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The first mite: insect genealogy in Hooke's *Micrographia**

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ABSTRACT

What happens when you take the idea of the biblical Adam – the first human – and apply it to insects? You create an origin story for Nature's tiniest creatures, one that gives them 'a Pedigree as ancient as the first creation'. This the naturalist Robert Hooke argued in his treatise, the *Micrographia* (1665). In what follows, I will retrace how Hooke endeavoured to show that insects – then widely believed to have arisen out of the dirt – were the products of an ancient lineage. These genealogies, while constructed from empirical observation, were conjectures of the imagination. Section 2 shows how Hooke introduced the concept of a 'prime parent' (an Adam-insect) to explain the anatomical similarities between 'mites'. Section 3 demonstrates how Hooke defined the family of 'gnats' as tiny machines built from the same components and relates Hookean genealogies to contemporary ideas about Noah's Ark. Section 4 shows how Hooke outlined the morphology of 'insects' (delineating what we now call arthropods). Section 5 explores how Hooke used fossils to study these animals in the distant past. In sum, Hooke was turning *natural* history – collecting and describing insects – into natural *history:* reconstructing their origins.

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Content

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1. Introduction

What happens when you take the idea of the biblical Adam – the first human – and apply it to insects? You create an origin story for Nature's tiniest creatures, one that gives them 'a Pedigree as ancient as the first creation'. This the English naturalist Robert Hooke (1635–1703) argued in his seminal treatise, the *Micrographia* (1665).[1] In what follows, I will retrace the steps that led Hooke down the path of insect genealogy. Hooke endeavoured to show how insects – then widely believed to have arisen out of the dirt – were the products of an ancient lineage. This paper will lay out, and explore, the various ways in which Hooke tried to study tiny animals in terms of their (family) history. While the fruits of these labours were heavily indebted to Hooke's skill as a careful observer, he could not have seen past genealogies through the lens of his microscope. Hooke used empirical means to make out the similarities between various insects; but he could only infer that these similarities derived from a common ancestor through a leap of the imagination. Hooke marks a turn: a move from *natural* history – collecting and describing Nature's productions – towards natural *history*: reconstructing their origins.

In the preface of the *Micrographia*, Hooke declared that his microscope would uncover 'the subtilty of the composition of Bodies, the structure of their parts, [and] the various texture of their matter'.[2] An example that can be (and often is) used to illustrate how the treatise delivered on this promise is observation no. 17, *Of the Schematisme and Texture of Cork*. There, Hooke described how he had cut off a piece from a cork oak, placed it onto a black object plate and examined it under the microscope, where he could 'plainly perceive it to be all perforated and porous, much like a Honey-comb' (Plate 1).[3]

The left slice (B) was a vertical cut into the cork from a sideways perspective, whereas the right slice (A) was a horizontal cross section that was obtained by looking from above. After contemplating the former, Hooke concluded that 'these pores, or cells, were not very deep, but consisted of a great many little Boxes'. Hooke then used these minute structures to *explain* why cork appeared to the senses the way it did. The reason why cork felt so light (compared to other types of wood) was because it was a 'very small quantity of a solid body, extended into exceeding large dimensions'. The reason why cork was so malleable was because it was made up of 'Bladders of Air, which is a substance of a springy nature'.[4]

[1]Robert Hooke, *Micrographia, or Some Phyisological Descriptions of Minute Bodies, made by Magnifying Glasses, with Observations and Inquiries thereupon* (London: John Martyn and James Allestry, 1665), p. 207. From now on: *Micrographia*.
[2]*Micrographia*, sig. a2v.
[3]*Micrographia*, p. 112–3.
[4]*Micrographia*, p. 113–4.

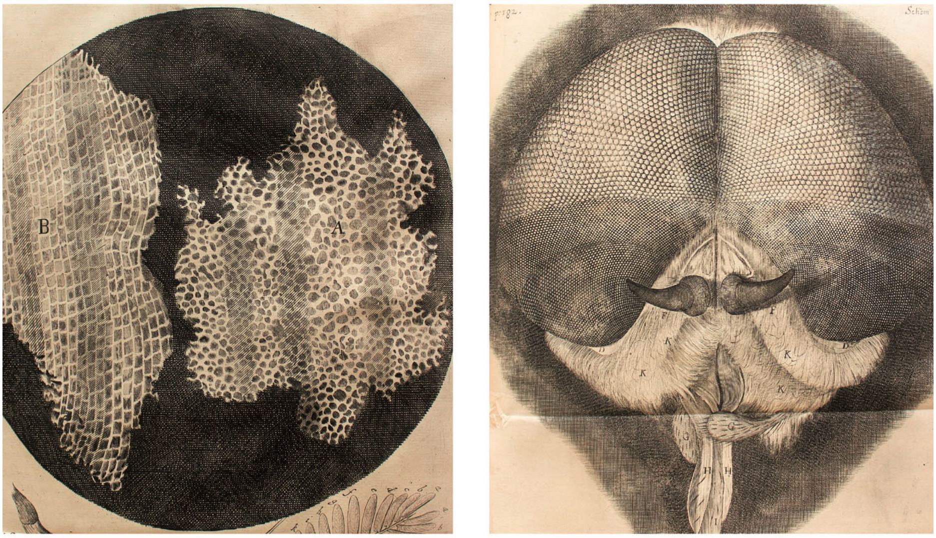

Plate 1. Inner structure of cork (left) and head of a 'drone fly' (right). Courtesy of the Trustees of the Edward Worth Library, Dublin.

The hope that the microscope would reveal the inner causes of outer appearances formed a leitmotif of the *Micrographia*.[5] If we turn to the scheme in observation no. 39, *Of the Eyes and Head of a Grey drone-Fly*, we can see Hooke's drawing of the compound eye. Hooke, of course, described its appearance in great detail. But what *caused* this type of appearance in the fly and other insects like it? Hooke, as I will show, didn't need to look inside the tiny creature to answer this question. Rather, he resorted to careful conjecture. What caused the eye to be like this, he maintained, was that it had been inherited from its parent, which had inherited the feature from its parent beforehand. The causal chain of inheritance ended in a 'prime parent' at the beginning of the Earth. Yet what was crucial about Hooke's argument was this: if the outer forms of insects were similar enough, then they also derived from one and the same cause: one and the same 'prime parent'.

Hooke conveyed certain ideas in the *Micrographia* by using his texts ('observations') as an interpretive aid for his drawings ('schemes').[6] Thus the text provided the reader with a set of instructions for how to decode the images. Hooke used the text to single out parts of an insect's body, describe their form and function, compare them to the parts of other insects, thereby

[5]A. R. Hall, *Hooke's Micrographia, 1665–1965* (London: The Athlone Press, 1966), p. 20. See also Marian Fournier, *The Fabric of Life: Microscopy in the Seventeenth Century* (Baltimore: John Hopkins University Press, 1996), which argues that this type of reasoning drove microscopy as a whole throughout the seventeenth century.

[6]Recent studies take a different tack, illuminating other aspects of Hooke's insect drawings. See Domenico Bertoloni Meli, 'The Representation of Insects in the Seventeenth Century: A Comparative Approach', *Annals of Science,* 67, No. 3 (2010), 405–29, here: 410–19; Janice Neri, *The Insect and the Image. Visualizing Nature in Early Modern Europe 1500–1700* (Minneapolis: The University of Minnesota Press, 2011), pp. 105–38; Meghan Doherty, 'Discovering the "True Form": Hooke's *Micrographia* and the Visual Vocabulary of Engraved Portraits', *Notes and Records of the Royal Society,* 66, Issue 3 (2012), 211–34.

guiding the reader's eye across the page until it rested on the significant features of his drawings. Reading the *Micrographia* involved folding out images, as well as flicking back and forth between pages, to synchronize words with their visual counterparts. While Hooke outlined the resemblances among the offspring of a 'prime parent' in his writing, his imagery visualized these claims and anchored them into an observed reality that his readers, then and now, could follow with their own eyes. Hooke's reader was led to *see* the commonalities between various insects within his drawings. Yet on top of this empirical foundation Hooke erected an edifice of theory which explained the observed similarities: family trees – genealogies – that reached back to the Earth's creation.

In order to understand what gave rise to these ideas we will have to place the *Micrographia* into context. In its preface, Hooke wrote that he was 'not a little incourag'd to proceed in it', his microscopic investigations, 'by the Incitements of divers of those Noble and excellent Persons'.[7] These individuals, 'my more especial Friends', were the fellows of the Royal Society – notably Robert Boyle, John Evelyn, Thomas Willis, John Wilkins and Christopher Wren – who held weekly meetings at Gresham College in the heart of London. As a curator of experiments, Hooke had been tasked with presenting his 'microscopical observations' at these meetings and it was there that the bulk of the *Micrographia* was formed.[8] The minutes of the Society chronicle Hooke's activity, the order in which he presented his work and the discussions he responded to. They will therefore be our point of entry – and remain an invaluable guide – as we navigate through the invisible world that was uncovered in the *Micrographia*.[9]

2. Man and mite: Hooke's theory of the Adam-insect

A newly founded institution was trying to impress a newly restored King. In 1660 Charles II reclaimed the throne. Subsequently, Christopher Wren – a fellow of England's new scientific academy, the Royal Society of London – presented the King images of a louse, flea and the wing of a fly.[10] The potential of illustrations made under the microscope quickly became apparent to Wren's friends at the Society. By August 1661, the task of 'drawing the Figures of small Insects by the Help of the Microscope' was handed over to Robert Hooke.[11]

[7] *Micrographia*, sig. g2v.

[8] For Hooke's social standing, see Mordechai Feingold, 'Robert Hooke: Gentleman of Science', in *Robert Hooke. Tercentennial Studies*, ed. by Michael Cooper and Michael Hunter (Aldershot: Ashgate), pp. 203–18. For the social context of the *Micrographia*, in particular, see John Harwood, 'Rhetoric and Graphics in *Micrographia*', in *Robert Hooke. New Studies*, ed. by Michael Hunter and Simon Schaffer (Woodbridge: The Boydell Press, 1989), pp. 119–47.

[9] Thomas Birch, *The History of the Royal Society of London*, Vol. 1 (London: A. Millar, 1756). From now on: Birch, *History*.

[10] J. A. Bennett, *The Mathematical Science of Christopher Wren*, (Cambridge: Cambridge University Press, 1982), p. 73. *Micrographia*, sig. g2r notes that Wren's 'draughts do now make one of the Ornaments of that great Collection of Rarities in the *King's Closet*'.

[11] Stephen Wren, *Parentalia: or, Memoirs of the Family of the Wrens […]* (London, 1750), pp. 210–11.

Months earlier, the Society's members had written to Wren, urging him 'to continue the description of several insects'. It was then that Hooke's mentor, John Wilkins, proposed 'as a subject worthy of consideration, the generation of several insects'.[12] The question of 'generation' (how was it that creatures came into being?) soon became a hotly debated issue in the Society's weekly discussions.[13] Following Wilkins' suggestion, one member was ordered to 'procure the history of insects'. Both Robert Boyle and John Evelyn were appointed 'curators for the observing of insects'. And a week later 'the committee for the examination of insects' was formed: the aim was to convene every Monday at 6 o'clock in Boyle's lodgings, where 'the generation of insects was discoursed of'.[14]

To facilitate discussion, two fellows had been ordered to acquire books on the topic. Reading texts wasn't eschewed in the Royal Society, even though its motto *nullius in verba* – incidentally, a phrase lifted from Horace – claimed otherwise. A statute of 1663 decreed that the 'business of the Society in their ordinary meetings' was to perform experiments, but also to 'read, hear and discourse upon letters, reports and other papers, containing philosophical matters'.[15] One such matter was insect generation. The conventional theory of 'spontaneous generation' derived from the Aristotelian corpus and held that insects arose randomly out of slime and other putrefying substances.[16] Aristotle himself had claimed that when sunlight hit water, a vital force (*πνεῦμα*) within water simply generated a variety of tiny animals.[17]

Aristotelian ideas about generation were closely linked to Hooke's microscopy. When Timothy Clarke reported in a meeting 'that the Barnet waters, on a hot sunshiny day, were found full of little insects', he and Hooke were sent out to investigate. It took only four weeks before 'Mr. Hooke was ordered to look upon them with a microscope and to draw the picture of them'.[18] What Hooke presented as 'a microscopical observation of a worm bred in rain-water and turned into a gnat'[19] eventually found its way into the *Micrographia* as observation no. 43, *Of the Water-Insect or Gnat*. There, Hooke argued against orthodoxy. It may be 'rationally suppos'd', he wrote, that 'these Gnats … were first dropt into this Water, in the form of Eggs'. In fact, these eggs were so small 'we need not wonder that we find not the Eggs themselves'. Neither should we be surprised if we hadn't seen

