

Robert Hooke's *Micrographia* and the Aesthetics of Empiricism

Robert Hooke's treatise on the microscopic study of the minute, *Micrographia* (1665), presents itself as a systematic account of scientific observation. Contained in his eulogy on the improvements of optical lenses, however, is the question of how knowledge can be expanded: '[b]y the means of *Telescopes*, there is nothing so *far distant* but may be represented to our view; and by the help of *Microscopes*, there is nothing so *small*, as to escape our inquiry; hence there is a new visible World discovered to the understanding'.¹ Apparently a mere description of a glance through the microscope, 'the new visible World' not only claims to be an objective description of a minute landscape but the metaphor expresses the blurred boundary between empirical observation and the projection of imaginary ideas. The study of perception and representation were the means through which seventeenth-century philosophy made sense of what it might mean to be human. Descartes's argument that the potential for self-representation of the thinking subject proves that there is an irreducible core of existence uses as its point of reference the limits of cognition. The formula '*cogito ergo sum*' arrests the process of doubting the reality of the self by means of pointing to the mind's own capacity to conceptualise itself. By implication, the essential property of the mind is shown to reside in its faculty for representation.²

It is telling that philosophical forays into the limits of understanding are contemporaneous with the rapid improvements of microscopic lenses. Seeing and knowing were henceforth pushed into new dimensions. Novel insight into the minute structures of matter demanded that the relationship between the eye and the mind had to be reconceptualised and a better understanding of cognition threw doubt on whether anything could objectively be known. This essay analyses in detail the language which Robert Hooke uses to account for the visual experience of the microscope, comparing it to the style of Henry Power's slightly earlier work, *Experimental Philosophy* (1664). Hooke, particularly, spent his whole life on the attempt to remove the gnawing doubts concerning the existence of certain knowledge.³ The

difficulties posed by such a task, I argue, were perceived to be the result of the tension between scientific and aesthetic considerations. Focusing on the imagination as a vital factor in the understanding of the microscopic image, both Hooke and the contemporary critic of the microscope, John Locke, addressed the problem that the microscope challenged existing assumptions about perception and self-perception.

The empiricist's view

The Enlightenment brought forth countless treatises on aesthetics. They were attempts to enclose the aesthetic experience in empirically verifiable categories, while they were also preoccupied with the much more general analysis of perception. The endeavour to attain a better understanding of the self generated a great deal of interest in the link between the self and its environment established by sensory experience. The microscopist's quest for an objective account of the 'world' observed under the lens made it requisite to understand how the enlargement of the minute affected the psychology of perception. Studies pursuing this objective could easily endanger the whole epistemological edifice because questions about perspective and dimension immediately challenged the possibility of a stable point of view.

From its earliest days, the development of the microscope met a great deal of suspicion. The potential of enlarging its object, particularly in the case of the drop microscope, was rapidly improved after 1660, and the inventiveness of, above all, Jan Swammerdam and Antoni van Leeuwenhoek discovered means of seeing the physiological structure of minute objects such as blood globuli and spermatozoa.⁴ A further difficulty concerned the fact that the better the resolution of the lens, the less light was available to illuminate the image. Even if we leave aside technological problems, its character of being a machine for representation made the microscope into a fundamental threat to the correspondence between image and reality. By magnifying its object, the microscope not only brought the minutest details within reach of the human eye, but also produced an awkward contrast between a conventional and an altogether new sense of relative dimension, the existence of which had only just been discovered. While John Locke sought to explain how the human mind makes sense of the world (that is to say, how the self relates to the world), microscopy revealed that there are other worlds apart from this one. In other words, it showed that the world is quite different from how it was commonly experienced.

The microscope did not simply expand existing knowledge but subjected it to a radical revision. When he claims that 'there is a new visible World discovered to our understanding', Hooke is therefore highly aware that the microscopic perspective challenges conventional modes of understanding. The larger context in which he makes this claim reads as follows:

By the means of *Telescopes*, there is nothing so *far distant* but may be represented to our view; and by the help of *Microscopes*, there is nothing so *small*, as to escape our inquiry; hence there is a new visible World discovered to the understanding. By this means the Heavens are open'd, and a vast number of new Stars, and new Motions, and new Productions appear in them, to which all the antient Astronomers were utterly Strangers. By this the Earth it self, which lyes so neer 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. (sig. b1v)

Hooke points out that optical lenses reveal altogether new dimensions. The idea of there being a formal resemblance between 'particle' and 'Universe', which he broaches implicitly, shows that he believes that even while the existence of radically different dimensions unsettles our experience of space he also counts on their respective structures being essentially accessible to our understanding: drawing on a commonsensical response towards the world, he implies that it is irrelevant how many universes are contained in a particle as long as the general idea of what it is like is grasped.

Interestingly enough, as John W. Yolton explains, '[f]or Hooke the eyes were not only our special access to the world, they were a "Microcosm, or a little World", a duplicate of the outer world'.⁵ He not only draws upon the eye's role of forming a self-contained representation of the world but he also posits that it possesses a special link with the mind. A further implication of this is, as Yolton puts it, that '[w]ith his notion of the eyes providing the brain with hands to touch objects, Hooke's optics give us something close to direct realism. At least we have a "perfect Picture, or Representation of all outward Objects"'.⁶ J. J. Macintosh shows that Hooke further developed the theories of vision proposed by Descartes and Boyle and was indeed among the most radical materialists of his time.⁷ Hooke credits perception (the privileged link between eye and mind) with the faculty of judging visual impressions, which view also demonstrates that he understands the microscope as a direct extension of the eye: the important point is that vision is subject to reason, irrespective of whether it is mediated by artificial means or not. The dimensionally distorting effect of the microscope, therefore, does not strike him as disturbing; he optimistically celebrates its potential and talks about the 'new visible World discovered to the understanding', portraying it as an unproblematic means to extend previous knowledge. I will return to his engagement with the more sinister implications of this idea.

The choice of the term 'a new visible World discovered to the understanding' is telling in itself and at this point I want to examine its range of meanings. At its literal level, it states that the optical instruments provide help in overcoming the limited faculties of the senses. Thus he explains that he made use:

of *Microscopes*, and some other *Glasses* and *Instruments* that improve the sense; which way I have herein taken, not that there are not multitudes of useful and

pleasant Observables, yet uncollected, obvious enough without the helps of Art, but only to promote the use of Mechanical helps for the Senses, both in the surveying the already visible World, and for the discovery of many others hitherto unknown, and to make us, with the great Conqueror, to be affected that we have not yet overcome one World when there are so many others to be discovered, every considerable improvement of *Telescopes* or *Microscopes* producing new Worlds and *Terra-Incognita's* to our view. (sig. d2r–elv)

Hooke parades the argument that ‘Mechanical helps’ improve the sense of perception but he is also conscious that there are strong objections to their use. His emphasis on the aesthetic aspect of studying ‘useful and pleasant Observables’ which do not require specially designed instruments implies a differentiation between the serious scientist and the amateur. Hooke was to become increasingly aggravated by the contemporary fashion for using the microscope as a means of examining the otherwise invisible structures of, for example, hairs and feathers for the sake of pleasure rather than knowledge.⁸ In a lecture delivered in February 1691/2, he complains bitterly that except for ‘Mr. Leeuwenhoek ... I hear of none other that make any other Use of that Instrument, but for Diversion and Pastime, and that by reason it is become a portable Instrument, and easy to be carried in one’s Pocket’.⁹ In *Micrographia*, though, he appears to argue that it is both pleasurable and useful to investigate the minute structures of nature as a means of emphasising how pleasurable it is to expand one’s knowledge. Catherine Wilson remarks that ‘what was said and done [in the Royal Society] between 1665 and 1675 was predominantly unscientific by modern standards: that the interest was antiquarian or virtuosic or amateurish’.¹⁰ It makes little sense to evaluate the scientific activities of the early Royal Society by modern standards. What is important is that its more or less random collection of quantifiable data contrasted dramatically with the tidy project of Aristotelian qualitative analysis, which suggests that Hooke is above all criticising the Royal Society for its amateurish procedures, and demanding that science should follow a more ordered path of investigation.

