieter Jacob Haaxman, who published the first Leeuwenhoek biography in 1875. He remembered one of the microscopes in a box of toys that he played with as a boy. He lost it.

In London, the science historians at the Royal Society had tried unsuccessfully to locate their bequest, and I set out to follow their fate through the dusty files of long-forgotten correspondence that lurked in the Society's archives. On Aug. 7, 1701, Leeuwenhoek had designated this set of 26 silver microscopes to be bequeathed to the Royal Society, and when he died in 1723, the small Indian box containing these delicate little instruments was sent by his daughter Maria to London. Henry Baker described them in his book *The Microscope Made Easy*, published in 1743: "The Cabinet of Microscopes left by that famous Man, at his Death, to the *Royal Society*, as a legacy, is standing upon my Table; and I can assure the World, that every one of the twenty-six Microscopes contained therein is a double convex lens, and not a Sphere or Globule." Imagine that. The original microscopes are sitting on the table of Baker's desk in London as he sets out to describe them. Leeuwenhoek has been dead for 20 years, yet he is still that "famous man" who, in Baker's words, "surprized the World so much, and introduced a new System of Philosophy and Reasoning."

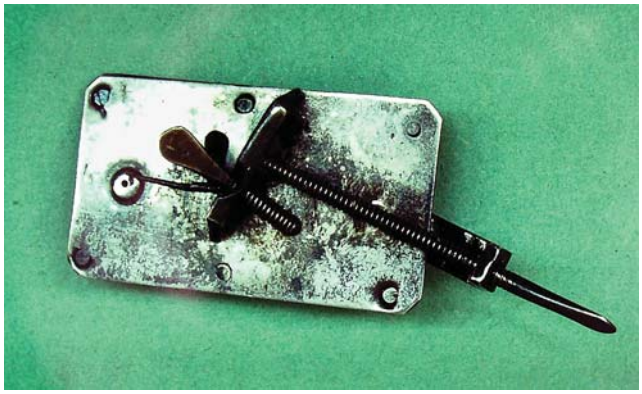
Many scholars have insisted that Leeuwenhoek used beads of glass; indeed, I also speculated on that back in the 1970s, but we were all wrong. As long ago as Dec. 4, 1710, Zacharias Conrad von Uffenbach reported that Leeuwenhoek displayed "great contempt" for glass beads and always used biconvex lenses for his investigations. Leeuwenhoek emphasized to Uffenbach that a spherical bead could not be held in place in one of his microscopes; there had to be a tapered rim to prevent it falling out. Yet the error persists. An account in a journal called *The Low Countries* (2006) says: "The most common type [of Leeuwenhoek microscope] consisted of two small metal plates clamped on to a small round glass ball, which functioned as the lens." It is not so, and never was.

A COLD TRAIL

The supremacy of Leeuwenhoek's lenses was still acknowledged in the 1820s, when an eminent surgeon, Sir Everard Home, borrowed them from the Royal Society for his own microscopical studies. I wanted to find out more, and in 1981, Royal Society President Sir Andrew Huxley encouraged me to investigate. Eventually, I unearthed in the Society's files a letter dated April 5, 1855 and written by Sir James South. It asked the Society's secretary to find out where the missing microscopes might be, though it was clear that South was pointing his finger at Home. The Society set up a committee to look into the fate of its property, but they failed to publish their report. Ten years went by and South wrote again on May 10, 1865, but once again he found nothing new — and there the trail went cold. Home had taken possession of a huge collection of manuscripts left by the anatomist John Hunter, and he was publishing papers describing Hunter's discoveries as if they were his own in a flagrant act of plagiarism. The Royal College of Surgeons threatened to seize the manuscripts and, rather than admit the facts, Home resolved to burn them all. The flames grew out of control and destroyed his apartment at the Chelsea Hospital. My late colleague Professor Derek de Solla Price of Yale concluded that, because the microscopes were made of silver, they melted away in the blaze. For me this meant the end of the search. I had to content myself with trying to work out what the missing microscopes had looked like, and I summarized that research in *Proceedings of the Royal Microscopical Society* (18:2, pp 118–124, 1983).

Here we have a saga of microscopes treated as toys, being locked away and forgotten, acts of flagrant plagiarism, secret discussions and covert conclusions. The whole story centers on carelessness, opportunism and dishonesty — just what you might expect from Victorian intrigue. Yet the same curious behavior marks out the most recent discoveries, and I was soon to find out that nothing has changed.

Only one of the surviving microscopes is still in the private possession of a Leeuwenhoek descendant. This is a brass microscope that has body plates measuring 17 × 40 mm and a lens magnifying 74×. It was listed in the original 1747 auction catalogue and was purchased by Dirck Haaxman who was a descendant of Leeuwenhoek's sister Margriete. It passed on down the family and is now privately owned by Dr. W. de Loos of Rotterdam, Holland. Another was inherited by Gijswijk van der Netten of Gouda, Holland, and on his death it was purchased by Andrinus Antonie Gijsbertus van Iterson, a wealthy industrialist who presented it to the local museum around 1880. The Gouda Museum subsequently donated it to the Museum Boerhaave in Leiden, where the curators found that the main screw was loose, so they put it on public display with a conspicuous blob of glue crudely holding it in place.