[12]Birch, *History*, pp. 21–2 (8 May 1661).
[13]Birch, *History*, pp. 54, 88, 114, 117–8, 212–3, 217–9, 226–7, 234, 269. On 'generation', see Domenico Bertoloni Meli, *Mechanism, Experiment, Disease. Marcello Malpighi and Seventeenth-Century Anatomy* (Baltimore, MD: John Hopkins University Press, 2011), pp. 208–233; Matthew Cobb, *Generation. The Seventeenth-Century Scientists Who Unraveled the Secrets of Sex, Life and Growth* (New York & London: Bloomsbury, 2006).
[14]Birch, *History*, pp. 22–4 (see also p. 25, 29).
[15]*The Record of the Royal Society of London*, Printed by The Royal Society of London 1912^3, p. 119. As an example of the bookish penchants of the Society's members, peruse Hooke's library at http://www.hookesbooks.com/, ed. by William Poole, Felicity Henderson and Yelda Nasifoglu.
[16]See Everett Mendelsohn, 'Philosophical Biology *vs* Experimental Biology: Spontaneous Generation in the Seventeenth Century', *Actes du XII congress interenational d'histoire de sciences,* Vol. 1-B (1971), 201–26; Daryn Lehoux, *Creatures Born of Mud and Slime: The Wonder and Complexity of Spontaneous Generation* (Baltimore, MD: John Hopkins University Press, 2017).
[17]Aristotle, *Generation of Animals*, 3.11, 762a19-26.
[18]Birch, *History*, p. 281 (21 July 1663), 288 (29 July), 294 (19 August).
[19]Birch, *History*, p. 301 (2 September 1663).

any parent near the water, as the eggs might have been 'ejected into the Air, and so, perhaps, carried for a good while too and fro in it'.[20]

Hooke's spirited defence of the egg – not some putrefying substance – as the *locus* of generation had discernible precursors in the Society. On 20 November 1661, a paper by Francis Willughby was read which argued that 'almost all insects' proceeded from eggs.[21] This question became a topic of heated discussion a year later: some fellows suggested (as did Willughby and Hooke) that a near-invisible egg might have been 'dispersed through the air' until it reached a substance 'disposed to ferment with it, for the production of this or that kind of animal'.[22] Perhaps Boyle was party to this too. After all, he had argued in *The Sceptical Chymist* (1661) that 'common water … will putrifie and stink, and then perhaps too produce … little Worms, or other Insects, according to the nature of the Seeds that were lurking in it'.[23] Other fellows took issue with this view in the meeting: if an egg had secretly been carried by the wind to putrefying water, they argued, then the egg's 'seminal virtue' would have been 'impaired, if not destroyed'. It is likely that Henry Power and Thomas Henshaw believed that the putrefying substance itself had birthed the insect. In the microscopic treatise *Experimental Philosophy* (1664), Power argued (similar to Henshaw) that 'not onley the Water, but the very Air itself' became 'full of Living creatures … when great putrefactions reign therein'.[24]

The origins of insects had long been believed to lie in the putrefaction of natural substances. It was a simple fact of observation that stinking cadavers and moldy cheese were soon found to be teeming with maggots and flies. How the decay of matter might have given rise to such insects was also of interest to the Royal Society. From October 1662 to June 1663, several of its fellows pursued experiments in which they filled either blood, grain or cheese into a vessel, sealed it (to prevent other insects from laying eggs inside) and then left the concoction to putrefy. Of course, nothing happened. Months later a seemingly irritated Evelyn declared that the whole affair had 'hitherto bred nothing'.[25] Did *that* refute spontaneous generation? The fellows' silence on this question speaks to the fact that it wasn't obvious what conclusions were to be drawn.[26] Thus while Hooke prepared his materials for publication by presenting numerous drawings

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[20] *Micrographia*, pp. 190–1.

[21] Royal Society Archives, Cl.P/15i/2, 3r-4v, here: 3r. For a discussion of Willughby and a transcription of his paper, see Brian Ogilvie, 'Willughby on Insects', in *Virtuoso By Nature. The Scientific Worlds of Francis Willughby FRS* (1635–1672), ed. by Tim Birkhead (Leiden & Boston: Brill, 2016), pp. 335–59.

[22] Birch, *History*, pp. 117–8 (22 October 1662).

[23] Robert Boyle, *The Sceptical Chymist […]* (London: Cadwell, 1661), p. 123. For an overview of Boyle's stance on seeds, see Peter Anstey, 'Boyle on Seminal Principles', *Studies in the History and Philosophy of Science Part C: Studies in the History and Philosophy of Biological and Biomedical Sciences,* 33, No. 4 (2002), 597–630.

[24] Henry Power, *Experimental Philosophy* (London: John Martin & John Allestry, 1664), p. 21. For Henshaw's observations, see *Philosophical Transactions,* 1 (1665), No. 3, 33–6, here: 35–6. The contemporary James Tyrrell (1642–1718) certainly thought that Henshaw's observations had shown 'the production of Flyes from May dew'. See Trinity College, Dublin, MS 454, 100r.

[25] Birch, *History*, pp. 118 (experiments proposed in October 1662); 212–3, 217 (continued in March 1663); 238 (May & Evelyn); 266–7 (June).

[26] In May 1665, Boyle drew up another 'catalogue of experiments relating to spontaneous generation'. Again, they yielded no results. See Birch, *History* (Vol. 2), pp. 48–9.

and observations of insects (Table 1), the experiments had no bearing on how these animals had come into being. For the author of the *Micrographia*, the 'generation' of insects was an open question without an empirical answer; hence it became subject to theoretical conjecture.

Table 1. Hooke's microscopic observations on insects at the meetings of the Royal Society.[27]

Date	Insect	*Micrographia*	Birch's *History*
Sept.–Oct. 1661	wandering mite	Obs. 50 | pp. 205–7	–
22 April 63	leeches in vinegar	Obs. 57 | p. 217	p. 219
29 April 63	6-eyed spider	Obs. 48 | pp. 200–2	p. 231
6 May 63	great belly'd gnat	Obs. 45 | p. 195	p. 234
6 May 63	tufted gnat	Obs. 44 | pp. 193–5	p. 234
20 May 63	head of an ant	Obs. 49 | pp. 203–5	p. 243
23 May 63	fly like a gnat	Obs. 43 | pp. 185–93	p. 243
27 May 63	male gnat	Obs. 44 | pp. 193–5	p. 248
10 June 63	sageleaves with spiders	Obs. 24 | p. 142	p. 255
1 July 63	viper powder	–	p. 270
8 July 63	millipede	–	p. 273
16 July 63	*tinea argentea* (moth)	Obs. 46 | pp. 195–8	p. 279
5 Aug. 63	snail teeth	Obs. 40 | p. 181	p. 292
19 Aug. 63	long-legged spider	Obs. 47 | pp. 198–200	p. 294
Sept.–Oct. 63	wandering mite	Obs. 50 | pp. 205–7	–
2 Sept. 63	worms in rainwater (gnats)	Obs. 43 | pp. 185–93	p. 301
9 Sept. 63	parts of fly	Obs. 37 | pp. 169–72	p. 303
14 Oct. 63	common fly	Obs. 42 | pp. 182–5	p. 316
21 Oct. 63	fly's wing	Obs. 38 | pp. 172–4	p. 320
28 Oct. 63	pismire (ant)	Obs. 49 | pp. 203–5	p. 322
4 Nov. 63	mite	Obs. 55 | pp. 213–5	p. 327
4 Nov. 63	different types of hair	Obs. 32 | pp. 156–62	p. 327
25 Nov. 63	silkworm's egg	Obs. 41 | pp. 181–2	p. 335
21 Sept. 1664	whealworm	–	p. 469
26 Oct. 64	viper tooth	–	p. 479

Of all the insects that Hooke scrutinized, mites caught his interest for the longest period of time. They were the first insects he investigated after he had been tasked with drawing images of insects in August 1661. At the beginning of observation no. 50, *Of the wandring Mite*, Hooke recounted these – his earliest – conjectures:

> In *September* and *October*, 1661. I observ'd in *Oxford* several of these little pretty Creatures to wander too and fro … When I first observ'd the former of these Insects, or Mites, I began to conjecture, that certainly I had found out the vagabond Parents of those Mites we find in Cheeses, Meal, Corn, Seeds, musty Barrels, musty Leather, &c.[28]

The word 'conjecture' here is important. Hooke *conjectured* – i.e. he advanced an hypothesis without empirical confirmation – that he was looking at the parents of all those mites that were supposedly generated from rotten substances. This was

[27]For the full list of observations, see John Harwood, 'Rhetoric and Graphics in *Micrographia*', in *Robert Hooke. New Studies*, ed. by Michael Hunter and Simon Schaffer, (Woodbridge: The Boydell Press, 1989), pp. 119–47, here: 124–5.
[28]*Micrographia*, pp. 205–6.

speculative. For after the *Micrographia* had been published, Francis Willughby, the Society's talented naturalist, was still 'trying, whether mites will breed of eggs, as they will in wood, cheese, pease, &c'.[29] By then Hooke had already advocated – in print – that mites originated from the eggs of 'vagabond Parents' who wandered into these putrefying areas. Of course, the frontispiece of William Harvey's *De Generatione* (1651) had already proclaimed *ex ovo omnia*, that 'everything derives from an egg'. Yet while it is unlikely that Harvey ever extended this principle to insects – like others he lacked empirical proof for this conclusion – Hooke 'conjectured' that even a mite had come out of the egg of a parent. Now that *ex ovo omnia* had also been made to apply to the lowliest of animals, the Harveyan principle was true to its word.[30]

Building on the assumption of parentage, Hooke speculated that 'the soil or body [mites] inhabit … seems to augment and nourish them also before they are hatch'd or shaped'.[31] In observation no. 55, *Of Mites*, he added:

> This Creature is very much diversify'd in shape, colour, and divers other properties, according to the nature of the substance out of which it seems to be ingendred and nourished, being in one substance more long, in another more round, in some more hairy, in others more smooth, in this nimble, in that slow, here pale and whiter, there browner, blacker, more transparent, &c.[32]

Presumably Hooke came to this conclusion because he had seen certain kinds of *mites* in certain kinds of *places*. Henry Power, a fellow microscopist at the Society, had inserted these places into his nomenclature of mites in order to establish classificatory distinctions: 'A Wood-Louse, or Wood-Mite', 'Mites in Cheese', 'Mites in Malt-dust and Oatmeal-dust', 'Mites, bred amongst Figs', 'The Mites, in Jujubes and Sebesten's', 'The red Mite, found on Spiders', 'The Mites or Lice found on Humble-Bees', 'Pond Mites'.[33] Hooke, of course, had studied these observations.[34] But he went far beyond them in theorizing that 'the bodies [the eggs of mites] are laid in being, as it were, half their mothers, have such an active power to change their forms'.[35] If the nurturing environment was to count as one half of the mother, then cross-breeding it with the other half – the maternal insect – would naturally produce offspring with altered bodily forms. Did this mean that one and the same parent-insect could generate differently shaped offspring by laying its eggs into different environments?

[29]Birch, *History* (Vol. 2), p. 48 (17 May 1665).
[30]Harvey seems to have accepted spontaneous generation. See his: *Exercitationes de Generatione Animalium* […], (London: L. Pulleyn, 1651), p. 122: 'Quaedam igitur animalia sua sponte nascuntur, ex materia sponte, vel casu concocta; ut *Aristoteles* videtur assere … Apes, crabrones, papiliones … casu orta'. For a more ambiguous passage, see p. 112
[31]*Micrographia*, p. 206.
[32]*Micrographia*, p. 214.
[33]Henry Power, *Experimental Philosophy* (London: John Martin & John Allestry, 1664), Observations 7, 12–18.
[34]See Hooke's letter to Boyle on 3 July 1663: 'There is very little in Dr. Power's microscopical observations but what you have since observed'. From: Michael Hunter, Antonio Clericuzio and Lawrence Principe (eds.), *The Correspondence of Robert Boyle*, Vol. 2 (1662–5) (London: Pickering & Chatto, 2001), p. 98.
[35]*Micrographia*, p. 206.

Scanning through the table of contents of the *Micrographia* suggests that we are on the right track. There, observation no. 55, *Of Mites*, is summarized as 'A description of the Mites of Cheese: and an intimation of the variety of forms in other Mites, with a Conjecture at the reason'.[36] A close look at Hooke's investigation of mites, then, promises to illuminate what kind of theory he proposed to explain bodily variations among mites and how he conveyed this to the reader with the help of his microscopic images.

