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The Metaphysics of Phenomena: Telescope and Microscope in the Works of Goethe, Leeuwenhoek and Hooke

1. Goethe's Misgivings

Goethe knew very well that modern science would never have come on track without instrumental techniques, despite proposing his own, phenomenological study of nature in opposition. He writes:

> Out of the greatest and the smallest likewise (and only presentable to man through most artificial means) emerge the metaphysics of phenomena. In the middle lies the particular, what befits our senses, what I rely on. Bless thus from the heart those talented individuals, who bring this region nearer to me.[1]

No sign of Goethe's much cited aversion to microscopes and telescopes can be found here. Since his youth, Goethe had used both of these instruments which had been so influential in setting the natural sciences; astronomy, biology, mineralogy and medicine in motion in the 17th century. He had eagerly consulted the microscope, in particular, in his botanical, zoological and mineralogical studies.[2] Both telescope and mi-

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1 "Aus dem Größten wie aus dem Kleinsten (nur durch künstlichste Mittel dem Menschen zu vergegenwärtigen) geht die Metaphysik der Erscheinungen hervor; in der Mitte liegt das Besondere, unsern Sinnen Angemessene, worauf ich angewiesen bin, deshalb aber die Begabten von Herzen segne die jene Regionen zu mir heranbringen." Johann Wolfgang von Goethe. "Maximen und Reflexionen Nr. 507." *Werke* [*Hamburger Ausgabe = HA*]. Ed. Erich Trunz. 14 vols. Hamburg: Wegner, 1961-67. Vol. XII, 435. Punctuation according to "Über Naturwissenschaft im Allgemeinen. Einzelne Betrachtungen und Aphorismen." *Sämtliche Werke, Briefe, Tagebücher und Gespräche* [*Frankfurter Ausgabe = FA*]. Ed. Hendrik Birus et. al. 40 vols. Frankfurt a. M.: Insel, 1989. Sec. 1, vol. 25, 100.

2 Cf. for example, the letter to Jacobi, January 12, 1785: "Before I write a syllable of meta physika, it is necessary that I complete the physika. [...] Set up a microscope in order to repeat the observations and control the experiments of v. Gleichen, known as Rußworm, at the onset of spring." In 1785 Goethe bought the book written by von Gleichen (1717-1783), a botanist: Wilhelm Friederich von

croscope had long been standard research instruments, despite their rejection by Thomas Sydenham and John Locke. They were also important props in spectacular scientific entertainment, in which astonishing experiments were presented both to educated audiences and at fairgrounds as popular amusement. They occupied a space between objective enlightenment and sensationalist charlatanry.[3] Goethe knew that as well.

In his aphorisms, however, Goethe emphasizes the serious side: the 'most artificial means' (one can also read here 'the most technical means')[4] open completely unknown worlds in the 'greatest' and 'smallest,' subliminal and supraliminal universes. This by no means implies the platonic topos of the *analogia entis* of microcosm and macrocosm, to which Goethe often refered. Instead, he uses the surprising phrase of 'the metaphysics of phenomena.' Microscope and telescope do indeed create 'phenomena,' namely experimental and observable sensory objects. But metaphysics? Does Goethe mean objects 'beyond,' 'behind' (meta) physics, in reference to the structure of Aristotle's works? But didn't both these instruments provide a basis for physics or at least extend them? Or does he believe that there are phenomena 'beyond' the *physis*, namely the 'nature' of the senses, another antique idea? Beyond the 'world of appearance' that presents itself to the 'unarmed' senses? Certainly. However, Goethe does not interpret this to mean other-

Gleichen (called: Russworm). *Abhandlung über die Saamen- und Infusionsthierchen, und über die Erzeugung: nebst mikroskopischen Beobachtungen des Saamens der Thiere und verschiedener Infusionen; mit illuminirten Kupfertafeln.* Nuremberg, 1778. Cf. idem. *Auserlesene Mikroskopische Entdeckungen bey den Pflanzen, Blumen und Blüthen, Insekten und anderen Merkwürdigkeiten.* Nuremberg, 1771. Cf. also Goethe's letter to Charlotte von Stein, June 27, 1785: "I am bringing my microscope with me. It is the best time to watch the dances of infusoria." Goethe to Jacobi, April 14, 1786: "Botany and the microscope are now my main enemies. [...] If infusoria were of any help to you, I could administer you several million." Goethe, it seems, still works in von Gleichen's wake. Notes on his microscope studies of infusoria are in *FA*, sec. 1, vol. 24, 46-61. Goethe uses the microscope regularly in both his zoological-anatomical and his botanical-morphological studies. Cf. the term "microscopic elementary biology" introduced by Goethe (*FA*, sec. 1, vol. 24, 801). A late document: Goethe's letter to Nees von Esenbeck, September 27, 1826.

3 See especially Barbara Stafford. *Artful Science. Enlightenment, Entertainment and the Eclipse of Visual Education.* Cambridge, Mass.: MIT Press, 1994. 95-152.

4 The term 'artificial' need not be interpreted pejoratively. It can also be interpreted according to the Latin root 'ars,' as art and technique. 'Means' means both instrument and medium, so that the sentence can be interpreted as follows: 'highly technical media' open new universes.

worldly objects. He qualifies precisely the 'phenomena' as metaphysical. But what does this mean?

'In the middle' lies the world of appearance, the world that Goethe also calls 'the particular' without, however, calling the experimental phenomena 'the general.' Belonging to both the 'metaphysics of phenomena' and to the particular of unarmed sensory perception is: presentation. What 'emerges' through the new instruments becomes 'presence' to 'the person,' just as a tree becomes on sight the presence of the onlooker. But a difference remains: no 'metaphysics of phenomena' 'emerge' from the perceived tree, but they do from the telescope and microscope. 'Emerge' is a conspicuous word in this context, as if these 'metaphysics' grow from alone out of the instrumentally revealed world. As sensitive to language as Goethe is, the conceptual tension contained in the expression 'metaphysics of phenomena' would not have escaped him, neither from the newest, Kantian philosophy nor from the older academic philosophy, and especially not from the prevailing understanding of metaphysics.[5] What becomes the 'middle' through the continuous extension of the limits of perception by the 'most artificial means,' namely the appearance, was never 'middle.' It was the naturally given. It was under the dome of or, in Kantian transcendental philosophy, based on metaphysical constructions that defied any realisation by the senses. As Goethe correctly observed, the appearance only becomes the 'middle' through margins that have neither essential nor categorical validity but, instead, delineate historically variable capacities of technical media.

The aphorism is, however, not only epistemological, but also confessional and normative. Goethe calls the middle realm of appearance 'that which befits our senses.' Instruments thus become 'unbefitting' or at least 'unsuitable.' Goethe gives unaided sensory experience a higher priority in a scale of values than technically mediated sensory experience.[6] At the same time, he admits that he depends on natural sensory

5 One solution would be a Spinozistic resolution of the "metaphysics of phenomena": "Quo magis res singulares intelligimus, eo magis Deum intelligimus." In the 80s, Goethe searched in this vein for "the divine in herbis et lapidibus" (Letter to Jacobi, June 9, 1785): In the 'particular' lies the presence of the divine. However, in the late aphorisms one cannot simply presume this identification. Quot. from: Carl Otto Conrady. *Goethe. Leben und Werk.* 2 vols. Frankfurt a. M.: Athenäum. Vol. 1, 419-20.

6 Goethe's practise by no means conforms to this dogmatic aphorism: "Microscopes and telescopes actually confuse man's clear senses." Johann Wolfgang Goethe. "Wilhelm Meister's Journeyman Years or The Renunciants." *Goethe's Collected*

perceptions (although they are themselves always theory, as he states elsewhere)[7]. The subject of Goethean science thus acknowledges that he is a subject constituted primarily by sensory experience. This does not, however, lead to a devaluation of instrumental sensory experience. Goethe blesses their inventors from the heart in an expressive gesture floating oddly between sentimentality and religiosity. These inventors 'bring' something 'nearer' to the Goethean subject. They are the 'gifted,' who have a gift to bestow: that which 'has been brought nearer,' the greatest and smallest worlds of 'metaphysical appearances.' Goethe is grateful for the technical inventions and experimental philosophy (in contrast to the relationship to Newton).

A careful reading reveals how polysemantic this aphorism is. It leads directly to the centre of the conflict-laden relationship between Goethe's science of the senses and the new science. The audacious expression 'metaphysics of phenomena' does not lose its tension. Ultimately, it suggests that the experimental sciences, which constitute themselves, not only alone, but also through technical means, contain a metaphysical philosophy or at least have metaphysical consequences. To show this, it is necessary to go back to the epoch in which telescope and microscope were invented and developed their scientific effect, the 17th century. To this Goethe remarks, "After the second half of the seventeenth century owed so infinitely much to the microscope, the eighteenth century tried to treat it with disdain."[8]

The development of the microscope did, in fact, largely stagnate in the 18th century, not in the least due to Newton's false dictum on the principle impossibility of constructing achromatic objectives.[9] Goethe, an enemy of Newton, may have been alluding to this. The telescope as

Works in XII Volumes. Ed. James K. Brown. Cambridge, Mass.: Suhrkamp, 1989. Vol. X, 301. In the following indicated as *WMJY*.

7 "The hightes wisdom would be to comprehend that everything factual is already theory. The blue of the sky reveals to us the primary law of chromatics. Do not look for anything behind the phenomena; the themselves are the lesson." Goethe. *WMJY*. 308. Precisely this correspondence between "fact" and "theory" does not apply in the sciences. It is, however, characteristic for Goethe's phenomenological study of nature.

8 "Nachdem man in der zweiten Hälfte des siebzehnten Jahrhunderts dem Mikroskop so unendlich viel schuldig geworden war, so suchte man zu Anfang des achtzehnten dasselbe geringschätzig zu behandeln." Goethe. *HA*. Vol. XII, 435.

9 Wolfgang Gloede. *Vom Lesestein zum Elektronenmikroskop*. Berlin: Verlag Technik, 1986. 66, 81. John Dolland and in particular Chester Moor Hall were the first to construct achromatic objectives. Cf. ibid. 88.

well only experienced a qualitative leap through William Herschel.[10] One must thus return to the 17th century, not forgetting the 'phenomenon' that provoked Goethe's phenomenology even more than telescope and microscope, namely the vacuum.[11] Like the world of the 'greatest' and 'smallest,' the experimentally created and investigated void represents just that sphere of the 'supernatural' that constructs modern science. And experimental arrangements of technical media play a crucial role. More than anything else the vacuum, created by the 'most artificial means,' belongs to the 'metaphysics of phenomena.'[12]

2. The Contemplation of the Heavens and the Telescope

The astronomy scene in Goethe's novel *Wilhelm Meisters Wanderjahre* refers to the time of the discovery of Uranus by William Herschel. At the same time, it alludes to Galileo's epochal discovery of the moons of Jupiter. For Wilhelm it is by all means characteristic that he interprets Jupiter astrologically as a 'favourable omen' and as a 'planet of good fortune.' As he contemplates the star "through a telescope, significantly enlarged and accompanied by its moons, as a wonder of the heavens" (WMJY 178) – the Galileo situation – he is not thinking of this epochal date in the history of astronomy. In the history of consciousness

10 William Herschel's fame was based on the discovery of Uranus in 1781. James Bradley presented the first reflecting telescope to the Royal Society in 1781 – a breakthrough. Herschel greatly improved this system and initiated the paradigm change, according to which optical enlargement was no longer paramount. Important was capturing as much of the weak light as possible from distant stars. To that end Herschel built his famous reflectors. Their pure capacity would, however, not have been as effective, had Herschel not been such an excellent analytical observer. Cf. Richard Panek. *Seeing and Believing. The Story of the Telescope or how we Found our Place in the Universe*. New York: Viking, 1998. 106-20.