This silver microscope at the Deutsches Museum in Munich is attributed to Leeuwenhoek and may be an early design. Its plates measure 25 x 45 mm (less than an inch across). The prominence of the lens mount is not typical of other surviving Leeuwenhoek microscopes, and the uneven spacing of the rivets around the lens is also unusual. Scanning electron microscopy (SEM) would be crucial in resolving the question of its authenticity.

BOX OF JUNK

More interesting is a silver microscope magnifying 69× that was once owned by Robert T. Maitland, a Victorian zoologist, who had lent it for display in 1875 at an exhibition in Delft to celebrate Leeuwenhoek's life. Maitland later acquired the works of Theodore Gerard Lidth, a professor at the Veterinary College in Utrecht, who had amassed a collection on zoology, and in 1881, Maitland sold the entire archive to the Natura Artis Magistral, Amsterdam's oldest zoo. Most of this was books and papers — but there was also a box of oddments, which still contained the Leeuwenhoek microscope. The zoo archivists were more interested in the documents, and the little box was ignored until 1978, when Dr. J.J. Willemse of Leiden University's zoological department took a fancy to the instrument. He asked the zoo director if he could buy the box; he paid 10 guilders ($5) for it. Willemse said that the director was pleased to get rid of this box of junk. In time, Willemse became known as the owner of a genuine Leeuwenhoek microscope. He was cited in catalogues, and was included in my book, *Leeuwenhoek Legacy* (1991). Willemse kept a low profile; if people inquired, he told them that he thought the microscope might be a replica, and that is how matters drifted on for 30 years. Only then did Willemse investigate ways of capitalizing on his little microscope, so he asked Christie's auction house in London to arrange its sale.

There may be a reason for that specific time interval. The traditional statute of limitation for the theft of an artifact in Europe was based on Napoleonic Law and was set at 30 years. Once that time had elapsed, Willemse could claim the proceeds of the sale, knowing that nobody could say the microscope had been misappropriated. As soon as news was released about the forthcoming auction, there was immediate action in Holland. The University of Amsterdam had recently set up a Centre for Cultural Heritage and Identity with funding from the Mondriaan Foundation, and one of the directors, Dr. Steph Scholten, launched an investigation into the legal status of the microscope. He spoke to past and present staff of the zoological department, but nobody had anything to say about it. The National Police and the State Inspectorate of the Ministry of Education and Science investigated having Christie's halt their auction, but although they interviewed everyone they could find, it appeared that nothing could legally be done. Scholten tells me things are different now; he reports that a UNESCO convention of 1970 has recently been ratified in Holland, which will in future protect items of cultural significance for a period of 70 years.

This Leeuwenhoek microscope was presented as an auction item on the blustery afternoon of April 8, 2009, in London. The description was intriguing, for Christie's were careful not to print that it was definitely "made" by Leeuwenhoek. His name was simply stated:

> A highly important Dutch silver microscope
> Antoni van Leeuwenhoek (1632–1723), circa 1690

The lens held between two riveted silver plates; stage with rounded step design, specimen pin and focusing screw; main screw with rounded handle, with angle bracket and securing screw. Marked with an incuse *3*, and two later Dutch sale marks (for the periods 1813–1893 and 1814–1831).

Dimensions of plates 39 × 22 mm. Found in 1978 among a box of laboratory impedimenta from the Zoological Department of Leiden University and purchased by the present owner. Believed to be no. 62 in the 1875 exhibition catalogue by Harting, and from the collection of the Dutch zoologist R.T. Maitland (1823–1904).

Bought at an unknown auction between 1814 and 1831.

The sale was the most remarkable I have ever attended. Fewer than 30 people were in the room. Early in the auction I participated in the bidding — not that I had any hope of buying it, but taking part was irresistible. I have purchased antique microscopes in the past from that same auction house, but this was a unique event. "I will start the bidding at £45,000 (about $70,000)," said the auctioneer, "£48,000, £50,000 now …" and I chased it up to £60,000 (about $100,000). Every time there was a new bid, it was promptly topped by a higher sum, as the auctioneer kept announcing, that came "from the back of the room." Within three minutes it had reached £200,000 ($300,000), and then the bidding suddenly stopped. There was a pause in the proceedings as muttered conversations on the telephones were heard. Nothing happened for nearly a minute. I was taking a video on my cellphone and interrupted the recording more than once to take a shot of the people on the phones. I think I heard the Museum Boerhaave bidding; another of the would-be buyers was the Royal Eise Eisinga Planetarium, an 18th century museum in Franeker, Holland, but neither could meet this fabulous price. Eventually, a bid came for £210,000, which was immediately topped by one "from the back of the room" for £220,000. There was another prolonged pause, longer than I have ever witnessed at an auction, until yet another bid was entered, which was, of course, promptly bettered by the bidder at the back. The sale continued, the electric atmosphere in the room buzzing with excitement; then after several more pauses and entreaties for additional bids, Willemse's microscope was sold for £260,000 to the buyer "at the back of the room." With the costs and the purchaser's premium, the total cost came out to £322,000 — a shade under a half-million dollars. Willemse was delighted. "I thought of telephoning Christie's only six months ago," he said. "I was not at the sale but followed the result online. I have five grandsons, and I can use that money to help finance their studies."

