FEMS Microbiology Letters, 366, 2019, fnz203

doi: 10.1093/femsle/fnz203
Advance Access Publication Date: 30 September 2019
Research Letter

RESEARCH LETTER – Professional Development

Historical microbiology – using a Van Musschenbroek microscope

Koen D. Quint[1,2] and Lesley A. Robertson[3,*]

[1]Historical Microscopy Foundation, Visseringlaan 25, 2288 ER, Rijswijk, The Netherlands, [2]Department of Dermatology, Leiden University Medical Centre, Albinusdreef 2, 2333 ZA,Leiden University, Leiden, The Netherlands and [3]Department of Biotechnology and Delft Science Centre, Delft University of Technology, Mijnbouwstraat 120, 2628 RX Delft, The Netherlands

*Corresponding author: Delft Science Centre, Delft University of Technology, Mijnbouwstraat 120, 2628 RX Delft, The Netherlands. Tel: +31-1-52-78-24-21; E-mail: l.a.robertson@tudelft.nl

One sentence summary: Simple samples have been used to work out how to use a microscope that was made over 300 years ago by Jan van Musschenbroek of Leiden.

Editor: Beatrix Fahnert

ABSTRACT

A single-lensed microscope made by the Van Musschenbroek workshops between 1690 and 1750 has been examined experimentally, and the method of use established. The results were compared with those obtained with facsimile van Leeuwenhoek microscopes. As might be expected, each microscope had its stronger and weaker points.

Keywords: Van Musschenbroek microscope; Van Leeuwenhoek microscope; single-lensed microscope

INTRODUCTION

Historical microbiology can be defined as the testing of historical instruments and experimental methods. In this way, it can often be seen why a particular researcher obtained specific results when others did not. Moreover, historical experiments can often be useful for teaching while staying within increasingly strict biosafety legislation (Robertson 2015).

After writing in 1679 (Hooke 1679) about the difficulties associated with the making and mounting of lenses for single-lensed microscopes, as well as the eye strain involved in their use, Robert Hooke (author of Micrographia, the first book on microscopy, (Hooke 1665)) went on to praise them, saying

> *"... though in truth they do make the object appear much more clear and distinct, and magnify as much as the double Microscopes[1]: nay, to those whose eyes can well endure it, 'tis possible with a single Microscope to make discoveries much better than with a double one, because the colours which do much disturb the clear vision in double Microscopes is clearly avoided and prevented in the single."*

Single-lensed microscopes were obviously common and appreciated in the 17th and early 18th centuries. Many of them were made by or for specific researchers according to their requirements (examples shown in Fig. 1) and featured modifications including rotating sample holders to allow more than one sample to be mounted at a time, interchangeable lenses and ways of controlling the light with different apertures. Van Leeuwenhoek produced a few microscopes with two or three lenses, side by side, to allow a fragile sample to be examined under different magnifications, and with a hole in the sample holder to mount a capillary (Robertson 2017). However, an instrument-producing workshop owned by the Van Musschenbroek family in Leiden included single-lensed microscopes for general sale in their catalogue (de Clercq 1997).

[1] Now known as compound microscopes.