11 It is characteristic that the only passage in which the void is elevated to the rank of the "metaphysics of phenomena" is a cynical remark from Mephistopheles on the occasion Faust's death: "Gone by and utter nothing are all one:/ Why then, does this Creating still go on?/ Gone by? What means it? – What a sorry trade!/ Making, and making nothing of what's made./ And then this nothing evermore we see/ Making pretence a something still to be./ So on it goes, the same dull circle spinning/ – 'T were better with the Eternal Void beginning!" Johann Wolfgang von Goethe. *Faust II*. Trans. John Anster. London, 1864. V. 11597-11603. In Goethe's opinion, the only role vacuum physicists could play was that of Satanists in disguise.

12 On the vacuum, I can only cite Hartmut Böhme. "Das Volle und das Leere. Zur Geschichte des Vakuums." *Luft*. Ed. Hartmut Böhme. Kunst- und Ausstellungshalle der Bundesrepublik Deutschland. Göttingen, 2003.

Wilhelm remains between the Warburgian poles of 'belief in the stars and knowledge of the stars,'[13] between a hermetic Renaissance-like astrology, as embodied in the corporeal-mystical characteristics of the mysterious figure of Makarie ('the Blessed'), and the beginning systematic telescopic observation of the heavens and mathematical calculations, as represented by the astronomer who leads Wilhelm to the observatory. First, Wilhelm's naked eye is confronted with the "brilliant realm of the ether" (WMJY 177).

> Overwhelmed and amazed, he covered both eyes. The colossal ceases to be sublime; it exceeds our power to understand, it threatens to annihilate us. 'What am I in the face of the universe?' he asked his spirit. How can I stand before it, stand in its very midst?" (Ibid.)

Well within the scheme of the Kantian sublime, Wilhelm *recognizes* neither the architecture nor the mechanics of the heavens. Instead, he *experiences* aesthetic marginality, namely the overwhelming, self-dissolving experience of a principle disproportion between spatial 'magnificence' and his own physical insignificance. He fends off this aesthetically overwhelming experience by closing his eyes. Kant has also called it a violence to the imagination.[14] Goethe speaks of an overextension of the 'power of aesthetic apprehension.' It summons up the reflexive question of the decentred self's ability to exist. Henceforth, the questionable 'middle' of the self stands in the foreground of Wilhelm's inner monologue. This "middle," which Goethe calls the middle of "what befits our senses" is by no means inherent to unarmed vision. It corresponds to the subject's previous centeredness, which is threatened in this situation in which the sense of vision is aesthetically overwhelmed. One finds here the Kantian correspondence between the "the starry heavens above me and the moral law within me."[15] This, in turn, echoes the pre-modern correlation of microcosm and macrocosm.

13 Aby Warburg, fully under the influence of his elliptical-dipolar thought, organized an exhibition with this title in the Hamburg planetarium. It opened posthumously in 1930. Uwe Fleckner et al., ed. *Aby Warburg: Bildersammlung zur Geschichte von Sternenglaube und Sternenkunde. Die Sammlung Aby Warburg im Hamburger Planetarium*. 2 vols. Hamburg: Dölling und Galitz, 1993.

14 Immanuel Kant. *Critique of Judgment*. Ed. and trans. Paul Guyer. Cambridge: Cambridge University Press, 2000. In the following indicated as *CoJ*. "[...] as it were doing violence to our immagination." Kant. *CoJ*. 129. "That is sublime in comparison with which" Ibid. 134. "[...] that surpasses every measure of the senses." Ibid. "[...] by which it does violence to the inner sense." Ibid. Cf. ibid. 143-48 etc.

15 Idem. *Critique of Practical Reason*. Ed. and trans. Lewis White Beck. New York: St. Martin's Press, 1993. 169.

After this self-reflexive turn at the sight of the heavens, the dispassionate, Galilean astronomer allows his guest to peer through the telescope.

Wilhelm then experiences an effect familiar from the early history of the telescope: a confusing loss of context. The 'most artificial means' focus on a tiny section of the heavens and "now it stands disproportionately in my imagination," (WMJY 178) Wilhelm remarks, and he therefore loses the relationship both to the heavens in their entirety and to himself. He no longer 'sees' the semantically meaningful constellation of Jupiter and no longer experiences the reflexive call of the uncentred self in the face of the 'monstrous.' He looks at an isolated object of the heavens, a star-thing without semantics and without reference to the self. Thus, Wilhelm experiences the epochal transition to an astronomy based on instrumental observation, with which modern science began. He experiences it as a loss and an abstraction. It provokes the well known criticism, which, however, cannot be attributed to Goethe, that the "aids with which we enhance our senses have no favourable moral effect." "Whenever I look through spectacles," Wilhelm reasons, "I am another person and do not like myself." (WMJY 178-79)[16] He thus anticipates the narcissistic slight to the ego through the Copernican turn, as Freud expressed it, or the humiliation of perfect instruments, as described by Günther Anders.[17] It applies analogously to the telescope and microscope and to all experimental-technical realisations of phenomena. 'The guardian of public morals' has a duty to watch over changes in humanity wrought by the technical media of his perception. One ought not simply follow Wilhelm's critical jab at technology (the author certainly does not), but neither should one ignore the effects the historical introduction of optical media had on the study of nature in the 17th century. They were inscribed as *faszinosum* or *tremendum*, in any

16 Wilhelm's experience here has been described by Goethe in a famous aphorism that succinctly summarizes his misgivings, which are based on a phenomenology of the body, about experimental systems and about Newton's in particular: "The human being in himself to the extent that he makes use of his sound senses, is the greatest and most accurate physical apparatus there can be; and that is the greatest disaster of modern physics, that it has effectively separated experimentation from the human element and recognizes Nature only in what artificial instruments can register, and indeed, wants to limit and establish thereby what Nature can achieve." Goethe. *WMJY*. 427.

17 Sigmund Freud. "Introductory Lectures on Psychoanalysis." *The Complete Psychological Works of Sigmund Freud*. Ed. and trans. James Strachey. 24 vols. London: Hogarth Press, 1953. Vol. XVI , 282. Günther Anders. *Die Antiquiertheit des Menschen. Über die Seele im Zeitalter der zweiten industriellen Revolution*. 2 vols. Munich: Beck, 1956/80. Vol. 2, 21-95.

case as a modifying power, into the experimental systems and the subject structure arranged within them.

3. Mediological *Episteme* in the 17th Century

In the 17th century, the basic assumption was that in order to conduct science, one must radically mistrust the 'world of appearances.' At the same time, sensory representations of previously unknown worlds were created in media-based controlled experimental situations. They became models of an *episteme* that operates through media. Science is constituted on the basis of the subliminal. This development provoked Goethe's loyalty to the middle realm of the senses. The scientistic world no longer means the experiential space of natural senses but the media-based, experimentally regulated world of observation.[18] Media-based processes create phenomena that are subjected to controlled observation and conceptual synthesis. 'Experimental systems' come into play.

The fields of objects created by media representation and control of the invisible are not the 'particular' of what 'lies in the middle' and 'befits our senses.' Nonetheless they are fundamental for the birth of the new sciences. Four fields of objects can be identified. Firstly, opaque inner realms of the body that are hidden by the skin were opened and dissected, but were also symbolically secreted. The scientification of medicine is based on anatomical visualization. Secondly, the invention of the telescope opened up the macroscopic world and led to mathematical astronomy. Thirdly, the subliminal world of the microscope placed in particular botany and zoology on a new foundation. Fourthly, neither the many pneumatic-hydraulic technologies nor Newtonian mechanics in general would have been possible without the experimental demonstration of the vacuum. These four forms of invisibility have nothing to do with metaphysical invisibility. Instead, they are front lines in the media-based presentation of what had *previously* been invisible, and what the new scientists maintain is the 'real' world, and, indeed, in comparison to the 'world of appearance' even predominant in this world.

[18] Cf. Gunnar Schmidt. *Von Tropfen und Spiegeln. Medienlogik und Wissen im 17. und frühen 18. Jahrhundert.*
Online at: http://www.medienaesthetik.de/tropfen.html.

In the 17th century it became generally accepted that that which is accessible to the 'unarmed' senses creates a false picture of the world. By trusting in the erring testimony of the eye, the so-called 'salvaging of phenomena,'[19] as practised both by defenders of the Aristotelian-Ptolemaic system and by Goethe, proves to be the wrong path. Typical for the epoch is also a 'boundless desire for sensory accessibility and visualization,'[20] an insatiable hunger for visual proof achieved through media.

This primacy of visual evidence is especially dominant in the experimental sciences that methodologically doubted the eye. There was no possibility of something being acknowledged as a scientistic fact, if it could not be made visible, observed, controlled, represented through media and calculated. The invisible does not belong to the 'metaphysics of phenomena' (Goethe). It is, in contrast, a relative and variable limiting category of the potentially visible, a contingent marker between what is 'already' visible and what is 'still' invisible. This de-materialisation of the invisible has an origin: For the first time, technical media of representation are extensively inserted between the traditional categories of visibility and invisibility: anatomical images, telescope, microscope, demonstrations of the vacuum. They all tie the relationship between visibility and invisibility to historical stages in the technical capacity of media and no longer to ontological distinctions. This is a far-reaching epistemological turning point.

The media of representation transform the invisible into a mere comparative of what has already been made visible. The scientist's ambition presses on to finer bodily tissues, into more minute dimensions of the subliminal world, further into the depths of the universe or from the fine vacuum to the ultra high vacuum. This effect of the media carries with it the shudder of infinity, the vertigo of infinitely great and infinitely small, the abyss of the absolute void. Blaise Pascal was the first to distinctly recognize this consequence of the scientific revolution. Pascal's analyses of mankind's precarious position between two infinities and the danger it faces of becoming a 'nothing' between them

[19] Cf. Jürgen Mittelstraß. *Die Rettung der Phänomene.* Berlin and New York: de Gruyter, 1962. Hans Rudolf Schweizer and Armin Wildermuth. *Die Entdeckung der Phänomene. Dokumente einer Philosophie der sinnlichen Erkenntnis.* Basle and Stuttgart: Schwabe, 1981. Theda Rehbock. *Goethe und die "Rettung der Phänomene." Philosophische Kritik des naturwissenschaftlichen Weltbildes am Beispiel der Farbenlehre.* Konstanz: Verlag am Hockgraben, 1995.

[20] Richard Alewyn and Karl Sälzle. *Das große Welttheater. Die Epoche der höfischen Feste in Dokument und Deutung.* Hamburg: Rowohlt, 1959. 64.

clearly react to the spatial revolution initiated by the telescope, microscope and infinitesimal calculus.[21] Kant's idea of the mathematical sublime (CoJ 131-43) can be traced to the extension of spatial dimensions and the infinite void. Seen thus, Goethe is right to speak of the 'metaphysics of phenomena.' In the cool pathos of their experiments, the sciences of the 17th century generate a metaphysical shudder that continues up to Nietzsche.