MYSTERY 'BIOTECH' BUYER

The unidentified buyer proved to be Rick Watson, a dealer in antique books. I was keen to inspect the microscope and see what the lens could reveal, but he explained apologetically that the buyer who had retained him was determined to remain anonymous. I inquired again at intervals until Sept. 14, 2009, when Watson was authorized to tell me this: "The buyer is a biotech company in a country within the European Union. It may ultimately go to a medical library/institution, and as soon as I have the details and permission I will let you know." Aha, it was narrowing down! A "biotech" company could be any area of the biosciences, but if they were thinking of exhibiting it at a "medical" establishment, that suggested they would themselves have medical connections and could be a pharmaceutical company. At intervals of a few months, Watson and I would exchange polite messages until I mentioned that I would be publishing this account of the whole affair. Naturally, I was hesitant because the cloak of secrecy paints the secretive new owner in an unfavorable light. Watson did not care for this reminder — he described it as hassling and said he would consult his attorney. Nothing more happened. This item of global importance has simply been spirited away.

Meanwhile, a previously unknown example had already come to light. It had emerged in 1982, and was the first to appear for more than a century. You might assume that this astonishing revelation would be celebrated across the world of science — but no, nothing was said about it and, to this day, hardly anybody knows that it exists. The discovery of this lost microscope was triggered by my discovery of Leeuwenhoek's specimens in 1981 (see "Critical Focus: The Story of the Leeuwenhoek Specimens," *The Microscope*, 59:1, pp 11–19, 2011). That remarkable revelation was announced in a paper for the Royal Society and by the BBC and became international news. It was reported in *Nature* (292, p 407, July 30, 1981; for a full bibliography, search online for "Leeuwenhoek specimens"). This was such an extraordinary development, far more revealing than discovering more microscopes because, for the first time, we could find out how Leeuwenhoek worked and marvel at the precision of his techniques. At Cardiff University, I carried out a systematic program of re-

search, and numerous papers were published in journals ranging from *New Scientist* and the *British Medical Journal* to *The Cell* and *Scientific American*, as we looked closely at the structure and significance of the specimens and what they could reveal.

The authorities at the Museum Boerhaave decided to capitalize on that unexpected development and organized a small exhibition that would highlight the specimens I had discovered. However, they didn't contact us. They put together a display highlighting the specimens, which omitted any mention of the research and blatantly plagiarized it all. They put the specimens on display as though they had discovered them. And then, when their exhibition catalogue was published in an English translation, they gave it the title "Beads of Glass" — a final insult to Leeuwenhoek. As we have seen, he had always considered glass beads to be beneath his dignity.

The Boerhaave did it again in 2000, when they published a new booklet featuring Leeuwenhoek's research with a foreword by their director A.J.F. Gogelein under the title *Antoni van Leeuwenhoek genezen in de Gouden Eeuw* (which has the curious meaning, "Antony van Leeuwenhoek, healed in the Golden Age"). On page 31, there is a report that reads, "A few hand-made preparations from Leeuwenhoek are preserved at the Royal Society." There follows a transcription of my original descriptions, and next to it they even reprinted my original photography. No permission was sought, no acknowledgment was given, and no source was cited. Of course, this is scandalous behavior and it is certainly unlawful, but it happens all the time. The penalty we pay by taking strides into new areas of science is being heartily plagiarized by these unscrupulous individuals. If "imitation is the sincerest form of flattery" then plagiarism is a sure sign of the significance of a scientific publication. Plagiarism has always been rife in microscopy, as I detailed in my article, "The Cheat and the Microscope: Plagiarism over the Centuries" (*The Microscope,* 58:1, pp 21–32, 2010). The Boerhaave's behavior caused me no consternation whatsoever because everyone who read those publications knew immediately what had been done, and I have dined out on it ever since. It is difficult to emphasize to students that plagiarism is dishonest when they see experienced officials indulging in the practice. Such breaches of protocol are commoner in Asia (where, in China, almost one-third of academic papers are said to be plagiarized) though this takes place in specialized areas where people pray their behavior is never detected. When it exists in fields of research that are globally well known, and which are widely reported in the popular press, it becomes harder to understand. The single lesson I take from these episodes is the extraordinary obtuseness of such plagiarists. They willfully commit themselves in public, knowing that print endures, so their conduct is immediately and ineradicably on display. It is like shoplifting in a store full of security cameras.