Received: 23 August 2019; **Accepted:** 27 September 2019

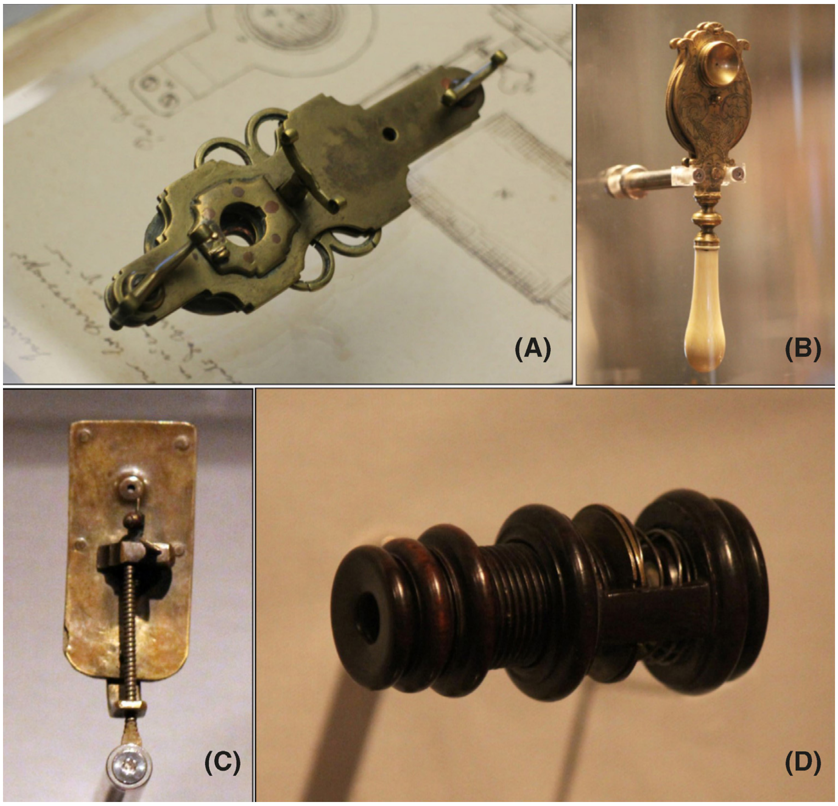

Figure 1. Single-lens microscopes in use at the end of the 17th and beginning of the 18th century. Their designers and/or makers were: **(A)** Christiaan Huygens (1629–1695), **(B)** Jean Depouilly of Paris (~1660–1710), **(C)** Antoni van Leeuwenhoek (1632–1723) and **(D)** Nicolaas Hartsoeker (1656–1725).

The Van Musschenbroek workshops

The Van Musschenbroeks began as Flemish refugees in the early 1600s (Daumas 1972; de Clercq 1997). They opened a brass foundry in Leiden around 1610, producing a range of products including domestic oil lamps. During the 1660s, they began specialising in scientific and medical instruments, gaining a reputation for making some of the finest instruments in Europe. Among their most famous products were vacuum pumps, telescopes and microscopes as well as special tools required by medical students. The company trademark has an engraving of an oriental brass lamp with the crossed keys of the Leiden city arms. After the death of Jan van Musschenbroek (1687–1748), the business closed and his books and instruments were sold by auction. His brother, Petrus (1692–1761), became Professor of mathematics, physics, astronomy and medical science at Leiden University.

The Van Musschenbroek workshops produced single-lensed microscopes for general sale as well as instruments to order for, among others, Reinier de Graaf, Jan Swammerdam and Christiaan Huygens. They also made and sold copies of van Leeuwenhoek's 'aalkijker', a device for watching blood flow in the capillaries of small fish and eels (Van Leeuwenhoek 1967), as well as dissecting microscopes for Swammerdam and Lyonette. Their trade catalogue also mentions 'a microscope for looking through 2 lenses at the same time', presumably a compound microscope (de Clercq 1997).

The stronger of their single-lensed microscopes is especially appropriate for illustrating the need to test theories of how such microscopes must have been used because there are a couple of confusing points in previously published work (e.g. Bradbury 1967; Davidson 2015).

Antique microscopes are rare, valuable and often fragile, and it is therefore entirely reasonable that their owners prefer to put them into glass cabinets, leaving others to theorise about how they were used. However, without testing such theories, those microscopes can become curiosities rather than the important scientific tools of which Hooke wrote. Moreover, comparing the instruments and techniques used by the various researchers of the day can shed light on how and why they obtained their results. One solution is to experiment using exact replicas but, although this has been done successfully with facsimiles of the van Leeuwenhoek microscopes (Robertson 2015, 2017), good facsimiles of most 17th/18th century microscopes are not readily available. This paper describes a study to determine the mode of use of an original single-lensed microscope made by Van Musschenbroek and commonly in use in the late 17th and early 18th centuries.