Now let us return to the statement that he uses ‘*Instruments* that improve the sense’: apart from the obvious meaning of overcoming the limits of the physiological capacity of vision, it also alludes to Francis Bacon’s claim that the fallibility of the human mind can be kept under control by means of ‘instruments’. What Bacon means by the term, of course, is a methodological approach which he describes at great length in his theoretical masterpiece *Novum Organum*, the title word ‘organon’ recalling Aristotle’s famous work of that name whose title translates as ‘instrument’ or more specifically ‘instrument of reasoning’.

Bacon’s narrator boasts in *New Atlantis*: ‘Wee have also Helps for the Sight, farre above Spectacles and Glasses in use. Wee have also Glasses and Meanes to see Small and Minute Bodies, perfectly and distinctly’.¹¹ But in the section on the Idols of the Mind, Bacon also warns against the potential of

optical instruments. Even though the microscope had not yet achieved the status of a properly functioning instrument in his lifetime, he still demonstrates awareness of its problematic role as a tool to write an objectively true account of natural history. He says:

For the sense in itself is a weak thing and prone to aberration, nor are instruments for magnifying or sharpening the senses of much use. But all truer interpretation of Nature is built up from instances, and adequate and suitable experiments, where the sense judges only of the experiment, the experiment of Nature and the thing itself.¹²

Bacon's emphasis on the 'thing itself' indicates that his view of the existence of an objective reality is defined *in relation* to the human observer. So he examines the world as it is perceived by the human sensory system. For his theory of how the erroneous elements of sensory perception can be kept to a minimum, he must argue that human experience can be ordered, or reflected on, according to firmly defined standards. The inductive method, his proposed solution for how to subject the senses to reason, therefore, is a means of mechanising the unconscious processes of perception or as Catherine Wilson puts it, '[t]he inductive method is the necessary device for dehumanizing the inquiry'.¹³

If human identity is defined through the senses, and if sensory perception is defined in relation to the world perceived, then an instrument for sharpening the senses also affects one's self-perception and challenges the notion of a stable identity. Hooke is intensely aware of the impact of the microscope on the self-perception of the scientist. He says that '[t]he next care to be taken, in respect of the Senses, is a supplying of their infirmities with *Instruments*, and, as it were, the adding of *artificial Organs* to the *natural*' (sig. a2r). What might come across as a threat that an artificial aid turns into a part of the body which alters its overall response to self and world, is treated as an instance of scientific progress. As part of his project of refining the physiological side of sensory refinement, his optimistic attitude suggests that he does not recoil from the idea of reinventing the body.

If we compare Bacon and Hooke once more, we notice that Bacon's metaphorical instrument of reasoning is reified into a literal instrument.¹⁴ But the instrument, of course, does not do away with the necessity of the mind exerting rigid control over these responses. While Bacon took reason to be the only instrument required, Hooke claims that reason cannot work as a kind of self-sufficient motor but needs to work through the machinery developed by the triumphal progress of science. The language of colonial expansion projected on to the discovery of the new worlds was already a strong element in Bacon's work and is eloquently underlined in the frontispiece of his *Novum Organum*: ships are sailing out between the columns which defined the boundaries of the old world, as a statement that knowledge aspires to new frontiers and thus presents an analogy to Britain's expansionist politics. In his

perceptive interpretation of the frontispiece, A. D. Burnett argues that the iconography which Bacon chose for the representation of scientific progress encapsulates a complex theory of sensory perception. It advertises the idea that science, similar to the expansion of the known world emblematised by the ships, harbours immense commercial possibilities. Apart from this it also implies that reasoning follows analogical principles. Bacon's 'metaphorical mode of knowledge', as Burnett calls it, marks him out as a Renaissance scholar who maintains a pre-modern understanding of cognition and who has not yet drawn a dividing line between an imaginative recognition of similarities – or analogies – and a 'neutral' scientific description of differences.¹⁵ The struggle between a metaphorical and a prosaic mode of description surfaces in the 1660s when Hooke's *Micrographia* seeks to correct the enthusiastically descriptive approach of Henry Power, that is to say when Hooke calls for a language of scientific description reflecting a manner of observation which M. A. Dennis calls 'disciplined seeing'.¹⁶ Even if, as Lotte Mulligan argues, Hooke's aspirations are exaggerated and he is ultimately unable to formulate a methodological programme with which to achieve certain knowledge, he was nevertheless deeply preoccupied with the question concerning the nature of science and the role of the scientist.¹⁷

In the preface to *Micrographia*, Hooke, like Bacon, strongly objects to the customary manner of studying nature, which he declares to have 'been already too long made only a work of the *Brain* and the *Fancy*: It is now high time that it should return to the plainness and soundness of *Observations* on *material* and *obvious* things ... Philosophy, by wandering far away into *invisible Notions* has almost quite destroy'd it self' (sig. b1r). He pits a desired revelation of the true nature of very small bodies against the objectionable untruths contained in '*invisible Notions*'. There is a strong rhetorical contrast between the immaterial (and hence invisible) nature of ideas and the material nature of the minute features of the natural world. The ambiguity of the term 'invisible' (something which cannot be seen because it is either too small or is not material at all) underlines this dichotomy. The ambivalent meaning of 'invisible' indeed is a moot point which demonstrates the Cartesian objection to the use of the microscope because, as Ruestow formulates it, they 'expected comprehensibility to rest on an understanding of the most basic level of natural processes, which they insisted no observations could reach'.¹⁸

A central issue in the pursuit of microscopic studies is the manner by which the self conceives an idea of itself; how it understands itself in proportional relation to its environment. Such a self-perception, in turn, affects the faculty of understanding. This is why the 'new visible World discovered to the understanding' inaugurates a persona for the natural philosopher which is almost coextensive with the meaning of the nineteenth-century term 'scientist'. M. A. Dennis reduces Hooke's hermeneutics to the formula that '[s]eeing and representing was understanding',¹⁹ and claims that whether the scientist could command the modes of representation recognised by the

Royal Society and its audience decided his social acceptance. That is to say, his success depended on whether he was able to fit his self-consciousness about scientific method into a standardised procedure. An interesting detail is that in the two passages where the term 'new World' occurs, one talks about it as having been *discovered* and the other as having been *produced*. So even while he calls for an unembellished mode of description, Hooke's language expresses ambivalence as to whether knowledge is like a real world that is being discovered or a fictional world that is being invented. So there is an ambiguity as to whether this 'new World' is of the order of a matter of fact which can be subjected to the categories of the old world or whether the 'new World' (as either a real or an imaginary place) defeats the old world's capacity of classification.

The chief problem concerns intelligibility. Poor conditions of visibility made it urgent to ask whether new discoveries were genuine or produced by preconceived ideas, or by the bad lighting of the object of observation. That the 'new Worlds' may not be compatible with the conventional categories of classification is a problem which grew increasingly important at the time. In an attempt to avoid forcing the description of new fields of knowledge into an old and reductive grid, the Royal Society advocated a rigorous reform of the modes of representation. The more they became aware that the ideal of a neutral and unbiased form of representation did not exist, however, the more avidly they searched for it.

