Surprise of the Century—Three More Leeuwenhoek Microscopes

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Leeuwenhoek's Legacy

Microscopes are envisaged as large and impressive items of equipment. A microscope symbolizes science. Everyone knows that microscopes can reveal hidden details that allow us to penetrate the otherwise invisible secrets of nature. Yet the science of microscopy originated with small and simple instruments. The pioneer of microbiology was the Dutch microscopist Antony van Leeuwenhoek (1632–1723) whose life was meticulously spelled out by Clifford Dobell [1]. Leeuwenhoek used single lenses to explore the world of microbes. He mounted the lenses in microscopes little larger than a postage stamp. Nine microscopes of this standard design claimed to be made by him were known to have survived, and I described them all in my book *Leeuwenhoek Legacy* [2]. Now we have an extraordinary revelation: three new examples have come to light after centuries during which all others were believed lost.

Leeuwenhoek was a draper and town official who discovered the world of microbes in 1674, using one of his tiny microscopes to observe lake water in which he described flagellates such as *Euglena* and algae including *Spirogyra*. In the following year he studied blood and erythrocytes, calibrating them alongside a sand grain 1/30 inch in diameter. He found that human red blood cells were "somewhat less than" 8.5 micrometers (μm) across. The living cells are actually 7.5 μm in diameter, showing how meticulous he was as an observer. In 1677 he recorded spermatozoa in a number of species; he also noted that although disc-shaped erythrocytes of humans have no cell nucleus, those of fish do contain a nucleus. In 1683 he certainly observed bacteria in tartar from the teeth, and also in feces. That same year he identified *Giardia* as an intestinal parasite. Many of his descriptions are so good that we can identify the organisms he described (including *Vorticella, Stentor* and *Volvox*). By 1684 he had described the pointed needles of uric acid associated with gout. He correctly recognized that the crystals caused the painful symptoms. In the early 1700s he was studying diatoms and rotifers, discovering that rotifers could be revived from the dried state (which we now term anhydrobiosis).

Robert Hooke's *Micrographia*

In 1981 I unearthed packets of original specimens that Leeuwenhoek sent to the Royal Society of London and which had not been investigated since [2]. Nobody could understand where Leeuwenhoek obtained his inspiration until I realized that the specimens he had sent to London were the same as Robert Hooke had described in his book *Micrographia* (and they were listed in the same order) [3]. Hooke's book was the first popular work on the microscope. It was published in 1665 and shortly thereafter Leeuwenhoek paid his only visit to London. Clearly he saw Hooke's book, for I recognized the importance of a previously overlooked section of the Preface of the book which described how to grind lenses of high power and how to mount them in small metal plates … precisely the method that Leeuwenhoek was to use [2].

Leeuwenhoek's Surviving Microscopes. The fate of all the microscopes left after Leeuwenhoek died remains unresolved, though traditional historians confidently list nine of them. For example, he bequeathed a box containing 26 silver microscopes to the Royal Society, and it was hoped that they might one day reappear. However, they were taken away by a celebrated Victorian surgeon, Sir Everard Home. Professor Derek de Solla Price concluded that they were melted by a fire that destroyed