Modern scientists thus follow the imperative to unconditionally visualize spaces that had previously been surrounded by metaphysical or intellectual taboos. Hence, they are more dependent upon visualization media than ever before, since their objects are altogether invisible. That is, the effects of these invisible objects must be made visible and accessible to investigation. But these effects must first be induced, fixated, represented, measured and calculated. This necessitates complex, media-based and technological experimental arrangements.

In his pre-critical phase, Kant would later remark in the aftermath of the earthquake of Lisbon, which he viewed as a gigantic natural experiment intended to maintain physical laws, 'What nature hides from our eyes and our direct experiments, she reveals herself through her effects.'[22] In his critical phase, Kant states more precisely, "Reason only perceives what it itself produces according to its own plans." (CoPR B12) We only see what we create. *Ubi generatio, ibi cognitio*. But in regard to the lively media consciousness of 17th-century scientists, theoretical Kant forgot the role of media in the experimental arrangements of categorized and synthesized phenomena. To be more precise, he hid the function of the media in his concept of 'schematism.' Kant reduces transcendental schemes that 'mediate' between concrete perceptions and abstract concepts to "a hidden art in the depths of a human soul [...] through which and in accordance with which the images first become possible," images that are "a product and as it were a monogram of pure *a priori* imagination." (CoPR B181) Kant overlooked, however, that this primordial ability to create images, this schematism of possible

21 Blaise Pascal. *Thoughts*. Trans. William Finlayson Trotter. New York: P. F. Collins, 1958. 26-32.

22 Immanuel Kant. "Geschichte und Naturbeschreibung der merkwürdigen Vorfälle des Erdbebens welches an dem Ende des 1755sten Jahres einen großen Theil der Erde erschüttert hat." *Geographische und andere naturwissenschaftliche Schriften*. 1756. Ed. J. Zehbe. Hamburg: Meiner, 1985. 44. Cf. Gerd Held. "Die Erscheinung einer Erscheinung. Zur Ästhetik des indirekten Gegenstandes bei Kant und Duschamp." *Unter Argusaugen. Zu einer Ästhetik des Unsichtbaren*. Ed. Gerd Held, Carola Hilmes, and Dietrich Mathy. Würzburg: Könighausen und Neumann, 1997. 11-32.

objects of experience had already been technologically enhanced and remodelled through the media of the 17th century. Kantian schematism is thus no longer an a priori principle of construction. It is itself the result of historical experimental systems and their compact media technologies. Kant's statement must be modified: Reason only perceives what it itself produces according to its own plans within the arrangement of applied experimental media.

In *Amintors Morgen-Andacht*, George Christoph Lichtenberg writes on telescopes and lenses, "that man may not have the power to form the world as he pleases, but he does have the power to grind lenses through which he can make it look any way we would like."[23] This remark is important both in terms of media theory and experimental history. It claims that we do not become sovereign over phenomena through transcendental schemes, but through media armament. Wilhelm experiences this domination as an ethically dubious consequence of instruments of sensory enhancement. Hans Blumenberg describes the "sheer symbolic status of the telescope for the confirmation of theoretical curiosity."[24] Elsewhere he mentions the "as yet unwritten history of the idea of the invisible" (that must also be a history of the media) and calls the telescope "the great, metaphysically unexpected and thus so relevant surprise of the beginning Modern Age."[25] "I began to doubt the faith of my own eyes," claims Tycho Brahe, who was unfamiliar with the telescope, programmatically.[26] That means that the perceptions of the eye must be controlled through disciplined observation and media armament, and both through calculation. Only thus did it become possible to refute both the Aristotelian world picture of appearance and the authority of the traditional corpus of knowledge. The project of media-supported experimental visualization conformed to the Royal Society's motto, "nullius in verbo," and emblems, the telescope and microscope. And the name of the illustrious Accademia dei Lincei, which counted

23 Georg Christoph Lichtenberg. *Werke in 6 Bänden*. Ed. Wolfang Promies. 5th ed. Frankfurt a. M.: Zweitausendeins, 1994. Vol. 3, 79. Reinhard Heinritz. "Teleskop und Erzählperspektive." *Poetica* 24.3/4 (1992): 341-55.

24 Hans Blumenberg. *The Legitimacy of the Modern Age*. Trans. R. M. Wallace. Cambridge, Mass.: MIT Press, 1983.

25 Idem. "Das Fernrohr und die Ohnmacht der Wahrheit." *Galileo Galilei, Sidereus Nuncius. Nachricht von neuen Sternen*. Ed. Hans Blumenberg. Frankfurt a. M.: Suhrkamp, 1980. 16.

26 Quot. from: Panek. *Seeing and Believing*. 50. The divine potency of the eye can be found as early as Alberti. Cf. Horst Bredekamp. "Albertis Flug- und Flammenauge." *Die Beschwörung des Kosmos. Europäische Bronzen der Renaissance*. [Exhibit. cat.] Duisburg, 1994. 297-392.

Galileo amongst its members, was given under the auspices of sharp-sighted perception. *Lincei* are lynxes.[27] In his book on the telescope, Richard Panek pushes the pathos of media-experimental scientists so far that they proceed "from being the apple of god's eye to being god's eye."[28]

This 'Copernican pathos'[29] driven by a new visual media aesthetics of the sublime, has another side, however. Blumenberg describes as follows: Galileo,

> by making the invisible visible and believing that he could thus prove the Copernican conviction, surrenders himself to the danger of visibility as the last authority of truth. At the same time, by using the telescope to create this visibility, he breaks with the visibility postulate of astronomical tradition and opens a space for the inescapable suspicion that, no matter to what extent it may be taken, technically mediated visibility is an accidental fact bound to conditions that are alien to the subject matter.[30]

That experimental media, claimed to possess the power of truth and to overcome the eye's deception, to objectify perception and to 'discover' unknown spaces and things, that they offer no protection from the aporia of accident but, in contrast, seem to provoke it – this belongs to the most unsettling experiences with experimental systems from the 17th century to the present day. There are many reasons for this. The image-generating apparatus was first and foremost subject to technical limitations such as chromatic and spherical aberrations, poor depth perception, weak light.[31] They especially impaired a definitive identification of the objects of perception: Does one see an object or is the object an effect of the instrument's optical imperfection or even a product of the observer's theoretical assumptions? Already in the 17th century, critics objected that it was possible to see anything one wanted to with a microscope.[32]

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27 Interestingly, the frontispiece of Robert Hooke's paradigmatic book on microscopy includes both the motto of the Royal Society, which financed the publication, and the motif of the lynx. Robert Hooke. *Micrographia: or some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses*. London, 1665 [reprint Stuttgart, approx. 1974].

28 Panek. *Seeing and Believing*. 61.

29 Blumenberg. "Fernrohr." 23.

30 Ibid. 21.

31 Goethe is well informed on the technical-optical problems of the telescope: Goethe. *FA*. Sec. 1, vol. 23/1, 410-13.

32 Goethe found the best expressions for the optical-hermeneutic problems I will be discussing in greater detail below. Remarking on Caspar Friedrich Wolff, the first epigenetic embryologist, he states, "Notwithstanding the excellence of these methods [the microscopic, HB], through which he achieved so much, the admirable man did not believe that there was a difference between seeing and seeing, that the eye of the spirit need operate in perpetual living connexion with the eye of the body. Otherwise, one risks the danger of seeing and yet overlooking." Goethe. *FA*. Sec. I, vol. 24, 432. This conforms to Goethe's quote from an osteological work of the painter, anatomist and archaeologist Eduard Joseph d'Alton on scientific illustrations in *Zur Morphologie* (1823): "[...] thus it is essential that every natural researcher possess the most complete knowledge of light and shadow and of linear and overhead perspectives. Without possession of this knowledge, one can neither make correct microscopic observations, since they do not allow confirmation through touch, nor can one adequately assess any illustration. The most complete knowledge of the laws of vision, through which the nature of phenomena is revealed, [...] cannot be deemed an unimportant formality in natural research." Goethe. *FA*. Sec. I, vol. 24, 601.

33 A type of visual 'recording system' of microscopic seeing was, however, created with the invention of the projection microscope, resp. the helioscope in the middle of the 18th century. At the same time, by projecting the visual image, it allowed several individuals to participate in the 'privacy' of the act of seeing in ordinary microscopes. This last aspect was particularly important for the attestation of what had been seen and for scientific entertainment. There are connections to the *camera obscura*. Projection microscopes had a particularly impressive effect when living objects were projected. One then had 'living images,' i.e. a sort of proto-cinema. Cf. Goede. *Lesestein*, 86-88. A beautiful illustration can be found on p 91. The entertainment value of microscopic presentations cannot be underestimated. Cf. Martin Frobenius Ledermüller. *Mikroskopische Gemüths= und Augen=Ergötzung: Bestehend, in Ein Hundert nach der Natur gezeichneten und mit Farben erleuchteten Kupfertafeln Sammt deren Erklärung*. 3 vols. Nuremberg, 1760, 1761, 1778. Ledermüller (1719-1769) was a lawyer and assistant to the chamber of curiosities in Bayreuth.

Secondly, and applicable to both telescope and microscope, the size of the sector open to observation decreased with the factor of enlargement. It became increasingly difficult to spatially and environmentally contextualize an 'image' and thus to situate it within the surrounding 'order' of the visual. Goethe points this out in his description of Wilhelm's confusion in the observatory. The result was an increase in uncertainty, for example, when interpreting what a microscopic segment actually 'meant' within the whole organism or a new star in a celestial system. In addition, the new devices do generate images, but the images disappear when no one is looking through the apparatus. The problem of image storage remained unsolved until microscope and telescope were coupled with photography in the 19th century.[33] Until then, 'image storage' meant making a sketch or letting someone else make a sketch or engraving of what one thought one had seen. Bredekamp has shown, using Galileo's splendid moon drawings as an example, what pictorial evidence with valid scientistic conclusions Gali-

leo drew from his sketches.[34] But if one looks at the moon today with a telescope of the same power as Galileo's, the visual findings will by no means agree with those of Galileo. What does one see, when one sees? And what is the status of the primary visual image in relation to its translation into another pictorial medium? In scientific papers, in addition, these secondary images, instead of the primary visual image, were usually also transformed into language. Thus, the object undergoes multiple transformations from one medium into another. This corresponds to the general fact that one medium 'translates' another medium (M. McLuhan), but it also increases contingency, or what can be called the epistemological risk of experiments based on mediating processes.

4. Microscopic Fundamentalism

On the title page prefacing the German translation of the English microscopist Henry Baker (1698–1774) is a quote from Pliny's *Natural History*: "Rerum natura nusquam quam in Minimis tota est" (Pliny, *Hist. nat.*, XI, c. 2).[35] Since the invention of the microscope around 1600, researchers have been driven by the idea of discovering the whole of nature in its most minute parts, even the atoms, the building bricks of nature (rerum natura). The *polyhistor* Athanasius Kircher recognizes the scientific significance of the microscope when he writes in *Ars Magna Lucis et Umbrae* in 1646:

> Of many things one did surely believe until today that they were completely without life and soul, whereas the microscope shows that they do indeed live. Who would have believed that vinegar and milk crawl with an infinite number of worms if the art of microscopy had not recently taught this fact, to the greatest amazement of everyone.