The language of observation

A comparison between Henry Power's first treatise on the microscope and Robert Hooke's redefinition of the task as a systematic pursuit (into a discipline in the twentieth-century sense of the term) illustrates what is involved in the struggle to understand the impact of rhetoric on scientific representation. Power's account of microscopy is the first work of its kind. Like Hooke after him, Power spends a lot of time in his preface celebrating the cleverness of recently developed optical instruments: 'modern Industry ... hath discover'd this advantageous Artifice of Glasses, and furnish'd our necessities with such artificial Eys, that now neither the fineness of the Body, nor the smallness of the parts, nor the subtility of its motion, can secure them from our discovery'.²⁰ The enthusiastic manner in which Power uses the term 'artificial Eys' shows that he is comfortable with the idea that optical instruments supplement the 'natural' body and equip it with a mode of vision that is not otherwise available to it.

In the process of discussing the significance of point of view in his preface, Power discusses the visual potential of the microscope by means of comparing the object of scientific analysis to a theatrical spectacle:

However, this I am sure of, That without some such mechanical assistance, our best Philosophers will but prove empty Conjecturists, and their profoundest Speculations herein, but gloss'd outside Fallacies, like our Stage-scenes, or Perspectives, that shew things inwards, when they are but superficial paintings.²¹

His indignation is directed at the contemporary fascination for rhetorical make-believe and theatrical illusion and he is worried that the fanciful devices of *trompe-l'oeil* take the place of serious scientific issues in the imagination of his contemporaries. What irritates him, above all, is the attitude according to which scientific questions are treated as a mere pastime. Against this background, he attacks the contemporary natural philosopher for falling prey to the dictates of fashion. In other words, speculation is as objectionable as toying with techniques of illusion, and consequently Power does not simply decry speculation for its incapacity to reveal any genuine truths, but also indicts the followers of speculative philosophy as charlatans and mountebanks whose only purpose is deception.

Power's reference to 'Perspectives, that shew things inwards, when they are but superficial paintings' juxtaposes nature with art by implying that it is not only art which, with elaborate techniques such as *trompe-l'oeil*, deceives the senses. However, Power also draws on the idea that nature does not want to deceive, and a contrast is established between a nature which 'wants' to be investigated and recognised and an art which draws the spectator into its play with illusion. Or rather, Power implies that a lack of the relevant optical instruments puts art and nature into a similar position and it is only those who are properly equipped with mechanical aids who can escape being dupes of illusion. While he uses the idea of theatrical make-believe to censure the conjecturists, the reference is peculiarly suited to convey the experience of what it is like to explore the minute patterns of nature. The comparison, moreover, reminds us of the self-conscious play with illusionary spaces demonstrated by contemporary painting which served the purpose of exploring the nature of space, rather than that of deceiving the spectator. Particularly as regards its self-conscious attempt to understand the position of the observer, it provides an evocative description of what it feels like to be a natural philosopher. Even while he is saying that *without* 'mechanical assistance, our best Philosophers will but prove empty Conjecturists, and their profoundest Speculations' will be comparable to 'our Stage-scenes', he acknowledges that there is an analogy between scientific observation and art.²² The manner in which he refers to illusion demands that we think about the role played by imagination in our responses to art and life. On the surface he may feel that the analogy between art and science trades illusion for objectivity. However, the parallels between science and art are drawn more strongly when we realise that the interpretation of what is seen under the microscope into spherical shapes, crevices or elevations, was indeed one of the most difficult tasks. These problems remain unexpressed – Robert Hooke admits

them circuitously by blaming Power for having arrived at a false conclusion – but awareness of their significance explains why Power sought to distance himself so strongly from illusions. While he rejects any resemblance between microscopy and an engagement with the art of perspective, he nevertheless takes on board the notion of nature as a theatrical spectacle.

Here it is worth remembering that the increasing fascination of the age with illusionary devices and deceptions of the senses was a parallel development to the loss of belief in the existence of an unbiased perspective in science and philosophy. The aesthetic dimension has its attractions for Power – his eulogy on the beauty of what he sees testifies to this – but when he draws his unfavourable parallel between the theatre and scientific observation, he struggles with the fact that the interpretation of what is seen both depends on one's previous experience and is guided by aesthetic categories. By distinguishing between a bad practice, according to which the truth of the minute structure of nature figures as a spectacle, and a good practice, which reveals the truth about nature, he contrasts an unattainable ideal with the existing situation. That he uses the reference to art to indict what he considers to be bad practice, is a rhetorical ploy to discourage any further pursuit of his comparison between science and art. If we explore it more closely, however, we note that the period sought to exclude from science the emotional response typically belonging to art. Lorraine Daston and Katherine Park argue that the wish to subject science to the dictatorship of reason suppressed the sense of wonder which had previously characterised the response to natural phenomena such as comets and monsters. Suppressing the marvellous element in the workings of nature, that is to say, rejecting the idea that nature brought forth objects whose sole purpose it was to breach the conventional rules, required a new understanding of the self and its capacities of knowing.²³

The microscope significantly contributed to destabilising conventional truths, particularly as they related to the perception of self. Before I delve into these issues any further, I want to examine the choice of style in Power's *Experimental Philosophy*. Even while he advocates an objective study of nature, a line of argument which Robert Hooke will then pursue further, and demands that the bad practice of conjecture be abandoned, his own style is by no means neutral. While his metaphors betray unwarranted projection of his expectation, or as Dennis formulates it, 'a failure to practice disciplined seeing',²⁴ they also gesture towards a psychological analysis of what it feels like to look through the microscope.

In spite of the scientific-sounding title, Power's *Experimental Philosophy* is written in a poetic style and it comes as no surprise that he also published a poem on the microscope.²⁵ His scientific observations are permeated by anthropomorphisms and a sense of empathy stimulates admiration for those small creatures which are commonly treated with contempt. His descriptions strike the tone of good-humouredly marvelling at the unexpected. A

metaphoric style which transcends the utilitarian perspective and touches upon the question of what it feels like to possess the physical characteristics of, for instance, a flea may be anathema to the ideal of a neutral scientific language; but it is a stylistic recipe which lends itself ideally to questioning the relationship between observer and that which is being observed, or in other words, between subject and object.

The description of the flea introduces Power's treatise, or rather, his collection of observations. It begins as follows: 'Of the Flea. It seems as big as a little Prawn or Shrimp, with a small head, but in it two fair eyes globular and prominent of the circumference of a spangle ... most admirable to behold'.²⁶ The simple statement that the flea 'seems as big as a Prawn or Shrimp' indicates the optical resolution of the lens; in psychological terms, it places the commonly scarcely visible flea on a different level of importance. That the flea occupies the first place in Power's examples is warranted not only by the fact that it was indeed found to possess a remarkable body but also because it had long been symbolically central. With the improvement of optical instruments, vision, the master sense of the Enlightenment, was now enabled to take a close look at those objects associated with the unwholesome aspects of the body; and of course, anything denoting physicality possessed strong moral overtones in which were mingled a guilty fascination with sexuality, disease and poverty. Now that disgusting creatures like the flea were available in visual form – rather than only perceptible by one of the more immediate senses like touch and smell – they became acceptable as matters for discussion by a 'polite' society which had previously striven to place their existence under a taboo of silence.²⁷ It is not simply because of the aesthetic effect of the flea's 'two fair eyes globular and prominent of the circumference of a spangle' but it is also for its connotations that it is 'most admirable to behold'; the term 'wonderful' underlining its remarkable nature, rather than praising its beauty.