The Van Musschenbroek workshop made two types of single-lens microscope between 1690 and 1750 (Clay and Court 1932; Daumas 1972; de Clercq 1997). Not all of their order books have survived, so it is not known how many were made, but examples are to be found on the websites of the various microscopy musea around the world, and occasionally on auction sites. Robert Hooke presented an example of the weaker microscope to the Royal Society in 1693 (de Clercq 1997). The microscope examined here is the stronger and more expensive of the two (Fig. 2) and is marked with the company trademark (de Clercq 1997). It has four lenses mounted in small brass plates, marked with impressed dots, and three sample holders (Fig. 3). According to the website of the owners, (Stichting Historische Microscopie), the strengths of the lenses (distinguished by the impressed dots) are as follows: 3 dots, 14×; also 3 dots, 21×; 4 dots, 30×; 2 dots,

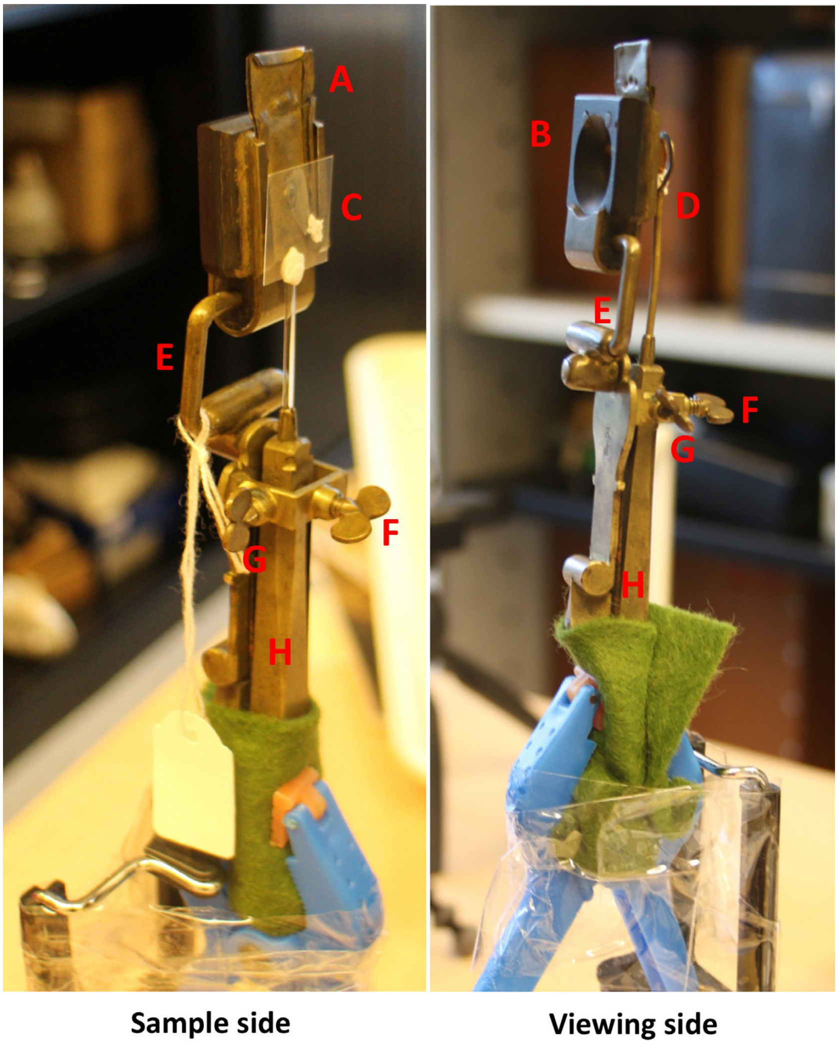

Figure 2. Both sides of the Van Musschenbroek microscope set up for use in this study. **(A)** Lens plate in place on the lens holder. **(B)** Lens holder from the user's side. **(C)** Sample between two glass cover slips, mounted on a glass rod with soft glue for later experiments. **(D)** Original sample holder. **(E)** Focus hinge. **(F, G)** Screws with 'Van Musschenbroek nuts' (De Clercq 1997). **(H)** Sample holder.