He then goes on to speak of the 'divine science of optics, which leads what is hidden out of the deepest darkness into an astonishing light.'[36]

The discoveries and mistaken identifications that were possible during the expedition into the seen and through which the tension Goethe describes between empiricism and metaphysics arises, will in

34 Horst Bredekamp. "Galileo Galilei als Künstler." *Übergangsbogen und Überhöhungsrampen*. Ed. B. Ecker and B. Sefkow. Hamburg: Hochschule für bildende Künste, 1996. 54-63.

35 Heinrich (Henry) Baker. *Das zum Gebrauch leicht gemachte Microscopium*. Zurich, 1753. Title page.

36 Quot. from: Richard Julius Petri. *Das Mikroskop. Von seinen Anfängen bis zur jetzigen Vervollkommnung*. Berlin, 1896. 10 note 3.

following be illustrated by the examples of the most famous microscopist of the 17th century, Antoni Van Leeuwenhoek (1632-1723),[37] and the Royal Society's ingenious experimenter, Robert Hooke, whose *Micrographia*[38] of 1665 provided Leeuwenhoek with crucial encouragement.

In 1680 Leeuwenhoek, a merchant and scientific amateur who had command of neither English nor Latin, was elected member of the Royal Society on the basis of his excellent, tiny, single-lens microscopes and the zoological, botanical, embryological and crystallographic knowledge obtained with them.[39] He reported continuously to this highly respected community of scientists on his research, submitting sketches and two hundred letters written in Dutch.

Leeuwenhoek believed he had 'seen' the decisive solution to the decades-old dispute on the question of generation (abiogenesis versus preformation; ovists versus spermaticists) in the microscope. He thought he had recognized complex anatomical and animated structures in microscopic semen (of animals and men), preformed beings that admittedly did not exhibit an identical morphology to fully formed crea-

37 Citations according to *Alle de Brieven van Antoni van Leeuwenhoek/ The Collected Letters of Antoni van Leeuwenhoek. A Complete Edition of the Works of Van Leeuwenhoek, Annotated and Considered in the Perspective of the History of Science and Medicine, with Special Reference to General and Biological Microscopy*. 15 vols. Ed., ill., and ann. by a Committee of Dutch scientists. Amsterdam and Lisse: Swets & Zeitlinger, 1949-1999. Quotations are abbreviated as Leeuwenhoek. *Collected Letters*. The numeration of the letters indicates the serial numbers of the this chronological edition, the numbers in square brackets are Leeuwenhoek's own, which are commonly used in previous editions, such as: Antoni van Leeuwenhoek. *Arcana naturae detecta*. Delphis Batavorum (Delft): apud Henricum a Krooneveld, 1695. Or Antoni van Leeuwenhoek. *Opera Omnia*. Vols. I-IV. Leiden, 1715-1722. Vol. II, 1-515 [reprint Hildesheim: Olms, 1971].

38 Quot. from: Hooke. *Micrographia*. Due to space limitations, I can only discuss Hooke briefly later.

39 Leeuwenhoek concludes Letter 33 to Hooke, November 12, 1680: "These, Sir, are a few of my observations which I thought fit to send to you and to the Honourable College of the Royal Society, one of whose humble Brethren I now am, thanks to the College's favours." Leeuwenhoek. *Collected Letters*. Vol. III, 341. Leeuwenhoek was proposed in 1673 by Reinier de Graaf and Constantijn Huygens in a letter of recommendation to Henry Oldenburg, Secretary to the Royal Society: Brian J. Ford. *Single Lens. The Story of the Simple Microscope*. London: Harper & Row, 1985. 28. In 1981 Ford discovered a bundle of unknown letters and preserved experimental objects from Leeuwenhoek in the collections of the Royal Society: (ibid. 40-59). With them he was able to prove the hypothesis that had until then remained unsubstantiated, "that Hooke was the genius from whom Leeuwenhoek's life work stemmed" (ibid. 59).

tures.[40] Leeuwenhoek differs thus from the Dutch mathematician, microscopist and instrument maker, Nicolaas Hartsoeker (1656-1725), who had made precisely this claim based on falsified images showing the semen as homunculi. Hartsoeker was a gambler among scientists anyway. He declared the discovery of spermatozoa by his acquaintance Leeuwenhoek to be his own.[41] Leeuwenhoek punished him henceforth by ignoring his works. For both of them, nonetheless, female eggs constituted a receptive vessel for male semen, which contained the entire developing living being within itself. The egg was merely a nutritive environment for the semen. None of the specialists for seeing had 'seen' this.

Nevertheless, it opened a double line of battle. On the one hand, it was believed to empirically refute the doctrine of spontaneous generation. According to this theory, which goes back to Aristotle (*De generatione animalium*), living creatures develop spontaneously out of decaying matter or mud. A false theory was battled with a false premise, admittedly one with an empirical gesture, and thus the preformation theory was born. It contained a correct premise: Life is created by sexual reproduction. But what was correct was based on a mixture of microscopic experiments and false interpretation. Living semen and eggs (follicles, to be precise) had really been identified, but both had been incorrectly interpreted. The so-called ovists, to whom the young anatomist Reinier de Graaf (1641-1673), also from Delft, belonged, then confronted the spermaticists, Leeuwenhoek and Hartsoeker. Graaf supported the hypothesis of the generative function of the female egg (although he considered the ovarian follicles that bear his name to be themselves the eggs), while still others attributed generative potency to *both* egg and semen. Hartsoeker and Leeuwenhoek were united in rejecting spontaneous generation, united in the (false) theory of preformation, but enemies in regard to priority in the discovery of spermatozoa, the function of which they both in unison incorrectly identified. Both agreed with de Graaf in regard to the preformationist premise, but they challenged his theories on the function of the eggs, which de Graaf had, in addition, incorrectly identified. For this reason, Leeuwenhoek thought that he had empirically refuted de Graaf, when he showed in

40 E. G. Ruestow. "Leeuwenhoek's Perception of the Spermatozoa." *Journal of the History of Biology* 16 (1983): 185-224. Brian J Ford. "First Steps in Experimental Microscopy. Leeuwenhoek as Practical Scientist." *The Microscope* 43.2 (1995): 47.

41 Ford. *Single Lens*. 1985. Such priority disputes were common, and Hooke as well was involved in many feuds.

his investigation of the follicles, which he also considered to be eggs, that they could not possibly assume a generative function. He believed he had thus micro-anatomically 'proven' his false dogma of generation through male semen alone.[42] To this is added the evocative power of images. The sketch of multiple, identical spermatic homunculi also gave visual support to the dogma of preformation and with it the 'claim of the singular responsibility' of male semen for the transmission of life. The discursive hegemony of preformationism was secured for a good century, until the epigeneticists were able to assert themselves.[43]

But what a chaos of correct and incorrect identifications of microscopic images, what a transformation of empirical findings by theoretical assumptions, what fantastic progress in the microscopic substantiation of the principle of the sexual creation of life, had this not been itself completely incorrectly interpreted! In summary, like the telescope, the microscope functioned as a symbolic instrument of worldviews with a high degree of uncertainty. When a respected expert observer believed he could identify a visual image as this or that, he 'translated' it into the medium of a sketch, which was then technically reproduced through printing, commented upon in language, theoretically generalized and, finally, formatted into a complete discourse. The 'epistemic thing'[44] of Leeuwenhoek, de Graaf or Hartsoeker was, in addition, an imagination certified by multiple media transformations. Experimental media must not necessarily generate phantasms, but they can. And yet, Leeuwenhoek's experimental microscopy represents a sound form of scientific rationality. He does not proceed any differently than Galileo did with his images of the moon obtained through a telescope, images that provided a veritable argument for Copernicanism. Leeuwenhoek's investigations of the blood are similar. He discovers the red blood cells and identifies within them so-called *globuli*, which

42 Leeuwenhoek. *Collected Letters*. Vol. IV, 11-17 (letter no. 70 [37], January 22, 1683 to the famous architect, Christopher Wren, who collaborated with Hooke). The conclusion states: "And why, seeing that the womb or tuba fallopiana is as it were an entire world in comparison with an animalcule in male sperm [...] cannot we imagine that [...] this animalcule will, within no time [...] assume the figure of a human beeing [...] having all the perfections of man?" Leeuwenhoek. *Collected Letters*. Vol. IV, 15-7.

43 Helmut Müller-Sievers. *Epigenesis. Naturphilosophie im Sprachdenken Wilhelm von Humboldts*. Paderborn, 1993. Peter McLaughlin. "Blumenbach und der Bildungstrieb. Zum Verhältnis von epigenetischer Embryologie typologischem Artbegriff." *Medizinhistorisches Journal* 17 (1982): 357-72.

44 Hans-Jörg Rheinberger. *Towards a History of Epistemic Things. Sythesizing Proteins in the Test Tube*. Stanford: Stanford University Press, 1997.

he occasionally also calls *corpuscula*. For him, they are analogous to atoms, the elementary building blocks of life described by Descartes. It is certain that Leeuwenhoek had not read Descartes, but he had heard of the *globuli* theory. What he *heard*, he then *saw*.[45]

Leeuwenhoek's theory of generation provides much evidence of the dogmatisation of empirical findings. He writes to Robert Hooke in 1680, as his almost obsessive study of the sexuality of fleas begins:

> And so I have now set myself to an examination of the male sex of the flea, solely to find out whether there are also animalcules in this male sperm. Finally to my great satisfaction, I discovered very distinctly a great quantity of animalcules which also had the shape of little snakes but were uncommonly long and thin [...]. But then I have constantly found that the animalcules in male sperm are not at all in proportion to the size of the animals.[46]

At least the discovery of semen containing *animalcula* does not lead him to automatically assume that these *animalcula* are morphologically identical to the future living organism. Nevertheless, the *animalcula* obtain the status of an empirical proof "that no animals, however small they may be, take their origin in putrefaction, but exclusively in procreation." At the same time, preformationist phantasms form: "Animals, from the largest down to the little despised animal, the flea, have animalcules in their semen."[47] In the *animalcula* theory, future living beings are completely encapsulated in the semen. In a letter to Christopher Wren from 1680, the male fantasy about "the ovary of Woman (as

45 Leeuwenhoek. *Collected Letters*. Vol. III, 301-9 (letter no. 65 [33], November 12, 1680). Vol. VIII, 13-55 (letter no. 110 [65], September 17, 1688). Vol. VIII, 69-113 (letter no. 113 [66], January 12, 1689).

46 Leeuwenhoek. *Collected Letters*. Vol. III, 325 (letter no. 65 [33], November 12, 1680). Leeuwenhoek naturally also reaps resistance for his *animalcula* theory, which provoked both followers of spontaneous generation and ovists. He responds that his critics know nothing of "correct observation" and that he sees the *animalcula* in the microscope as clearly as he sees fleas, mosquitoes or scampering mice with the naked eye. Leeuwenhoek. *Collected Letters*. Vol. III, 331.