SPECIMENS YIELD MICROSCOPE

My discovery of Leeuwenhoek's specimens in 1981 brought him back into the spotlight. The newspaper reports caught the eye of one Dutch resident, and a truth suddenly dawned: They had one of these microscopes at home in a drawer. It was taken to the Museum Boerhaave, who looked at it closely and concluded that it was genuine. This was the first new Leeuwenhoek microscope to be identified for centuries, and an unprecedented development of immense importance for scholars. And what did the Boerhaave decide to do? Nothing. There was no announcement. The microscope was locked away in a cupboard and not a word about it was said.

There might have been a reason for this. The Dutch authorities have issued legal guidance on their current law of possession, which states that the ownership of an object can be claimed through what they call acquisitive prescription: "The possessor who continuously has possessed an object during three years (possession in good faith of a movable object), ten years (possession in good faith of an immovable property) or twenty years (possession in bad faith of a movable or immovable object) automatically obtains the ownership of the object." They add: "In the Netherlands this rule still applies in favor of thieves and crooks." If you were a sceptic, which I of course am not, you might conclude that this was the reason why the Boerhaave kept quiet about their new acquisition before they announced it. That was eventually published in Dutch by an eminent historian of the microscope, Marian Fournier, in an obscure journal named *Gewina* (25, pp 70–74, 2002). Fournier's account reports that this is the smallest of all the Leeuwenhoek microscopes, with body plates measuring 17 mm × 34 mm. The lens magnifies 68×, and its specifications are very similar to those of the de Loos microscope in Rotterdam. Fournier's report was published in the Pandora's Box section of *Gewina*, which was devoted to newly described instruments. The discovery has never been cited by any scholar, and the journal has since ceased publication. The date of Fournier's publication was precisely 20 years after the microscope was brought

In 1982, the Boerhaave Museum in Leiden organized an exhibition to display the Leeuwenhoek specimens that the author discovered in London the previous year. A local resident owned this microscope and brought it to the Boerhaave, which kept it from public view for 20 years, the length of time required by the Dutch statute of limitations to attain ownership.

into the Boerhaave and therefore, legally, the museum could claim ownership under the Dutch convention of acquisitive prescription. Willemse had been roundly condemned by the authorities for hiding behind the statute of limitations, but those criticisms could apply equally to this episode. Clearly, the Victorian tradition of double-dealing and covert behavior seems to be alive and well.

More remarkably, so is the idea of a Leeuwenhoek microscope being regarded as a toy, just as Pieter Jacob Haaxman reported in 1875. In March 2014, I was invited to call to visit Christie's auction house. They gave me some astonishing news: A box of dollhouse toys had been brought in, and it was thought that one of the items looked like a Leeuwenhoek microscope. At their offices in London their instrument specialist laid the mystery object on the baize-covered table. In front of me was a Leeuwenhoek microscope made of silver that had been exuberantly polished, and still bore traces of the polish around its lens. Like the other silver Leeuwenhoek microscopes, it bore the distinctive hallmarks from the period 1814–1831, though these did not unduly excite my attention. Hallmarks are not themselves definitive because they can be forged, and a fake could be made from ready-hallmarked silver (cut from an old coffee pot, for example). Nonetheless, this one looked genuine.

CERTAINTY THROUGH SEM

But how could we be sure? I am regularly asked about microscopes that turn out to be copies. Therein lies the problem: Authenticity should not rest on any single person's opinion. These are instruments of science, and they are being appraised by a scientist. I was forming the view that we needed minutely to examine the process of production, and felt that scanning electron microscopy (SEM) could give us the detailed insights we need. Curiously, the vendor was not interested. It turns out he was terminally ill and wanted urgently to sell the microscope to raise funds for specialist medical treatment. In the event, no auction was arranged and tragically, the owner died in June 2014.

Christie's, meanwhile, contacted the privately owned Planetarium Zuylenburgh collection in Holland, which was in the market for antique scientific instruments, and asked the proprietor if he would like to purchase the microscope. This was Bert Degenaar, a wealthy property developer and collector with a passion for vintage automobiles. Christie's took the microscope to the Museum Boerhaave, which agreed with my view that this had all the appearances of a genuine Leeuwenhoek microscope. Degenaar flew over to discuss it with me in Cambridge accompanied by his friend Huib Zuidervaart, a researcher at the Huygens Institute for the History of the Netherlands in The Hague. I took them both to The Eagle, the pub where Frances Crick went on Feb. 28, 1953 to announce that he and James Watson had determined the structure of DNA. Degenaar brought with him a small present, an exact replica of a brass Leeuwenhoek microscope made for sale as a souvenir by the Museum Boerhaave. It was a gracious gift and something I would come to

treasure. I excitedly explained my new proposal for using SEM macrographs to elicit the fine structure of these microscopes, but to my surprise Degenaar was not interested. What he wanted to do was to own the microscope and feature it in his collection. After our lunch, I took both men to the Whipple Museum for the History of Science, which has its own microscope collection, including a replica Leeuwenhoek.