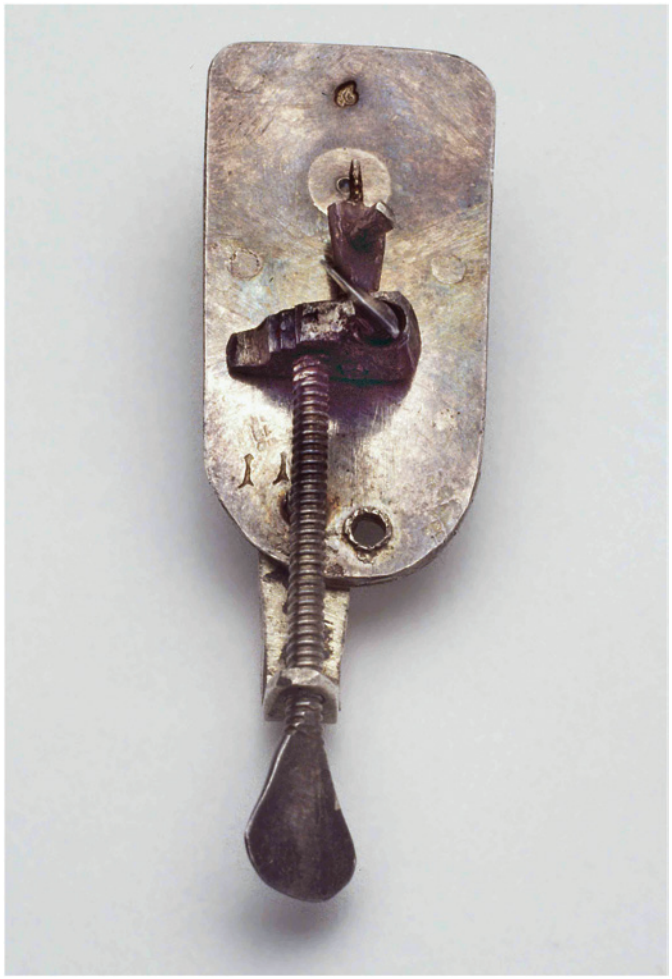

Figure 1: Much media interest in Leeuwenhoek followed my discovery of his specimens in 1981 [2], and this microscope was subsequently brought into the Boerhaave Museum in Leiden, Netherlands. It is the smallest of them all; the plates measure 17×34 mm. It was locked away in the museum for twenty years until it became the subject of a single paper in an obscure journal in 2002 [6].

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Table 1: Microscopes attributed to Antony van Leeuwenhoek.

No	Metal	Plates (mm)	Magnification	Owner	Place	Provenance	Authenticity	Believed Genuine
1	Brass	16 × 40	118×	Boerhaave Museum	Leiden, Netherlands	Since 1747	Documented	Yes
2	Brass	17 × 40	74×	W. de Loos	Rotterdam, Netherlands	Since 1747	Documented	Yes
3	Brass	24 × 46	266×	University Museum	Utrecht, Netherlands	Since 1843	Documented	Yes
4	Brass	28 × 47	110×	Royal Zoological Society	Museum for History of Science, University of Gent, Belgium	Since 1914	Included in a catalog dated 1914; previously unknown	Dubious
5	Brass	28 × 37	112×	Deutsches Museum	Munich, Germany	Since 1906	Supplied in 1906 without documentation	Doubtful
6	Silver	19 × 32	80×	Boerhaave Museum	Leiden, Netherlands	Hallmarked before 1831	Known since 1872 and accepted	Yes
7	Silver	22 × 39	69×	Undisclosed	Purchased at Christie's, London	Since 1866	Accepted as genuine	Yes
8	Brass	22 × 46	No lens	Boerhaave Museum	Delft, Netherlands	Since 1745	Documented	Yes
9	Silver	25 × 45	167×	Deutsches Museum	Munich, Germany	Since 1906	Supplied in 1906 without documentation	Doubtful
10	Silver	17 × 34	68×	Boerhaave Museum	Leiden, Netherlands	None	Authenticated by Boerhaave Museum	Yes
11	Silver	22 × 39	248×	Planetarium Zuylenburgh	Oud-Zuilen, Netherlands	None	Authenticated by the author and Boerhaave Museum	Yes
12	Brass	17 × 41	[180×]	Camacho Pallas Collection	Vigo, Spain	None	Authenticated by the author after SEM macrography	Yes

Home's apartment in 1832. One recent account [4] considers 18 Leeuwenhoek microscopes since 1875 of which most have since been lost.

Table 1 shows a list of the standard Leeuwenhoek microscopes beginning with the nine accepted ones, followed by three newly authenticated examples. Table items 1, 2, and 8 are of documented provenance via the descendants of Leeuwenhoek himself. Most of the remainder are accepted as genuine, though this author has cast doubts on items 4, 5, and 9. One known example made of silver was sold by auction in London in 2009 (table item 7). Clearly, this was recognized as an extremely important instrument, and its value was reflected in the money paid by the purchaser—a total of half a million dollars [5].

However, not all the microscopes attributed to Leeuwenhoek are of reliable provenance. One is part of the Henri van Heurck collection of the Royal Zoological Society, which for over a century was in Antwerp (#4). In 2002 it was moved to the Museum for the History of Science at the University of Gent, Belgium. Although the microscope looks somewhat like an original Leeuwenhoek microscope, the lens housing is of crude conception and seems too prominent; it lacks the subtlety of the genuine article. Similar doubts can be expressed about another brass example at the Deutsches Museum in Munich, Germany (#9). As was said in my book [2], it "seems to show a more modern approach to manufacture."

