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Microscopy, Surfaces and the Unknowable in Seventeenth-Century Natural Philosophy (from Lucretius to Margaret Cavendish)

Kevin Killeen

[1] Catherine Wilson's *The Invisible World* depicts the problematic history of surfaces in the seventeenth century, how ostensibly smooth, composite, uninterrupted matter turned out, under the gaze of amplificatory technology, to be a treacherous, gnarly landscape, pocked and intricate, not only permeable, but in a state of continual streaming with effluvia and an oozy unsolidity. The microscope offered a long series of encounters, both textual and visual, with the minimal, as counter-intuitive as quantum physics proved to the twentieth century. 'Science' Wilson points out, or at least science in the process of discovering new things, 'is *improbable*' (Wilson 1995: 7). Here were surfaces so utterly unlike anything the unaided senses could discern, that they could not but bewilder, with their demand both that the augmented senses be trusted as the conduit of knowledge of nature and that we concede they were deceived in the first place. Microscopy was deployed to support a resurgent corpuscularity, albeit there was scepticism about what exactly was being seen. As Christoph Meinel noted, the imaginative work of producing atoms from what could be seen through the lens was considerable (Meinel 1988: 81-4; also Wilson 2002: 168-9). The coordinates by which one could map the surface to the inner structure of things became ever more complex, not least in the response of Margaret Cavendish to early microscopic publications (Cavendish 1666), which was to elaborate on the relationship between exterior and interior knowledge, not in regard to what the observer knew, but how surfaces themselves – vital and after a fashion perceptive – knew and responded to their surroundings.

[2] Early modern surfaces, scientifically and atomically speaking, were discovered to be a hilly, steamy rind of reality, characterized less by a common-sense solidity of objects than by their poor borders, leaky in all directions. Robert Boyle was far from alone among early modern scientists in being troubled by sweat, 'the great plenty of matter that is daily carried off by Sweat, and insensible Transpiration', as he put it in his *Experiments and considerations about the porosity of bodies* (Boyle 1684: 9). Effluvia and extramissive qualities by which objects gave off their atomic exfoliations meant that few or no surfaces could be deemed solid, deep down (so to speak). Solidity was a matter of scale and a failure of attention to the minute. Porosity and permeability, the openness of bodies to the external, came to seem a fact about matter which was startlingly new. Innovative and strange as they might be, and dependent upon a microscopy whose epistemological corruption was still up for debate, the sciences of augmented reality were for Boyle a quintessentially Baconian mode of unknotting nature's intricate structures:

> I scarce doubt, but if such little things had not escaped the sight of our Illustrious *Verulam*, he would have afforded a good Porology (if I may so call it) a place, (and perhaps not the lowest neither,) among his *Desiderata* (Boyle 1684: 2).

Boyle's Bacon would have produced a science of neglected surface, a 'Porology' to map the topographical terrain of the only apparently smooth. Bacon's expansive wish-list of things

missing from the purview of human knowledge, his *Desiderata*, was a repeated reference point in the early modern rejuvenation of science, placing special heuristic value on the anomalous in nature (the 'prerogative instances' in *Novum Organum*) and for Boyle, the microscope revealed a majestic strangeness and profusion of new discoveries in need of explanation (Keller 2015: 167-98; Hunter 2015: 26-32). Microscopy would discern the secret conduits and 'perforations that pass quite through the leather' of the skin, the disturbing correlates of which include Boyle's presumably offhand comment: 'when a mans skin is tanned it is of a greater thickness then one would expect' (Boyle 1684: 11). The permeability of things, their lack of borders, was not only a matter of anatomical curiosity, however. It produced, in early modern writers a sense of a new, near-sublime texture to things.

[3] Whether fluid or firm, the stuff of nature might intuitively be deemed continuous. Surfaces kept the in in and the out out. There could of course be objects whose characteristics included the perforated and porous, but matter could nevertheless be thought of for practical (and even scientific) purposes as uninterrupted. An Aristotelian legacy firmly opposed to atomic speculation, and presuming the continuous nature of matter, albeit under qualified circumstances, was part of the furniture of philosophical learning (Meinel 1988: 70-1). Beneath the threshold of the senses, as Boyle phrases an interim 'objection' to his speculations, 'the body must appear an uninterrupted or continu'd one'. However, Boyle was not prepared to concede much ground to this merely common-sense idea, when he addressed the subject in his *History of Fluidity and Firmness*, published in *Certain physiological essays* (Boyle 1669: 189-90). His corpuscularity, chemical as much as mechanical, had little time for an illusory continuity (Clericuzio 2001: 103-48; Principe 2000: 63-90; Wojcik 1997: 151-188, Anstey 2011). Boyle's sense of omnidirectional porosity depicts the surfaces of things as never more than contingent and temporary:

> A Body then seems to be Fluid, chiefly upon this account, That it consists of Corpuscles that touching one another in some parts only of their Surfaces (and so being incontiguous in the rest) and separately Agitated to and fro, can by reason of the numerous pores or spaces necessarily left betwixt their incontiguous parts, easily glide along each others superficies (Boyle 1669: 164).

Fluids are in this sense, illustrative of the motile reality in which, atomically speaking, constant motion is the very nature of things. Spherical corpuscles 'conduce to their easie rouling upon one another', a continual turning upside-down and a churning of apparent surface. Discussing how Salt-Petre in gunfire 'emulates a fluid body', he wonders whether this fusion involves 'the Ingress and transcursions of the atoms of fire themselves' into the nitre, and concludes that the 'pervasion of a foreign body' is the most plausible explanation, not in the relatively gross manner of liquid diffusing into liquid, but a 'more thin and subtil' invasion and interpenetration (Boyle 1669: 184-9). Natural philosophy sought, in such a formulation, an account of the forces that governed the 'unloosable mobility of Atoms' and the inter-atomic 'cement to unite them', why things remained together (Boyle 1669: 165, 189, 210). To assert the boundedness of things, the simple integrity of objects, was not enough.