Preoccupation with appearances, rather than scientific objectivity, characterises Power's work. To illustrate his use of metaphor to describe his observations, I will quote another extract from the analysis of the flea:

He has also a very long neck, jemmar'd like the tail of a Lobstar, which he could nimbly move any way. His head, body, and limbs also, be all of blackish armour-work, shining and polished with jemmar's, most excellently contrived for the nimble motion of all parts: nature having armed him thus *Cap-a-pe* like a Curiazier in warr, that he might not be hurt by the great leaps he takes. To which purpose also he hath so excellent an eye, the better to look before he leap: to which add this advantageous contrivance of the joynts of his hinder legs which bend backwards towards his belly ... that he might thereby take a better rise when he leaps.²⁸

Rich metaphorical imagery is paired with an unreserved expression of his fascination; not only with the little creature itself but first and foremost with the ingenuity of nature that bothers to furnish its diminutive beings with such

precision and such intelligence. His style is that of describing a toy house. While he seeks to bring us closer to his object of observation, he corroborates the fiction of our access to the life sphere of this small creature and he demands that we empathise with the daily necessities in a flea's life and even try to get some inkling of what it feels like to be a flea.

Power creates a deeply anthropomorphised psychology of nature: he not only draws us into imagining the life world of this other dimension but he invites us to share in his interpretation of *nature's plots*. When he goes beyond mere description and seeks to give us the reasons why things are as they are, he speculates about the causality which determines the particular appearance of the flea. The idea of the flea armed 'Cap-a-pe like a Curiazier in warr' is a pretty image that is extremely well suited for visual representation. While it is not far removed from E. T. A. Hoffmann's description of the flea in the Romantic story 'Master Flea' (1822) in 'beautiful golden boots with diamond spurs',²⁹ it is nevertheless couched in the rhetorical marker 'like', which indicates that this is a simile, or a mental image, and not a literal truth. Because comparisons always work both ways (not only is the flea like a Curiazier but the Curiazier is also like a flea) the conventional point of view is destabilised and it does not take much for the imagination to run riot. Through its engagement with the perceptual dimension of the flea, human and insect qualities are confused, so that the observer gets caught in the fantastical world of the microscope: or rather, by giving free rein to the imagination, the observer loses the capacity of distinguishing between truth and fiction and thus the world of the microscope becomes fantastical. It was meant as an instrument that would reveal the true nature of those realms that are not naturally available to the human perceptive organs and it turns into an instrument that produces fictional accounts of the relationship between the human being and the world, in its different dimensions and guises. While the microscope began as an instrument that was meant to open novel perspectives and improve the understanding of the world, the impossibility of evaluating the new findings objectively requires that we have recourse to our imagination. So the world observed comes across as a projection of the mind and the microscope corroborates doubts concerning whether the world exists, except in the mind.

Hooke's theories of perception and knowledge

Robert Hooke shows himself highly aware of the problems resulting from Power's approach and even while he demonstrates skill in satisfying the aesthetic desires of his readership,³⁰ he spends a lot of energy on the attempt to exert control over the influence of imagination on science. In the context of discussing new optical developments in his much later 'Discourse concerning Telescopes and Microscopes' (1691–62), he explicitly addresses the status of

the knowledge gleaned from improvements in optical technology. He argues that the improvement of telescopes and microscopes will not only make possible the project of:

perfecting and compleating the Knowledge of those Particulars which have been already, in Part, detected; but also for making of other new Discoveries, which as they are yet much further removed from the Power of the Senses to comprehend, so they have been, upon that Account, never afforded Entrance into the Imagination and Intellect; if at least *Aristotle's* Maxim be true, That there is nothing in the Intellect, but what was first in the Sense: And tho' there are many Things that may be imagined, and guessed at, by Analogy, and the Uniformity of the Proceedings and Productions of Nature; yet there are certain Non-Pareils of Nature, of which Kind, possibly, nothing like them have been produced in all those Particulars, which are more common and obvious ...³¹

This is a crucial passage which demonstrates the problems stemming from Hooke's attempt to reconcile a strictly materialist theory of the world with an immaterialist view of mental processes. He subscribes to empiricism and makes no attempt to refute the maxim that 'there is nothing in the Intellect, but what was first in the Sense'; yet he qualifies the core principle of empiricism by claiming, as Mulligan describes it, that knowledge has an 'empirical base'.³² For Hooke, it is not good enough to locate the origin of thought processes in sense experiences; he wants to explain the intermediary processes. His major revision of empirical methodology concerns analogical thinking. He fully accepts the idea that there should only be one epistemological method of reasoning, but so as to achieve new insight, it is necessary, as Mulligan formulates it, to move 'from the "seen" to the "unseen" – from the senses to the realm of the abstract, but at each step empirical reference was imperative'.³³ His attempt to produce certain knowledge, therefore, was an attempt to rationalise the interpretation of sense experience by means of emphasising the sensory foundation of mental processes.

In his preface to *Micrographia*, Hooke discusses technological problems resulting from the still very limited optical capacities of seventeenth-century microscopes at the same time as he engages with an epistemology of perception:

For it is exceeding difficult in some Objects, to distinguish between a *prominency* and a *depression*, between a *shadow* and a *black stain*, or a *reflection* and a *whiteness in the colour*. Besides, the transparency of most Objects renders them yet much more difficult then if they were opacous. The Eyes of a Fly in one kind of light appear almost like a Lattice, drill'd through with abundance of small holes; which probably may be the Reason, why the Ingeneous *Dr. Power* seems to suppose them such. In the Sunshine they look like a Surface cover'd with golden Nails; in another posture, like a Surface cover'd with Pyramids; in another with Cones; and in other postures of quite other shapes; but that which exhibits the best, is the Light collected on the Object, by those means I have already describ'd. (sig. g1v)

Refraining from the aesthetic lures of pyramids, cones and regular lattices is one thing, but gaining objective insight into the 'real' structure of a fly's faceted eyes is quite another. Accurate interpretation of the landscape observed under the microscope not only requires a carefully crafted machinery but also a particular methodology of looking. This is why Hooke repeatedly returns to the fact that he carried out his experiments under different lighting conditions. He implies that an eye which is accustomed to the difficulties involved in figuring out the three-dimensional quality of the observed microscopical image – one that has mastered disciplined seeing – will not be duped by appearances. A striking fact is that even while he draws attention to the difficulties of interpreting what is seen under the microscope, he downplays the daily problems of microscopic studies and disguises the fact that his conclusions were based on images which were blurred both because of the quality of the lenses and the fact that the eyes watered easily during the process of trying to determine the true nature of the objects of observation. Hooke reduces the complex of problems to the single argument that the deceptive nature of appearances can be circumvented by means of changing the contextual factors of the individual act of observation. Implied in the description of his experimental set-up of his microscopic studies is the claim that microscopy, or a certain method of conducting microscopic experiments, is an exercise with which the senses can be subjected to reason or, as Steven Shapin and Simon Schaffer describe the situation, '[s]cientific instruments therefore imposed both a correction and a discipline upon the senses. In this respect the discipline enforced by devices such as the microscope and the air-pump was analogous to the discipline imposed upon the senses by reason'.³⁴

Hooke's treatise presents itself as a rational analysis of knowledge. As is illustrated in the following claim, he is committed to promoting the growth of knowledge: 'the *Arts* of life have been too long *imprison'd* in the dark shops of the *Mechanicks*, & there *hindred from growth*, either by ignorance or self-interest' (sig. g2v). But then he also seeks to place contemporary knowledge into perspective and to examine it in relation to the social and political parameters which determine its precise shape. This self-conscious and self-critical stance helps us understand why the dedicatory epistle of *Micrographia* to King Charles II, the patron of the Royal Society, concludes with the following statement:

Amidst al those *greater* Designs, I here presume to ... offer some of the *least* of all *visible things*, to that *Mighty King*, that has *establish't an Empire* over the best of all *Invisible things* of this World, the *Minds* of Men.