Figure 3. The lenses, lens holders and sample holders belonging to the Van Musschenbroek microscope used in this study. The dots engraved on the sample holders indicate the strength of the lens.

58×. For use, the lens plates can slide into place on the holder on the microscope (Fig. 2A). This particular microscope does not have the box and aperture plate seen on other examples of the same microscope.

METHODS

To protect it, the handle of the microscope was wrapped in felt and then held in a plastic clamp. The clamp was then taped to a table-top tripod. Fig. 4 shows the construction of the system. As the camera (Canon EOS M10) was replacing the user's eye, the end of the adaptor was as close to the lens of the microscope as possible. The adaptor, which replaces the camera's lens, is made and sold by different companies online. It is generally advertised as a replacement for the ocular on astronomical telescopes, but functions equally well with antique and modern microscopes. Direct views by eye were always better than photographs because of technical limitations imposed by the camera, especially the limited depth of field.

Figure 4. Set-up for photography with a Canon EOS M10 fitted with an eyepiece adaptor and fossil diatoms on the camera's screen.

The distance from the sample to the sensor in the camera must, as with an optical system, affect the final magnification, but whether the formula used for calculating this with camera lenses is valid for a mixed optical and electronic configuration has not yet been determined, available micrometers being too heavy. Since the exact magnification of the samples is not critical here, size bars have been replaced by a photograph of the insect used together with a coin (Fig. 5D). Magnifications quoted for comparison refer to those of the lenses only.

For the first samples, the original sample holder was used (Fig. 2D), but for later experiments, it was replaced by a glass rod (Fig. 2C) to reduce handling of the original holders. Samples mounted on glass cover slips were attached to the sample mount with soft glue. The samples included diatom fossils and the wing of a lacewing insect.

As used previously with facsimiles of the vVn Leeuwenhoek microscopes (Robertson 2015, 2017), the samples were lit using an LED lamp. The light level was controlled using a diaphragm and simple diffuser.

RESULTS AND DISCUSSION

Figure 5 shows examples of the photographs obtained using two of the lenses. The images were a little clouded, possibly because of the age of the lenses. As with experiments using facsimile van Leeuwenhoek microscopes, the view through the microscope with the naked eye was always better than that obtained while using a camera, largely because of technological limitations including depth of field. The images shown in Fig. 5 are all focus-stacked combinations of two to four photographs to reduce this problem.

Microscope configuration

Diagrams showing this microscope set up for use are not common. In the mid-20th century, Bradbury (1967) published one which suggested that the 'focusing hinge' (Fig. 2E) should lie at right angles to the stem of the microscope, forming three sides of a square around the sample mount (Fig. 2H). The lens holder would be attached to the hinge lying just above screw F, with the lens plate closest to the sample (Fig. 2C). This arrangement restricts sample manipulation and means that one of the 'van Musschenbroek nuts' (Fig. 2F) is in contact with the user's face when the microscope is in use. While the microscope was still in commercial production, Zahn (1702) published a different diagram showing hinge E upright and the lens holder on top (Fig. 6). The lens plate faced the sample (Fig. 2A and C). Zahn's configuration is the most likely since there are no obstructions to the use of the microscope, and it was used during this study.

Focusing

Some authors (e.g. Bradbury 1967; website of Davidson (2015)) have speculated that one or both of the two Van Musschenbroek nuts' (Fig. 2G and F) were intended for focusing. In fact, they are both mainly needed for positioning the sample mount in its vertical holder. Focus is mainly achieved by means of the hinges at the top of the sample holder and the bottom of the lens holder (Fig. 2E), although 'nut F' can aid fine focus if used with care. Loosening the nut too much allowed the sample mount to drop out of the microscope.