[4] The emergence of scientific modernity is often still viewed as a sad but necessary putting aside of the poetic, a coming into rationality that is almost a narrative of the Fall.

Whether via the disenchantment of the world, as Max Weber and others have posited, or via the Foucaudian epistemic shift away from analogical 'world view', a loss of the metaphoric capacity of reality was part and parcel of this epochal shift (Weber 1917: 9, Foucault 1970). Joseph Amato, in his 2013 *Surfaces: A History* describes just such a denuding of the poetics of the world that pits De Vinci against Descartes. The medieval was engrossed in its 'immanence and transcendence of every surface', embodied in the cathedral's lithic, luminous being, whose hulking blocks of stone could nevertheless orchestrate light and colour, an experience of immense if not impossible geometry inside the stony lung of the outsized church. He tells the tale of this soaring, spatial encounter with the ineffable, which in the seventeenth century came up against an 'antithetical way of reading surfaces', the Cartesian calculus, which could map the curve in astringent mathematics and a precision rationality which 'washed the surfaces of the visible world clean of their sensuality and textures', along with the cosmological flight and ontological acrobatics of the medieval (Amato 2013: 119, 127). If ever there was a Fall, this was it, science and philosophy hand in hand with wandering steps and slow: 'gone too were the whorls and shells of analogies, metaphors and symbols that had enwrapped entire peoples' (Amato 2013: 135).

[5] Microscopy has similarly been crafted into a narrative of pigeon-stepped empirical progress, hubristic and cack-handed occasionally, but in essence marching to the drum of rationalism and technological progress, ousting the idea of occult qualities and inching, by degrees, towards a more coherent understanding of forces (Hutchison 1982; Henry 1986). There is no doubt some accuracy in this, and yet it remains the case that the intellectual *terra incognita* of the surface, newly available to the minuscule gaze of the seventeenth century, provided an epistemological jolt, a new and counterintuitive texture of reality that mesmerized natural philosophers. Surfaces, those least metaphorical, most literal of things – the opposite of deep – became objects of untrustable paradox. This was experienced in writer after writer as an almost mystical buckling of reality; the definitively dull and paradigmatically ordinary-superficial had become mysterious. Scholarship on the Fall as a pervasive supposition in early modern thought has accustomed us to the era's encounters with things beyond the ken of mere humans, cosmologies too immense, or creation too intricate to fathom (Harrison 2009). But microscopy presented something new, and this essay traces the amazement of early modern natural philosophy in the face of the newly unknowable, when the apparently smooth and continuous surface of the real proved calloused, inscrutable and inconstant. The argument of this essay is neither one of the triumph of rationalism over poetics, nor the reverse; but rather it traces their enfoldedness. It deals firstly with early microscopy, arguing that its florid rhetoric was less an ornamental addition to empirical description than a tactical poetics; a rhetorical mode that inoculated their descriptions of micro-reality from the harsh strictures of plain description that Restoration science prided itself on. The body of the essay, after that, deals with scientific uses of Lucretius in early modernity, how writers found in him a model and a language for addressing the apparent irreality of scale and texture they encountered in microscopy. The essay concludes with one of the most vehement, strange and brilliant responses to microscopy, the still under-read natural philosophy of Margaret Cavendish, whose attention to surface, to the discontinuities of inner and outer, exemplifies the scope of the philosophical puzzle that the seventeenth century found itself faced with.

[6] Early modern natural philosophers describe, with some excitement and some vertigo, the disorientating experience of the small, and the shifting scales of reference by which the

straight line came to seem pocked, the smooth surface became jagged and the barely perceptible fleck of an insect proved intricate beyond any imagination. The complex response to such discovery involved, in the first instance, and in the first publications, a recourse to the poetic. Merely to communicate the strange sights, the dazzling order and bewildering disorder, the earliest accounts of microscopic vision sound at times like travel marvels, and elsewhere as though they need to coin a labyrinthine vocabulary to convey the remarkable world of the tiny: a nettle appeared to Henry Power like a 'Sword-Cutler's Shop, full of glittering drawn Swords, Tucks, and Daggers'. Describing a 'line drawn upon paper', he notes how it 'appears all ragged, indented, and discontinued by the rugosities and seeming protuberances of the paper' (Power 1664: 51, 53). Writing about 'the Edge of a Razor', Robert Hooke notes that this most exact of objects, with its 'affinity to the sharpest Point in Physics, as a line hath to a point in Mathematicks' seems so only 'till more closely viewed by the Microscope, and there we may observe its very Edge to be of all kind of shape, except what it should be', a jagged 'roughness of those surfaces', such that one: 'may find reason to think there is scarce a surface *in rerum naturâ* perfectly smooth' (Hooke 1665: 4-5). Microscopy's discovery in the period was the outlandish irregularity of things, the illusion of plain surface, and its findings took Restoration London by storm (Hunter 2013; Hunter, 2010; Jardine, 1999).