47 Leeuwenhoek. *Collected Letters*. Vol. III, 329. In letter no. 140 [85] of November 30, 1694 Leeuwenhoek describes sexual reproduction succinctly as a principle of nature. At the same time, he declares species to be stable, thus conforming to preformationist dogma and far removed from any notion of evolution: "It is again apparent to us that provident Nature acts almost in the same way in all created things. And by this – contrary to the theories of Aristotle and his followers, who have provided us with so many fables about generation and even do not scruple to maintain that many Animals spring from putrified matter, decayed things or from mud, so that we are disgusted when we read this nonsense – all intelligent people must become convinced even more so than before that every animal, however insignificant it may appear in their Eyes, depends on a creature similar to that created in the beginning." Leeuwenhoek. *Collected Letters*. Vol. X, 165.

it is now called)" becomes principle: Ovaries supposedly contribute nothing to procreation; they are "nothing but the discharge of some vessels."[48] That is not without a touch of humour. Leeuwenhoek micro-anatomises Graaf's follicle under de Graaf's assumption (he is only named indirectly as a 'learned Doctor of Medicine and Anatomy') that these are the 'so-called eggs.' And he 'proves' that they *cannot* anatomically be these eggs. It is paradoxical. Leeuwenhoek proves through impeccable microscopic-anatomical findings that the follicles, which are considered to be eggs, are not eggs. And he thus 'knows' that women contribute nothing to procreation. The microscope gives birth to male fantasies.

> But now that I have discovered that the animalcules also occur in the male seed of quadrupeds, birds and fishes, nay even in vermin, I now assume with greater certainty than before that a human being originates not from an egg but from an animalcule that is found in male sperm, the more since I remember having seen that in the sperm of man and also of a dog there are two sorts of animalcules. Seeing these I imagined that one sort were males and the other sort females.[49]

With implied rationality, the instrument microscope makes not only the invisible but also the imaginary visible. The 'envisioned' is presented to the Royal Society, this bulwark of science as "observations and reasoning."[50] With reference to Goethe, one can, indeed, one must call this the 'metaphysics of phenomena.'

Leeuwenhoek is still working on the sexuality of fleas in 1693. Returning to his studies of 1680 and 1682, he details his many experiments in a letter of over twenty pages in length (fig. 1). These meticulous studies and visualizations of flea development can even be called a pilot study of the sexual behaviour of minute life forms. Before Leeu-

48 Leeuwenhoek. *Collected Letters*. Vol. IV, 5-7 (letter no. 70 [37], January 22, 1683).

49 Leeuwenhoek. *Collected Letters*. Vol. IV, 11 (letter no. 70 [37], January 22, 1683). Leeuwenhoek reacts above all rhetorically to a letter from George Garden of Aberdeen, who quite convincingly explains the generative function of the ovaries: "I know that it might be objected against me: since provident Nature has not made anything in vain, what is the use of the Female 'balls' or ovaries? But to this I could say that we see many things the reason of which are hidden from us. For what is the use, in our opinion, of the Nipples of Male Quadrupeds? Nay what is the use of the Nipples which we Men have on our Chest? [...] And just as (to my knowledge) the Nipples on the Chest of us Men are not used, in the same way I think the imagined Ovaries are not used in Women." Leeuwenhoek. *Collected Letters*. Vol. X, 59 (letter no. 135 [81], March 19, 1694).

50 Leeuwenhoek. *Collected Letters*. Vol. III, 349 (letter no. 66 [34], November 4, 1681).

wenhoek's eyes the flea reveals itself to be a true sex maniac. Leeuwenhoek is particularly interested in the copulation positions and performance of fleas and is amazed that the male flea mates the female flea from beneath (!). The sexual activity these tiny animals exhibit under the microscope seems to him so exorbitant that, Leeuwenhoek fantasizes, it would be fatal for larger animals. Something to imagine: death by copulation. What an intensity, frequency, variation spectrum and potency in the universal and in the subliminal especially virulent sex life! No mention of spontaneous generation! (fig. 2) The flea's sex orgies are a welcome proof against the Roman authority of Athanasius Kircher, which he denounces, but not without a touch of humour:

> Now if we are to believe Kircherus, we must assume for certain that Fleas in Italy are of quite a different structure and procreation. [...] *If he had been equipped with magnifying glasses, he would have judged differently.* I must say that, if Kircherus had spent a few days in studying Fleas with a good magnifying glass and keen observation, just as I have lost many days doing this, he would have spoken quite differently about the procreation of fleas, even apart from the manifold fables about procreation and other fantasies he put on paper, and as it were scattered abroad.[51]

Without a doubt, Leeuwenhoek considers the microscope to be an instrument of truth. Due to this 'instrumental' bias, he is susceptible to using the microscope not only as an instrument for seeing. It is also as an instrument for projecting his own imagination, which is then published, attested and proven.

In Letter 83 of the *Arcana* from April 30, 1694, Leeuwenhoek polemisizes against the excellent microscopist, natural researcher and curator of the Museum Collegii Romani Kircherianum, Filippo Bonanni (1638-1725). In his *Recreazione dell'occhio e della mente nell'osservazione della chiocciole* of 1681 Bonnani had taken the side of his teacher, Kircher, in a dispute with Franscesco Redi, an ovist (*Omne vivum ex ovo*). Bonnani supported the theory of spontaneous generation and repeated it in his later *Observationes circa viventia* (1691).[52] Leeu-

[51] Leeuwenhoek. *Collected Letters*. Vol. IX, 259 (letter no. 126 [76], October 15, 1693). The description of the flea is in: Leeuwenhoek. *Arcana*. 353-374. Idem. *Opera Omnia II*. 321-343.

[52] Filippo Bonanni (Buonanni). *Observationes circa viventia, quae in rebus non viventibus reperiuntur, recognitae ad vivum experimentur*. Rome, 1691. Bonanni not only built very good variable compound microscopes that were completely different from Leeuwenhoek's single-lens apparatus, but which were the model for the so-called screw-barrel microscopes (which are usually attributed to Hartsoeker) throughout Europe. In this book he also reported with much specialist competence on different techniques of microscope construction. His illustrations of molluscs and insects are superb.

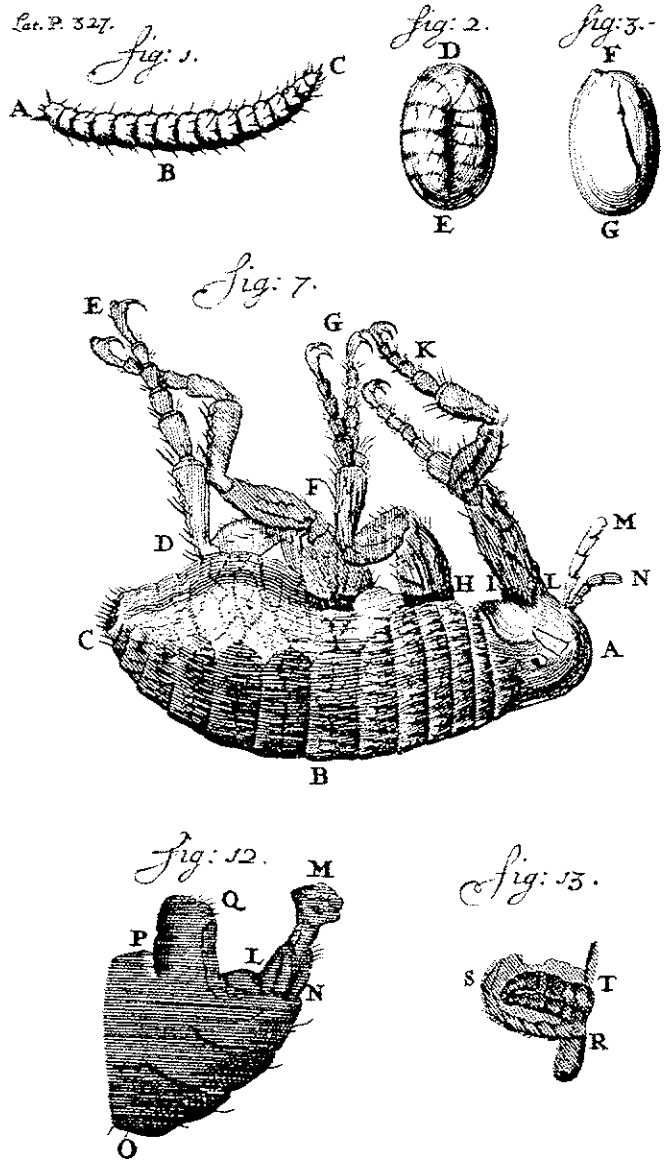

Fig. 1: *Flea studies* from Antoni van Leeuwenhoek *Arcana Naturae Detecta* (Leiden, 1722).

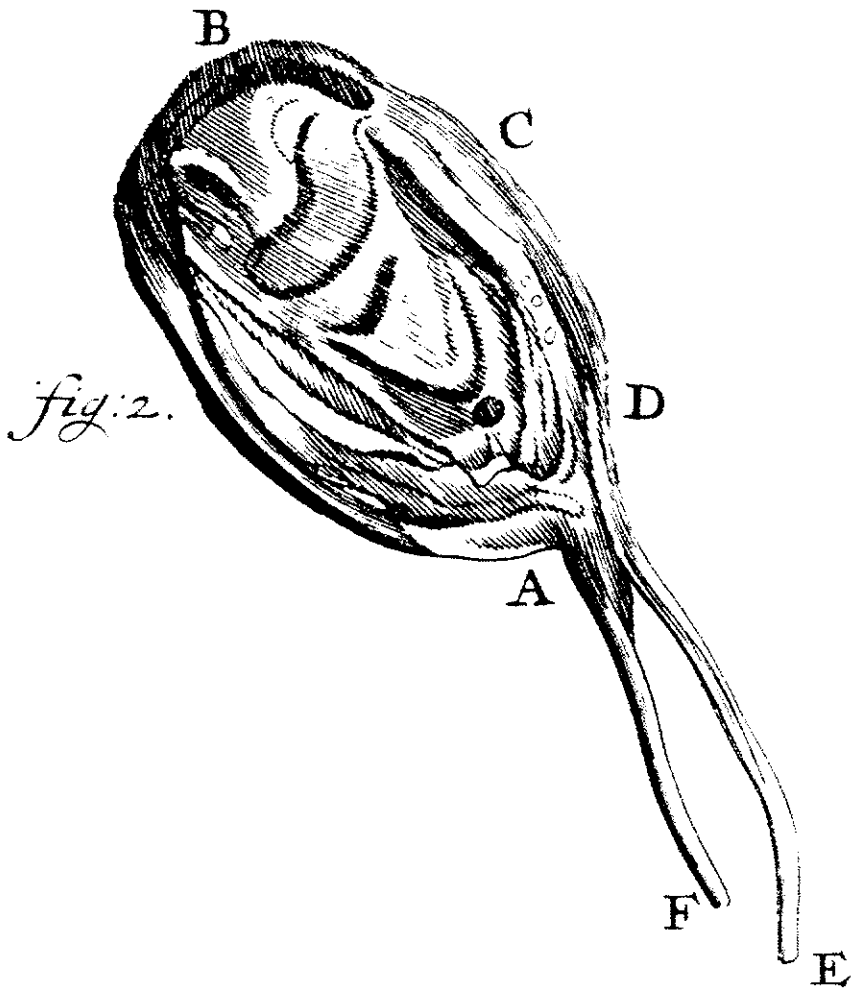

Fig. 2: *Flea testis* from Antoni van Leeuwenhoek *Arcana Naturae Detecta* (Leiden, 1722).

wenhoek now intends to prove sexual generation on Bonanni's main example, molluscs. But the result is clear from the outset. He opens the letter with a quote from the letter of an unnamed scholar: "Since the Author of this Book [Bonanny] holds to the Opinion of the Ancients, in particular of Aristotle, about the generation of the shell-fishes, asserting that they are born spontaneously in mud or sandy earth, etc." And with this quote, Leeuwenhoek turns to his London colleges, certain of their agreement: "Here it is seen, Very Noble Sirs, how the [the opinion of] some of the Members of the Royal Society is disputed, who have exerted themselves in studying generation, and the numerous observations made by them as well as myself, and who always found that no creature is produced except by generation."[53]