Comparison with van Leeuwenhoek's style of microscope (Fig. 1C)

Comparing the use of the Van Musschenbroek and Van Leeuwenhoek styles of microscope design, they each have their stronger and weaker points.

The ability to change lenses by simply replacing one lens holder with another on the Van Musschenbroek microscope is a major advantage over the need with most Van Leeuwenhoek microscopes to detach the (often fragile) sample and attach it to another microscope to use a different magnification. The Van Leeuwenhoek 'aalkijker' uses a similar system (Van Leeuwenhoek 1967).

Similarly, sample changing is more convenient and less damaging for fragile samples with the Van Musschenbroek model with its detachable sample holders.

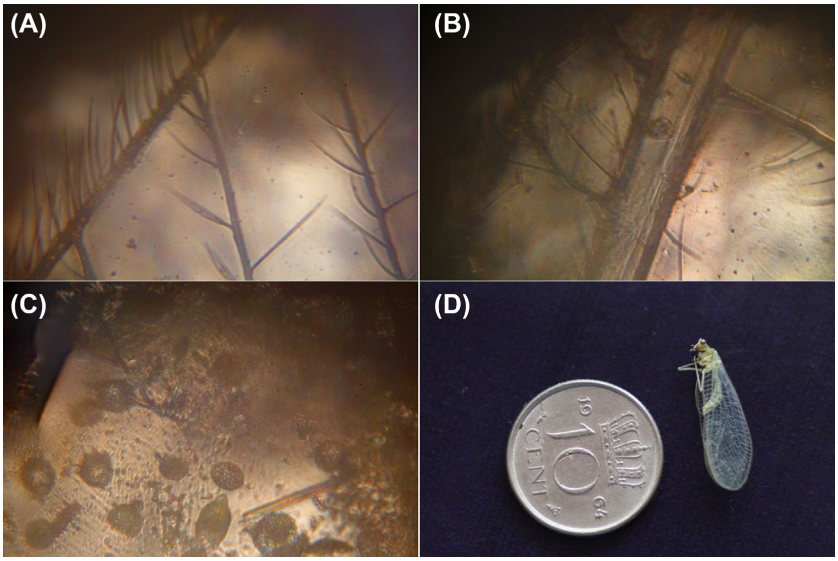

Figure 5. Images obtained with the Van Musschenbroek microscope and different lenses. **(A)** Wing of lacewing, 4-spot lens (magnification ×30). **(B)** Wing of lacewing, two-spot lens (magnification ×58). **(C)** Fossil diatoms, two-spot lens (magnification ×58). **(D)** Lacewing with 10 eurocent coin to show scale.