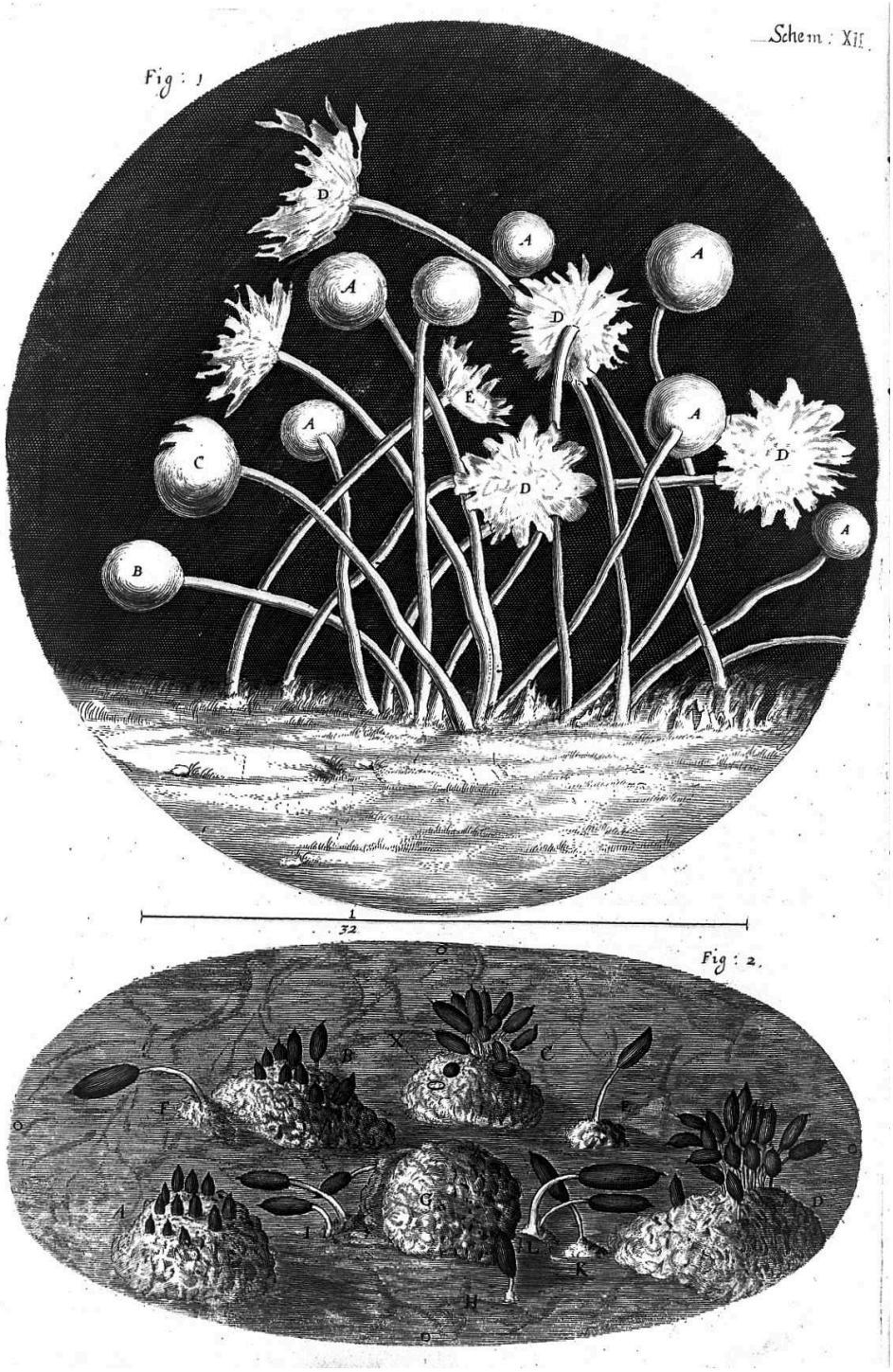

Figure one: Robert Hooke, *Micrographia*, 'Of blue mould, and of the first principles of vegetation arising from putrefaction, Of a plant growing in the blighted or yellow specks of Damask-rose leaves'.

[7] Power, a writer who secluded in Halifax remained peripheral to the tumult of Royal Society and Hartlibian science, was one of the earliest enthusiasts for microscopic exactitude (Hughes 2010). Where Hooke, publishing a year later, commissioned and made his intricate, beautiful, monstrous and outsized pictures of fleas, gnats, or the eye of a grey-drone fly, all swollen to the size of a football, Power's *Experimental philosophy* depends upon intricately wrought prose for its effect, depicting the world from its immensity to its most minute in a state of constant motion, such that there is no 'absolute quiescence', neither in the pulsating heavens nor in the infinitesimally small. He argued, citing Bacon, that natural philosophy had for too long been held hostage to mere sight, in all its

limitations, while its task ought more properly be to discern the intricate surface of matter, by augmenting lenses as well as deductive inference: 'whatsoever is invisible, either in respect of the fineness of the Body it self, or the smalness of the parts, or of the subtlety of its motion, is little enquired' (Power 1664: sig. c2^{r}). Power's Faustian ambition was to discern the previously indescribable streaming of bodies, both celestial and effluvial:

> and as for the Opace [opaque] and Planetary Bodies of the Universe, they are all porous, and the aetherial Matter is continually streaming through them, their internal fire and heat constantly subliming Atoms out of them, the Magnetical Atoms continually playing about them … the supreme Being (who is Activity it self) never made any thing inactive or utterly devoid of Motion… (Power 1664: sig. B4^{v}-C1^{r})

Not only did matter subsist in motion and mutability, a ceaseless subliming of itself, but God himself consisted in theological seething and insurgence, the raw principle of activity.

[8] Magnification, Power argued, did not distort as much as ordinary sight, which was doomed to the intractably flat, a surface no closer to reality than a painted, perspectival stage-set. The quotidian gaze was an epistemological trick and any honest natural philosophy demanded that it be rectified by a technology to circumvent our planate human habits of perception: 'without some such Mechanical assistance, our best Philosophers will but prove empty Conjecturalists, 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' (Power 1664: sig. c3^{v}). Power noted the decay of sensory powers as a facet of the long, slow Fall of the senses, asking whether the 'Aged world stands now in need of Spectacles' and whether our 'Primitive father Adam might be more quick & perspicacious in Apprehension,' a passage we might suppose to be itself quite porous and absorbent of Joseph Glanvill's wonderful claim that 'Adam needed no Spectacles. The acuteness of his natural Opticks (if conjecture may have credit) shew'd him much of the Coelestial magnificence and bravery without a Galilaeo's tube' (Power 1664: sig. a4^{r}; Glanvill 1661: 5).

