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Livre 2009

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The quest for the invisible : microscopy in the Enlightenment

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This publication URL: https://archive-ouverte.unige.ch//unige:18496

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Introduction
Reasons for a New Historiography

The main question of this work relates to the construction, during the Enlightenment, of scientific objects that escaped natural sight. At a time when only a few institutions defended scientific discourse and practice, when scholars were working to establish their legitimacy as a new power in Western society, on what grounds could such a new scientific object be constructed? Limiting the investigation to the framework of natural history, this object was the barely-visible or invisible body, only accessible at that time thanks to certain microscopes. Far from being the invisible world, or the atoms over which many savants of the previous century had argued,[1] these microscopic things were considered to be whole and living organisms, and eventually determined to be species. We shall thus have to face several historically constructed aspects: understanding what contributed to making this scientific endeavour a lasting one and what did not; describing, within the various sociocultural contexts and marketplaces of the Enlightenment, the relationship between building, advertising and using microscopes; showing the existence of various networks interested in this object and evaluating the impact of their investigations on the further development of microscopical research.

Creating an audience that trusts the discourse on these microscopical bodies is not the least of these aspects, and is key to its impact. Contrary to relativism, my claim is that there are not several epistemological ways that permit a community to create shared scientific objects such as microscopical bodies. My central thesis is that doing science means dealing both with communication and cognition; or, in other words, constructing a scientific object means addressing the communication components in a body of knowledge as if they were cognitive problems. As we shall see, though many scholars have addressed the cognitive problems raised by the microscopical bodies – Are they animals? What is their method of reproduction? What are their sizes? and so forth – only a few of them have addressed both the communication *and* the cognitive problems. Even fewer tried to actually solve the communication issue, according it as much importance as any scientific problem. While there are many roads to nowhere in Enlightenment microscopical research, I claim that there was only *one* heuristic way to create the foundation for stable microscopical knowledge, and that was by approaching the communication (and

[1] See Catherine Wilson, *The Invisible World: Early Modern Philosophy and the Invention of the Microscope* (Princeton, 1995); Edward G. Ruestow, *The Microscope in the Dutch Republic: The Shaping of Discovery* (Cambridge, 1996); and Christof Lüthy, 'Atomism, Lynceus, and the Fate of Seventeenth-Century Microscopy', *Early Science and Medicine*, 1 (1996): 1–27.

thus also the social) issue as a scientific problem. This has little to do with building a scholarly career, but it directly relates to the way a new scientific field can appear, become demarcated, and ultimately flourish.

My story also radically contradicts claims in the tradition of the history of microscopy, which I shall outline briefly. Concerning the instrument, it is said that there was practically no optical improvement of the microscope in the eighteenth century. Yet, it was at this time that many morphological improvements led the microscope to acquire its modern shape.[2] As a consequence of the preceding thesis concerning *microscopes*, the eighteenth-century *use of the microscope* is always presented in an unfavourable light in comparison to the treatment of seventeenth- and nineteenth-century microscope use. Such a portrayal strengthens the contrast between the 'good research' carried out in the seventeenth century and the 'amateur work' of the eighteenth century. As Maria Rooseboom typically put it: 'After the great discoveries of the pioneers, the 18th-century brought little sensational news in the fields of microscopes and microscopy'.[3] Held by historians of the microscope since long before the 1960s, this view did not really change in its more recent version, maintaining that the seventeenth-century scientific 'programme of microscopy' did not continue during the Enlightenment.[4]

There is a discrepancy between data showing that a great number of microscopes existed in the eighteenth century, and this 'absence' of a programme. What were the microscopes used for? According to historians they served as amusements. With the exception of the Netherlands, the 'decline of microscopy' started between 1690 and 1710,[5] after which time microscopes were prized as entertaining toys for amateurs: 'The programme of microscopy does not survive into the eighteenth century as a resource for natural philosophy except at the relatively popular level'.[6] Some historians believe the microscope was also used by a few scholars as a scientific device.[7]

As a consequence, eighteenth-century microscopical research has been very poorly studied, in contrast with that of the seventeenth century. Nevertheless, a cursory glance over Enlightenment sources throws serious doubt on this general

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2 See Reginald S. Clay and Thomas H. Court, *The History of the Microscope* (London, 1932).

3 Maria Rooseboom, *Microscopium* (Leiden, 1956), p. 7.

4 Ruestow, p. 276.

5 Marian Fournier *The Fabric of Life: The Rise and Decline of Seventeenth-Century Microscopy* (PhD thesis, 1991), pp. 4, 16–17.