This clever, rhetorical performance of a coalition with the 'strongest regiment' of the 17th century is followed by the empirical part of the letter containing a micro-anatomy of molluscs. (fig. 3) The letter concludes:

> Here we see, Very Noble Sirs, that when we try to speak about some truth, and especially the generation of small Creatures, which we can never witness with our Eyes, we should not rely on reports or hearsay, but on our own findings, and that we should not treat a matter lightly, but must preserve a long time and indefatigability if we are to find the truth.[54]

Revealing for the letter's performative quality is the anecdotal section. Leeuwenhoek confronts a mussel fisher who adheres to the mud theory of *generatio* with his microscopic findings. Although the fisher interrogates a ninety-year-old colleague, who, as to be expected, also supports the mud theory, he is convinced by Leeuwenhoek's microscopic evidence: "He was amazed and added: 'you know more than we do.'"[55]

5. Attestation and Visual Documentation

Here, we come to a principle dilemma of the new experimental systems that operate with the invisible: They are by no means self-evident. They require additional confirmation. In his apostrophe to the members of the Royal Society, Leeuwenhoek, in a gesture of rhetorical comprehen-

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53 Leeuwenhoek. *Collected Letters*. Vol. X, 91 (letter no. 137 [83], April 30, 1694). Leeuwenhoek already mentions Bonanni's new book, which he, admittedly, had not read, Letter 60 from March 26, 1694. As was often the case, the contents of the book, which was written in a language he did not understand, were summarized for him. Leeuwenhoek. *Collected Letters*. Vol. X, 31 (letter no. 134 [80], March 2, 1694).

54 Leeuwenhoek. *Collected Letters*. Vol. X, 135 (letter no. 137 [83], April 30, 1694).

55 Ibid. The persuasive aspect of visualisation also emerges clearly in the following quote: "I only had this little animal depicted in order to convince those who still maintain with all the force of ignorance that living Creature can be generated from putrefaction and to show the wonderful structure of so small and despictable a Fish, of which not one Man in a thousand knows that it exists in the World, apart from a great many more admirable Vessels, Sinews and Organs which one perceives in so small a Creature when it has just been taken from its little Shell or when the parts of the body are still moist." Leeuwenhoek. *Collected Letters*. Vol. X, 123.

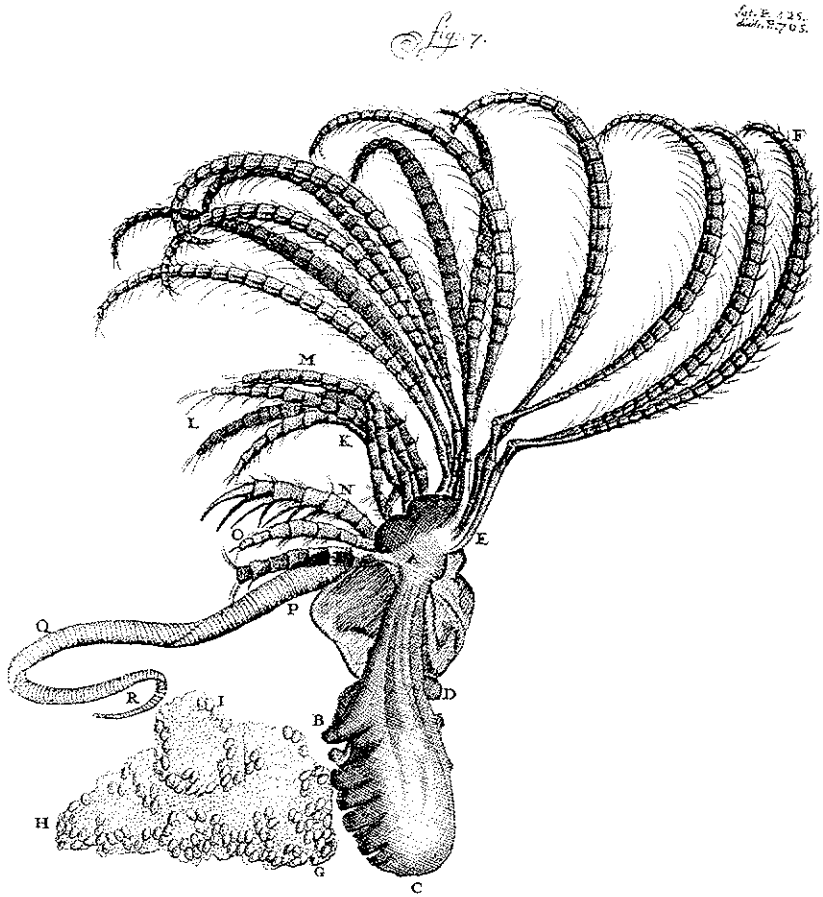

Fig. 3: Mollusk with eggs (so called little fish = *pisciculi*) from Antoni van Leeuwenhoek *Arcana Naturae Detecta* (Leiden, 1722). "I had the animal drawn with the intention of convincing people who stupidly still stick to the opinion that such creatures emerge from decay, by presenting to them the wonderful formation of these pathetic little fish, which isn't known to even a thousand members of human society, although it is worth the greatest admiration [...]." (*Opera Omnia*. Vol. II, p. 433.)

sion, draws the highly authoritative scientific community to his side. He shows that he conforms to their maxims of research practises: "own experiences, observations, experiments" are the laborious, but certain paths to 'truth.' The use of the old topos of 'two paths' secures, in addition, the ethical dignity of the 'arduous effort' of the experimental method. Leeuwenhoek stylises himself as Hercules.[56] The scientifically

[56] For Hercules as an ethical hero of labour on the 'right' path see Erwin Panofsky. *Herkules am Scheideweg und andere antike Bildstoffe in der neueren Kunst*. Studien der Bibliothek Warburg 18. Leipzig and Berlin, 1930.

insignificant but rhetorically effective anecdote of the aged and young fisher, in which the latter affirms Leeuwenhoek's cognitive superiority, secures, in addition agreement with the "very learned and distinguished Gentleman."[57] Leeuwenhoek has skilfully strategically surrounded the Aristotelians both from the side of the new scientific elite and from that of 'common sense.' Aristotelians take the path that is 'comfortable,' ethically inferior, 'unsensible,' irrational, fabulous, dogmatically obdurate and immune to experience. The tactic of accusing the adversary of self-immunization, however, immunizes one's own position as well. Revealing another's dogmatism disguises one's own. In a way, Leeuwenhoek dogmatises empiricism itself. It becomes a pretext for leading phantasms and imaginations to victory.

This is supplemented by techniques for enacting attestation and self-performance, the self-fashioning of a scientist. Leeuwenhoek has a talent for both, as can be illustrated by the example of the microscopic visualization of the arterial and venal thigh connection in the circulatory system. With his extremely powerful single-lens microscope, Leeuwenhoek is able to demonstrate this connection like no one before him. In Leeuwenhoek's age, blood circulation, discovered in 1628 by William Harvey, had become widely accepted.[58] Harvey had not worked with a microscope and could not have known of the transition from the arterial to the venal part of the circulatory system, namely the capillary system, which cannot be seen by the naked eye. Thus, the decisive component necessary to perfect the idea of the circulatory system was missing. A first degree of success was achieved, unsurprisingly, by a microscopist, namely the Italian professor of medicine, Marcello Malpighi (1628-1694) in Bologna in 1660. An influential embryologist, he founded microscopic plant anatomy and was, more importantly in this context, the first to close the circulatory system by discovering the pulmonary alveoli and capillaries in a frog.[59] In the footsteps of Malpighi, but also in those of the entomologist Jan Swam-

[57] Leeuwenhoek. *Collected Letters*. Vol. X, 165 (letter no. 140 [85], November 30, 1694).

[58] William Harvey. *An Anatomical Disquisition on the Motion of the Blood in Animals*. Trans. Robert Willis. London: Parsons, 1923. See also Thomas Fuchs. *The Mechanization of the Heart: Harvey and Descartes*. Trans. Marjorie Greene. Rochester: Rochester University Press, 2001.

[59] Marcello Malpighi. *Opera Omnia*. 2 vols. London, 1686. Vol. I is on plant anatomy. Relevant for blood circulation is in vol. 2 "De viscerum structura exercitatio anatomica. Dissertationes eiusdem de polypo cordis, et de pulmonibus."

merdam (1637-1680), whose studies on frog larvae Leeuwenhoek read, Leeuwenhoek turns his attention in 1688 to frogs, spawn, tadpoles and newly hatched fish (since they are transparent, they are especially suited to microscopic experiments). Leeuwenhoek achieves sensationally clear insights into the capillary exchange system of arterial and venal blood, not an epistemological, but an optical breakthrough (fig. 4).

> I concluded that just as many times as this very rapid push forward was caused, so many times was the blood driven from the Heart. Nay, I saw this movement as clearely as I or anyone else could ever imagine the whole propulsion of the blood from the Heart, and the Arteries (at the place where they join up together) into the Veins. Although I contemplated this sight many times to my exceedingly great pleasure, I did not want to keep it only to myself, but I showed this circulation of the blood to five prominent Gentlemen who declared to me that they had never yet seen anything of mine that was so worthy of being beheld.[60]

He writes in the same letter:

> This sight, too, I did not wish to keep all to myself, but I showed the same to two prominent learned Gentlemen; [...] how the blood was carried from the large Artery to the end of the tail, and that there lay near to this also large Veins which continuously carried the blood to the Heart [...].[61]

These remarks, and there are many similar ones, show not only Leeuwenhoek's enthusiasm and his pride in the discovery, they also show characteristic methods of negotiating secrecy and publicity. He surrounds the techniques of his microscopes – and he did not sell or give away a single one during his lifetime – with a theatrical mysteriousness, one which was palpable for visitors and contributed much to the aura of his discoverer persona. His research results, enacted in the intimate private space between the eye of the observer, the single-lens microscope directly in front of it and the object, need 'publication,' that is, to be portrayed (usually through a commissioned draughtsman), presented in written language, certified by honourable gentlemen and brought into public circulation. Not only Leeuwenhoek's frequent references to the "agreeable" or "fascinating sight" reveal that this is all a *theatrum*.[62]

60 Leeuwenhoek. *Collected Letters*. Vol. VIII, 23-24 (letter no. 110 [65], September 7, 1688).
61 Leeuwenhoek. *Collected Letters*. Vol. VIII, 37.
62 Leeuwenhoek. *Collected Letters*. Vol. VIII, 45.