[9] Power's optimism in this 'mechanical assistance' was thorough-going and uncompromising in its call for whatever might bring us closer to the reality of the miniature, to atoms in their oscillation and the secret motions of microscopic being. Indeed, he suggested that the sight of and insight into effluvia itself was not far off:

> we might hope, ere long, to see the Magnetical Effluviums of the Loadstone, the Solary Atoms of light (or globuli aetherei of the renowned Des-Cartes) the springy particles of Air, the constant and tumultuary motion of the Atoms of all fluid Bodies, and those infinite, insensible Corpuscles (Power 1664: sig. c2^{v}-c3^{r}).

Later in the body of the text he seems to backtrack on any imminent prospect of understanding how effluxions function, suggesting, in a phrase from Thomas Browne that it is 'A part of Philosophy but yet in discovery; and will, I fear, prove the last Leaf to be turned over in the Book of Nature' (Power 1664: 58; Browne 2014: 168). This uncertainty of scale – how much further humans would need to go to sound the bottom of physical reality, and what additional unsettling paradoxes one might meet in probing down – was not just a

question of technological boundaries. It presented also a serious epistemological problem. If atoms remained beyond the visible, what kind of demonstration was philosophically sufficient to make assertions about their nature? Seventeenth-century theorization of atoms, from Gassendi through Sennent, to Power and Charleton was deeply invested in analogical models from the visible world, motes in the sun or clouds on mountain-tops whose solidity proved illusory (Boyle 1669: 191; Browne 2014: 194). In the absence of any empirical demonstration of atoms (see Wilson, 2008; Meinel 1988), natural philosophers had to make do with extrapolation and metaphor and early modern science was adept, indeed formidable in this respect. 'I have more than once taken pleasure to look upon an heap of swarming Bees' wrote Boyle, 'for though they make not up a liquid but coherent body, which may be turn'd upside down without losing its coherence … yet these motions of the particular Bees destroy not the coherency of the heap' (Boyle 1669: 203).

[10] Microscopy 'takes away the privilege of a surface' writes Catherine Wilson. The closer one looked, the more it became evident, that the merely similar, and microcosmic correspondences based on them, was a flawed way of looking. Surfaces were open to their own interiors in the sheer knotty complexity of fibres and pores and 'in the interior of things there is no resemblance', Wilson continues (Wilson 1995: 62). The surface that looped in on itself, that dipped into its own involuted interior revealed just enough of itself, to demonstrate its unfathomable nature, 'Implexions and Entanglements … Omnifarious Particles, jumbling together with infinite variety of Motions', as Ralph Cudworth wrote, not kindly, of neo-Lucretian atomic speculation (Cudworth 1678: 98). 'The division between inner and outer is just a tactic' writes Steven Connor, in his excellent history of skin. Its exchanges are chronic and intrinsic and as unmappable as smoke: 'A column of smoke possesses no simple inside or outside, but the supposition of interiority and exteriority, repeatedly insurgent and abandoned' (Connor 2004: 39). To speak of a 'tactic' of reality might seem, initially at least, at odds with the Restoration desire for plain language in its science. But much early modern natural philosophy would be wholly at home with Connor's formulation of a turbulent inner and outer. Early modern writers were positively effusive and irredeemably poetic about the epistemological involutions, the baffling irreality that microscopy suggested. The surface of things was pocked; there were scaly rinds where we presumed things smooth; there were shadow valleys dipping ever-inward on the exterior of things, labyrinths folding in on themselves. To explain such epistemological chaos, writers turned frequently to the poetic, which provided some surprising ready-made resources.

[11] Natural philosophy in the second half of the seventeenth century saw a surge of interest in Lucretius, the Roman epic 'paraphrast' of Epicurus (Charleton 1654: 100, also Boyle 1669: 165). He is quoted in early modern philosophical writing out of all proportion to his 'scientific' worth. His atoms were slightly preposterous by most seventeenth century corpuscularian standards (Lüthy 2001; Pyle 1995; Kargon, 1966). His fantasies of omni-explanatory philosophical breadth – that what explains the first grass, also explains the weather and sex and feeling plaguey – were wholly beyond the philosophical pale. They were the opposite of Baconian sobriety, or Cartesian precision, or even the theo-physics of those who would attempt a biblical mechanics of creation. He denied and indeed mocked divine providence, the immortality of the soul, and was frequently seen as straightforwardly atheist, albeit occasionally Christianized (Charleton 1664; Fotherby 1622: 122-3). He was derided for the tale, apparently originating in Jerome, that he had fallen victim to a love philter, given to him by his wife, which drove him to suicide (Heywood 1626: 217;

Montaigne 1613: 191; Anon 1665: 451). Any one of these things might have precluded his being taken seriously, and yet early modernity could not stop thinking about Lucretius (Palmer 2014; Gillespie 2007, Brown, 2010). Some worried that he was too good, with the seductive elegance of his poetry, 'by the extraordinary Goodness of the Verse, the Badness of this Epicurean's Notions is (I fear) unhappily instilled into the Minds of young Gentlemen' (Edwards 1696: 119; also Wright 1694: 4-5).