First Newly Discovered Microscope

In 1982 the first new candidate to appear unexpectedly emerged. Following my discovery of original specimens by Leeuwenhoek, there was renewed interest in his work, and a member of the public recognized that they possessed a microscope (Figure 1, #10) similar in appearance to one made by Leeuwenhoek. It was taken to the experts at the Boerhaave museum in Leiden, Netherlands, where nothing was done and it was locked away in a cupboard. Only in 2002 was it published in an obscure Dutch journal [6]; few other investigators have heard of its existence. This in itself was an extraordinary event, bringing the total of presumed Leeuwenhoek microscopes to ten.

Second Newly Discovered Microscope

The next example emerged in March 2014 when an item of silver was delivered to auctioneers in London. I was contacted for an opinion and concluded that this was almost certainly a genuine Leeuwenhoek microscope (Figure 2, #11). Regularly I am asked to opine about instruments similar to these, and they have invariably been copies rather than originals. Although opinions are the ultimate resort in matters of authentication, I was now beginning to form the view that we needed a more objective rationale. The proposed technique of SEM macrography described next should resolve the issue.

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Figure 2: This silver instrument was the first of two identified by the author in 2014. It appears to be a genuine Leeuwenhoek microscope and had been found in a box of toy trinkets. There are air bubbles in the lens, as in some other Leeuwenhoek microscopes. It was never offered for public sale but was sold privately to a Dutch collector.

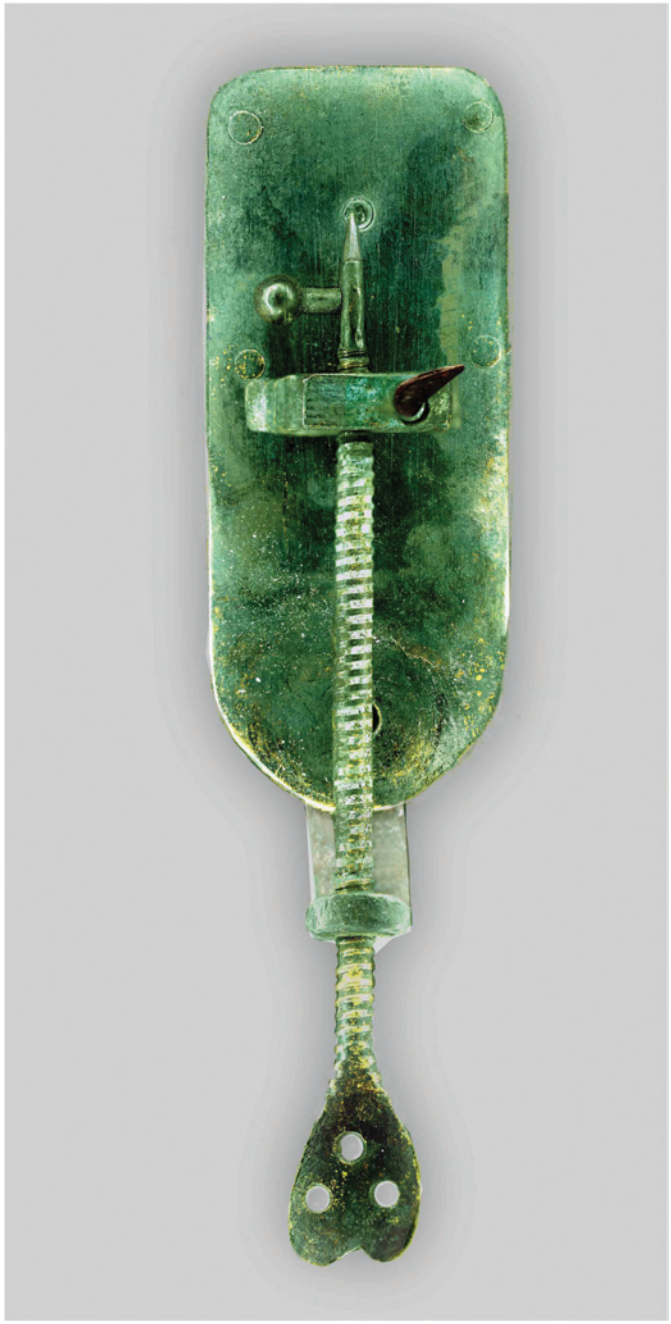

Figure 3: Metal detector enthusiasts excavated this microscope from mud that had been dredged from a canal in Leeuwenhoek's hometown of Delft, and it was offered for sale on eBay in December 2014. It was sent to Cambridge by the purchaser, Spanish toxicologist Dr Tomás Camacho, for appraisal. This example is a near-twin of a genuine microscope in the Boerhaave Museum.