6 Jim Bennett, 'Malpighi and the Microscope', in Domenico Bertoloni Meli (ed.), *Marcello Malpighi Anatomist and Physician* (Florence, 1997), pp. 63–72, p. 72. See also, on the microscope and other instruments considered as toys, Gerard L'E. Turner, 'A Very Scientific Century', in Turner, *Scientific Instruments and Experimental Philosophy 1550–1850* (Aldershot, 1990; first pub. 1973), paper XIV, p. 19.

7 See Fournier, *Fabric of Life*, p. 2, and Ann F. La Berge, 'The History of Science and the History of Microscopy', *Perspectives on Science*, 7/1 (1999): 111–42, pp. 111–12.

view. Upon further investigation, it can be seen that the thesis of the ‘absence of microscopy’ virtually explodes on contact with supplementary sources, and the question is therefore whether these sources were intended for scientific purposes. Setting aside microanatomical research in the eighteenth century, I focus on the natural history of small-scale and invisible organisms. The construction of the microscopical object refers here to invisible and barely-visible organisms considered as independent wholes, and not microscopical parts of bigger organisms. Challenging the current credo that there was no scientific microscopical programme during the Enlightenment, I claim that there was a scientific microscopical design, and furthermore, that it was eighteenth-century scholars who established the conditions that made it possible for nineteenth-century research on microscopical bodies to be carried out.

Constructing a Scientific Object

The Historian’s Avenues

During the eighteenth century, particular conditions made the take-off of microscopical research possible. To reconstruct the many failures and successes of that story, it is not enough to follow the endogenous development of a concept. Indeed, it is commonly believed that scientific use of the microscope *could not* be present because the epoch lacked the cell theory, or the concept of bacteria (identifying microscopical entities as the true causes of specific illness), or because optical microscopes were subject to inherent imperfections such as chromatic aberration. Yet this historical perspective emphasized the cognitive and technical aspects and ruled out the issue of communication.

In order to understand the construction of this scientific object, I was thus required to forge a historical methodology that addresses technical, communication and cognition issues. The major methodological challenge was to move beyond the many smaller-scale case studies to create a macro-history. Moreover, to avoid misinterpretation of the sources, I also had to find ways to understand what they do and do not say. I believe the act of interpreting a source should be augmented and revised in accordance with the content of many other related sources. To produce this history, I did not deal just with discrete sources, but with intertwining *networks of sources* that define a space in which scientific objects are negotiated. The study of these networks analyses sources and groups them according to criteria such as similarity, interquotation, network coherence and consistency. This methodology is split into four parts: systematical research and exploitation of primary sources (two classic methods), serial citation and statistical study of sources. With serial citation, that is identifying similar quotations of arguments or ideas in various authors, one can identify consistent or widespread features in a network of sources. It enables one to sense when, where and between whom particular ideas or practices were shared. Statistical survey of sources plots one or several aspects of a network of sources into a chart or a table.

To obtain the bibliographical data for Charts 1.1, 4.1, 4.2, 5.1 and 9.1, I combined the following methods:

1. Comprehensive use of previous known sources and secondary literature on the history of microscopy.
2. Comprehensive analysis of Jona Dryander, *Catalogus bibliothecae historico-naturalis Josephi Banks* (4 vols, Londini, 1796–98), Achille Percheron, *Bibliographie entomologique* (Paris, 1837) and Louis Agassiz, *Bibliographia zoologiae et geologiae* (4 vols, London, 1848–54), looking for works on microscope/y, and for microscopical studies.
3. Making an index of topics and titles of the main eighteenth-century works on microscope/y, with sources located in the Max Planck Institute für Wissenschaftsgeschichte, Berlin Stadt-Bibliothek, Library of the Wellcome Institute in London, British Library, Bibliothèque publique et universitaire and Musée d'histoire des sciences in Geneva, Landmarks of Science and Gallica.
4. Searching in titles of books for the root microscop-/lens and related words, in English, French, Latin, German and Italian, using search engines of the Libraries: BVB-Munich, British Library, Bibliothèque nationale-Paris, Library of Congress.
5. All this material was analysed.
6. I also analysed 100 eighteenth-century scientific journals and periodicals and there unearthed many unknown papers dealing with microscope/y. (The 63 journals cited in the bibliography of my PhD, are here reduced to 16 for the sake of publication).
7. I used published and manuscript correspondences to find new data such as names of users or makers of microscopes.
8. All the data was entered into a Word file – now containing 2,900 titles – and a database. Works in the five languages that did not contain microscope or lens- (and any relating only to astronomy) were removed from the database.

All the statistics were computed using a Macintosh software statview + graph, and all this work was done between 1997 and 2001.