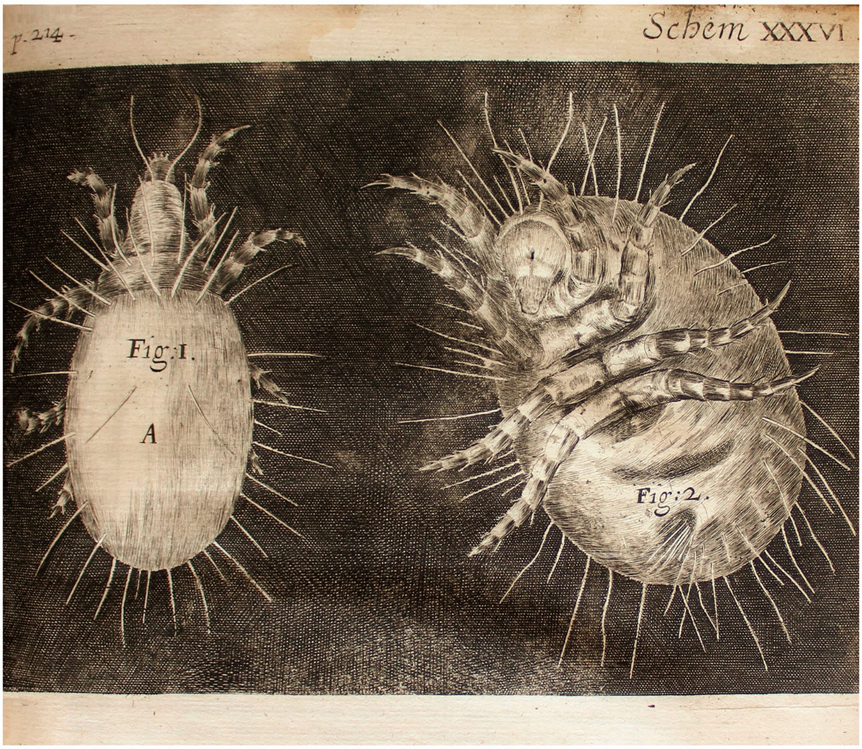


Plate 2. Two 'ordinary Cheese mites'. Courtesy of the Trustees of the Edward Worth Library, Dublin.

The plate accompanying observation no. 55 depicts two 'ordinary Cheese mites' (Plate 2). As one of only two schemes in *Micrographia* portraying multiple insects, it was meant to invite the reader to make visual comparisons. Hooke pointed to several commonalities between both mites: 'each of them [was] furnished with eight well shap'd and proportioned legs', a shell that was 'white' or 'pretty transparent' and a snout-shaped head.[37] Yet both mites also had variations within their common features. If one looks more closely, keeping in mind the features that Hooke designated as alterable (what we as the readers

[36]*Micrographia*, p. [254].
[37]*Micrographia*, pp. 213–4.

should be looking for), one recognizes that the second mite is rounder, more hairy and slower, due to its larger size. Indeed, Hooke said of the two figures that it was ‘the first whereof is a prospect of a smaller sort of Mites’ (Plate 2, Fig. 1).[38] The rotated close-up perspective of the second figure was carefully chosen to evoke this difference in size (in addition to opening up a view of the underbody). Hence, Plate 2 was not just a mere image of minute creatures: Hooke used the depiction of both mites, side by side, to highlight that even two seemingly identical mites had a certain range of anatomical variability.

This teaches us that the act of comparison was crucially important when reading Hooke’s illustrations. It cannot be a coincidence that the only other scheme depicting multiple insects also portrayed a mite. But this time, it was a mite of a different kind, one which Hooke baptized the ‘wandring mite’. This creature naturally had many similarities with the two mites depicted in Plate 2; yet Hooke chose to place it next to what he called a ‘crab-like insect’ (a pseudoscorpion). Once the reader had folded out the scheme in its entirety, the juxtaposition of both animals could develop its suggestive force (Plate 3).

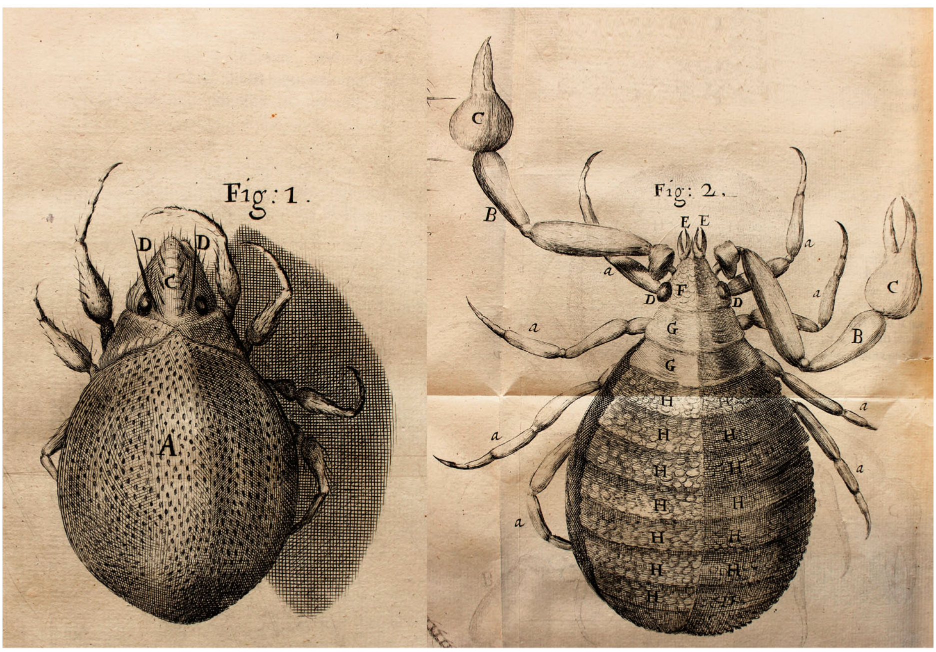


Plate 3. The ‘wandring mite’ (left). The ‘crab-like insect’ or ‘mite-Worm’ (right; resized). Courtesy of the Trustees of the Edward Worth Library, Dublin.

Nomenclature alone suggested that the ‘wandring mite’ (Plate 3, Fig. 1) was closely related to the ‘Cheese mites’ in the previous image. If we compare the mites in Plates 2 and 3, we can see that they share many common features:

[38]*Micrographia,* p. 214.

the crustaceous shell, snout-like head, arrangement of eight legs. Yet what was distinctive about the wandering mite, Hooke noted, was that it 'seemed to be a kind of black Mite, but much nimbler and stronger then the ordinary Cheese-Mites'.[39] The dark colour of the wandering mite seems obvious enough if one considers the inversion of the background colour (object plate) in Plates 2 and 3. But why was the wandering mite nimbler? Hooke draws our attention to its crustaceous legs, each of which was 'provided with a very sharp talon, or claw at the end, which this little Animal, in its going, fastened into the pores of the body over which it went'. And why was it stronger? If we look at the wandering mite's compact shell, it becomes apparent why Hooke recalled that this creature was 'very easily [able] to tumble a stone or clod four times as big as its whole body'.[40] All in all, the wandering mite was presented to the reader as a darker, speedier, more robust variant of the ordinary cheese mite.

Yet Hooke chose to continue the observation entitled *Of the wandring Mite* (no. 50) not with the cheese-mites in *Of Mites* (no. 55), but with *Of the Crab-like Insect* (no. 51). The reason for this was that he was cleverly expanding the web of kinship relations to include the 'crab-like' insect depicted as Fig. 2 in Plate 3. Hooke likened this creature to a 'large mite' and previously had labelled it a 'Mite-worm', implying both similarity of form and sameness of kin. But he also observed that it had 'very sharp claws … like those of a Crab, which in many other things also this creature resembled'.[41] The strong resemblance that this insect bore to mites was, in turn, reinforced by pointing to the crab-like features of 'Cheese Mites'. In observation no. 55, *Of Mites*, Hooke observed that their legs were 'bendable in eight several places, or joynts' and noted that 'the contrivance of the joynts seems the very same with that of Crabs and Lobsters legs'.[42] The cheese mite, just like the wandering mite, was closely related to the crab-like insect and vice versa. Hooke was using the two plates above to convey that all of these 'mites', despite there being variations between them, shared a similar anatomy.[43]

At the end of observation no. 55, *Of Mites*, Hooke derived these similarities from a common ancestor:

> [I]t seems probable, that some kind of wandring Mite may sow, as 'twere, the first seeds, or lay the first eggs, in those places, which Nature has instructed them to know convenient for the hatching and nourishing [of] their young; and though perhaps the prime Parent might be of a shape very differing from what the offspring, after a little while, by reason of the substance they feed on, or the Region (as 'twere) they inhabite; yet perhaps even one of these alter'd progeny, wandering

[39] *Micrographia*, p. 205.
[40] *Micrographia*, pp. 205–6.
[41] *Micrographia*, p. 207. For the mite-worm reference: p. 178.
[42] *Micrographia*, p. 214.
[43] Hooke's use of the term 'mite' shows its broad semantic range: 'wandring mites', 'cheese-Mites', 'mite-Worms' as well as the 'small Vine-Mites' of observation no. 56, *Of a small Creature hatch'd on a Vine*.

> again from its native soil, and lighting on by chance the same place from whence its prime Parent came, and there settling, and planting, may produce a generation of Mites of the same shapes and properties with the first wandring Mite: And from some such accidents as these, I am very apt to think, the most sorts of Animals, generally accounted *spontaneous*, have their *origination*, and all those various sorts of Mites, that are to be met with up and down in divers putrifying substances, may perhaps be all of the same kind, and have sprung from one and the same sort of Mites at the first.[44]

This 'Pedigree', Hooke contended, was 'as ancient as the first creation'.[45] But where had he gotten the idea of an ancient family tree?

'*Adam* … was the first man', a London minister reasoned six years earlier,

> so Original sin properly is not derived from the proximate Parents, but the prime-parent … one comprehending the whole root, representing the whole stock, the seed and generation of mankind.[46]

Hooke took the concept of a 'prime parent', a concept from human genealogy, and applied it to Nature's smallest creatures. Mites, too, were all descendants of one prime parent. From this primordial parent they derived original (anatomical) properties. Just as there was a first *man*, there was a first *mite*.[47]

How the 'Adam' mite had produced offspring with such a wide range of properties was a question that could be answered by thinking through the analogy. Environmental influences – the different climate, nourishment and soil of the Earth's regions – had served as an explanation (since the Middle Ages) of why humanity had become so diverse after its geographical dispersion following Noah's Flood.[48] Thus, in the case of mites too, Hooke attributed alterations of progeny to 'the substance they feed on, or the Region (as 'twere) they inhabite'. Indeed mites, he argued, 'might be quite alter'd from the hew of their *primogenitors*, and, like *Mores* translated into Northern *European* Climates, after a little time, change both their skin and shape'.[49] Hence the *black* 'wandring' mite traipsed over the different territories of the microworld, leaving behind offspring of a changed colour and form like the *white* 'cheese' mite. The

[44] *Micrographia*, pp. 214–5.
[45] *Micrographia*, p. 207.
[46] Thomas Case, *The Morning Exercise Methodiz'd […] Sermons, by several Ministers of the City of London […] at Giles in the Field, May 1659*, (London: E.M. for Ralph Smith, 1659), p. 136.
[47] Note that in this period 'prime parent' stood for either Adam or Eve (but usually the former); 'prime parents' stood for the couple. For alternating usages, see, e.g. John Gaule, *Sapientia Justificata […]* (London: N. Paris & Thomas Dring, 1657), p. 19, 43; Richard Turnbull, *An Exposition upon the Canonicall Epistle of Saint James* […], (London: John Windet, 1592), 7v, 219v, 241v; Edward Gosynhyll, *The Prayse of all Women […]*, London? 1542, [5v]. The Latinate counterpart *primus parens* had long been in use since the Middle Ages.
[48] For environmental theories of human difference and their varying contexts see (in chronological order): Nicolàs Wey Gòmez, *The Tropics of Empire. Why Columbus Sailed South to the Indies*, in *Transformations: Studies in the History of Science and Technology*, ed. by Jed Z. Buchwald (Cambridge, MA & London: MIT Press, 2008), pp. 69–92; Margaret Hodgen, *Early Anthropology in the Sixteenth and Seventeenth Centuries* (Philadelphia: University of Pennsylvania Press, 1964), pp. 207–94; Joyce Chaplin, 'Natural Philosophy and an Early Racial Idiom in North America: Comparing Indian and English Bodies', *The William and Mary Quarterly*, 54, No. 1 (1997), 229–52; Rhodri Lewis, 'William Petty's Anthropology: Religion, Colonialism, and the Problem of Human Diversity', *Huntington Library Quarterly*, 74, No. 2 (2011), 261–88, esp. 273–84.
[49] *Micrographia*, p. 206.

Wanderlust of the prime parent, or 'wandring' mite, ensured that the trunk of the family tree branched out into different types of progeny. Thus the reader came to see Plate 2 and 3 in a new light. These didn't just show the composition of minute bodies. They illustrated theoretical conjectures. Could one not *see* that such creatures were products of the same lineage? Despite their apparent diversity, Hooke argued, these animals were all 'mites' originating from one and the same parent.