Figure two: Lucretius, *De rerum natura*, Vat. lat. 1569 fol. 1 recto medbio04 NAN.13

[12] Lucretius mattered to the era's natural philosophy, I would suggest, not because he provided any particularly convincing demonstrations of atomism that would meet the exacting if speculative standards of early modern scientists, but for reasons more tangential:

first, because of his poetics of *scale*, and second, because he spoke so impressively about *texture*. The disorientation of microscopic scale by which continuity of surface proved only illusory has its direct correlate in *De Rerum Natura*, which produces similar perspectival shifts that defy or mock the senses. Explaining how 'although all atoms are in motion, their totality appears to stand totally motionless', Lucretius describes their elusive motion below the range of the senses by reference to two scenes, one of pastoral stillness and serenity and the other, a ferocious melee, both of which, from a lofty enough stance, seem to be nothing of the sort: 'Often, on a hillside fleecy sheep, as they crop their lush pasture, creep slowly onward, lured this way or that by grass that sparkles with fresh dew, while the full-fed lambs gaily frisk and butt', but from a distance, this is only as motionless a hill as any other (Lucretius, 2.309-10); or in a battle: 'Mighty legions, waging mimic war, are thronging the plain with their manoeuvres'. But from a height, the wheeling of horses and flashing of armour means nothing, 'a blaze of light stationary upon the plain' (Lucretius, 2.317-20).**[1]** An apparent stillness of surface tells us only so much about its real vibrant life. Just as the tumult of atomic activity passes below the range of any human scrutiny, so too scale renders emotion insignificant – the slow lovely pastoral, or the intense tumult of battle – are, from some lofty perspective, negligible, indistinguishable. From the distance of the gods, who will not be gazing down, from the perspective of the indifferent universe, nothing significant has changed; the surface is placid, the world unruffled. *De Rerum Natura* makes divine indifference key to haughtily neutral matter; atoms have no design on or care for human welfare.

[13] But the reader's disorientation, in quick-fire flight between scenes, does matter. Lucretius produces endlessly reframed analogies for how atoms move or are combined and the reader has to adjust the scale of reference with some agility; they are, by turns, like motes in the sun in their chaotic streams; like the flotsam of a wrecked flotilla of ships, 'thwarts and ribs, yard-arms and prow'; like racehorses let loose with coiled energy; like the delirious un-replicable mass of individual faces (Lucretius, Book 2. 115, 553, 264, 346). Any one of these is just model and metaphor, but in their consistent rapid reconfiguring of images, they produce their perplexing, but far from innocent, effects. It is not just that atoms are 'like' these things, but that they in fact become them; the tiny anarchic atom produces the anarchy of the sea. John Evelyn, who translated the first book of *De Rerum Natura* wrote in his animadversions on the manner in which the apparently invisible, unobservable atoms, could manifest themselves though their cumulative effects:

> ...which though they consist indeed of Atomes altogether inconspicuous to our weak organs, yet do their monstrous effects (which he there compares to that of precipitating Rivers and Cataracts, which have violated their banks, and spoil'd the adjacent places) prove them to be bodies (Evelyn 1656: 127).

The Lucretian poetic embodies the stochastic, the scattered event, the infraction of the normal course of things, the *clinamen* whose almost undetectable deviation from its flow produces its cataclysm of variety (Passannate 2011: 76-82; Shearin, 2015). And this ability to replicate life at large on the scale of the infinitesimal proved an attractive quality both in the poetic and the proto-scientific deployment of Lucretius.

[14] Thomas Creech, in the notes following his translation of Lucretius, attacks his author on many fronts, including his atheism and 'endeavour to disgrace Religion', but is also concerned throughout with his scientific (im)plausibility, in the course of which Creech

makes reference to the 'many experiments of the Honorable Boyl', and other early modern natural philosophers, on for instance the nature of air, fluidity and continuum, and on the Epicurean ascription of weight to atoms, with the corresponding implications for their motion, 'resilition' (rebound) and declination (Creech in Lucretius, 1682: sep. pag. 39, 22, 17-18). Boyle, in the preface or 'Advertisement' to the *History of Fluidity and Firmness*, explained that he was only eclectically Epicurean: 'The Authors Explicating things chiefly according to the Atomical Principles will not be thought strange, nor be lookt upon as a sure Argument of his being wedded to the particular opinions wherein the Atomists differ from other modern Naturalists'. Indeed he notes the merely strategic explanatory value of Lucretius, and that he is quite content to dispute or augment, when necessary:

> especially since he [Boyle] has on some occasions plainly enough intimated the contrary, by proposing, together with the Atomical ways of resolving a thing, another Explication more agreeable to the Cartesian, or some other modern Hypothesis (Boyle 1669: 161-2).

This claim to strategic use of *De Rerum Natura* should, I think, be taken at face value, rather than supposing a nervousness about appearing too Lucretian – Lucretius answered a very particular set of seventeenth century needs in natural philosophy, one of which was the Latin poet's conception of scale. Another not unrelated use of Lucretius was his phenomenal imagining of texture and touch, the knottedness and entanglement of matter up close, the atomic variety of texture explaining the diversity of things. This had its correlate in the early modern experience with the intricate (if synaesthetic) tactility of the microscope, revealing the knobbed, rugged and fibrous surface of things.