Hooke structures his treatise as a contrast between the visible and the invisible. While the eulogy to Charles II praises (or indicts) him for possessing unlimited power over his subjects, this passage also celebrates the empire of reason. Although Hooke will not explicitly pursue this line of thought, he implies that there are ways and means to lay bare the structures of the mind,

as exemplified by the micro-structures of experience. What is only implied in *Micrographia* is that, analogously to how the scientist uses the microscope to reveal what is invisible to the bare eye, the perceptive thinker figures out the structures of a political hierarchy. The massive success of Hooke's work, therefore, is not only owing to its highly detailed microscopical studies but also to its tacit claim that there are no secrets from the rational mind, especially if it is assisted by mechanical tools capable of overcoming the limits of human perception.

So as to emphasise the mandates of progress, Hooke begins his preface as follows:

It is the great prerogative of Mankind above all other Creatures, that we are not only able to behold the works of Nature, or barely to sustain our lives by them, but we have also the power of *considering, comparing, altering, assisting,* and *improving* them to various uses. And as this is the peculiar privilege of humane Nature in general, so is it capable of being so far advanced by the helps of Art, and Experience, as to make some Men excel others in their Observations, and deductions, almost as much as they do Beasts. (sig. a1r)

From the very beginning of his treatise, Hooke makes it clear that he is engaged in an epistemology of perception and representation. He alludes to the old dispute concerning whether nature or art holds the position of supremacy but leaves no doubt that a proper understanding of nature requires help from art. 'Art' as he uses the concept is almost coextensive with reason, or the faculty of reasoning. The grammatical symmetry within the sentence between 'Art' and 'Experience' illustrates that he differentiates between a natural, and hence uncouth, state of existence and a cultivated state in which the human mind reflects on its experience and strips it of the random influence of the passions. He privileges interpretation over the objects of observation in themselves, because observation requires a disciplined evaluation of what is seen: when he contrasts 'to behold the works of Nature' with 'the power of *considering* ... them', he implicitly demands that a scientific perception of nature consists of the act of self-consciously questioning one's impressions.

In the next paragraph, he even talks of 'rectifying the operations of the Sense, the Memory, and Reason'. The idea that the senses are deceptive is certainly not new (it goes back to Sextus Empiricus and the earlier sceptics); what is new is that the assistance of scientific machines is posited as a means of eradicating sensory arbitrariness. The microscope, the artificial aid implied here, is presented as an instrument of verification that disentangles knowledge from the deceptiveness of the senses. His argument is similar to Power's call for 'microscopical Eys'. But he is much more insistent that the rational mind of the observer needs to be in control, thus following Bacon's call for an intellectual instrument with which to teach inexperienced newcomers to the field and to make sure that they do not respond naively to the objects of their observation.

So what is the methodology according to which *Micrographia* contrasts the regularity of natural patterns with the imperfections inherent in representation? The very first observation, which concerns the sharpness of the point of a needle, serves to remind the reader of the erroneous nature of conventional sense perceptions:

Now though this point be commonly accounted the sharpest (whence we would express the sharpness of a point the most *superlatively*, we say, As sharp as a Needle) yet the *Microscope* can afford us hundreds of Instances of Points many thousand times sharper: such as those of *hairs*, and *bristles*, and *claws* of multitudes of *Insects*; the *thorns*, or *crooks*, or *hairs of leaves* and other small vegetables ... [his emphases] (p. 2)

When Hooke begins his treatise by dismantling the conventional figure of speech 'As sharp as a Needle', he subjects language to his analytical machinery and reveals that the comparison might have its subjective validity while it is far from accurate in objective terms.

His strongest indictment of a mistaken view of things concerns the printed point, the full stop:

I found ... the most curious and smoothly *engraven strokes* and *points*, looking but as so many *furrows* and *holes*, and their *printed impressions*, but like *smutty daubings* on a matt or uneven floor with a blunt extinguisht brand or stick's end. [his emphases] (p. 3)

When he scrutinises the full stop through his glasses and discovers with dismay that the printer's marks are an utterly imprecise business, he does not simply despoil them of their artistic neatness: he dismantles the aura surrounding print and the linguistic medium of representation.³⁵ He says that 'a very ordinary *Microscope* ... inabled me to see that what the Writer of it had asserted was *true*, but withall discover'd of what pitifull *bungling scribbles* and *scauls* it was compos'd ...' (p. 3). It is by no means accidental that the text which is analysed for its quality of print should be taken from the Bible. When Hooke remarks that he found the contents of his chosen example to be true, he offers a coy caveat to protect himself against sacrilege. The very fact that he introduces discussion of truth shows him to be engaged in fundamental questions concerning objectivity. His close examination of the medium of print reveals it to be no more than a loose approximation. When the dirty and sloppy essence of the printer's art is compared to nature's precision, Hooke implies, there must be such a thing as truth. That it is notably absent from representation suggests that the rationality which uncovers it is outside language. But then, truth (true observations) can only be communicated through language and however rough they may be as approximations, metaphors like 'as sharp as a needle' are indispensable for our orientation in our everyday life.

John Locke's *An Essay Concerning Human Understanding* contains a telling objection to the microscope as an instrument for the study of nature.

Incorporated into a detailed discussion of the boundaries between real and imaginary substances, Locke discusses the possibility, or usefulness, of mechanical devices for sensory perception. Slightly later than Robert Hooke's eulogy on the possibilities of refining the capacity of the senses, Locke scathingly dismisses 'those learned quick-sighted men, who look so deep into them [the substances], and talk so confidently of something more hidden and essential'.³⁶ What he indicts, first and foremost, is the implicit claim of the microscopists that they have discovered the truth about material essences, and his satiric bite is directed against their claim of possessing privileged insight into the nature of things. Locke is arguing against people like Malpighi who used the microscope as a tool to prove his thesis that the body was 'an ensemble of micromachines whose true structures and operations are invisible to normal vision', an argument which rewrites Cartesian theory to the effect that the physiological principles which structure the body are themselves of a material nature.³⁷

Another dig at the pretensions of the microscopists is woven into Locke's detailed discussion of 'our faculties of discovery'. He says:

Nay, if that most instructive of our senses, seeing, were in any man a thousand or a hundred thousand times more acute than it is by the best microscope, things several millions of times less than the smallest object of his sight now would then be visible to his naked eyes, and so he would come nearer to the discovery of the texture and motion of the minute parts of corporeal things; and in many of them, probably, get ideas of their internal constitutions. But then *he would be in quite a different world from other people*: nothing would appear the same to him and others; the visible ideas of every thing would be different. So that I doubt whether he and the rest of men could discourse concerning the objects of sight, or have any communication about colours, their *appearances* being so wholly different. And perhaps such a quickness and tenderness of sight could not endure bright sunshine, or so much as open daylight; nor take in but a very small part of very near distance. And if by the help of *such microscopical eyes* (if I may so call them) a man could penetrate farther than ordinary into the secret composition and radical texture of bodies, he would not make any great advantage by the change, if such an acute sight would not serve to conduct him to the market and exchange. [my emphases]³⁸

This passage makes an attempt to conceptualise the experience of looking through a microscope. In the above passage, Locke is stepping outside the boundaries of science proper and investigating the psychology of microscopical vision. In *An Essay on Man*, Alexander Pope explores the implications of the sharpening of the senses effected by the microscope on the experience of the conventional human dimensions in:

Why has not Man a microscopical eye?
For this plain reason, Man is not a fly.
Say what the use, were finer optics given,
T'inspect a mite, not comprehend the heaven?³⁹

In *The Rape of the Lock*, Pope structures an elaborate social drama around the question of what happens if the minute details are on the conventional scale of human perception.⁴⁰ The fantastical world in which the conventional human scale has been breached inspired Pope's best poetry. Its frightening potential, as Locke was already to realise, is due to the fact that such a perception of reality does not lend itself to reasoned judgement.