Hooke's argument attempted to dispel the idea that insects arose 'spontaneously' from rotting matter. Were anatomical similarities – the ones that Hooke so carefully brought out under the microscope – mere artefacts of chance? Hooke offered an alternative explanation by tracing them back to a common parent, the 'prime parent'. Years before Francesco Redi's *Esperienze Intorno alla Generazione degl' Insetti* (1668) and Jan Swammerdam's *Historia Insectorum Generalis* (1669) cast serious doubt on spontaneous generation with observation and experiment, Hooke had done it through conjecture and argument.[50] Yet Hooke conceded that 'whether indeed this Creature, or any other, be [spontaneously generated] or not, I cannot positively, from any Experiment, or Observation, I have yet made, determine'.[51] This admission had obvious consequences: if spontaneous generation *did* turn out to hold true (a question that was still open), then the different types of mites had simply arisen out of putrefying matter. Their resemblances, hence, would not be explicable in terms of a common ancestor. Nevertheless, Hooke deemed it 'probable' that all mites originated from the same parent, thereby making a theoretical leap that wasn't grounded in what he himself considered to be the experimental method.

The famous 'cells' of cork had actually been *observed*. Yet the invisible web of ancestral relations was never seen by Hooke through the lens of a microscope, but *inferred* – as a conjecture – after comparing the bodies of multiple insects.[52]

In what remains, I will circumscribe the nature and scope of Hooke's genealogical theorizing. How were insects grouped into families? What even was an 'insect'? And who were their most ancient ancestors? These questions will take us deep into the thought of Robert Hooke.

[50]Compare: Francesco Redi, *Esperienze Intorno alla Generazione degl' Insetti […]*, edited with an introduction by Walter Bernardi, (Florence: Giunti, 1996), pp. 86–9, 91. And: Jan Swammerdam, *Historia Insectorum Generalis, ofte, Algemeene Verhandeling van de Bloedeloose Dierkens […]*, (Utrecht: Meinard van Dreunen, 1669), pp. 56–168 & appended 'Verclaringe ofte Uitlegginge, van de vier Orderen der veranderingen'. For Swammerdam's context, see Eric Jorink, 'Snakes, Fungi and Insects. Otto von Marseus van Schrieck, Johannes Swammerdam and the Theory of Spontaneous Generation', in *Zoology in Early Modern Culture: Intersections of Science, Theology, Philology, and Political Religious Education*, ed. by Karl Enenkel and Paul Smith (Leiden & Boston: Brill, 2014), pp. 197–234, esp. 214–28. For Redi's, see Paula Findlen, 'Controlling the Experiment: Rhetoric, Court Patronage and the Experimental Method of Francesco Redi', *History of Science,* 31, No. 1 (1993), 35–64. See further: Domenico Bertoloni Meli, *Mechanism, Experiment, Disease*, pp. 179–86, 195–201.

[51]*Micrographia*, p. 214.

[52]Readings of the *Micrographia* that identify the book as 'an apologetic and as a kind of experimental philosophy' or 'a prescriptive model … for the safe and reliable attainment of knowledge' need to be complicated. Cf., respectively, Michael Aaron Dennis, 'Graphic Understanding: Instruments and Interpretation in Robert Hooke's *Micrographia*', *Science and Context,* 3 (1989), 309–64, here: 312; Adrian Johns, *The Nature of the Book: Print and Knowledge in the Making* (Chicago: University of Chicago Press, 1998), p. 428.

3. Many machines, same components: common ancestry in a mechanistic universe

The early modern period witnessed a craze for genealogies. Noblemen and royalty were keen to demonstrate, often with illustrated family trees, how their lineages went back as far back as antiquity.[53] For Hooke, 'mites' were representatives of an ancient family too. Like humanity, they traced back to an ancient ancestor. Unlike humanity, they did not seem to leave behind documents that established such a history. Hooke, as I will show later, attempted to *read* fossils as 'Records' of the oldest animals. But how did Hooke determine which creatures in the present came from the same family?

Hooke had presented four illustrations of 'gnats' in rapid succession at the Royal Society. Between 6–23 May 1663 he showed (see Table 1) a 'great belly'd gnat', 'tufted gnat', 'fly like a gnat' and 'male gnat'. During these meetings, James Long 'related divers considerable observations of his, concerning insects', whereafter the fellows asked him 'to continue his curiosity, in observing farther their various productions and changes, at what times, and upon what plants or leaves they breed'.[54] In the *Micrographia*, Hooke followed this suggestion too. The 'tufted gnat', he observed, was similar to those that 'hatch'd out of those little Insects that wriggle up and down in Rain-water'. While 'many were of this form', Hooke found 'others to be of quite other kinds'. Thus there were gnats 'of the same shape, but much smaller and tenderer … creep[ing] up and down upon the leaves of Trees … in places very remote from water'. In the springtime Hooke had observed swarms of gnats that were even smaller, 'though very much of the same shape, which makes me ghess, that each of these swarms might be the offspring of one onely Gnat'.[55]

Hooke immediately went on to express the notion of a shared genealogy in the language of mechanism:

> And indeed, so various, and seemingly irregular are the generations or productions of Insects, that he that shall carefully and diligently observe the several methods of Nature therein, will have infinitely cause further to admire the wisdom and providence of the Creator; for not onely the same kind of creature may be produc'd from several kinds of ways, but the very same creature may produce several kinds: For, as divers Watches may be made out of several materials, which may yet have all the same appearance, and move after the same manner, that is, shew the hour equally true, the one as the other, and out of the same kind of matter, like Watches, may be wrought differing ways; and, as one and the same Watch may, by being diversly agitated, or mov'd, by

[53]Anthony Grafton, *What was History? The Art of History in Early Modern Europe* (Cambridge: Cambridge University Press, 2007), pp. 146–65; William Poole, *The World Makers: Scientists of the Restoration and the Search for the Origins of the Earth* (Oxford: Peter Lang Ltd, 2010), pp. 75–87.
[54]Birch, *History*, p. 242 (20 May 1663).
[55]*Micrographia*, p. 193.

> this or that agent, or after this or that manner, produce a quite contrary effect: So may it be with these most curious Engines of Insect's bodies; the All-wise God of Nature, may have so ordered and disposed the little *Automatons*, that when nourished, acted, or enlivened by this cause [i.e. the environment], they produce one kind of effect, or animate shape, when by another they act quite another way, and another Animal is produc'd.[56]

For Hooke, an insect was a living machine. He noted that an intelligent agent could take one and the same machine and 'agitate' its inner machinery in various ways. This caused the parts to behave differently (e.g. the hands of a watch to move in alternate directions or at varying speeds) and thereby produced different types of devices with varied effects. That was a way of expressing how one could start with one machine, a 'prime parent', and end up with many different kinds of machines, the various types of offspring.

Yet the true power of Hooke's analogy lay in its likening of an insect's body to a pocket watch. Hooke – himself a skilled instrument maker – was intimately acquainted with the construction of watches: their inner machinery consisting of the wheels, escapement and spring, as well as the outer arrangement of the face and hands.[57] These components, Hooke noted, could be 'made out of several materials' and were replaceable by similar parts of varying shapes and sizes as the same material 'may be wrought differing ways'. Thus there could be many different-looking pocket watches; yet they counted as the same kind of device because they all told the time. The reason that the mechanical watches of Hooke's world could 'shew the hour equally true' (they, in fact, didn't) was because they were constructed along the same structural plan. If one examines actual pocket watches from early seventeenth-century London, it is not hard to see that these portable timekeepers relied upon a shared set of components, which nevertheless allowed for certain forms of variation (Plate 4).

If insects were machines that just happened to be built up of other components than pocket watches – legs, feelers, wings etc. – which also came in different shapes, sizes and materials, then indeed it was true that the 'same kind of creature may be produc'd from several kinds of ways'. The watch served Hooke as an important analogy with which he was able to articulate genealogy within the language of mechanism. By drawing on the fact that a diverse assortment of pocket watches all counted as timekeeping devices by virtue of the

[56]*Micrographia*, pp. 193–4.

[57]Among the Society's inventions in the years before the *Micrographia* was published, Thomas Sprat's *History of the Royal Society […]*, (London: J. Martyn, 1667), p. 247 records 'several new kinds of *Pendulum Watches* for the Pocket, wherein the motion is regulated, by Springs or Weights'. Hooke later claimed that he had invented the pocket watch with a spring attached to the balance wheel, sparking a famous priority dispute with Christiaan Huygens. See Richard Waller, *The Posthumous Works of Robert Hooke […]* (London: Sam Smith & Benj. Walford, 1705), pp. v–vii; Robert Hooke, *Lectures De Potentia Restitutiva, or Of Spring* (London: John Martyn, 1678), p. 6; Rob Iliffe, '"In the Warehouse": Privacy, Property and Priority in the early Royal Society', *History of Science,* 30 (1992), 29–68.

Plate 4. Pocket watches manufactured in London (ca. 1600–1640). Courtesy of the Metropolitan Museum of Art. Gifts of J. P. Morgan, 1917. www.metmuseum.org.[58]

same components, Hooke expressed the idea that a diverse group of insect automata counted as members of the same family in virtue of their shared anatomic components, ones that had been provided by a 'prime parent'. Offspring varied from its primordial parent, just as the same kind of pocket watch could vary in the size, shape and material of its individual components. Thus Hooke masterfully integrated his speculative notion of genealogy into mechanistic orthodoxy.

This line of thought delivers a plausible reason why Hooke made four presentations of different kinds of gnats within three consecutive meetings. He wanted to show the fellows of the Royal Society that gnats – like pocket watches – exhibited distinct variations, but relied on the same set of components. In observation no. 45, *Of the great Belly'd Gnat or female Gnat*, Hooke began to pinpoint commonalities and variations between the male ('tufted') and female ('great belly'd') gnat in order to illustrate his point vividly (Plate 5):

> The second [female] Gnat, delineated in the twenty ninth *Scheme*, is of a very differing shape from the former [male]; but yet of this sort also. … The *thorax* of this, was much like that of the other, having a very strong and ridged back-piece, which went also on either side of its leggs; … its head was much differing from the other, being much bigger and neater shap'd, and the horns that grew out between his eyes on two little balls, were of a very differing shape from the tufts of the other Gnat … The formost horns or feelers, were like those of the former Gnat.[59]

[58]Left: 'Watch in the form of a Lesser George', built in ca. 1600 by Nicholas Vallin, a leading London clockmaker. Middle: 'Clock watch', built in London in ca. 1610 by Michael Nouwen. Right: 'Watch', built in ca. 1640 by Edward East, a co-founder of the London Clockmakers' Company.

[59]*Micrographia*, p. 195.

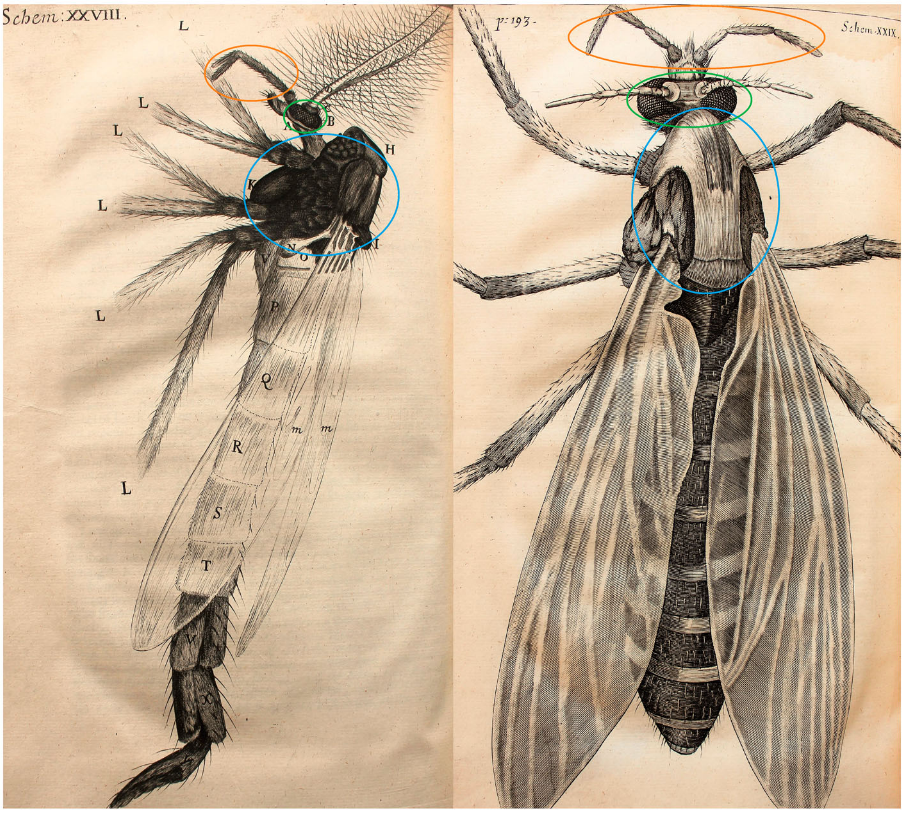


Plate 5. Insect Machines. Male (left) and female (right) gnat. Courtesy of the Trustees of the Edward Worth Library, Dublin.