[15] Boyle deploys Lucretius in both parts of his *History of Fluidity and Firmness*, first to illustrate the 'gliding of the Corpuscles' and the 'easy rouling' of their spherical form, and then to demonstrate their knitty and gnarly complexity. Atoms are, he asserts, constructed in intricate protrusions, 'some like buttons, others like loops, some like male, others like female screws' (Boyle 1669: 165, 235). They snag with hooks or 'slender twigs'. Quoting from the Lucretian account of touch – 'tactus enim, tactus, pro divum numina sancta'; 'This touch, this touch! O sacred deities', as rendered by Lucy Hutchinson, (Lucretius: 2. 434) – Boyle extols how their design, albeit for Lucretius chance design, produces superlative strength from minimal components. He gives among his examples 'of the power of the bare Texture of many small Bodies' how slender threads produce 'Ropes and Cables; where only by twisting together and wreathing the slender and flexible threds the Cable is made up of, they are so well as it were wedg'd in between and fasten'd to one another'. They can hold fast a ship violently driven by storms, in their intricate corpuscular strength, of which he notes: 'This figuration of the Corpuscles that make up consistent Bodies, seems to have been the chief if not only cause of their consistence in the Judgment of the antient Atomists, this being the account that is given of it by *Lucretius*' (Boyle 1669: 235, quoting Lucretius, 2.444-9).

[16] Atoms, continually re-forming in their *ars combinatoria* out of which everything constructed itself, produce what Michel Serres in *The Birth of Physics*, calls the 'voluptuous knowledge' of *De Rerum Natura*, its coordinating of multi-faceted godless life, scientific, mythic, emotional and all-encompassing, the 'physics of Aphrodite', voluptuous of theme, and sensual in its epistemology, a world abrasive, alive, emerging 'like Aphrodite from a flux of elements … complex, twined, twisting its long thick hair' (Serres 2000: 107, 104-5).

Touch not vision, is the coordinating sense and even vision, in the work's extramissive sight theory, in which frail simulacra produce a universe of phantoms in continual exfoliation from every surface, is tactile. Walter Charleton citing Lucretius, concludes that 'all Sensation is a kind of Touching', (Charleton 1654: 248). The crush that natural philosophers had on Lucretius in the second half of the seventeenth century derived, at least in part, from the seductive, dangerous nature of this tactility, that 'most exquisite and delicate sense of Touching' as Charleton comments, before shifting from natural philosophy to temptation 'the titillation whereof transports a man beyond the severity of his reason, and charmes him to the act of Carnality' (Charleton 1654: 249; Booth, 2006).

[17] *De Rerum Natura* provided a poetics of *texture* for describing the physical world, which anticipated the counter-intuitive ruggedness of things at a material level. This preceded, but was augmented by the discovery of microscopic roughness, and the new-found technical ability to penetrate surface-illusion of uninterrupted, erugatory form. Atoms were unresting. Walter Charleton, narrating the history of Epicurean-Lucretian atoms, recounts their perpetual warring motion, his sheer adjectival bombardment in imitative atomic action:

> on all sides crowding, impelling, and justling each other … a long, long afflux, reflux, conflux, elevation, depression, coagmentation and other various and successive agitations and molitions of these Atoms (Charleton 1652: 41-2).

The boundedness of objects made of vigorous atoms was, for early modern scientists, a thing of wonder, that elements so motile could nevertheless through sheer texture prove so solid. Atoms existed in a ceaseless and delirious movement, the 'circumvolution, gyration, or vertiginous eddy of them … [an] immense vortex, wedged in each other into the form of an integument or cortex', and yet, at the level of everyday things, they constituted all that was solid, their thick texture producing an illusion of surface that was whole and calm (Charleton 1652: 46).

[18] Lucretius provided a model of perception as perpetual wrong-footedness, and disorientation of scale, in a work that is by turns intricate, then vast, an immensity of the tiny that replicated the conceptual vertigo of the microscopic. Those who speculated on the new experience of the miniature in the seventeenth century were all too well aware of perceptual distortion, and of the speculative nature of any atomism. The gambit of truth by which atoms might just approximate to reality was very much Lucretian, a poetics of natural philosophy that was uniquely able to enfold plain and complex 'involution' of truth: 'Parabolical and Poetical Fictions conduce *am ad lumen & illustrationem, quàm ad involucrum & velum*, as well to the illustration of darker, as the involution of more evident peices [sic] of Truth' (Charleton 1652: 198-9). Elegance of poetry did not of course imply a thing to be true, but the widespread incorporation of Lucretius into natural philosophy spoke to a pressing need for a mode of seeing the unseeable (e.g. Casaubon 1646: 9-10; More 1668: 182, 185; Culverwel 1652: 196). If the infinitesimal was to remain beyond human perception, truth might have to be glimpsed rather than laid out in full splendor.

[19] Microscopy provoked a number of antagonistic responses, some philosophical, some medical and some just itchy. A 1668 text on the profoundly uncomfortable experience of small life spoke of 'several species of wormes macerating and direfully cruciating every part of the bodies of mankind' (Ramesey 1668). Gideon Harvey wrote against the College of

Physicians in an aspersive account of 'their intrigues, frauds, plots against their patients', ridiculing their microscopic practices and the self-publicising chicanery, in which they collected 'whatever false appearances are glanced into their eyes, these to obtrude to the World in Print, to no other end, than to beget a belief in people, that they who have so profoundly dived into the bottomless pores of the parts, must undeniably be skilled in curing their distempers' (Harvey 1686: 25). If Boyle could extol the idea of a Porology, for Harvey plumbing the bottomless pores was mere chicanery, and mountebank rhetoric.