The idea that the microscopists become incapable of orienting themselves in the conventional world is one whose comic potential was explored at length in contemporary literature.⁴¹ Locke objects to exactly the same ineptitude at following ordinary occupations as the satirists when he indicts microscopy because it privileges detail to a dangerous degree and by so doing loses the commonsensical level of abstraction. The term 'microscopical eyes' shows awareness that the visual aid becomes a part of the body of the microscopist and Locke, unlike Power before him, radically objects to the idea, claiming that the microscope's effect of sharpening the senses reduces the powers of the mind. For Locke, understanding is a relationship between the mind of the observer and the world observed; if this relation is unbalanced, it may be possible to gain better vision of minute parts but that involves a loss of the ability to see through appearances and to reflect upon the ideas of the senses. Optical instruments, he therefore concludes, lead us to forget the differences between reality and appearances.

Interestingly enough, Locke uses the same idea as Hooke when he says that the person looking through a microscope 'would be in quite a different world from other people'. While Hooke is fascinated by the thought of exploring these new terrains, Locke reduces these new worlds to a source of trouble: he says that the microscopist does not simply study their precise shape but indeed inhabits its other dimension. Drawing on the assumption that what you see determines how you understand yourself and the world you move in, he warns against venturing into new realms of vision because, as he puts it, then 'the visible ideas of every thing would be different'. If we all inhabited different worlds, we would no longer be able to arrive at a consensus about the nature of our field of experience and hence would no longer be able to communicate. So as to maintain a shared system of meaning, he claims, we need to have a shared realm of experience. That the 'visible idea of every thing would be different' contains the fear that the description of observed facts might be reduced to aesthetic impressions. The term 'visible idea' thereby reduces the essence of a substance to a superficial appearance and leads to a collapse of the representational capacity of language. Locke's motive for opposing the claims implied by Hooke's hermeneutics depended on his claim that the senses did not have the power to convey direct knowledge of the essential nature of things.⁴² The dispute ultimately boiled down to the point that Hooke claimed that a certain disciplined approach to experimentation and observation could overcome shortcomings of the senses. Locke objected to this notion so virulently because he interpreted Hooke's

disciplined method, not as a reasoned reflection on sense experience, but as a system by which it is the senses which reflect on sense experience.

While he was aware of the objections which Locke was to articulate, Hooke, of course, refused to abandon microscopy; or indeed decided that what was needed was an epistemology and a hermeneutics that could teach the human mind how to attain different spatial dimensions without losing its sense of identity. In his later work, 'Lectures of Light', therefore, Hooke engages with the problem at length. He begins with a discussion of why Descartes introduced the term 'indefinite' as a means of qualifying the meaning of the term 'infinite', explaining that 'indefinite' 'differs only from infinite in this, that the one has absolutely no Bounds or End, and the other that it can have none assigned'.⁴³ Apparently establishing a differentiation between two genuinely different matters of fact, he extends his argument from referring to aids for the senses to aids for the imagination. He specifies the indefinite as the category of those items which are 'beyond our reach to conceive'. But he offers his own version of a theory of induction which pushes the boundary of that which can be known beyond the limits of empirically verifiable sense experience. In the context of discussing the infinite extension of light, he says:

it is evident, that Light extends it self to the utmost imaginable Parts; and by the help of Telescopes, we collect the Rays, and make them sensible to the Eye, which are emitted from some of the almost inconceivably remote Objects: And since we find, that still larger and better Telescopes do discover to us smaller and smaller fixt Stars, which in Probability are farther and farther removed from us, and that we cannot set Bounds to the Extent of it; it follows, I say, that the Extension of the Propagation of Light is indefinite, immense, and beyond our reach to conceive, yet nevertheless we see by Induction that so it must be, though we do not presently well conceive how.⁴⁴

Even though he claims to proceed by induction, his method diverges significantly from Bacon's inductive method to which the Royal Society officially subscribed. As Dennis points out, Hooke had always thought that a rigidly observed inductive method yielded only limited insight and had tacitly adapted it to his purposes.⁴⁵ Hooke was known to be critical of the Society's methodological conservatism,⁴⁶ but as long as he was in the inferior role of assistant to Robert Boyle, he had to keep his objections to himself; in the 1680s, however, when he had established his reputation as an independent scientist, he finally was in a position to express openly his own theories.

What he calls 'clear Induction', therefore, is a blend between observation and extrapolation of observed facts. Although he depends on empirical evidence as the foundation for his argument, he resorts to speculation to make sense of his data. Furthermore he uses his optical instruments to bridge the gap between observation and speculation. The premise of the above extract is that light diffracts infinitely and, therefore, the universe must be suffused

by it to the whole extent of its infinity. In a second step, Hooke argues that 'by the help of the Telescopes, we collect the Rays, and make them sensible to the Eye', thus implying a similar theory of vision to that which Newton describes in his *Opticks*.⁴⁷ The telescope enables sensory experience but Hooke is not interested in sensory experience as much as in the question of how sensory experience is made possible by artificial devices. He concludes his argument concerning the infinite diffusion of light with the remark: 'So it appears to our Sense and our Reason, and therefore we cannot doubt it, but set it down as an undoubted Principle'⁴⁸ and claims that appearance should be admitted as legitimate evidence in the description of matters of fact, as long as it is validated by both 'Sense' and 'Reason'.

The manner by which Hooke parallels 'Sense' and 'Reason' reflects the fact that his theory of cognition stands in direct relation to his theory of vision. The eye, for him, is a black box in which 'infinitely infinite Rays' depict the world at large and thus produce a 'Microcosm, or a little World'.⁴⁹ On account of thinking about our sense of time which, as he explains, cannot be registered by a physical organ, he posits the existence of a meta organ: memory, the faculty to retain sense impressions thereby is taken to coordinate our sense impressions.⁵⁰ Ideas, for him, are produced analogously to past sense experience. Then it is reason which, by comparing them with remembered experience, determines their validity. Therefore, he concludes that 'Thinking is partly Memory, and partly an Operation of the Soul in forming new Ideas'.⁵¹

The excursion into Hooke's concept of perception and cognition yields some insight into the role played by imagination in his theories. Vision is explained as a mechanical process of registering corpuscular light which, in the mind, produces Ideas which he 'suppose[s] to be material and bulky'.⁵² And yet his theories are steeped in hypothetical thinking and make heavy use of the appeal to imagination. Since imagination stands on the threshold between mental representation of physical images and the mind's projection of analogous images, Hooke maintains that its presence virtually makes thinking possible. Being defined as a material entity, moreover, it conforms to a purely materialistically conceived understanding of mind. This is to say that Hooke not only materialises imagination. By treating it as if it was itself one of the senses – or more specifically by defining it as the sense which makes possible the experiences required for empirical investigation – he also legitimizes imagination as a necessary element in an inductive method which offers objectively validated insight and thus guarantees scientific progress.