In the text Hooke singled out two shared components. First, both gnats had been constructed with a similar thorax, holding their legs and wings in place (blue/lower circle). Second, the same types of antennae had been attached to both insects (orange/upper circle). In previous remarks, Hooke had also discerned features that the male gnat shared with the 'common fly'. Given that his group presentation also included a 'fly like a gnat', these observations are just as applicable here. Hooke recognized that the male gnat possessed 'two clusters of pearl'd eyes … whose pearls or eyeballs are curiously rang'd like those of other Flies' (green/middle circle & compare with Plate 1). He also noted that the male gnat had 'six long and slender legs … shap'd just like the legs of Flies, but spun or drawn out longer and slenderer'. In fact, the legs of both gnats were so long that Hooke was only able to fit a fraction of them onto the plate. Finally, he mentioned the 'two oblong, but slender transparent wings' that gnats and flies were equipped with.[60]

By focusing on commonalities, Hooke outlined the shared set of components that made up gnats and flies. Yet while these tiny machines had been assembled

[60]*Micrographia*, p. 194.

from the same components, these parts also differed in shape and size. Indeed, Hooke singled out individual parts that showed such variation. He pointed out that the female's abdomen ('belly') was considerably shorter and a lot wider. Turning to the head of the male, Hooke observed that the pair of 'feelers' that protruded from the area between its eyes exhibited prominent tufts. In order to mark these differences, Hooke christened the female the 'great belly'd' and the male the 'tufted' gnat.[61] When communicating these findings to the Royal Society, Hook had 'exhibited a microscopicall observation of a female gnat, distinguished from the male by the bigness of her belly; that of the male being thin and lank, the male having also a tuft'.[62] In the passage quoted above, Hooke stated that the female was of a 'very differing shape' than the male, hastening to add 'but yet of this sort'. Now, it seems like an obvious claim that females and males of the same 'sort' were related; but Hooke had no principled method for distinguishing their biological sex. He only treated them both as 'gnats' because they shared so many anatomic parts.[63] Thus Hooke's notion that these insects were the same kind of machine, i.e. that they were assembled from the same stock of components, made a substantial claim about their ancestral relatedness.

Hooke began to highlight anatomical similarities across a much wider range of different insects. But such observations did not always imply genealogical claims, but also served to integrate insects into a broader category of classification. Inside Hooke's presentation of four gnats at the Royal Society one image sticks out: the 'head of an ant' (see Table 1). Thus we turn to observation no. 49, *Of an Ant or Pismire*, an insect that Hooke drew by sedating it within in a pool of brandy, which 'knock'd him down dead drunk' (Plate 6).[64]

The anatomical resemblances between this ant and the gnats immediately strikes the eye. There is the head with its two antennae; a pair of pearled eyes; the shell-covered body with a thorax holding in place six long and hairy legs. In the text, Hooke compared the ant with the 'blue fly', just as he had compared the male gnat with the 'common fly'. Thus he noted that the ant's head had 'two protuberant eyes, pearl'd like those of a Fly but smaller BB' and 'two horns CC, of a shape sufficiently differing from those of a blew Fly, though indeed they seem to be the same kind of Organ'.[65] Hooke concluded:

> It [the ant] had only six legs, shap'd like those of a Fly, which, as I shewed before, is an Argument that it is a winged insect, and though I could not perceive any sign of them in the middle part of its body (which seem'd to consist of three joints or pieces EFG,

[61] *Micrographia*, p. 195.
[62] Birch, *History*, 234 (6 May 1663).
[63] *Micrographia*, p. 195. Hooke mentions 'several particulars' of both 'gnats' (without specification), from which he deduces their sexes.
[64] *Micrographia*, p. 204.
[65] *Ibid*.

Plate 6. The drunken ant. Courtesy of the Trustees of the Edward Worth Library, Dublin.

> out of which sprung two legs), yet 'tis known that there are of them that have long wings, and fly up and down in the air.[66]

Hooke couldn't identify any wings on the ant, yet still he argued that it was a winged insect. Perhaps he knew from experience that most ants had nuptial flights, a period when thousands of temporarily winged virgin queens from different colonies swarmed.[67] Hooke had preceded his second showing of an ant with two illustrations of a 'fly's wing' and a 'common fly' (see Table 1). And as Hooke compared ants, gnats and flies with each other in the *Micrographia*, he was empirically establishing that they were 'winged insects'. But here, the similarity of their parts did not necessarily imply common ancestry, but common classification.

Ants and gnats were also classified as 'winged insects' in another work of the Royal Society published three years later. In 1668 John Wilkins, Bishop of Chester, unleashed *An Essay Towards a Real Character, and a Philosophical Language*. This ambitious work hoped to reform existing languages (believed to be defective) into one universal language that mirrored the '*nature of things*'.[68] Wilkins drew up various tables for his new language, among them also tables of plants and animals which he devised with the assistance of

[66] *Micrographia*, pp. 204–5.

[67] Otherwise, a textual authority for winged ants was: Georg Margrave & Willem Piso, *Historia Naturalis Brasiliae* (Antwerp: Johannes de Laet, 1648), p. 252: 'Reperitur hic Formica volans, unum digitum longa'. Hooke knew this work (see *Micrographia*, p. 188.)

[68] John Wilkins, *An Essay Towards a Real Character, and a Philosophical Language* (London, Sa. Gellibrand & John Martyn, 1668), sig. b2r. From now on: Wilkins, *Essay*. For the *Essay*, its context and significance, see Rhodri

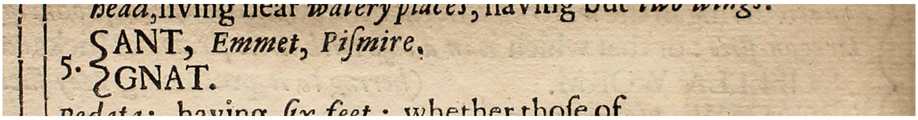


Plate 7. Confusing ambiguity. One 'species' of insect comprising two insect 'species' in John Wilkins' *Essay* (1668). Courtesy of the Trustees of the Edward Worth Library, Dublin.

Francis Willughby and John Ray. Hooke, too, was involved, although in what capacity remains unclear.[69] Wilkins' classification scheme was built on the Aristotelian notion of genus and species (as expounded in Porphyry's introductory work of logic, the *Isagoge*). According to Wilkins' gloss, a genus (e.g. here: 'exanguious animals') was divided into differences (e.g. here: 'naked' vs. 'sheathed winged insects'). These divisions were then carried out again and again, until they generated a 'species': a type of animal (Plate 7, no. 5). Such a 'species' comprised two animals, which were grouped together as a pair for the 'better helping of the Memory'.[70]

While the term 'species' here designated a type of animal, the term could also signify a family. For Wilkins, as for Hooke, 'ANT' and 'GNAT' were each a separate species-family. A 'species' in this sense comprised a set of animals deriving from the same parent.[71] And, as Hooke lectured in 1668, 'there may have been divers new varieties generated of the same Species'. For 'the alteration of the Climate, Soil and Nourishment', he continued, was 'the reason of that great variety of Creatures that do properly belong to one Species'. He gave as an example that all 'Dogs' belonged to one species-family, the same went for 'Sheep, Goats, Deer, Hawks, Pigeons, &c'.[72] These families could be found in Wilkins' classification tables. Moreover, the Bishop illustrated how these species-families traced back to their ancestors inside Noah's Ark (Plate 8).[73]

A literalist interpretation of Noah's Ark provided a framework – and a chronological marker – to think about animals genealogically. If humans had survived in the Ark and repopulated the world after the Flood, inhabiting new regions and diversifying accordingly, then animals had done the same.[74] Bishop Wilkins incorporated animal genealogies into Biblical accounts of the

Lewis, *Language, Mind and Nature: Artificial Languages in England from Bacon to Locke* (Cambridge: Cambridge University Press, 2012).

[69]For the acknowledgement of Ray and Willughby, see Wilkins, *Essay*, sig. c1r. Furthermore, see Rhodri Lewis, *Language, Mind and Nature*, pp. 151–3.

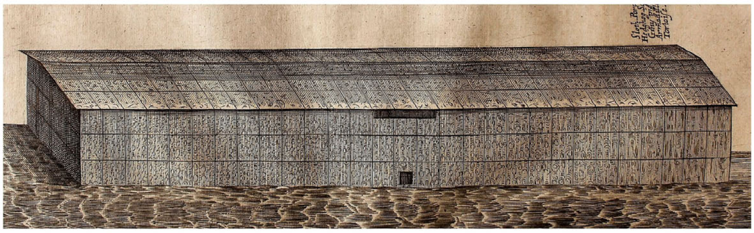
[70]Wilkins, *Essay*, p. 22, 126. See further: Rhodri Lewis, *Language, Mind and Nature*, pp. 160–3.

[71]This idea of 'species' was already present in William Harvey, who wrote that (non-insect) animals come 'from one beginning (namely, from the same species), [and] follow one another to all eternity'. See his: *Exercitationes de Generatione Animalium* [...], (London: L. Pulleyn, 1651), p. 122: 'sanguinea terrestria, vel aquitilia, quae ab univoco principio (nempe ab eadem specie) aeternitatem consequuntur'. Later, John Ray famously defined a species of plant as all those individuals which 'arise from the seed of the same plant' See: John Ray, *Historia Plantarum [...]*, Vol. 1, (London: Maria Clark, 1686), p. 40: '... ex eiusdem ... plantae seminae oriuntur.'

[72]Richard Waller, *The Posthumous Works of Robert Hooke [...]* (London: Sam Smith & Benj. Walford, 1705), pp. 327–8.

[73]Wilkins, *Essay*, p. 164.

[74]This view was later summarized in: Matthew Hale, *The Primitive Origination of Mankind [...]* (London: William Godbid for William Shrowsberry, 1677), pp. 199–203.



Beaſts feeding on Hay.				Beaſts feeding on Fruits, Roots and Inſects.				Carnivorous Beaſts			
Number.	Name.	Proportion to Beeves.	Breadth of Stalls feet	Number.	Name	Proportion to Sheep.	Breadth of the Stalls. feet	Number.	Name	Proportion to Wolves.	Breadth of their Stalls. feet
2	Horſe	3	20	2	Hog	4		2	Lion	4	10
2	Aſſe	2	12	2	Baboon	2		2	Beare	4	10
2	Camel	4	20	2	Ape	2		2	Tigre	3	8
2	Elephant	8	36	2	Monky			2	Pard	3	8
7	Bull	7	40	2	Sloth			2	Ounce	2	6
7	Urus	7	40	2	Porcupine	7	20	2	Cat	2	6
7	Biſons	7	40	2	Hedghog			2	Civet-cat		
7	Bonaſus	7	40	2	Squirril			2	Ferret		
7	Buffalo	7	40	2	Ginny pig			2	Polecat		
7	Sheep	1		2	Ant-bear	2		2	Martin		
7	Stepciſeros	1	30	2	Armadilla	2		2	Stoat	3	6
7	Broad-tail	1		2	Tortoiſe	2		2	Weeſle		
7	Goat	1						2	Caſtor		
7	Stone-buck	1	30			21	20	2	Otter		
7	Shamois	1						2	Dog	2	6
7	Antilope	1						2	Wolf	2	6
7	Elke	7	30					2	Fox		
7	Hart	4	30					2	Badger	2	6
7	Buck	3	20					2	Jackall		
7	Rein-deer	3	20					2	Caraguya		
7	Roe	2	36								
2	Rhinocerot	8									
2	Camelopard	6	30								
2	Hare										
2	Rabbet	2 Sheep.									
2	Marmotto										
		92	514							27	72

Plate 8. Animals inside Noah's Ark in John Wilkins' *Essay* (1668). Courtesy of the Trustees of the Edward Worth Library, Dublin.

Flood. He listed the sets of parents in the Ark and calculated the vessel's dimensions. This, in fact, was meant to refute those 'hereticks' and 'Atheistical scoffers' who doubted that the variety of the animal world could have arisen out of the confines of a small ark.[75] Hooke (as we shall see) would later use fossils to put a big question mark behind the Noachic story.

In Wilkins' Ark insects were marginal. They only warranted inclusion as food for the 'Beasts' (see the middle column). Yet when it came to the higher animals, Bishop Wilkins made bold genealogical conjectures. Wilkins was convinced that

[75]For the whole defense: Wilkins, *Essay*, pp. 162–8.