On the ground of this bibliographical research, the reconstruction of a network of sources was largely based on the interquotation of authors. Following those networks, I explored occasions and contexts where the microscopical object was at stake. Both virtual and actual travels yielded significant sources, the contributions of known and unknown scholars and *gens de lettres* from many European countries. As a first step, this enquiry required extended searches for many sources, both printed and manuscript, looking specifically for articles and *mémoires* in journals – the scientific forums of the Enlightenment. Half of the books I have analysed were already discussed by historians – usually in the context of national historiographic traditions. But historians have simply never known a vast majority of the *mémoires* analysed in this work. Much of this abundant material is new to academia and can be synthesized under the general category of the construction of a scientific object.

Moreover, many of the histories of microscopy praised particular authors within national contexts while failing to show the role of the European networks that kept all of these scholars alive and well. Everyone agrees that anachronism should be banished from the history of science. Yet studying local or national history for historical scientific information while in fact everything was based on much more far-reaching networks is a geographical anachronism. Europe itself thus became a central object of investigation in this work. Historians of modern science during the *Ancien Régime* should at least think within the framework of Europe.

Structures and Behaviours Shaping the Construction of the Microscopical Object

How does this construction work within the actual history and from the viewpoint of the actors? On what structural basis, on what behavioural components, did Enlightenment scholars produce stable and *longue durée* knowledge of invisible things? In this section I shall evaluate three dimensions or axes, related to this issue. The first deals with finding the balance between size and communal visibility for microscopical objects, the second deals with adaptation to the constraints of the instrument, and the third involves two major naturalistic traditions making use of the microscope – systematics and experimentalism. As fundamental interpretative tools, communication and cognition are discussed for each of these axes.

Balancing the size and visibility of microscopical objects As we shall see, the first seventeenth-century wave of research on microscopical bodies ebbed in the early Enlightenment. At the same time, certain scholars decided, to put it in modern language, to reboot microscopical research entirely. Many of the previous century's observations on invisible bodies were not actually reproducible. A question that structured many debates at that time concerned both the reproducibility and the shared visibility of an observation. The distrust, controversies and silence concerning invisible bodies such as spermatic animalcules, and the neglect of the subject after 1720 show that scholars, contrary to the historian's credo, were actually resetting criteria for microscopical research. They did not remove microscopes from cabinets, but abandoned a style of irreproducible scientific investigation. Eliminating microscopes would have deprived them of an instrument they acknowledged had the potential for discovery. But, it had to be used with caution and obey the communication rules of the scholars' networks. So the best way to use it was to avoid research on truly invisible bodies, those too small to ensure repetition and consensus within the scientific community. Striving to observe the minutest microscopical objects had fascinated seventeenth-century users of the microscope, but they forgot to temper that fascination with shared visibility.

Although applied previously, it was really only at the turn of the century that the criterion of shared vision emerged to balance the magnification. Given the lack of standardization in microscopes, it was necessary to find good microscopical objects conducive to the sharing of images *and* suited to the type of microscopes generally used. Ideal microscopical objects turned out to be small yet not invisible bodies, such as seeds, insects and their parts. During that period, scholars learned to use the microscope not as a super-performing instrument revealing a marvellous invisible world to only *one* scholar, but as a tool with particular technical constraints regarding scientific communication. The size of the microscopical objects – seeds and insects – would later be reduced, gradually becoming more invisible. During the 1740s came another radical change in the status of the microscopical naturalist object. Trembley's polyp shifted the debate from insects towards aquatic animalcules and opened the door to a new world in nature, the world of invisible organisms. A series of questions emerged – Were these invisible beings animals, vegetables, or molecules? What was their method of reproduction? Were these things species? Were scholarly ideas and practices adapted to these new scientific objects? How should scholars negotiate the balance between shared knowledge and invisible organisms?

Following this axis of interpretation through the whole century, there is no doubt that this shared microscopical object became more invisible, more abstract, from the time of Joblot and Réaumur to that of Müller and Spallanzani. The 'microscopical object' relates thus to bodies observed through a microscope, either small-scale and almost visible organisms (first part of the century), or true invisible bodies (second part of the century). What mattered for the eighteenth-century hard line of research on microscopical bodies was, contrary to the seventeenth-century style, to keep the balance between size and shared vision.

Communication constraints on the microscope Three major instrument-specific constraints defined the space in which users of the microscope could move: optical uncertainty, the 'antisocial microscope' and the lack of standardization.