[20] But there were also more substantial philosophical arguments against microscopy, among which those of Margaret Cavendish, Duchess of Newcastle, are most intriguing. Having repudiated her early interest in atomism, by the mid-1660s, she was challenging both the theories of perception that were the premise of microscopy and the framework of matter theory, into which any understanding of surface and under-surface should be figured. Her extensive philosophical writings of this period return frequently to the discontinuity between 'interior and exterior', and the nature of self-knowledgeable matter, surface that was aware of its own superficiality. Cavendish's *Observations upon Experimental Philosophy* (1666) has some scathing comments on the epistemological value of microscopy and the over-enthusiasm of Hooke and Power for the nascent technology in their recently published works, arguing that the science 'is not able to discover the interior natural motions of any part or creature of nature; nay the question is, whether it can represent yet the exterior shapes and motions, so exactly, as naturally they are' (Cavendish 1666: 7). In the early part of the work, Cavendish's concerns centre on perception, how the artifice (art) of microscopy deforms and mis-shapes the very objects it purports to 'see', failing to acknowledge or understand where sight gave way to conjecture, 'interposing and intermixing parts, forms and positions, as the truth of an object will hardly be known'. Such technology skewed what one saw, producing 'hermaphroditical' knowledge, 'mixt figures, partly artificial, partly natural' and Cavendish was perplexed that it had 'intoxicated so many men's brains' into attending only to the nature of surface and exterior, such that they valorized 'superficial wonders, as I may call them'. Indeed in calling for a more utile science, she urged, with fine-tuned condescension, that natural philosophers should properly adopt the mantle of Bacon, and not act 'as boys that play with watery bubbles or fling dust into each other's eyes, or make a hobby horse of snow' (Cavendish 1666: 10-11; see Clucas 2003, 1994; Broad 2002; Sarasohn 2010: 149-172).

Figure three: Margaret Cavendish, Frontispiece from *Grounds of natural philosophy* (1668)

[21] However, Cavendish's opposition to microscopy was more thoroughgoing (and more interesting) than merely exposing its ineptitude in what it claimed and aimed to do. When she writes of exterior knowledge and interior knowledge, she does not mean what *we* can know from the outside and what we might like to know about the inside. Rather, she means what the exterior of an object *knows* and the different knowledge of the interior. Cavendish's world is vitalist; its matter is alive, aware and perceptive, even while that world is quite some distance, tonally and philosophically, from any kind of mysticism we might associate with vitalist thought. It is not infused with the divine, and if formally it constitutes panpsychism, it nevertheless has little sense of an *anima mundi* or a world electric with god. This makes for a curious reading experience that is the converse of the microscopists. Where Power, Hooke and Charleton produce baroque and elegiac prose, awe-struck empiricism at the intricacy of the universe, whose wonder borders on psalm-like prayer,

Cavendish might be said to be at the nit-picking and pedantic end of the spectrum of philosophical rhetoric. At times, she repeats her ideas into the ground, and yet in themselves, they are exquisitely strange and original. 'I am of opinion' she says, 'that nature is a self-moving, and consequently a self-living and self-knowing infinite body', the correlate of which was a world never at rest: 'I do not mean exteriorly moving … but interiorly, so that all the motions that are in nature, are within herself' (Cavendish 1666: 135).**[2]**

[22] Cavendish's matter is triune; it is on the one hand inanimate, but it is, without exception, imbued and suffused with animate qualities of both the sensitive, in that it perceives, and the rational, in that it 'knows' how to respond to contiguous matter. This tripartite 'commixture' of qualities is the constituent and universally-present nature of matter. As Karen Detlefson writes: 'no portion of material nature, regardless of how small it is, lacks any of the three aspects, and so every portion of material nature is self-moving, sensitive, and rational as well as limited in its abilities', its inanimate portion acting as a fetter on its ability to self-move (Detlefson 2007: 163-4).**[3]** Matter *senses* other matter and knows how to react. The proximity of other bodies prompts things to respond accordingly, not in any purely mechanistic interaction, but with a degree of free will on the part of the matter. It is less that cause produces effect than that one object is the 'occasion' of an interaction to which the matter responds, knowingly (James, 1999: 222-5; O'Neill, in Cavendish 2001: xxix-xxxiii; Detlefsen 2006). Cavendish explicitly and frequently refuses to distinguish between kinds of matter, whether mineral or animal, and indeed between matter in general and matter already preformed into discrete figures, whether pebbles, flowers or humans: 'such composed figures, as, for distinctions sake, we call finite wholes; as for example, an Animal, a Tree, a Stone'. What is important and what unites these is how matter knows, a thing's dynamic knowledge of its own being.

[23] In explicating and differentiating between 'exterior knowledge' and 'interior knowledge', Cavendish is less interested in an observer's putative knowledge of the outside of a thing (produced by 'patterning out' an always imperfect copy), than in how matter 'knows' how to respond to the world (see Clucas 2014). Remarkably, a thing knows in different ways on its surface and in its interior. Outside and inside respond to different impulses, and kinds of potential motion simultaneously. There is the 'figurative motion', by which the object's 'outward figure or shape' reacts, but there is also action athwart this, a 'retentive motion', by which an object produces its own longevity, the 'preservation and continuance' of itself: 'By which we may plainly see that one figure lies within another, one corporeal figurative motion is within another, and that the interior and exterior parts or figures of Creatures, are different in their actions' (Cavendish 1666: 197-8). Matter dances to several tunes at one and the same time, and the example she gives returns us to Boyle's interest in the complex fluidity:

> the ebbing and flowing, or the ascending and descending motions of water, are quite different from those interior figurative motions that make it water (Cavendish 1666: 198, c.f. Stroll, 1988: 10).

The complex plunge of water as it falls, whose state is intricately distinct from moment to moment produces its shapely reaction to any contiguous surface, be it air or solid, that it 'senses'. Its gush 'knows' and responds to the 'occasion' of any surrounding and proximate object. In one sense, this is like Lucretian smoke, its continual reformulation of itself, its involutions resembling Connor's contingent tactics of inner and outer. But Cavendish's

matter is purposeful. It wills how to act in so far as it knows how to act, both at its external edges and in its interior being, its 'retentive motions', by which it moves and remains the same, 'those interior figurative motions that make it water'. Matter knows to act both when it is considered in undifferentiated clump-form, and when it is composed into discrete figures.