'*Urus, Bisons, Bonasus* and *Buffalo*' (who had distinct parents in the Ark) 'be not distinct species from *Bull*'. First, there was 'much less difference betwixt these, then there is betwixt several Dogs'. Second, the reader should consider 'what various changes are frequently occasioned in the same species by several countries, diets, and other accidents'.[76] Hooke, too, had criss-crossed genealogies when he examined 'small Vine-Mites' and took 'a ghess at their original'.[77] 'If these Minute creatures were *Wood-lice*', Hooke speculated, 'as indeed from their own shape and frame … one may with great probability ghess', then 'Mites' would merely be 'the young ones, of much bigger Insects, and not the generating, or parent *Insect*'.[78] Was the ancient family of mites in fact a family of wood-lice? Hooke thought deeply about the familial relations between insects based on observations of their 'shape' and 'frame'. Descriptive morphology could sometimes accrue layers of genealogical meaning. Hooke's analogy with the pocket watch perfectly encapsulated this idea.

4. Variations on a crab: the morphology of arthropods, Hooke's 'insects'

What kind of machine were insects? Hooke had preceded his study of these creatures with a study of their parts in an effort to already familiarize the reader with their basic components.[79] This leads us back to the iconic piece of machinery presented at the outset of this paper: the compound eye. Hooke argued that 'this curious contrivance is the organ of sight to all those various *Crustaceous* Animals'. And he noted – correctly – that 'the eyes of Crabs, Lobsters, Shrimps, and the like, are *Hemishper'd*, almost in the same manner as these of Flies are'.[80] Hooke made it clear that the compound eye – comprising thousands of 'pearls' or 'knobs' – was only one among many components in a wide range of 'crustaceous' animals:

> And if in *crustaceous* Sea-animals, then it seems very probable also, that these knobs are the eyes in *crustaceous* Insects, which are also of the same kind, onely in a higher or more active element [i.e. earth and air]; this conformity or congruity of many other parts common to either of them, will strongly argue, their *crustaceous* armour, their number of leggs, which are six, beside the two great claws, which answer to the wings in Insects; and in all kind of Spiders, as also in many other Insects that want wings, we shall find the compleat number of them, and not onely the number, but the very shape, figure, joints and claws of Lobsters and Crabs, as is evident in Scorpions and Spiders, as is visible in the second Figure of the 31. *Scheme* [the 'long-legg'd

[76]Wilkins, *Essay*, pp. 164–5.
[77]*Micrographia*, p. [254].
[78]*Micrographia*, pp. 215–6.
[79]See Observations no. 37, *Of the Feet of Flies, and several other Insects* (pp. 169–72); no. 38, *Of the Structure and motion of the Wings of Flies* (172–5); no. 39, *Of the Eyes and Head of a Grey drone-Fly, and of several other creatures* (175–80); no. 40, *Of the Teeth of a Snail* (180–1).
[80]*Micrographia*, pp. 177–8. See, e.g. in 1700, Antonie van Leeuwenhoek's microscopic dissection of a lobster's compound eye, later published in his *Epistolae ad Societatem Regiam Anglicam […]* (Leiden: John Arnold Langerak, 1719), pp. 181–3 & figs. 2–3.

> spider'], and in the little Mite-worm, which I call a Land-crab, describ'd in the second Figure of the 33. *Scheme* [the 'crab-like insect'] … [81]

Hooke summarized this as the argument that 'Crabs, Lobsters, Shrimps, seem to be water Insects, and to be framed much like Air Insects'.[82] 'Insects' on this definition possessed the same 'frame': the same plan.[83] They were machines that had been assembled from a common stock of components: an exoskeleton, pearled eyes, six jointed legs, and either one pair of pincers or wings. Hooke's remark on the interchangeability of the pincers and wings suggested that the arrangement of the parts wasn't rigidly fixed. He referred to observation no. 51, *Of the Crab-like Insect*, where he considered whether this eight-legged insect might possess wings, yet firmly judged: 'but I suspect the contrary; for I have not found any wing'd Insect with eight leggs, two of those leggs being always converted into wings'.[84] We must be cautious. Asserting that two of the eight potential legs were in the perpetual state of 'being always converted into wings' did not necessarily mean that an actual transformation had occurred.[85] It could also mean that the pair of wings on a six-legged insect were the equivalents of the two additional legs found on an eight-legged insect (which is why the six-legged ant had to be 'winged'). Either way the underlying point remained that the overall 'frame' was preserved in spite of such variations.

The structural frame of 'insects' that Hooke described outlines the morphology of what we now call arthropods.[86] If the parts of crabs and lobsters were also built into the tiny creatures of the microworld, then the anatomical *terra incognita* became more intelligible. Yet the bridge that Hooke was building between the micro- and macroworld connected their respective inhabitants in a much deeper way: Hooke claimed above that insects were 'also of the same kind [as crabs], onley in a higher or more active element'. Tracking the components which were 'common to either of them' served to verify the close bond between the tiny 'Air Insects' moving (almost invisibly) up above and the huge 'water Insects' down below. The most distinctive feature of crabs and lobsters were their pincers. Hooke pointed out that such pincers were also to be found on the 'crab-like insect', which he classified as a 'Land-crab',[87] as well as on the

[81]*Micrographia*, p. 178.
[82]*Micrographia*, p. [253].
[83]See 'frame' in OED.
[84]*Micrographia*, p. 208.
[85]Although note: Hooke certainly used the word 'convert' in all other contexts to denote dynamic transformation: when, for example, he spoke of transmutation, of iron that was 'converted' into steel or wood into charcoal. See *Micrographia*, p. 51, 106.
[86]The phylum *Arthropoda* has several subphyla which, in turn, are subdivided into various classes, some of which we now identify as insects (e.g. gnats, flies, ants), arachnids (e.g. spiders, mites, pseudoscorpions) and malacostracans (e.g. crabs, lobsters, shrimps). Hooke's expansive definition of 'insects' includes all of these creatures and foreshadows Linnaeus' (equally expansive) *insecta* in the *Systema Naturae* (1735; 1758). For the latter, see Mary Winsor, 'The Development of Linnaean Insect Classification', *Taxon,* 25, No. 1 (1976), 56–67, here: 62–3. For the insect classification that was conventional in Hooke's time, see Brian Ogilvie, 'Beasts, Birds, and Insects. Folkbiology and Early Modern Classification of Insects', in *Wissenschaftsgeschichte und Geschichte des Wissens im Dialog – Connecting Science and Knowledge*, ed. by Kaspar von Greyerz, Silvia Flubacher and Philipp Senn (Göttingen: V&R unipress, 2013), pp. 295–316.
[87]See *Micrographia*, p. 171, 178.

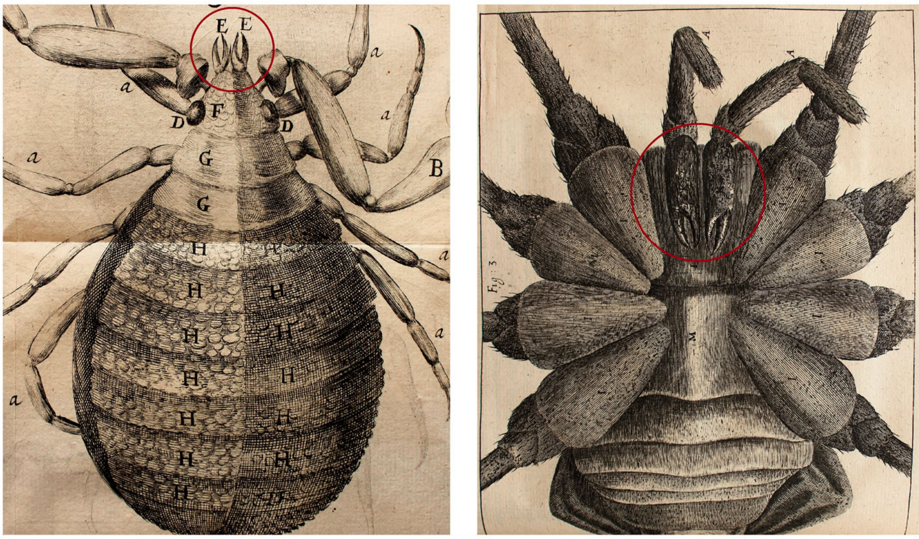


Plate 9. The 'crab-like insect' or 'Land-crab' (left). The 'long legg'd spider' or 'Air-crab' (right). Courtesy of the Trustees of the Edward Worth Library, Dublin.[88]

Plate 10. *Leiobunum Rotundum*. Hooke's 'long legg'd spider' or 'Air-crab'. Courtesy of Rosemary Winnall.[89]

underbody of the 'long legg'd spider', which he classified as an 'Air-crab' (Plate 9).

[88]The pincers (*chelicerae*) on these creatures are not (!) Hooke's fabrications. There are 'spiders' that have such pincers, namely, *Opiliones*, an order of arachnids, commonly known as 'harvestmen'. Hooke's specimen is such a harvestman, of the genus *Leiobunum*, and most likely of the species *Rotundum*. See Mark Jervis, 'A zoologist's

In observation no. 47, *Of the Shepherd Spider, or long legg'd Spider*, Hooke spent a fair amount of space describing the spider's jointed legs, mouth and two pincers – all features which he deemed 'not unlike the parts of a Crab, which this creature does in many things, very much resemble'. In fact, the long-legged spider 'seems to be nothing else, but an Air-crab, being made more light and nimble, proportionable to the *medium* wherein it resides' (Plate 10).[90]

That this spider should be an air-based version of the crab is a highly imaginative claim. Hooke tried to imagine – like an instrument-maker rearranging the parts of a machine – how the body parts of a crab had to be restructured to suit it to a new environment. The resulting idea was simple yet powerful: while a normal crab with its heavy exoskeleton and large body could never make it up into the air, a much smaller and lighter variant of it would. Such reduction in bodily size and weight was considered by Hooke to be 'proportionable to the *medium*' because 'as Air seems to have but one thousandth part of the body of Water, so does this Spider seem not to be a thousandth part of the bulk of a Crab'.[91]

How else did one reconfigure a crab for the higher medium to make a spider? Hooke's nomenclature supplies the important clue. While describing the 'long legg'd' spider, Hooke repeatedly expressed amazement at the 'prodigious length of its leggs', remarking that 'the eight leggs are each of them jointed, just like those of a Crab, but every of the parts are spun out prodigiously longer in proportion'.[92] If there was to exist a crab that inhabited air, then its short legs had to be extended relative to its body. The length of the legs, therefore, represented another anatomical variation that distinguished the 'Air-crab' from a common one in the water. The 'long legg'd spider' could hover above ground with its light body and elongated legs, hence it was an 'Air-crab'. The 'crab-like insect' was also a miniaturized version of the crab, but without the long legs, hence it was a 'Land-crab'. Minute insects, then, were what happened when a large 'insect' (the crab) was taken outside of water and readjusted to the lighter elements.[93]

perspective on Robert Hooke's *Micrographia* (1665) studies of marine and terrestrial invertebrates, and his contemplations on invertebrate 'generation' and mutability', *Journal of Natural History*, 48, No. 23–4 (2014), 1375–411, here: 1389. Let me also mention that *Pseudoscorpiones*, another order of arachnids, have exactly the pincers at their mouths as shown by the 'crab-like insect' above. Hooke's pseudoscorpion probably is the *Cheiridium Museorum* and he has been credited with the earliest British record of this species. See Gerald Legg and Richard Jones, *Pseudoscorpions (Arthropoda; Arachnida): Keys and Notes for the Identification of the Species* (Leiden: Brill, 1988), p. 91.

[89]This male *L. Rotundum* was photographed in Wyre Forest, Worcestershire, England on 17 October 2009. The *Leiobunum* that Hooke presented to the Royal Society centuries earlier, it was noted, was 'standing out upon a stem' (Birch, *History*, p. 294).

[90]*Micrographia*, pp. 199–200.

[91]*Micrographia*, p. 200. N.B.: Hooke had actually weighed air with respect to water in February 1664. See Royal Society Archives, Cl.P/20/25, 42r.

[92]*Micrographia*, p. 199.

[93]This type of thinking differentiates Hooke from his fellow naturalists. Observations on Hooke's 'Air-Crab' were published 13 years after the *Micrographia* by the Society's arachnologist, or 'spider man', Martin Lister. See Lister's *Historiae Animalium Angliae Tres Tractatus. Unus de Araenis […]* (London: John Martyn, 1678), pp. 95–

That the size and shape of component parts were tailored to fit the various elements explained why both big and small ‘insects’ should exist at all. It also meant that the way these parts were reassembled into various machines wasn’t random, but purposeful, suiting them to their respective environments. In observation no. 37, *Of the Feet of Flies, and several other Insects*, Hooke developed this line of reasoning in a great level of detail. He argued that the legs of the mite and ‘Land-crab’, which had ‘one small very sharp Tallon at the end’, were to be contrasted with the legs of the louse, which were ‘very much differing … but more convenient and necessary for the place of its habitation’.[94] Once the enormous image belonging to observation no. 54, *Of a Louse*, had been folded out (Plate 11), the reader could attend to Hooke’s observations.