Under the first constraint, eighteenth-century scholars worked with optical uncertainty due to several types of defects in lenses. Because they were not ground uniformly in every part and the glass contained imperfections (bubbles, scratches, and so on), the light rays were not always equally refracted, and could produce unclear images. Strong magnification produced spherical aberration, transforming points into small circles, while compound microscopes (with eyepiece and objective lenses) could yield an image stippled with rainbow colours – that is, chromatic aberration. Well aware of these technical defects, scholars actually *compensated for* them, often by using several microscopes and lenses to observe one particular body, despite claims that simple microscopes were the tool for microscopical discoveries.[8] For many investigations scholars used *several*

8 See Brian J. Ford, *Single Lens: The Story of the Simple Microscope* (New York, 1985).

microscopes, including compound microscopes, using comparison to monitor the relationship between the images and the real microscopical body.

As regards the second constraint, using a microscope is essentially looking at an object that *no one* can see at the same time in the same way. Such a style of observation differed from those in many other scientific fields: for example, people assembled around a table for dissections, in a camera obscura, around an air pump, or attending a plant demonstration in a garden. Moreover, the shape and motion of the bodies were incommensurable with the perceptive and visual patterns of everyday life. An antisocial instrument, the microscope separated the observer from the simultaneous perceptual experience of others, and thus the problem was to socialize the discourse opened by the instrument, finding suitable language for the description.

On the third point, since microscopes were made by individual artisans, the lack of standardization increased the difficulty of communication. Consequently, it was never certain that the reproduction of an observation would yield the same result. Scholars employed various strategies in an attempt to enable reproduction of observations. They used iconographical techniques, specified quantification of the magnification, mentioned microscope makers, described their instrument or used a solar microscope, shared microscopes in local communities, and sought to formulate a standardized language.

To work with a microscope in this way was to operate under multiple constraints, ranging from the technical to the cognitive and to the communicative. The answer to these multiple constraints gradually took shape as a unifying, historically developed yet 'simultaneous solution':[9] this 'global solution' was to tackle communication as a scientific issue. Scholars pondered how to communicate their findings so as to close the gap opened when using the instrument. They were also confronted with a choice between two styles of communication. Some scholars fully disclosed their method to others and encouraged a comprehensive repetition of their original procedure. Others concealed the methods and procedures they had used to achieve a particular result or description, of either an analytical procedure or of tools and microscopes used. I call the former case, use of the 'shared microscope'. There, the text aims at analytically recreating the smallest detail concerning observations and procedure. The latter case, in which the text does not provide analytical means to reproduce the observation, I shall call use of the 'exclusive microscope'. Using one or the other impacted, in radically different ways, the process of trusting the microscopical object.

The microscope between the systematical and experimental traditions During the Enlightenment, the microscope was used for both experimental and systematical purposes, and mostly in the natural sciences, as opposed to the mechanical sciences. Natural sciences deal with types of languages and logic different from

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[9] See Peter Galison, 'Multiple Constraints, Simultaneous Solutions', *Proceedings of the Biennial Meeting of the Philosophy of Science Association*, 2 (1988): 157–63.

those of experimental sciences. Describing, naming and classifying natural objects were constitutive issues mainly for the natural sciences as they developed in the Latin-language natural history tradition, known as systematics. Although distinct historiographic traditions split them in two fields, systematics and natural experimentalism will be discussed together, because they interacted strongly in Enlightenment microscopical research.[10]

Many historians, including Steve Shapin and Simon Schaffer, Peter Dear, and Christian Licoppe, have discussed the *experimental report* to grasp the process of forming convictions. Yet, using the experimental report alone does not entitle the historian to describe as a whole the trust-production processes that occurred in the eighteenth-century natural sciences. Research with the microscope dealt also with classification and nomenclature, that is a set of *logical, linguistic and formal technologies* irreducible to the three *pragmatic* technologies, literary, material and social, discussed by Shapin and Schaffer.[11] Notably the management of conviction and reproducibility runs differently in the systematic and experimentalist traditions, for the latter reproduced phenomena and pragmatic knowledge while the former 'reproduced' organisms through their determination. The *experimental report* promoted repetition of experimental phenomena, whereas the *systematical report* enabled the sharing of knowledge, through description, naming and classification of organisms. Moreover, this picture is complicated by the growing pre-eminence of the Latin naturalist history tradition that slowly took a Linnaean shape during the second half of the century.