One person who was intrigued by my proposal for SEM macrographs was Tiemen Cocquyt, the curator at the Museum Boerhaave. He is their specialist for telescopes and is also responsible for microscopes. Cocquyt wrote to me saying: "That seems an interesting method to apply to Leeuwenhoek's microscopes." Cocquyt compiled a report on the silver from which the microscope was made and sent it over to me as soon as it was ready. X-ray fluorescence analysis (XRF) revealed that the body plates were composed primarily of 89.215% silver plus 8.812% copper — a standard alloy in which the admixture of copper gives greater strength to the soft silver. This is the type of alloy used for antique silver coins. There is also a small amount of lead, 0.674%, which would be anticipated, plus 0.685% chromium. The chromium is a surprise; that element was not discovered until 1797 and first came into use a century after Leeuwenhoek had died. Chromium is a conventional component of contemporary silver polish. When I first saw the microscope, it had clearly been polished, and this is entirely consistent with the presence of elemental chromium on the metal surface.

This brightly polished silver microscope lay among a drawer of dollhouse toys that turned up at Christie's auction house in London in 2014. It is a near-twin of Maitland's microscope and has all the signs of being genuine. The vendors did not wish to proceed with SEM analysis to verify its authenticity; instead, it was sold privately for a sum possibly one-tenth its market value.

AUCTION GONE AWRY

There was another astonishing development. On Dec. 1, 2014, a random assortment of antique objects appeared for auction on eBay. They included small implements (including a scalpel) and coins (from the Dutch East India Company) that had been excavated from mud in a landfill. Among the recognizable objects was one which the seller described as a "weird kind of drawing instrument" — and it was recognized by the cognoscenti as bearing the positioning handle typical of a Leeuwenhoek microscope. $99.99 was the opening price on the eBay auction page. On Facebook, the Field Microscopes and History of Microscopes groups opened a discussion. I received a number of inquiries and could say only that, yes, it certainly had the appearance of a Leeuwenhoek microscope. Then at 9:47 a.m. on Dec. 4 the eBay auction was abruptly terminated. The seller explained in an email that someone had told him there might be an important microscope in his lot, so he had decided promptly to terminate the auction. None of this helped me to respond to inquiries, though I realized that there were several photographs on the eBay page in which the microscope had appeared. I had taken the precaution of downloading them, and so I set out to assemble an image that could give us an impression of the entire object. It did, indeed, look exactly like a Leeuwenhoek microscope. It was the second time in one year that I was faced with a newly discovered example. This was extraordinary.

Photo from eBay.com

These antique medical instruments and 17th century coins were excavated from the muddy canals in Delft, The Netherlands, and appeared on eBay in December 2014 with a starting bid of $99.99. The lot included a "weird kind of drawing instrument" that resembled a Leeuwenhoek microscope. Dr. Tomás Camacho of Spain purchased the lot after wrangling with the eBay seller, who abruptly terminated the auction.

The mystery of the canceled eBay auction was solved when an email arrived from Dr. Tomás Camacho in Vigo, Spain. Camacho had contacted me a few years ago about my giving a lecture, and now he revealed that he was the mystery purchaser. There was a further twist to the tale: The seller was now saying that it had been lost and he was returning Camacho's money. Camacho forwarded the emails to me and asked for advice. One of the seller's messages read:

> "I have a small problem. At home I put the items in a box and bring them downstairs where we there have 175 meters of home construction going on. but I also use this for store items, packing, etc so I do not have all I sell in oure living aerea. I spend all weekend searching for your lot but I cannot find it at the moment. There are a few possibilities....last Wedsnesday is a old paper collecting day, and every Wedsnesday we throw away old boxes. My wife did this last Wednesday. Perhabs she throw away a wrong box. Or I did send other items and it was evidently in one of these boxes. or ... I just cannot locate it at this moment. Again I am very sorry for this. I am returning your €1,400."

This is equivalent to $1,580. Because I had photographs of both instruments on file, I published a preliminary account in London (*Laboratory News,* p 6, Feb. 3, 2015), and I suggested to Camacho that because he had purchased the item, it was still his property. Returning the money was a separate arrangement, and I felt he could argue that it did not affect the validity of his ownership. From details retrieved from the emails, I could methodically ascertain the identity of the seller, and eventually his address, email, phone number and (through the intrusive surveillance of Google Earth) even a picture of his house. The seller backed down and wrote:

> "Could it be that small items went thru the basket … so if we found the two coins and microscope and i would send it to you, would that be the end of your "case" and problem with me, and you and i would be at peace, and you would forgive and forget the rest of the lot, and would say that this is okay by you?"

QUEST FOR AUTHENTICITY

Camacho and his wife Dr. Estrella Pallas, an ear nose and throat surgeon, agreed and on Jan. 27, 2015, they finally received this prize possession. A few days later it was delivered to me by courier. I settled down to carefully examine it and found it that it was a genuine Leeuwenhoek microscope.