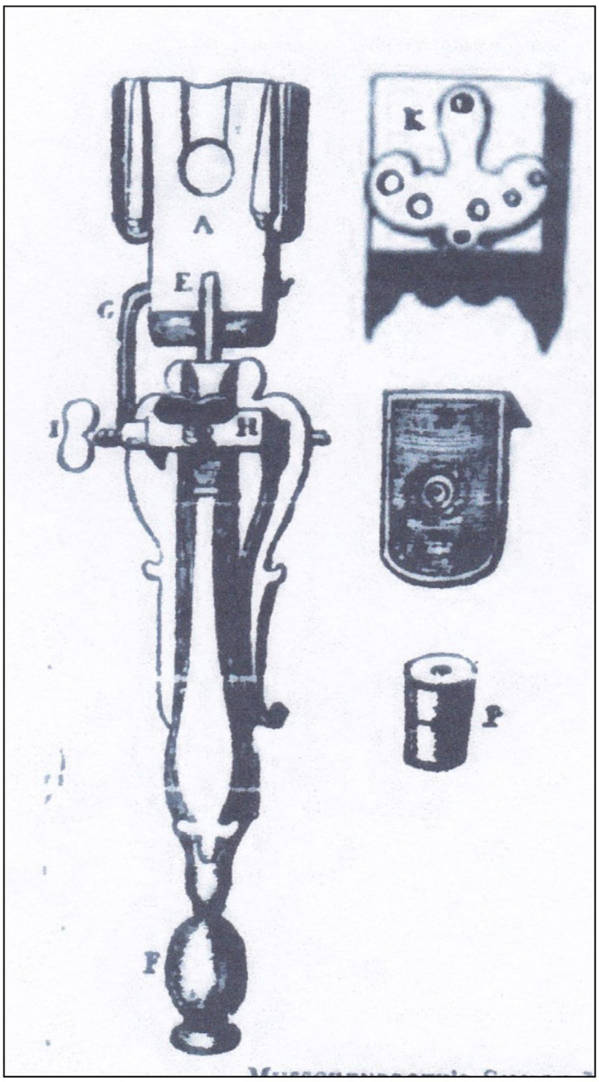

Figure 6. Configuration of Van Musschenbroek's 'large microscope', according to Zahn (1702).

Focus is less precise with Van Musschenbroek's two hinges than with the simple screw of the Van Leeuwenhoek form.

Sample manipulation is also more precise with Van Leeuwenhoek's simple screw than with Van Musschenbroek's loose sample mounts.

In some ways, this comparison is unfair as it involves comparing microscopes made for general sale to the interested public with those made by an end user for his own exacting needs, in much the same way as one might compare modern compact and professional single-lens reflex cameras. They are both good, but for different purposes. Sadly, the microscopes made by the Van Musschenbroeks for other equally exacting end users such as Swammerdam do not seem to have survived. Hopefully, it will become possible to compare these results with others obtained with microscopes such as shown in Fig. 1 or facsimiles of them.

ACKNOWLEDGEMENTS

The authors thank the Historical Microscopy Foundation for permission to use their authentic van Musschenbroek microscope. Fig. 3 and the Graphic Abstract are by Lia Koene and Ad Labrujere, and appear with their permission.

Conflicts of interest. None declared.

REFERENCES

Bradbury S. *The Evolution of the Microscope*. Oxford: Pergamon Press, 1967.

Clay RS, Court TH. *The History of the Microscope*. London: Charles Griffon and Company, 1932.

de Clerck P. *At the Sign of the Oriental Lamp*. Rotterdam: Erasmus Publishing, 1997.

Daumas M. *Scientific Instruments of the 17th and 18th Centuries and Their Makers*. London: Portman Books, 1972.

Davidson MW. *Optical Microscopy Primer, Museum of Microscopy*. 2015. https://micro.magnet.fsu.edu/primer/museum/musschenbroekhigh.html(8 October 2019, date last accessed).

Hooke R. *Micrographia*. London: Royal Society, 1665.

Hooke R. Microscopium. In: *Lectures and Collections made by Robert Hooke, Secretary of the Royal Society*. London: J. Martyn, 1679.

Robertson LA. Historical microbiology, is it relevant in the 21st century? *FEMS Microbiol Lett* 2015;**362**:fnv057.

Robertson LA. Lighting van Leeuwenhoek's samples. *FEMS Microbiol Lett* 2017;**364**:fnx247.

Stichting Historische Microscopie. http://stichtinghistorischemicroscopie.nl/microscopen/enkelvoudig-passermicroscoop-sm-32/ (8 October 2019, date last accessed).

van Leeuwenhoek A. Letter 113 [66]. In: Swart JJ (ed). *Anthoni van Leeuwenhoek, Alle de brieven. Deel 8: 1688–1692*. Amsterdam: N.V. Swets & Zeitlinger, 1967, 66–117.

Zahn J. *Occulus Artificialis Teledioptricus*. Nuremburg: Johannis Ernesti Adelbulneri, 1702.