Constructing a scientific object relied also on many means analysed more precisely in the course of the book. How and when was the microscope regarded as a scientific tool, a routine instrument, and by whom? What was its relation to the laboratory? How did a particular piece of knowledge become established? How did new pieces of knowledge support subsequent pieces of knowledge? How can one distinguish the long-term from the short-term impact? Is there a relation between the scientific object and the production of microscopes? A suitable environment for stable knowledge was within the use of both traditions in a particular work. Indeed, each tradition formulated its own solution to the communication issue and their conjunction regularly entailed a heuristic shift. The connection occurred

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10 Concerning the language and classification of the Latin natural history tradition see William T. Stearn, *Botanical Latin: history, grammar, syntax, terminology and vocabulary* (Newton Abbot, 1993), pp. 10–16, 41–4; Peter F. Stevens, *The Development of Biological Systematics* (New York, 1994), pp. 202-10; Mary M. Slaughter, *Universal languages and scientific taxonomy in the seventeenth century* (Cambridge, 1982), pp. 55–64, 76–82; Michel Foucault, *Les mots et les choses* (Paris, 1966), pp. 140–50. On experimentalism, see Jacques Roger, *Les sciences de la vie dans la pensée française du XVIIIe siècle* (Paris, 1971), and Walter Bernardi, *Le metafisiche dell'embrione, scienze della vita e filosofia da Malpighi a Spallanzani, 1672–1793* (Florence, 1986).

11 Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump, Hobbes, Boyle, and the Experimental Life* (Princeton, 1985), p. 25.

when an author took resources for his work from the two traditions, and linked together systematics and experimentalism, objects and phenomena. Or when knowledge circulated from one field to the other, which occurred in many instances, independently of their truth-value. Marsigli's flowers of coral, Breyn's investigation of *Coccus*, Réaumur's definition of species, Trembley's polyp, Müller's infusoria, all displayed examples of this circulating knowledge. Many experimental research projects led to changing the place of certain beings in the systematical distributions or defined physiological characteristics included thus into the systematical definitions. Similarly the founding works of systematics led experimentalists to exhibit more precision in the determination of species, thus making the replication of their experiments much easier. New cultures of negotiating knowledge allowed the discussion of new questions and the shaping of a scientific object. Yet, many authors, such as Leeuwenhoek, Joblot, Buffon, Needham, Baker and Spallanzani, used almost exclusively experimental reports and had few systematical concerns. As will be shown, their research had less impact both on the long run and on establishing the microscopical scientific object. Trembley and Müller caused a major impact because both tackled the problem of communication as a cognitive issue, connecting experimental and systematical concerns.

Structure of the Book

This book examines several case studies, from the end of the seventeenth century to the beginning of the nineteenth century. It discusses various scientific designs apropos the microscopes used while shaping the construction of the microscopical object. For each case study I tried to distinguish features from all axes of interpretation, which led me to clarify, through examples, the concepts involved. While scrutinizing the culture of negotiating knowledge through which the microscopical object emerged, my plan is also to show that, although in the natural sciences few research projects achieved unanimous reception, all participated in the process of constructing the object.

Part I discusses the heritage of seventeenth-century microscopical research and the reactions from new scholarly networks by tackling the problem of constructing a shared microscopical object. First, Chapter One assesses the early European market place for microscopes, then Chapter Two on Joblot presents a little-known microscopical work that demonstrated for the first time, in 1718, the vacuity of spontaneous generation in microscopic 'animalcules of the infusions'. This work signalled the end of the early wave of research on invisible bodies. Chapters Two and Three show the shift in attitude of Enlightenment scholars, armed with microscopes, before the 1740s, that led to the reconstruction of a scientific object. A new programme of microscopical research was then designed that balanced standardized visibility and suitable magnification, and called for non-invisible objects such as insects and seeds.

Part II sets out the change in the microscopical object in the 1740s and 1750s, and provides elements showing the break with the previous object. Chapter Four discusses the making and marketing of microscopes among several countries and points out the break in the 1740s. Chapter Five analyses Trembley's strategy of communication that signalled a new kind of investigation with the microscope, while Chapter Six examines Needham and Buffon's coup against the scholarly shared forms of communication and explains their impact on further research.

Part III investigates the 'true microscopical objects', when, from the 1750s onward, scholars again dealt with invisible microscopical objects and changed once more the balance between size and shared vision. Chapter Seven discusses the impact of quantification on the construction, use of and trust in the microscopes. In particular, attempts at standardization are echoed in the spirit of quantification in microscopy. Chapter Eight analyses the emergent systematics of microscopical bodies that led to Müller's work and to the modern accepted solution for communicating about microscopical species. Finally, Chapter Nine investigates the microscopical experimental field and the switch from the spontaneous generation issue to the animality issue.

The Conclusion first deconstructs the classic history of microscopy while investigating the early nineteenth-century impact of the achromatic microscope. The new instrument led scholars to invent a heroic memory for late seventeenth-century research while ignoring the vital contribution of the Enlightenment.