The Boerhaave, meanwhile, had taken some close-up photographic studies of the instrument. These conventional images revealed little detail, reinforcing my determination to employ SEM examination.

Two months later, Degenaar formally acquired his silver microscope. He purchased it for a modest five-figure sum and received it on March 16, 2015. Thus it had been sold for perhaps one-tenth of what it might have fetched at auction (even though the Willemse microscope sold at Christie's five years earlier had cost a half-million dollars, it had no documented provenance). Degenaar insisted on keeping the news of his microscope secret, and at one stage said he would not be announcing anything for a year. Camacho was eager to see his acquisition published, and so — like my discovery of Leeuwenhoek's specimens in 1981 — this was duly reported in *Nature* (521, p 423, May 23, 2015). That very week Degenaar suddenly invited me to Leiden, where he had decided to announce his new microscope at the Museum Boerhaave on June 3, 2015; but the notice was too short and I could not find the time for a trip to the Netherlands. What a remarkable situation this

was: both newly discovered instruments were now in the public domain. After my casual remarks at school 60 years earlier about a quest for missing Leeuwenhoek microscopes, it had all come true — two of them being presented to me for authentication in one year.

As an academic, Camacho was impressed by my proposals for SEM analysis. At the Cavendish Laboratory in Cambridge, department head Professor Richard Langford offered his full cooperation, and my technical colleague J.J. Rickard recommended that we use the Hitachi S-3400N variable-pressure microscope because of its large specimen chamber. Conventionally, the goal of SEM is to attain the highest magnification, but here I was concentrating on obtaining low-power images of high resolution and maximum depth of field. An accelerating voltage starting at 10kV was used with 8×–20× magnification, which was increased to obtain detailed studies of components (e.g. the lens, screw threads, etc.) typically to 60×.

The detail we were revealing was startling, and a team from national television news came along to report the experiments. The provisional results were published in November 2015 as "Surprise of the Century — Three More Leeuwenhoek Microscopes," *Microscopy Today* (23:6, pp 38–43, 2015). Meanwhile, a series of digital images was obtained using the Zuiko Digital 35 mm macro lens with an Olympus E-500 camera. From these correlated sessions, detailed studies were assembled to produce final images measuring up to 27,000 pixels (2,185 mm) in height, i.e. greater than 7 feet. Almost 1,000 photographs were acquired. It was a prodigious effort, and my preliminary report, "New Protocol for Old Microscopes," appeared in *Laboratory News* (pp 20–21, July 3, 2015).

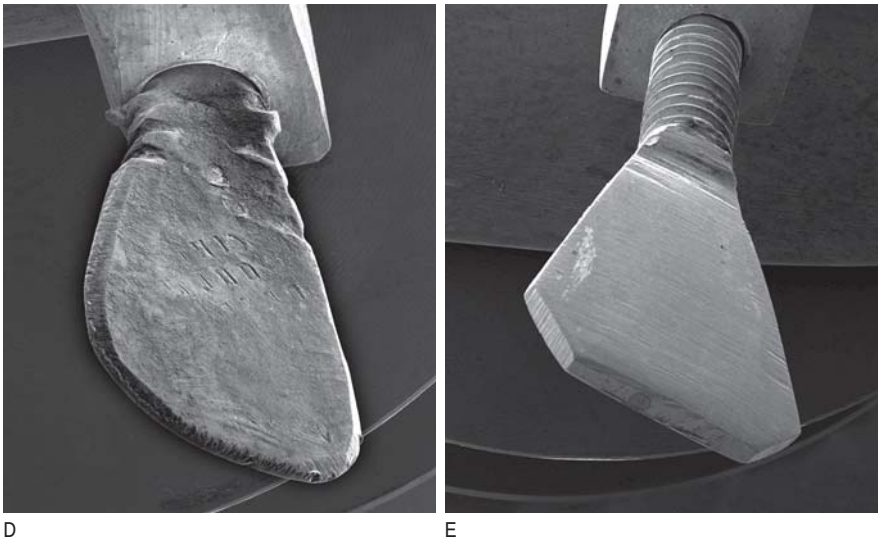
Camacho banished all time constraints for the research. We both wanted to gain as much information as possible using the procedures to enlighten us about the way the microscope had been constructed and also to build up an understanding of how this novel approach of an SEM macrograph might evolve into a protocol for authenticating other antique instruments. This is crucial, because I am certain that not all the original nine known Leeuwenhoek microscopes are genuine.

The first on my list, the brass microscope at Leiden, is of proven provenance because it was continuously owned by descendants of Leeuwenhoek's family. Curiously, it is a near-twin of the Camacho microscope. Similar comments apply to No. 2, the Rotterdam microscope we discussed earlier, which magnifies 74×. Both are family heirlooms. No. 3 is the best of them all, magnifying 266×. Constructed from brass, it has an aspheric lens that has not been ground. The late Jan van Zuylen, who was Holland's greatest authority on these lenses, ingeniously discovered that it could have been made by blowing a large bubble of glass, perhaps one foot across, and harvesting the apical "nipple" of glass that naturally forms. The resulting lens provides a dramatically wide field of focus. This microscope has been documented only since 1843, more than a century after Leeuwenhoek's death. It was traditionally said to be from Leeuwenhoek, and its lens is greatly superior to any other of its type. Although the design of the attachments is consistent with Leeuwenhoek's handiwork, it is not typical of the other Leeuwenhoek

Camacho sent his microscope to the author in Cambridge for SEM analysis. It has all the signs of authenticity, however, it is heavily tarnished after remaining buried at the bottom of a Delft canal for more than three centuries.