The ultimate test would assuredly lie in eliciting the minutiae of construction, of which a forger would be unaware. It seemed that surface images from a scanning electron microscope (SEM) would give unique and unprecedented insights. Ordinarily we use the SEM for high-magnification imaging, but I proposed a radical alternative: to use the instrument for high-resolution macrographs at low magnification. These would be uniquely revealing. However, neither the vendor nor the auction house was attracted to this proposal, and the diminutive microscope was never put up for auction. Instead, it was privately sold to an enthusiast, a property developer and scientific instrument collector in the Netherlands. The Boerhaave Museum shared my belief that it appeared to be authentic, though no SEM investigations have been undertaken. Thus, there were then eleven Leeuwenhoek microscopes.

Third Newly Discovered Microscope

Nine months later a further example was one of several artifacts located by metal detector enthusiasts who were trawling through a Dutch landfill. The mud had been excavated in the 1980s when the canals of Delft were being refurbished, and Delft is where Leeuwenhoek had lived and worked. The discolored little artifact was offered for sale on the online auction site eBay, and the purchaser emerged as a leading Spanish toxicologist and

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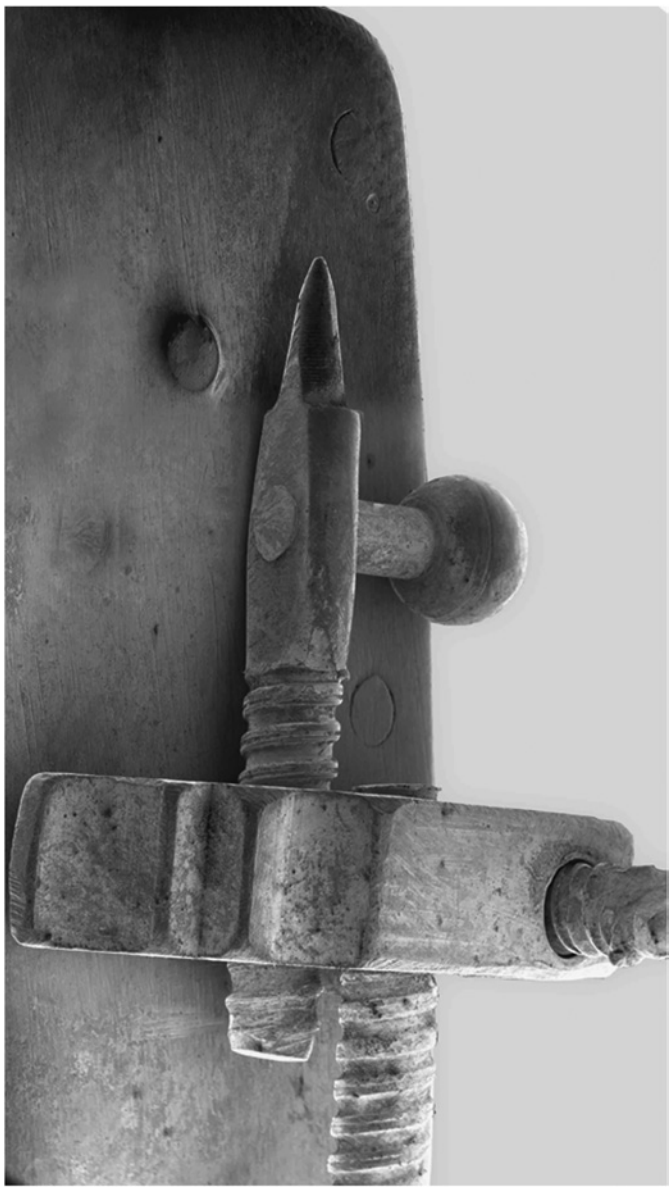

Figure 4: SEM macrography of the microscope from the Delft canal. A crew from the British program *News At Ten* filmed studies with the Hitachi S-3400N variable-pressure SEM at the Cavendish Laboratory, Cambridge. We demonstrated that macrographs could reveal fine manufacturing details. This example shows the block stage (below), the abraded lens (upper left) and the specimen pin (center) with its positioning knob.

microscope collector, Dr. Tomás Camacho. He sent it to us at Cambridge, England, by secure courier and asked for my opinion. The microscope seemed to be as authentic as one could judge by appearance (Figure 3, #12), though I remained convinced that objective criteria were needed [7].