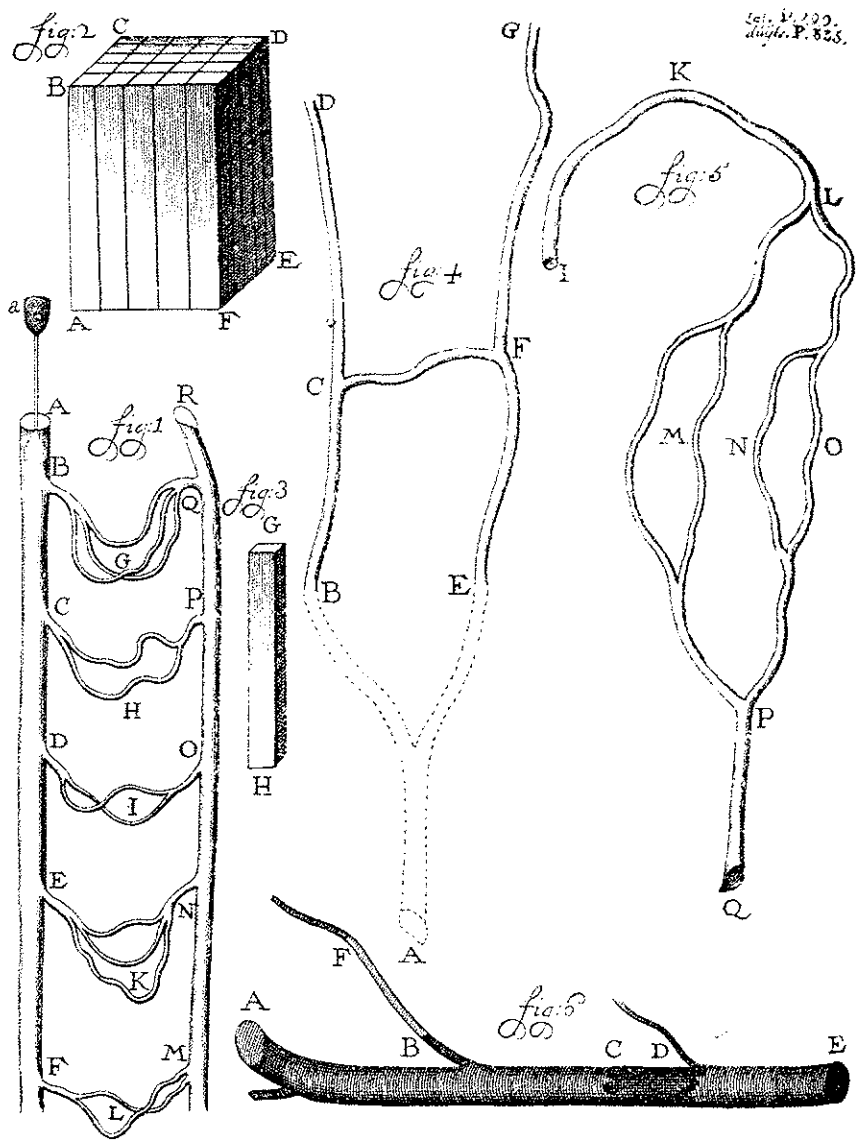

Fig. 4: Arteries and veins connections in fish from Antoni van Leeuwenhoek *Arcana Naturae Detecta* (Leiden, 1722). Leeuwenhoek measures the flow and pulse of blood. He proposes quantitative *relations* of blood circulation. He investigates hydraulic and hydrostatic rules. He supports the visualising of blood vessels by injecting mercury and wax.

Here, theatre means literally the scene of sight, the stage on which science creates itself by experimentally staging its results.[63]

Witnesses have here a similar function as sketches. They are 'mediators' between the *idios kosmos* of the private researcher and public recognition of his observations and conclusions as the 'truth.' Leeuwenhoek writes, and quite often in this vein, "I have put a fish before the magnifying glass, and ordered the Draughtsman to draw everything that he came to see; which is indicated here by fig: 9."[64] This statement contains multiple levels of suggestion. The draughtsman 'records' what he sees, and what he sees is seen by 'us' 'here' as figure 9 on the page of a book. It suggests a correspondence between 'drafted image,' 'optical image' and 'object,' implying that we are seeing as readers here and now 'the same' thing that Leeuwenhoek had seen. At the same time, the object, on which Leeuwenhoek had often worked for weeks, has already been rearranged, and this has naturally been done according to his directions. Of course, the draughtsman's perspective is also not unbiased, as if he were standing over a microscope for the first time. Experimenter and draughtsman cooperated long-term, since the latter also needed to demonstrate a degree of expertise, and discussions and arrangements, for example, do take place between experimenter and draughtsman.[65] Every 'object' that is handed over to the draughtsman or a witness for contemplation has already been selected by Leeuwenhoek, extensively manipulated, prepared, dissected or visualized

63 Cf. Helmar Schramm. *Karneval des Denkens. Theatralität im Spiegel philosophischer Texte des 16. und 17. Jahrhunderts*. Berlin: Akademie Verlag, 1996.

64 Leeuwenhoek. *Collected Letters*. Vol. VIII, 47 (letter no. 110 [65], September 7, 1688).

65 The following passage shows that disagreements could arise between draughtsman and experimenter: "Nor did I intend to have the Flea drawn, but because a certain learned Gentleman strongly urged me to do so, adding that it would thus be possible to convince the world that Fleas are not generated by corruption but by procreation, I caused it to be done. And although very many blood vessels could be seen, especially in the abdomen, he was able to draw only a few of them, saying that it was impossible to depict the others. This Flea as drawn appears to my eyes to be some eight times bigger, and this as looked through the same glass as drawn here, although the Draughtsman says he does not see it any bigger. I could not imagine that there was such a great difference in men's eyes as I now see. This Draughtsman was shortsighted." Leeuwenhoek. *Collected Letters*. Vol. IX, 231-3 (letter no. 126 [76], October, 1693). Indirectly, this passage makes it clear that Leeuwenhoek wants his sketches made in exactly the same dimension as the microscope enlarges the object, so that the reader assumes that what he sees in the book is exactly what is seen through the microscope. This is, of course, an illusion.

through mercury injection.[66] By implying an equivalence of original experimental situation, draughtsman's eye, drawing and reader's gaze, attention is deflected away from the many transformations and media formations that generate the 'result' and create the community between scientist and public. It is to be forgotten that all images follow a persuasive rhetoric.

The researcher's credibility is especially at stake when confronting the invisible. This is why Leeuwenhoek purposefully implements the model of attestation. (fig. 5)

> Before taking my leave I feel compelled to add to this that, some time ago when I was reporting to a certain Professor of Medicine my discovery relating to the circulation of the blood, this Gentleman told me that, when people were discussing my observations, and referring to them in confirmation of certain Matters, the response frequently was: are we to believe it just because Leeuwenhoek says so; what certainty do we have of it. For which reason that Gentleman warned me, and said that I would do well to produce an attestation of a few prominent persons who might have been eye-witnesses to these my discoveries, in order that I might suffer less contradiction in such related matters.[67]

Similar is a passage on embryonic eels in the so-called eel matrix, which Leeuwenhoek believes to support his preformationist assumptions (and the *animalcula* theory):

> This was no small pleasure for me to contemplate, on the one hand because, after so much indefatigable work, I had last discovered the procreation of the Eel, and on the other hand because it silenced the People who would often say the following behind my back: *Since he seeks to establish that all Animals are procreated, let him demonstrate to us how Eels are procreated.* I did not wish to keep to myself the sight of these young, perfect, and unborn Eels, although they were quite fifty times thinner than a hair of our head, as stated heretofore, but I communicated it to some of my acquaintances, who were amazed that such small creatures were so perfect.[68]

Clearly, there is a performative aesthetics of experiments, and it is supplemented by the performance of witnessing. Both serve to create an

66 For that reason, Hooke, who is a much more critical draughtsman and also spoke openly about the optical illusions of the microscope, explains in his preface the circumstances under which the visual representations of his objects are made and considers also optimisation possibilities and sources of error. Hooke. "Preface." *Micrographia*. N. p. (= 24-32).

67 Leeuwenhoek. *Collected Letters*. Vol. VIII, 55 (letter no. 110 [65], September 7, 1688).

68 Leeuwenhoek. *Collected Letters*. Vol. IX, 155-7 (letter no. 123 [75], September 16, 1692).

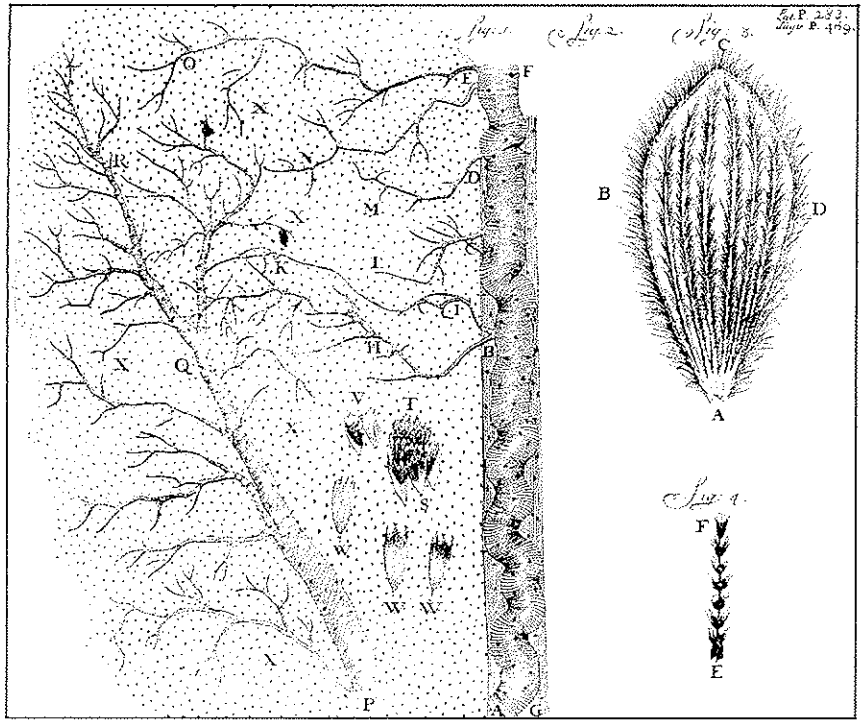

Fig. 5: Blood vessels of a butterfly wing from Antoni van Leeuwenhoek *Arcana Naturae Detecta* (Leiden, 1722). The scales – still indicated with the letters VTSWWW – have been removed. AG-EF describes a large blood vessel. PQR = branching blood vessel.

apparent self-evidence of truth and factuality, one that has, in the process, erased the traces of its stylisation. Included in this setting are the addressees of the letters, the highly respected honourable scholars of the Royal Society. Leeuwenhoek knows that his experimental methods conform to theirs, but just as important is that his letters' opening addresses, their translation from the Dutch and their publication in the *Philosophical Transactions of the Royal Society* have a rhetorical effect. It raises the provincial into the universal, the petty bourgeois into the intellectual elite. As the institution that sets the standards, the Royal Society certifies Leeuwenhoek's authority, even in his weirdest phantasms. The performative quality of the letters creates a powerful aura; it raises prestige and increases symbolic capital. The empiricism that is born wears the features of the century, the *saeculum theatralicum*.

6. Micrography as Art

Robert Hooke's (1635-1703) *Micrographia* (1665)[69] contains 38 magnificent folio illustrations of exceptional artistic worth. A talented draughtsman, Hooke is here carrying on an artistic tradition that began with illusionist representations of minute animals and plants. One need only look at Albrecht Dürer's watercolours of a crab, the wing of a roller, the Large Turf; Wenzel Jamnitzer's miniature sculptures, Bernhard Palissy's works in ceramics, the miniature-painters Joris and Jacob (Son) Hoefnagel, Thomas Moufet's insect theatre. It is perpetuated in the superbly illustrated books of the first microscopic era by Francesco Stelluti and Frederico Cesi, Marcello Malpighi, Filippo Bonanni, Jan Swammerdam and into the hand-made sketches of Hooke and Leeuwenhoek, which were later translated into engravings.