The aesthetics of empiricism

What are the wider cultural implications of the awareness that science cannot objectively capture the essence of nature? A self-conscious engagement with natural philosophical issues is only one effect. If we recall how strongly

questions of science were dependent on religion, politics and a gendered understanding of nature, we realise how close was the connection between changing attitudes about the role of the scientist and a range of other changes.⁵³ Alvin Snider discusses the language used for the self-definition of the natural philosopher and remarks that between Bacon's death and the late 1660s there is a marked desire to liberate 'knowledge from infantile dependence on nature'.⁵⁴ Hooke is doing exactly this when he seeks to integrate the study of the self into the attempt to understand the nature of scientific enquiry; for, as Adrian Johns describes the situation, he maintained that '[t]he philosopher must "find out of what Constitution one self is, and to what one is either naturally or accidentally most inclin'd to believe".'⁵⁵ The loss of the illusion that there is an authentic language of description, among other things, produces the separation into nature as the object and the scientist as the subject of investigation. It is the impossibility of obtaining objective knowledge which thus produces the subjectivity of the scientist: in his endeavour (and this subject is conceived of as male) to come to terms with this originary split, he is asked to identify with a relative position vis-à-vis knowledge which, however, also guarantees his authority as a suitable witness of a scientific experience or event.⁵⁶

Preoccupation with the limits of understanding was, of course, an issue which extended to all intellectual activities; in particular it inspired an intense interest in aesthetics, as an attempt to explain in what ways affective elements determine sensory perception. So it is no coincidence that losing the illusion of objectivity was a parallel development to the emergence of treatises on aesthetics. My concern here is not simply with the impact of this loss on the self-definition of the scientists of the early modern period but with its influence on an empirically conceived theory of aesthetics, and ultimately with the mutual dependence of epistemology and aesthetics.

Treatises on the microscope had a privileged relationship with aesthetics for two separate but related reasons: (1) an epistemological investigation of the premises of microscopic observation required a close examination of vision, or rather, of the relationship between the physical eye and the mind (or the imagination); (2) since the objects viewed under the microscope had an immediate aesthetic appeal (which ensured a wide popularity that was in fact against the interests of the serious microscopists), it elicited interest in the detail of those objects, and in the relationship between general and particular.

Theories of vision, or of the experience of seeing, effected an ever widening gulf between the subject and object of observation which indeed explains why there was such a need to explain the relationship between them. The world of the minute revealed by the microscope posed a particular threat to a stable perception of the relationship between self and the world. It is no surprise, therefore, that Burke concentrates on the disturbing potential of the minute in his highly empiricist *Enquiry into our Ideas of the Sublime and the Beautiful* (1757) because here 'the imagination is lost as well as the sense

[and] we become mazed and confounded at the wonders of minuteness'.⁵⁷ In the eighteenth century, engagements with the sublime became increasingly numerous. Circumventing the question of how sense experience could be used as objective evidence, they concentrated almost exclusively on formal features, because the sublime, in the words of Frances Ferguson, 'comes to seem merely a version of empiricism without induction'.⁵⁸

The minute drove a wedge into any commonsensical division between the general and the particular and Jonathan Lamb points out that there was a dispute about whether a detailed investigation of an object or idea could appeal to the sublime.⁵⁹ At issue is a conflict between those who wish to analyse the properties of the sublime as part of an empirical study of the interaction between the sublime object and human consciousness and those who insist that the sublime exceeds all critical categories and is precisely an experience that cannot be theorised. A transition from one dimension to another, an ecstasy in the sense of stepping out of one's customary context, intrinsically belongs to the experience of the sublime. The sublime, therefore, disrupts the possibility of upholding previous ideas as to the position of the self in its environment. It questions the fundamental nature of the subject and thus precisely describes the disorienting effect on the observer which Locke associated with microscopical studies. In so far as it also offers a challenge to the stability of the subject and demands that the observer be part of the act of observation, the minute, therefore, challenges the rational order of nature which is all-important for contemporary philosophers.

To return to Robert Hooke: his chief contribution to the late seventeenth-century discussion on the nature of perception and understanding consisted of the fact that he sought to domesticate the subversive potential of the minute through a method of keeping control over sensory perception. His objective was to structure microscopical enquiry so that it could offer objectively true insights. He was bound to encounter a logical impasse, however, when he tried to reconcile the project of excluding the subjective potential of the interpretation of sense experience with that of legitimizing the use of hypothesis in scientific method, since such hypotheses cannot be arrived at on purely empirical grounds but involve some subjective content. It is the inevitable tension between these two goals which turns Hooke's challenging engagement with the self of the scientific observer into a method of interrogating the available means of representing and interpreting observations.

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Notes

- 1 Robert Hooke, *Micrographia, or some physiological descriptions of minute bodies made by magnifying glasses with observations and inquiries thereunto*, ed. R. T.

- Gunter, facsimile of the edition of 1665 (New York, Dover Publications, 1938), sig. b1v; all references in the text are to this edition. For a detailed discussion of the problems encountered by the task of conceptualising the world of the minute, see Marjorie Hope Nicolson, *Science and Imagination* (Ithaca, Cornell University Press, 1956), particularly the chapter 'The Microscope and English Imagination', pp. 155–234.
- 2 For a discussion of Descartes's theory of perception, see John W. Yolton, *Perceptual Acquaintance from Descartes to Reid* (Oxford, Basil Blackwell, 1984), pp. 18–41; note particularly Yolton's explanation that Descartes broke with the scholastic theory according to which the forms of the world are in the understanding and replaced it with a theory according to which the connection between mind (and cognition) and the world is 'significatory, not resemblance or causal', see p. 30.
 - 3 For a detailed discussion of Hooke's attempts to overcome the obstacles to certain knowledge, see Lotte Mulligan, 'Robert Hooke and Certain Knowledge', *The Seventeenth Century*, 7:2 (1992), 151–69.
 - 4 For a detailed historical account of the development of the microscope in the seventeenth century, see Edward G. Ruestow, *The Microscope in the Dutch Republic* (Cambridge, Cambridge University Press, 1996).
 - 5 John W. Yolton, 'As in a Looking-Glass: Perceptual Acquaintance in Eighteenth-Century Britain', *Journal of the History of Ideas*, 40 (1979), 212.
 - 6 Yolton, 'As in a Looking-Glass', p. 212.
 - 7 J. J. Macintosh, 'Perception and Imagination in Descartes, Boyle and Hooke', *Canadian Journal of Philosophy*, 13:3 (1983), 328.
 - 8 Cf. Catherine Wilson, 'Visual Surface and Visual Symbol: The Microscope and the Occult in Early Modern Science', *Journal of the History of Ideas*, 49:1 (1988), 86.
 - 9 'Dr. Hooke's Discourse concerning Telescopes and Microscopes', in Robert Hooke, *Philosophical Experiments and Observations* (London, Frank Cass, 1967), p. 261.
 - 10 Catherine Wilson, *The Invisible World: Early Modern Philosophy and the Invention of the Microscope* (Princeton, Princeton University Press, 1995), p. 33.
 - 11 Francis Bacon, *New Atlantis*, in Brian Vickers (ed.), *English Science from Bacon to Newton* (Cambridge, Cambridge University Press, 1987), pp. 40–1.
 - 12 Francis Bacon, *Novum Organum*, trans. Peter Urbach and John Gibson (Chicago, Open Court, 1994), Book 1, § 50, p. 60.
 - 13 Wilson, *Invisible World*, p. 48.
 - 14 Cf. Wilson, 'Visual Surface', p. 96.
 - 15 A. D. Burnett, 'The Engraved Title-Page of Bacon's *Instauratio Magna*', The Durham Thomas Harriot Seminar, Occasional Paper No. 27 (Durham, 1998), see particularly pp. 30–3.
 - 16 For an analysis of Hooke's attempts to exclude the subjective elements contained in the observation of scientific experiments by means of schooling the microscopists' manner of seeing and interpreting what they saw, see M. A. Dennis, 'Graphic Understanding: Instruments and Interpretation in Robert Hooke's *Micrographia*', *Science in Context*, 3:2 (1989), 309–64, p. 323ff.
 - 17 Mulligan, 'Robert Hooke and Certain Knowledge'.
 - 18 Ruestow, *The Microscope*, p. 65.
 - 19 Dennis, 'Hooke's *Micrographia*', p. 335.
 - 20 Henry Power, *Experimental Philosophy*, in Brian Vickers (ed.), *English Science:*