[24] Cavendish remains adamant that merely mechanical action, of cause and effect, is an insufficient explanatory model. When a hand encounters a ball, there are, she insists, two acts of self-motion, the ball not less decisively part of the action than the hand:

> Therefore when a man moves a string, or tosses a Ball; the string or ball is no more sensible of the motion of the hand, then the hand is of the motion of the string or ball, but the hand is onely an occasion that the string or ball moves thus or thus (Cavendish 1666: 159-60).

Kourken Michaelian notes of this passage, the extent to which Cavendish embraces the seemingly outrageous implications of this: 'she holds that the hand is not necessary for the motion of the ball on the specific ground that the ball moves itself, so that it could have moved as it does even had the hand not been present – the actual cause of a thing's motion is always the thing itself' (Michaelian 2009: 45-6; Detlefsen 166). Not only is the ball perceptually aware of the hand, but its movement in a particular trajectory is a matter of its own knowledge (of how it should move) and decision (that it will move):

> I will not say, but that it may have some perception of the hand, according to the nature of its own figure; but it does not move by the hand's motion, but by its own: for, there can be no motion imparted, without matter or substance (Cavendish 1666: 159-60).**[4]**

For Cavendish, matter is wholly aware of what is contiguous. It knows not only itself (in interior fashion) but also what it comes into contact with, such that its surface perceives other surfaces: 'the infinite parts of Nature have not onely interior self-knowledg, but also exterior perceptions of other figures or parts, and their actions; by reason there is a perpetual commerce and entercourse between parts and parts' (Cavendish 1666: 160-1). While the perceiver may know an object, the object, it seems, knows back.

[25] At the same time, however, nature's perceptive qualities are curtailed in composite figures by the inability of one part to know another, an 'ignorance of forreign parts, figures or actions, although they be parts of one composed figure' (Cavendish 1666: 198). This idea is threaded through the *Observations*, as the faultline in perception, that sight does not understand touch ('It is known that man has five senses and every sense is ignorant of the other') and even that one touch cannot quite make sense of another ('one of his hands knows not the sense and perception of his other hand; nay, one part of his hand knows not the perception of another part of the same hand'). This radical discontinuity of the 'sensitive' parts is mitigated by the rational, which can coordinate and rectify its insufficiencies ('Whatsoever the sensitive perception is either defective in, or ignorant of, the rational perception supplies') but Cavendish creates in her human condition of nescience and partiality a state in which the perceiving surface is, after a fashion, more cognizant than the perceiver (Cavendish 1666: 1, 3, 164).

[26] What do Cavendish's ideas of animate matter have to do with microscopy, beyond the fact that its inadequacy apparently prompted her formulation of ideas about substance whose interior and exterior might have different notions of what they want to do? The answer, this essay suggests, lies in the nature of surface, a category newly troubled and troubling in seventeenth century thought. Natural philosophy of the post-restoration era returned repeatedly to the idea that surfaces are not staid. Continually and in a streaming litany of matter, bodies exude, and the occluded stuff of nature is emitted and absorbed. The omnidirectional pulse of matter that is present in Boyle or Power has its correlate in the perceiving matter of Cavendish, quite different in many respects, but sharing an attention to the complexity of surface, its non-obvious, non-quotidian nature. Prompting something akin to vertigo, the surface imagined up close become monstrous, in the shifting scale by which the atomic and human-sized became conflated. Imaginative shrinkage produced for early modern writers a perceptual disequilibrium. The early modern microscopist was something of a Gulliver, startled in Brobdingnag to discover at close quarters things terrifying to his sensibilities, whether outsized bees, or the Maids of Honour who use him a sexual toy, whose nakedness and magnified smells so horrify him. Up close, the natural philosopher fumbled through the blasted landscape of magnified textures, in a state both of shock and awe. Early modern surfaces were anything but straightforward. They might produce involutions such that outer and inner became perplexingly similar, like a Möbius strip whose surface has only one side, and they might, in Cavendish's case have their own perceptual powers. But surfaces presented to the seventeenth century a new kind of ignorance, in which the plain and the ordinary demanded a poetics of the strange.

University of York

NOTES

[1] I quote R.E. Latham's engaging translation, *On the Nature of the Universe* (Penguin, 1951), while citing the Latin from the Loeb of W.H. Rouse, rev. Martin Smith, *On the Nature of Things* (Harvard, 1992), '... Omnia cum rerum primordia sint in motu, summa tamen summa videatur stare quiete ... (2.309-10); 'nam saepe in colli tondentes pabula laeta / lanigerae reptant pecudes quo quamque vocantes / invitant herbae gemmantes rore recenti, /et satiati agni ludunt blandeque coruscant' (2.317-20) 'praeterea magnae legiones cum loca cursu / camporus complent, belli simulacra cientes ... et tamen est quidam locus altis montibus unde / stare videntur et in campis consistere fulgor.' (2.323-32).**[back to text]**

[2] c.f. p. 69, 'that Nature is a perpetually self-moving body, dividing, composing, changing, forming and transforming her parts by self-corporeal figurative motions'.**[back to text]**

[3] See Cavendish, *Observations upon Experimental Philosophy*, p. 191, 'For there is such a commixture of animate and inanimate matter, that no particle in Nature can be conceived or imagined, which is not composed of animate matter as well as of inanimate.'**[back to text]**

[4] A parallel passage in Cavendish's *Philosophical Letters* (1664), pp. 444-5, develops the example with a bowl instead of a ball ('When I throw a bowl, or strike a ball with my hand'), either a dramatic kitchen moment, or an early modern Frisbee. The argument in both cases is premised on what Cavendish views as the incoherence of concussive, mechanical, theory, based on the transfer of motion without a loss of matter, which fails to account for

diminishment in material substance, see O'Neill, intro, pp. xxix-xxxiii.**[back to text]**

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