When Hooke declares in his introduction that "a new visible World" has been discovered, in that the telescope has opened up the heavens, and "the Earth itself, which lyes so neer to us, under our feet, shews quite a new thing to us, and in every little particle of its matter, we now behold almost as great a variety of Creatures, as we were able before to reckon up in the whole Universe it self:"[70] then he has experienced that through mechanically enhancing the power of the eye, the world of middling magnitude has been joined by two new, manifold and teeming universes. The antique peripatetics would be unsuspecting strangers in these new worlds, states Hooke, claiming that he and his contemporaries live in a new 'picture' of the world, and this 'picture' is that of 'experimental Philosophy,' as it is constituted by the microscope and telescope.

It is revealing that Hooke dedicates much space to a critique of the natural senses. Their imperfect capacities and susceptibility to error, our anthropologically deficient basic equipment, imprison us, Hooke claims, in an imperfect and false world. It is thus necessary to artificially enhance and model the senses, in order to compensate for the disproportion of our erring perceptions in relation to the true nature of things. Hooke develops a utopian future, in which all five senses are instrumentally enhanced and mechanically perfected, making unforeseen capabilities and treasures accessible. The Goethean 'middle' of the

69 Informative: Allan Chapmann. "England's Leonardo: Robert Hooke (1635-1703) and the art of experiment in Restoration England." *Proceedings of the Royal Institution of Great Britain* 67 (1966): 239-75. Simon Schaffner and Michael Hunter, eds. *Robert Hooke: New Studies*. Woodbridge: Boydell Press, 1989.

70 Hooke. "Preface." *Micrographia*. N. p. (= 12).

'particular,' that which 'befits our senses,' is for Hooke a deficient, limited, imperfect and defective world.

If one compares Hooke to Leeuwenhoek, it is conspicuous that Hooke uses the microscope less as an instrument of research than of observation. He rarely and only unsystematically asks questions about functional processes or causes. Neither does he pursue the 'great' questions of contemporary discourses, such as generation, sexuality, or blood circulation, which occupy Leeuwenhoek's mind and lead him to systematically apply the microscope. Nor does he practise the combination of anatomy and microscopy, a kind of micro-anatomy, that is characteristic for Leeuwenhoek or Malpighi and actually does lead to new knowledge. He did not even recognize the significance of the discoveries that have been attributed to him, such as cell structure (on a piece of cork). When he becomes interested in the obligatory parasites like fleas, lice, mites etc, he does not extend his research to general questions such as the parasitic infestation of agricultural crops, as Leeuwenhoek did. If he had possessed a microscope as powerful as Leeuwenhoek's, one that would have enabled him to discover oral bacteria, it is certain that he would have drawn no conclusions for oral hygiene. Hooke's gaze is neither particularly analytical nor causal or application-oriented. The results of his written and pictorial presentations of plants and animals represent breakthroughs in neither botany nor zoology. His strengths lie elsewhere (fig. 6).

Hooke is perhaps the strongest representative of the *res et verba* formula or the motto from Cato, *rem tene, verba sequentur*, which was held in such high esteem by the Royal Society.[71] He 'captures' the 'object,' namely the visual image, most precisely and lets the 'words' 'follow.' His written descriptions, as well, are superb examples of a scientific style of description. He is a master of scientistic ekphrasis. In word and image, Hooke aims for maximum morphological comprehension of a thing, a plant, an animal, and with such clarity that the function of the portrayed detail – the eye of a fly, an insect trunk – illuminating itself, as it were, enlightens the reader or viewer. Instead of proceeding from a causal-analytical model, Hooke takes a phenomenological-morphological approach to the aesthetically fascinating object (and

71 Both editors of the reprint of Sprat's history of the Royal Society emphasis this, referring to Howell and Williamson. Thomas Sprat. *A History of the Royal Society of London*. Ed., intro., and notes I. Jackson Cope and Harold Whitmore Jones. St. Louis and London: Washington University Press, 1959. XXIX-XXXI.

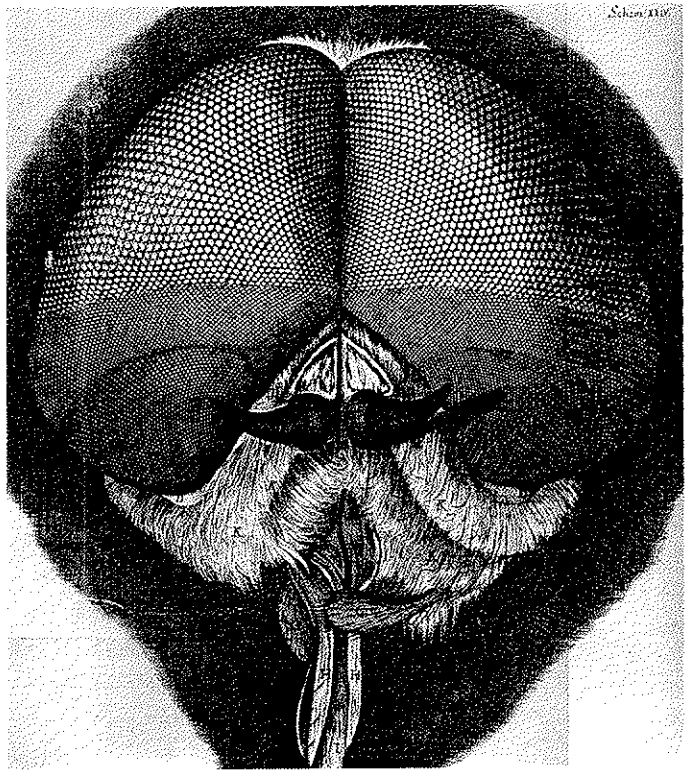

Fig. 6: Head of a grey drone fly with faceted eyes from Robert Hooke (London, 1667).

is thus closer to Goethe than to Newton).[72] Filled with an artist's marvel and obsession with presentation, Hooke takes visual evidence to the extreme and lets the written *descriptio* merge fully into the object that has become an image.[73] But there is yet more proof that Hooke is an experimental artist.

It must be shown that the *Micrographia* offers 'pictorial proof' with its perfect illustrations. Its aesthetic fascination is based on the elevation of the most mundane and negligible of things, a bit of cloth, a mite, a snow flake, a flea, the blade of a knife, the eye of a fly, a thistle leaf, to *nobility*. This enriches not only art and the senses, but also the reflecting consciousness. It changes the position of humanity. Things that

72 Goethe did not notice this. Cf. his rather derogatory characterisation of Hooke, in: Goethe. *FA*. Sec. 1, vol. 23/1, 741-42, 1053.

73 A first attempt in this direction is undertaken by John T. Harwood. "Rhetoric and Graphics in 'Micrographia.'" Schaffer, Hunter. *Robert Hooke*. 119-47.

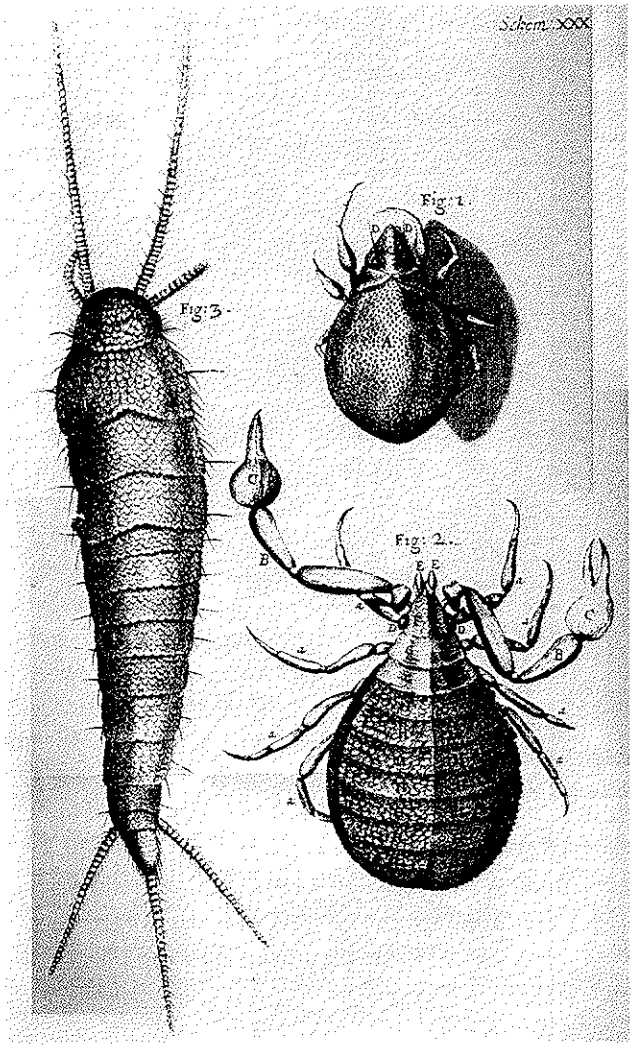

Fig. 7: Illustration of trombidiid and plant mites, a 'crab-like insect', that Hooke couldn't clearly determine (book-scorpion), and a 'silver-coloured bookworm' (silver fish). from: Robert Hooke *Micrographia* (London, 1667).

appear to be mundane are only so because of the blindness of our senses. Under the microscope, they reveal themselves as they really are: as art, *ars naturae*.[74] Never before, or at least not before the era of the

[74] The otherwise splendid volume from Ford does not even approach to this idea. Brian J. Ford. *Images of Science. A History of Scientific Illustration*. London: Oxford University Press, 1992. Just as naive in this regard is Harry Robin. *The Scientific Image: from Cave to Computer*. Historical foreword by Daniel Kevles. New York: H. N. Abrams, 1992. The situation is better in anatomy: K. B. Roberts and J. D. W. Tomlinson. *The Fabric of the Body: European Traditions of Anatomical Enlightenment Art and Medicine*. New York: Clarendon, 1992.

microscope, could the – for want of a better expression – artistic dignity of things appear in such a light as here. The microscopic not only humbles the senses, but with them also traditional knowledge and traditional art. The wealth of minute forms and constructions is a cabinet of curiosities that surpasses every human collection. It inspires not only the human progress of knowledge and civilisation, but also gives birth to an unforeseen artistic enthusiasm and aesthetic satisfaction unknown to the unaided senses (fig. 7):

> And I do not only propose this kind of Experimental Philosophy as a matter of high rapture and delight of the mind, but even as a material and sensible Pleasure. So vast is the variety of Objects which will come under their Inspections, so many different wayes there are of handling them, so great is the satisfaction of finding out new things, that I dare compare the contentment which they will enjoy, not only to that of contemplation, but even to that which most men prefer of the very Senses themselves.[75]

Too little attention has been paid to the fact that this empiricist, technician and curator of experiments of the Royal Society, who is given no opportunity to approach the scientific greatness of a Boyle or a Newton, develops a grandiose aesthetic programme here, one that belongs as much to the history of art as to science. *Micrographia* is not only the performative development of a scientific paradigm, it is also an artistic program, and both are oriented towards the civilizing utopia of enormously enhanced senses. Contained with the empiricism of the hour is a new Epicureanism, which is celebrated as a release from the anthropological constraints imposed by our physiological equipment. This is, first and last, the message of the images.

Translation: Elisabeth Neswald

[75] Hooke. "Preface." *Micrographia*. N. p. (= 23).

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