This newly discovered brass microscope from Delft is very similar to an instrument of undoubted provenance at the Boerhaave Museum (#1), which had been purchased in 1774 at auction from Leeuwenhoek's possessions and has a documented provenance to the present day. Though the newly found microscope is not a copy of the original, the screw pitch and dimensions are comparable. The Boerhaave Museum's microscope has body plates that are rectangular, whereas the base plates of the newly found microscope have a curved profile.

Figure 5: Microscope from Delft canal. Higher magnification reveals the scratches left by Leeuwenhoek. The lens surface (lower left) had been badly abraded so no magnified image can be created by this microscope. Facets on the central specimen pin show it was cold-forged, whereas replicas are simply turned on a lathe. Note also the neatness of the rivet (upper right), which secures the brass plates together.

The Boerhaave Museum has for some years provided replicas of this brass microscope for sale, and thus we have similar instruments—one ancient, one modern—that can be compared.

SEM Macrography. As a leading clinical academic, Dr. Camacho shared my preoccupation with criteria of authenticity and was eager to encourage further investigations. In the event, his microscope remained with us in Cambridge, England, for five months. A series of macrographs was taken using an Olympus E-500 camera and Zuiko Digital 35 mm macro lens. At the Cavendish Laboratory of Cambridge University, Professor Richard Langford offered generous access to the SEM suite where Jon Rickard provided much useful advice and access to the Hitachi S-3400N variable-pressure SEM. To invoke macrography, an unusual application for an SEM, an accelerating voltage of 10 kV was used, and the secondary electron image was generated at an initial magnification of 10× or less. This gave a unique depth of field so that the precise nature of the fabrication methods could be elicited over the entire object. For instance, we can observe the construction of the screw thread and the stage block. We were also able to use energy-dispersive X-ray spectroscopy to determine the elemental components of the brass alloy and the glass from which the lens had been produced.

Correlated microscopy has now allowed us to discern the details of manufacture (Figure 4). We can observe the scratches on the brass surface, the finishing of the rivets, and the manufacturing artifacts of the specimen positioning screw and the stage block (Figures 4–6). These may be unique features of a true Leeuwenhoek microscope and inimitable. Ordinarily, one source of comparison would be the lens, though in this microscope the lens surface has been badly abraded and no longer generates an image.

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Figure 6: Microscope from Delft canal. Details of the metal shaping can be studied on this image of the stage block. The screw thread shows it was rolled and not cut using modern die techniques; this may be diagnostic of a genuine Leeuwenhoek microscope. The slight splaying of the positioning screw (above center) and the detail of the filed-down rivet head (top center) disclose Leeuwenhoek's diligence.

Conclusion

Three new Leeuwenhoek microscopes have thus been added to the list of nine, giving a total of twelve. None of the new arrivals is of certain provenance, though our research at Cambridge shows that SEM macrography could provide insights that are otherwise unattainable. Each has an unusual story: one being locked away for two decades, another emerging from a box of silver trinkets, the third found in mud dug from the bottom of a canal. Once an agreed SEM protocol is available, it is certain that the number of accepted Leeuwenhoek microscopes will begin to reduce: the brass microscopes at Munich and Gent evoke serious doubts of authenticity, and several others need meticulous reappraisal [8].

The fundamental conclusion is that the emergence of two unsuspected Leeuwenhoek microscopes in the space of a year reminds us that there may be others awaiting discovery. Leeuwenhoek made at least 500 microscopes during his lifetime [4]. After centuries of silence it suddenly seems possible that others could still appear.

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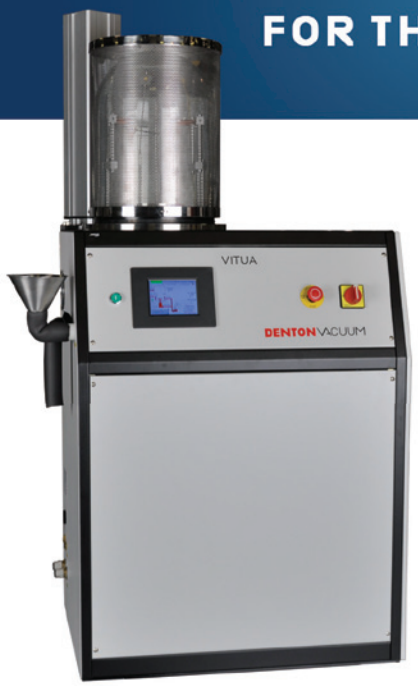

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