The louse, Hooke noted, possessed ‘legs, covered with a very transparent shell, and joynted exactly like a Crab’s, or Lobster’s’. To which he added: ‘at the end of

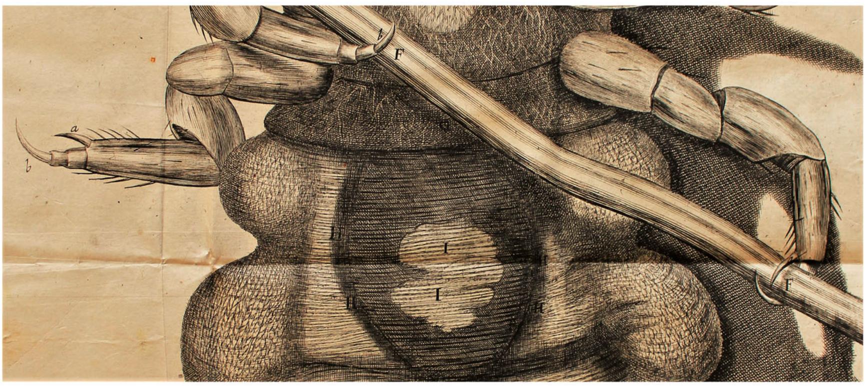


Plate 11. The louse clutching a (Hooke’s) hair. Courtesy of the Trustees of the Edward Worth Library, Dublin.

each leg it has two claws, very properly adapted for its peculiar use, being thereby inabled to walk very securely on both skin and hair’.[95] Hooke then explained that the combination of a shorter and longer claw (labelled *a* and *b* on the tip of the left leg) ‘could not be made more commodiously’ for ‘climbing up the hair of a mans head’, because ‘the [three] small joynts of the longer claw’ *(b)* enabled the louse to ‘bend it round, and so with both claws take hold of a hair’ – as represented by the clasping position of the leg on the right.

Hooke distinguished between the louse’s leg as a tool to grasp hair and a tool to move across the scalp. When it ‘walks on skin’, he noted, ‘the shorter [claw *(a)*] touches not [the skin], and then the feet are the same with those of a

9. Lister translates and quotes Hooke’s observations, yet leaves them without comment, only describing the spider’s body and habitat. Lister’s depiction of it (table 1, fig. 36) shows no anatomical detail. Earlier in 1668, John Ray had also mentioned the spider to Lister in a letter. For this, see Anna Marie Roos (ed.), *The Correspondence of Dr. Martin Lister (1639–1712). Volume One: 1662–1677* (Leiden & Boston: Brill, 2015), p. 193.

[94] *Micrographia*, p. 171.

[95] *Micrographia*, p. 212.

Mite'.[96] Now, Hooke would also highlight that in mite legs 'the contrivance of the joynts seems the very same with that of Crabs and Lobsters legs'.[97] But the idea he was targeting with his remark was that the mite's leg 'terminated with a very sharp claw or point' which was 'fastened into the pores of the body over which it went'.[98] Indeed, he realized more generally that 'creatures, as Mites, the Land-Crab, &. have onely one small very sharp Tallon at the end of each of their legs, which … innable these exceeding light bodies to … fasten themselves to any surface'.[99] The implication was that the pointed legs of these creepy-crawlies made them well-suited to navigate across the porous surface of minute environments, like the one observable in cork (revisit Plate 1).

Insects, more generally then, had the same type of legs – jointed and spiked like those of a crab – but their legs had also been individually shaped to accommodate a specific habitat. The mite on the ground had legs exclusively for scuttling; the louse in the hair had legs for clasping; the aeronautical spider had legs for hovering. 'And can any be so sottish, as to think all those things the productions of chance?' Hooke asked rhetorically. Just a few lines previously he had already let slip the comment that 'Nature does always appropriate the instruments, so as they are most fit and convenient to perform their offices'.[100]

The notion that body parts had been 'adapted' or 'fitted' for their uses was later deployed by Robert Boyle and John Ray to prove God's design within Nature.[101] That the human body was equipped with functional 'instruments' (*ὄργανᾰ*) – that the eyes, for example, had been made for seeing – traced back to Galen's *De Usu Partium*.[102] Hooke injected empirical content into this ancient notion: he *showed* how bodily parts functioned in the environment they were used in and why their makeup could not be accidental. That the environment was thought to change bodily features meant that this idea wasn't static. 20 years after the *Micrographia*, the Society's fellows were still debating 'the alteration of the form of animal bodies, by the variety of food, climate, soil and usage'.[103] The last word is important. Hooke argued that bodily parts were 'adapted' for a 'peculiar use'.[104] And the fellows were debating whether *use* was a possible cause of 'the transformation of creatures'. External

[96]*Ibid.*
[97]*Micrographia*, p. 214.
[98]*Micrographia*, p. 214, 205.
[99]*Micrographia*, p. 171.
[100]*Ibid.*
[101]See Robert Boyle, *A Disquisition about the Final Causes of Natural Things […]* (London: H.C. for John Taylor, 1688), esp. pp. 15–9, 56–61, 65–70, 146–50. And: John Ray, *The Wisdom of God Manifested in the Works of Creation* (London: R. Harbin for William Innys, 1717), pp. 139–56. For discussion, see Jessica Riskin, *The Restless Clock. A History of the Centuries-Long Argument over What Makes Living Things Tick* (Chicago & London: University of Chicago Press, 2016), pp. 84–7.
[102]Galen, *On the Usefulness of the Parts of the Body*, transl. by Margaret Tallmadge May, Vol. 2, (Ithaca, NY: Cornell University Press 1968), pp. 463–503. See further: Daryn Lehoux, *What did the Romans know? An Inquiry into Science and Worldmaking* (Chicago: University of Chicago Press, 2012), pp. 116–21.
[103]Birch, *History* (Vol. 4), p. 141, 143 (12 April 1682).
[104]See, e.g. *Micrographia*, p. 123, 159, 165, 183, 189, 212.

influences from the environment transformed animate bodies. Why would this process be random rather than purposeful in God's universe?

One case of insect transformation that actually had been observed in full was 'metamorphosis'.[105] In observation no. 43, *Of the Water-Insect or Gnat*, Hooke meticulously documented how in a glass of rain-water a 'Water-Insect' (in reality a larvae) transformed over the course of two weeks, before it 'flew about the glass a perfect Gnat'.[106] Indeed, when Hooke was first 'ordered to make observations upon the insects of rain-water', he was to 'see whether they will change into other kinds'.[107] Hooke thought of the insect's metamorphosis as 'Nature, as it were, fitting and accoutring it for the higher Element, of which it was now going to be an inhabitant'.[108] Given that crabs were 'water Insects', it wasn't absurd for Hooke to muse 'whether there not be some kind of transformation and metamorphosis in the several states of *crustaceous* water-animals, as there is in several sorts of Insects'.[109] Yet nowhere did he elaborate on this point. In the *Micrographia*, 'insects' inhabited water, earth and air, both tiny and large. Their bodies were built along the same 'frame', but 'fitted' to different environments. Variations on a crab.

5. 'As ancient as the first creation': how insects acquired a history

A genealogy of insects implied that their anatomy was the product of history. Once the *Micrographia* had appeared, Hooke set out to map the history of the Earth within an extensive series of lectures (1668–1700).[110] In these lectures Hooke picked up ideas in the *Micrographia* – most notably, the organic origins of fossil stones – and explored their implications. In the 1670s, moreover, Hooke founded a 'club' that met in London coffee houses to discuss the Earth's creation. One topic of discussion were the heresies of the French theologian Isaac La Peyrère, according to whom a world full of 'pre-adamite' humans had existed before the biblical Eden.[111] Hooke recorded in his diary that he and his group of undesirables had 'discoursd … about preadamits and of Creation. about Insects'.[112] Hooke's diary provides no further

[105]For an overview, see Brian Ogilvie, 'Order of Insects: Insect Species and Metamorphosis between Renaissance and Enlightenment', in *The Life Sciences in Early Modern Philosophy*, ed. by Ohad Nachtomy and Justin Smith (Oxford: Oxford University Press, 2014), pp. 222–46.
[106]*Micrographia*, pp. 187–8.
[107]Birch, *History*, p. 297 (26 August 1663).
[108]*Micrographia*, p. 187
[109]*Micrographia*, p. 178.
[110]Richard Waller, *The Posthumous Works of Robert Hooke […]* (London: Sam Smith & Benj. Walford, 1705), pp. 279–450. From now on: *Posthumous Works*. I do not follow Waller's faulty dating of these lectures, but that given by Rhoda Rappaport, 'Hooke on Earthquakes: Lectures, Strategy and Audience', *The British Journal for the History of Science,* 19, No. 2 (1986), 129–46, here: 143–6.
[111]On Hooke's 'club', see William Poole, 'The Genesis Narrative in the Circle of Robert Hooke and Francis Lodwick', in *Scripture and Scholarship in Early Modern England*, ed. by Ariel Hessayon and Nicholas Keene (Aldershot: Ashgate, 2006), pp. 41–57; on La Peyrère, see Anthony Grafton, 'Isaac La Peyrère and the Old Testament', in idem, *Defenders of the Text: The Traditions of Scholarship in an Age of Science* (1991), pp. 204–13; on pre-adamism, see William Poole, 'Seventeenth-century Preadamism, and an Anonymous English Preadamist', in *The Seventeenth Century,* 19 (2004), 1–35.
[112]London Metropolitan Archives, CLC/495/MS01768, 44v. (The date is 18 December 1675). Cf. Henry Robins & Walter Adams, *The Diary of Robert Hooke, M.A., M.D., F.R.S. 1672–1680 […]* (London: Taylor & Francis, 1935), p. 202.

details. How might certain insects have looked like in a time *before* (their) Adam? Hooke never endorsed the expanded non-Biblical chronologies. Nonetheless, he did keenly point out that the creatures of 'former Ages' must have been quite different from the animals known now.

In his very first lectures in 1668, Hooke famously – and controversially – argued that 'divers Species' had been 'wholly destroyed and annihilated'. But also, that others had been 'changed and varied'.[113] In his lecture on 29 May 1689, Hooke elaborated on just how drastic such changes might have been over time:

> there are now divers *Species* of Creatures which never exceed at present a certain Magnitude, which yet, in former Ages of the World, were usually of a much greater and Gygantick Standard; suppose ten times as big as at present; we will grant also a supposition that several *Species* may really not have been created of the very Shapes they are now of, but that they have changed in great part their Shape, as well as dwindled and degenerated into a dwarfish Progeny; that this may have been so considerable, as that if we could have seen both together, we should not have judged them of the same Species.[114]

Hooke had examples of the 'Gygantick' ancestors from former times. The 'more youthful Ages of the World', he claimed, 'might produce Men of much longer Life, bigger Stature, and with greater accomplishments of Mind'.[115] Thus the humans of the present were mentally and physically degenerated versions of their ancient forefathers. Yet this idea wasn't uncommon amongst Hooke's contemporaries and it suited well the notion that humanity had fallen – a prevalent topos in the seventeenth century.[116]

But 'by what means can we judge of any such preceding Age?' Hooke queried in his lecture. Hooke's answer wasn't Scripture. It was: 'possibly the petrified Shells that lye in the Repository'.[117] The repository of the Royal Society housed countless fossil-shells of marine animals.[118] 'Many, nay most, of them', Hooke proclaimed, were 'of somewhat a differing Shape, and of a much greater Magnitude than are the Shell-Fishes of the like Animals to be found upon the Coast of *Portland*'.[119] Already in 1668, Hooke noted that the repository contained gigantic 'snail stones' (ammonite fossils) weighing up to 400 pounds and measuring 2.5 feet in diameter. A credible source had even informed him that there were ones '3 or 4 times as big as these'. The latter elicited astonishment in him as they seemed 'much more to excel in bigness all

[113] *Posthumous Works*, p. 327 (before 15 September 1668).
[114] *Posthumous Works*, p. 435. (29 May 1689).
[115] *Posthumous Works*, pp. 379–80 (4 January 1688).
[116] For an example of the human degeneration thesis, see John Ray, *Miscellaneous Discourses concerning the Dissolution and Changes of the World […]* (London: Samuel Smith at the Prince's Arms in St. Paul's Churchyard, 1692), pp. 42–3, p. 103. For the Fall of Man, see Philip Almond, *Adam and Eve in Seventeenth-Century Thought* (Cambridge: Cambridge University Press:, 1999), pp. 20–32; William Poole, *Milton and the Idea of the Fall* (Cambridge: Cambridge University Press, 2005); Peter Harrison, *The Fall of Man and the Foundations of Science* (Cambridge: Cambridge University Press, 2007). For Hooke on the Fall, see *Micrographia*, sig. a1r, b2r-v.
[117] *Posthumous Works*, 380 (4 January 1688).
[118] See Nehemiah Grew, *Musaeum Regalis Societatis, or A Catalogue & Description of the Natural and Artificial Rarities belonging to the Royal Society and preserved at Gresham College* (London: W. Rawlins, 1681), pp. 253–65.
[119] *Posthumous Works*, p. 342 (8 December 1686 to 19 January 1687).