- Bacon to Newton* (Cambridge, Cambridge University Press, 1987), p. 88. For the complete text, see Henry Power, *Experimental Philosophy, in three books: containing new experiments microscopical, mercurial, magnetical* (London, T. Roycraft, 1664).
- 21 Power, *Experimental Philosophy*, p. 89.
- 22 His reference is to the decoration of the stage and not explicitly to art as such. The fact that he concentrates on the artistic elements which are specifically used to delude the observer is an expression of his fears, but the passage still deals with the aesthetic dimension of knowledge.
- 23 Cf. Lorraine Daston and Katherine Park, *Wonders and the Order of Nature 1150–1750* (New York, Zone Books, 1998), particularly the chapter 'The Enlightenment and the Anti-Marvellous', pp. 329–63.
- 24 Cf. Dennis, 'Hooke's *Micrographia*', p. 338.
- 25 *Dr. Henry Power's Poem on the Microscope* (Bruges, The Saint Catherine Press, 1934 (Offprint from *ISIS*, No. 60, 21.1, 1934)).
- 26 Power, *Experimental Philosophy*, p. 89.
- 27 For a detailed discussion of the contemporary significance of the individual senses see Ann Jessie Van Sant, *Eighteenth-Century Sensibility and the Novel: The Senses in Social Context* (Cambridge, Cambridge University Press, 1993).
- 28 Power, *Experimental Philosophy*, pp. 89–90.
- 29 E. T. A. Hoffmann, 'Master Flea', *The Golden Pot and Other Tales*, trans. Richie Robertson (Oxford, Oxford University Press, 1992), p. 278.
- 30 Cf. John T. Harwood, 'Rhetoric and Graphics in *Micrographia*', in Michael Hunter and Simon Schaffer (eds), *Robert Hooke: New Studies* (Woodbridge, Boydell Press, 1989), p. 130.
- 31 Hooke, *Philosophical Experiments*, p. 262.
- 32 Mulligan, 'Robert Hooke and Certain Knowledge', p. 164.
- 33 Mulligan, 'Robert Hooke and Certain knowledge', p. 164.
- 34 Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 1985), p. 37, compare above all the chapter 'Seeing and Believing', pp. 22–79.
- 35 For a discussion of the scope and aspiration of *Micrographia*, particularly as concerns its images and graphic presentation, see Adrian Johns, *The Nature of the Book: Print and Knowledge in the Making* (Chicago, University of Chicago Press, 1998).
- 36 John Locke, *Works* (Aalen, Scientia Verlag, 1963), vol. II: 3.6.24, p. 223.
- 37 Wilson, *Invisible World*, p. 97.
- 38 Locke, *Works*, vol. II: 2.23.12, p. 17.
- 39 Alexander Pope, *An Essay on Man*, in Pat Rogers (ed.), *Alexander Pope* (Oxford, Oxford University Press, 1993), Book 1.193–96, p. 277.
- 40 For a study of Pope's poetic technique of contrasting with each other objects and entities belonging to different scales and dimensions, see Robert W. Williams, 'Pope and the "Microscopic Eye"', *Sydney Studies in English*, 14 (1988–89), 21–37.
- 41 See, for example, Thomas Shadwell, *The Virtuoso* (1676) or Aphra Behn, *The Emperor of the Moon* (1687).
- 42 For a discussion of Locke's theory of sensory perception see Yolton, *Perceptual Acquaintance*; see also David Paxman, 'Aesthetics as Epistemology, or Knowledge without Certainty', *Eighteenth-Century Studies*, 26:2 (1992–93), 290ff.
- 43 Robert Hooke, *Posthumous Works*, facsimile of 1705 edition (London, Frank

- Cass, 1971), p. 76.
- 44 Hooke, *Posthumous Works*, p. 77.
- 45 Cf. Dennis, 'Hooke's *Micrographia*', especially section 4 on 'Seeing things', pp. 330–8.
- 46 For a critical analysis of Hooke's role as curator of the Royal Society, see Stephen Pumfrey, 'Ideas Above his Station: A Social Study of Hooke's Curatorship of Experiments', *History of Science*, 29 (1991), 1–43.
- 47 John Yolton explains that '[a]ccording to Newton's axiom 6 in his *Opticks*, the rays flowing from all the points of the object meet again after converging by reflection or refraction. They make "a Picture of the Object upon any white Body on which they fall". Each point of the object illuminates "a correspondent Point of the Picture"'; see *Perceptual Acquaintance*, p. 10; for a discussion of Hooke's 'perceptual optics', see pp. 124–8.
- 48 Hooke, *Posthumous Works*, p. 77.
- 49 Hooke, *Posthumous Works*, pp. 120–1; for a discussion of the seventeenth-century view that the visible world was represented in the mind as in a camera obscura, see Johns, *Nature of the Book*, pp. 387–97.
- 50 Here Hooke argues analogously to Descartes's claim that the *sensus communis* was responsible for coordinating the sensory experience of the different senses, see, for examples, Johns, *Nature of the Book*, pp. 389–97.
- 51 Hooke, *Posthumous Works*, p. 146.
- 52 Hooke, *Posthumous Works*, p. 142.
- 53 Cf. Ruth Salvaggio, *Enlightened Absence: Neoclassical Configurations of the Feminine* (Champaign, University of Illinois Press, 1988).
- 54 Alvin Snider, 'Bacon, Legitimation, and the "Origin" of Restoration Science', *The Eighteenth Century*, 32:2 (1991), 122.
- 55 Johns, *Nature of the Book*, p. 432.
- 56 See for example Peter Dear, 'Totius in verba: Rhetoric and Authority in the Early Royal Society', *ISIS*, 76 (1985), 145–161; see also Shapin and Schaffer, *Leviathan and the Air-Pump*.
- 57 Edmund Burke, *A Philosophical Enquiry into the Origin of our Ideas of the Sublime and the Beautiful*, ed. J. T. Boulton (London, Routledge, 1958), Part II, Section VII, p. 72.
- 58 Frances Ferguson, *Solitude and the Sublime: Romanticism and the Aesthetics of Individuation* (London, Routledge, 1992), p. 15. For a discussion of the sublime in the context of the Newtonian project of harmonising theology with science, see Robert Markley, *Fallen Languages: Crises of Representation in Newtonian England, 1660–1740* (Ithaca, Cornell University Press, 1993), pp. 183ff.
- 59 Cf. Jonathan Lamb, 'The Sublime', *The Cambridge History of Literary Criticism*, vol. IV: *The Eighteenth Century*, eds H. B. Nisbet and Claude Rawson (Cambridge, Cambridge University Press, 1997), p. 413.

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