The lens of the Camacho microscope had been severely abraded, perhaps because Leeuwenhoek decided to reject it. Traces at the margin had survived (blue) and a speculative reconstruction allows us to infer that the radius was 1.2 mm. Note also the minimal distortion of the brass plates to hold the lens in place.

A B C



D E

A: This positioning handle of the silver microscope compiled by the author from two close-up photos by the Museum Boerhaave shows little fine detail, and the resolution of conventional museum photography is insufficient to be useful. B: Our Olympus E-500 camera with a Zuiko Digital 35 mm macro lens was used for close-up studies of the Camacho microscope. Grooves can be discerned along the crest of the screw thread, leading to the conclusion that the screws were rolled rather than cut with a die. C: An SEM macrograph of the handle shown in image B reveals the crystalline nature of the brass. There is also a curious bilateral asymmetry in the contour of the outline. Leeuwenhoek frequently cut the body plates of his microscopes in this uneven manner, which may be a feature for authentication. D: The focusing screw handle of the Camacho microscope reveals characteristic detail when viewed in the SEM at 8× initial magnification and an accelerating voltage of 5 kV. The peripheral bezel is revealed with file marks from the finishing process. The indentations are possibly grip marks from a bench vice. E: The handle of a replica made by Hansen van Walle of Antwerp, Belgium shows fine finishing and a plane surface typical of sheet brass. Instead of a beveled edge, this handle has been cut at right angles, and the thread is die-cut rather than rolled.

microscopes. Surely, nobody else could have produced a microscope lens of such peerless optical quality.

It is with microscope No. 4 that we encounter our first major problem. It came from the museum of Henri van Heurck, a pre-eminent Victorian diatom specialist and avid collector of microscopes. His entire collection was put on display in 1891 at the Antwerp Museum, though at that time there was no mention of a microscope by Leeuwenhoek. However, after his death, a catalogue of his microscopes was made public and there was "a Leeuwenhoek microscope" in the list. No mention was made of its origins. Although it magnifies 110× it is of crude construction compared to Leeuwenhoek's design, with a coarsely designed protuberance where the lens is secured. For a century, the van Huerck collection was in Antwerp, though Dirk Teunis, a Belgian microscope enthusiast, tells me that the instrument collection has been moved to the Science Museum in Gent, Belgium. This microscope needs reappraisal.

Similar doubts apply to No. 5 in the list, a brass microscope magnifying 112× in the collections of the Deutsches Museum in Munich, Germany. In 1906 the Museum reportedly ordered a replica Leeuwenhoek microscope from the instrument makers Filibri. When the order came in, the item was listed as a genuine Leeuwenhoek microscope and has since been claimed as such. It does not look authentic to me. Microscope No. 6, which is the microscope from Gouda that van Iterson donated, certainly passes the test of authenticity. No. 7 is also rated as genuine. This is the silver Willemse microscope sold by Christie's in 2009 and which has since disappeared. It is a Leeuwenhoek microscope (though it lacks documentary provenance) as is No. 8, which — although it now lacks its lens — is also a microscope from the Haaxman family, who are descended from Leeuwenhoek. This one was for many decades on display in a glass-fronted display case set into the foyer of the Technical University of Delft. It looked so impressive illumined by down-lights behind a thick plate glass surrounded by polished stone and solidly set into the wall. It looked as secure as Fort Knox. Yet, when the director had it brought out for me to examine, the janitor opened the door of a broom closet behind the display case, turned a small clip, and lifted out the plywood board on which the instrument rested — in reality, it was not very secure. I pointed out how it needed better protection from casual visitors; it was subsequently taken from its glass case and returned to the Museum Boerhaave. The replicas sold by the museum are made by Paul Steenhorst using a cellphone camera lens and a British Standard Whitworth 2.3 mm diameter screw thread, about which Steenhorst says: "The Pitch is finer though, but tests have proven that only real experts will see the difference." Those tests do not include examination with the SEM, which will tell us the difference at once.

We return to Munich to find microscope No. 9, a silver instrument magnifying 167× with a wrought-iron specimen pin. It is listed as a genuine microscope, but there are features that give me pause for thought. First, the prominence of its lens housing is not typical of Leeuwenhoek's design, and second, its lens aperture is not centrally situated between the rivets. It could be argued that, as an early model, it shows features that Leeuwenhoek later modified, and that is a reasonable proposition. This example has some features in common with Baker's drawing of the Royal Society's lost microscopes, which I noted in my paper, "What Were the Missing Leeuwenhoek Microscopes Really Like?" in *Proceedings of the Royal Microscopical Society* 18:2, pp 118–124, 1983). Here my SEM examination would be crucially important, for only this could reveal the fine details of components such as the screw thread and the disposition of the rivets.

So now we have three more microscopes: No. 10, magnifying 68× and brought in to the Boerhaave by that unknown Dutch resident; then No. 11, the silver microscope that was never put to auction and was privately sold for what might be a small fraction of its real value (its magnification is claimed to be 248× and is yet unconfirmed); and No. 12, which was put up for auction on eBay, peremptorily withdrawn from sale and finally purchased for a small sum. Reconstructing the lens gives us the impression that it would have magnified 118×, the same as its near-twin in Leiden.

The stories of secrecy, intrigue and back-room dealing are as much a feature of these new microscopes as we found in the Victorian era. The Camacho/Pallas microscope is the only example so far made available for a more objective appraisal, and the SEM macrographs have proved to be uniquely revealing. At last we have an objective basis on which to claim authenticity.

LENS OF INTRIGUE

This final example to emerge poses the most intriguing mystery of all: What fate befell its lens? Under low magnification the surface seems misted and scratched. Under the SEM we can see the reason: Both sides have been ground away, destroying the structure of the lens. As we have seen, Leeuwenhoek did not give away microscopes, except in very rare circumstances to royalty, so the damage must surely have

Tomás Camacho (far right) joins Abel Ramón Caballero Álvarez (second from left), the mayor of Camacho's hometown of Vigo, Spain, at a reception honoring the announcement of the new Leeuwenhoek microscope. They are joined by the author (far left) and Councillor Carlos López (second from right).

been done at his residence and presumably by him. He is known to have been a perfectionist about lenses, even though he paid little attention to finely finishing the metal from which his magnificent microscopes were made. Perhaps he resolved to ruin the lens because it did not meet his high standards so he threw the useless microscope out the window. It was later to emerge, in 2014, from landfill that contained piles of mud dredged from the canals in Delft, and its story was published in the Proceedings of the Royal Microscopical Society (*InFocus*, 40, pp 31–43, Dec. 2015).

We can never be sure what took place that day, but irascibility may offer an answer. Leeuwenhoek was a short-tempered and precise individual who reminds me most of Sheldon Cooper, the character played by Jim Parsons in the television sitcom "The Big Bang Theory." It may be that he had Asperger's syndrome. It was the pleasure of detached observation and the thrill of discovery that drove Leeuwenhoek, yet he was indifferent to social niceties. One can easily envisage how he ground away a substandard lens and in a fit of wounded pride threw the microscope away.

The fact that three previously unknown examples of his microscopes have dramatically come to light reminds us that there is just a chance that there may be more. If any do emerge, do not expect them to be announced with dignity. There will be skulduggery and sleight of hand, double-dealing and duplicity — and if some plagiarism is thrown into the mix then you will have it all.

So, what is the current situation? The half-million dollar microscope, the only example to be auctioned in recent centuries, remains lost to science and, whoever the new owners might be, they have deprived scholars from studying it. The 10th microscope to be recognized remains unknown and ignored even though — as the smallest we know — it has many secrets to reveal. The 11th microscope is due to be loaned to the Golub collection in California for temporary display, but sadly the collector, Dr. Orville Golub, died on Sept. 28, 2015 at the age of 100, testimony to the longevity of microscopists. The 12th microscope (with its deliberately damaged lens) was given a civic mayoral reception in Spain, and subsequently became a key exhibit in the Year of Light conference organized by UNESCO in Paris, France. An exquisitely produced book about the Camacho/Pallas collection has just been published, in which this latest Leeuwenhoek microscope takes pride of place. Camacho is reluctant to expose it to risk and has declined some proposals for exhibition. There are now plans for it to feature in a special exhibition of the Camacho/Pallas microscope collection at the Museum for the History of Man at Burgos, near Madrid. The inauguration may even be attended by the King or Queen of Spain, which would have given Leeuwenhoek immense satisfaction.

Already, we know more about this modest little microscope than almost any other antique scientific instrument in history. Yet still the findings are based on my conclusion that this microscope is authentic. What we need next is a program of investigation in which all the others will be scrutinized by SEM macrography. This is when the value of the technique will become paramount. I believe that we now need to apply these newly conceived protocols to all the others, because only then we can master how they were made, how much care went into constructing them, which metals went into their making, and how the details of their design can be determined. At last we will know which microscopes were truly made by Leeuwenhoek and which are fake. The technique offers us a revolution in determining authenticity, and it will find widespread applications across the spectrum of scientific enquiry. This will be a matter of reality, not opinion — without subterfuge or secrecy and with no dishonesty or duplicity. With SEM macrography we will be able to determine objectively which antique scientific instruments are authentic, and we will know it for sure. This opens a new era in the study of scientific instruments, for it offers truth rather than mere opinion. ■