Plate 12. Giant ammonites. Richard Waller's drawing of a 1.5-foot specimen, inserted into Hooke's 1668 lecture (left). A 2-foot specimen in front of Portland Museum, Isle of Portland, Dorset, England (right). Courtesy of the Trustees of the Edward Worth Library, Dublin (left) and Stephan Czapiski (right).[121]

other Shell-fishes we know, than the Giants (Stories tell us of) did exceed the ordinary Size of Men now living' (Plate 12).[120]

That Hooke used the fossils of giant animals to check the myths about giant humans reveals just how similar he thought the patterns in their genealogical histories were. Crucially, Hooke argued that fossils were 'Monuments and Records to instruct succeeding Ages of what past in the preceding'.[122] This attitude encapsulates the turn from *natural* history – collecting and describing Nature's productions – towards natural *history*. How did fossils cease being collectible curiosities – stones that looked *like* animals – and start speaking about the past? They were placed into Hooke's hands, where they were treated like any other artefact of human history. Fossils became 'Monuments': the remains of an organism that once existed, just as pyramids were the ruins of a

[120] *Posthumous Works*, p. 284 (before 15 September 1668). See also Hooke's 'Twelfth Proposition' at 333–4, 337–8. Ironically, Hooke's opponent Robert Plot would later (in *The Natural History of Oxfordshire* (1677), misattribute the fossil-bone of a *Megalosaurus* to ancient Giants and Titans. For this, see Justin Delair and William Sarjeant, 'The Earliest Discoveries of Dinosaurs', *Isis,* 66, No. 1 (1975), 4–25, here: 6–7. For more on giants in the early modern imagination of the past, see Antoine Schnapper, 'Persistance de gèants', *Annales. Historie, Sciences Sociales,* 41, No. 1 (1986), 177–200; Walter Stephens, *Giants in Those Days: Folklore, Ancient History and Nationalism* (Lincoln & London: University of Nebraska Press, 1989).

[121] Richard Waller, the editor, drew the left image after a trip to Keynsham in 1686 and then inserted it into the posthumous publication of Hooke's 1668 lecture. Keynsham's 'snail stones' (ammonite fossils) were already explicitly singled out by Hooke in *Posthumous Works*, p. 284 (Hooke's 1668 lecture) and in *Micrographia*, p. 109. For specifics, see Sachiko Kusukawa, 'Drawings of fossils by Robert Hooke and Richard Waller', *Notes and Records of the Royal Society,* 67, No. 2 (2013), 123–38, here: 125–6 (incl. fn. 10), 132–3.

[122] *Posthumous Works*, p. 321 (before 15 September 1668).

lost civilization. And fossils became 'Records': an archive of Nature whose documents could be read and arranged into chronological order, just like human records. In the conventional view, fossils were a joke (*lusus*) of Nature, an aberration from her usual course, curious rocks strangely resembling animal forms. In Hooke's hands, they became the 'dumb Witnesses' of Nature's past.[123]

Given the evidence provided by fossils, one would expect that even the *smallest* animals had once been 'Gygantick' and undergone a similar process of bodily decay. In *A General Scheme*, an essay drafted one year after the *Micrographia*, Hooke suggested that natural history should proceed by observing 'such Variations as happen to Bodies from their being produc'd at different times, or in differing Places, of the same Medium, or in differing Mediums'. As an example of the effect of time he gave the 'Difference between the Stature, Age, Strength, Shape &c. of Men at the beginning of the World and now' and of the effect of place he gave the difference 'between a Crab and a Spider, &c. the one being an Insect of the Water, and the other of the Air'.[124] There are two distinct notions here. One is that *time* had left its palpable imprints on animals, now shrunken in size; the other is that *place* modified the same type of animal into different variations. Yet both ideas were intimately connected. Time, in Hooke's history of the Earth, changed places.

In his first lecture in 1668, Hooke had proposed both the extinction of and alteration within a given species.[125] One reason, he claimed, lay in the fact that earthquakes and floods destroyed or altered the habitats of species over time. A 'great part of the Surface of the Earth hath been since the Creation transformed,' Hooke declared. Thus 'many parts which have been Sea are now Land'. England, too, had once been 'cover'd with Sea' and had 'Fishes swimming over it'.[126] How this (Aristotelian) view of Earth's history related to insects would seem clear.[127] If present-day countries had once been submerged under water, only to emerge much later through the forces of earthquakes, then water-

[123] *Posthumous Works*, p. 285 (before 15 September 1668). See further: Paolo Rossi, *The Dark Abyss of Time: The History of the Earth and the History of Nations from Hooke to Vico*, transl. by Lydia G. Cochrane (Chicago: University of Chicago Press, 1984), pp. 1–88, esp. 12 ff. More recent work on the history of fossils has emphasized their theological and alchemical dimensions. For these, respectively, see William Poole, *The World Makers: Scientists of the Restoration and the Search for the Origins of the Earth* (Oxford: Peter Lang Ltd, 2010), pp. 115–34. And: Anna Marie Roos, 'Salient Theories in the Fossil Debate in the early Royal Society', in *Controversies within the Scientific Revolution*, ed. by Marcelo Dascal and Victor Boantza (Amsterdam & Philadelphia: John Benjamins Publishing Company, 2012), pp. 151–70.

[124] *Posthumous Works*, p. 56. See also p. 23: 'The History of Sea Insects, compar'd with Terrestrial and Aerial'. A convincing case for a 1666 dating of *A General Scheme* (which stretches across *Posthumous Works*, pp. 1–70) was made by Mary Hesse, 'Hooke's Philosophical Algebra', *Isis,* 57, No. 1 (1966), 67–83, here: 68.

[125] *Posthumous Works*, p. 327 (before 15 September 1668).

[126] *Posthumous Works*, pp. 290–1. See also p. 298, 328 (before 15 September 1668).

[127] Hooke later claimed to have already argued for England's prior submersion under water in 1664 and 1665. See his: *Lectures De Potentia Restitutiva, or Of Spring* (London: John Martyn, 1678), pp. 48–9. For the Aristotelian origins of this view, see most recently: Ivano dal Prete, '"Being the World Eternal … ": The Age of the Earth in Renaissance Italy', *Isis,* 105, No. 2 (2014), 292–317. And: William Poole, *The World Makers: Scientists of the Restoration and the Search for the Origins of the Earth* (Oxford: Peter Lang Ltd, 2010), pp. 95–114.

crabs had existed long before 'Land-crabs' and 'Air-crabs'. In a later lecture of 1687, Hooke proposed that

> such Regions as have for a time been Submarine, and produced Substances of Animals or Vegetables proper for them, when they come to be dry Land to lye above the Waters, must produce Animals and Vegetables proper and peculiar to that Soil, Element and Climate they are then furnish'd with; preserving in the mean time the Characteristicks and Marks of the former Qualifications, when in another Condition.[128]

The crab-components of insects – the shell, jointed legs and pincers – can certainly be interpreted as the 'Characteristicks and Marks' of a crab under 'another Condition'. In the *Micrographia*, Hooke understood 'insects' to be one type of machine readjusted to the different elements. That this implied a historical chronology – first large *water*-crabs, then tiny *land*- or *air*-crabs – was only brought out in his subsequent lectures. Most of the fossils within the Society's repository – those ancient 'Monuments' – represented sea-creatures. In 1663 Hooke was elected the first Keeper of the repository.[129] Three years later a 'petrified Bone of a prodigious bigness' was added to the repository, together with reports on more 'great Bones', all of which 'clearly resembles the Bones of Whales and great Cetaceous Animals'.[130] In the *Micrographia*, Hooke discussed the fossils of giant ammonites and nautili.[131] And starting with his first lecture in 1668, Hooke began to draw these water-creatures. He even drew a 'petrify'd crab' (Plate 13).[132]

There can be no doubt that this fossil led Hooke to regard crabs as ancient sea-creatures with a long (family) history. Hooke's drawing belonged to a set of schemes depicting watery giants from a bygone age. Unfortunately, his description of the crab-fossil is lost.[133] What 'dwarfish Progeny' had this 'water Insect' left behind?

Hooke, like the stone, remains silent on this question. Yet he did point to its explosive implications for the Biblical narrative. 'The Flood of *Noah*', he argued, 'could not afford time enough for the production and perfection of so many and so great and full grown Shells'.[134] For the Flood – that is, *a* flood that lasted 'two hundred Natural Days' – could not 'produce and perfect those Creatures in so short a space to the bigness and perfection they seem to have had'. A much longer flooding of the Earth was required for animals to swell to the largeness that fossils attested to. Hooke also pointed to other floods mentioned in Greek mythology to show that the 'notion of a Deluge' extended across

[128] *Posthumous Works*, p. 348 (26 January 1687). See p. 339, for Hooke on the 'Characteristicks' of animals.
[129] Birch *History*, p. 316 (November 1663).
[130] *Posthumous Works*, p. 313 (before 15 September 1668).
[131] *Micrographia*, pp. 109–12.
[132] These drawings are printed in: *Posthumous Works*, 283–6 (Tabs. I–II, IV–V). For discussion, see Sachiko Kusukawa, 'Drawings of Fossils by Robert Hooke and Richard Waller', *Notes and Records of the Royal Society,* No. 2 (2013), 123–38.
[133] In the 1668 lecture Hooke acknowledged 'Crabbs' among the fossils he had considered. See: *Posthumous Works*, p. 293.
[134] *Posthumous Works,* p. 341 (8 December 1686 to 19 January 1687). See also: 433.

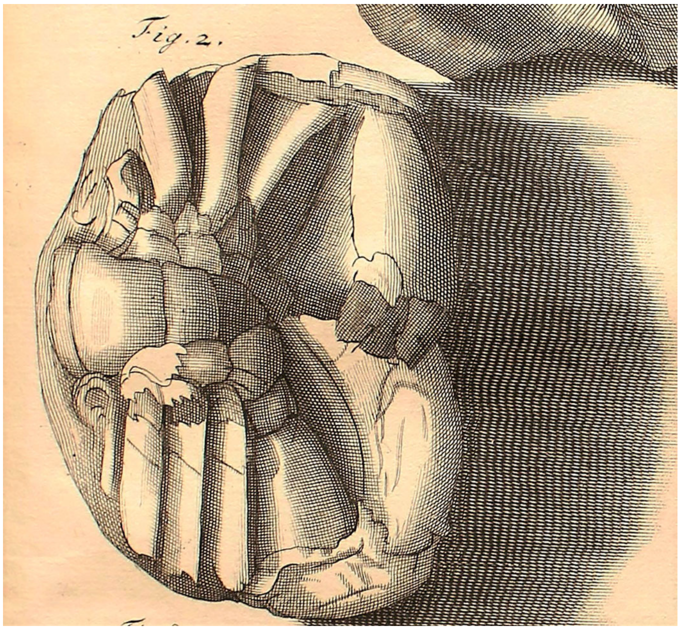


Plate 13. Hooke's drawing of the fossil of a crab. Courtesy of the Trustees of the Edward Worth Library, Dublin.

time.[135] This was the attempt to *read* fossils like 'Records', to *use* them as evidence to reconstruct how Nature in the past had differed from Nature in the present. And it was only after Hooke immersed himself into the study of fossils that he had to admit that it was 'very difficult to read them, and to raise a *Chronology* out of them'.[136]

Hooke's vision of 'natural Chronology' – using fossils to construct a timeline of Nature's past – was never realized. Nevertheless, he was certain that fossils 'antidate all the most ancient Monuments of the World, even the very Pyramids [and] Obelisks' so as to 'afford more information in Natural History, than those other put altogether will in Civil'.[137] The most ancient relics from Nature's past – fossils – were lying in the repository of the Royal Society. '*This Repository*', Thomas Sprat wrote in 1667, Hooke 'begun to reduce under its several heads, according to the exact Method of the Ranks of all the *Species of Nature*', that is, the method 'compos'd by Doctor *Wilkins*'.[138] Bishop Wilkins acknowledged that fossils were 'made of *Animals* or parts of *Animals* petrified', but rejected the idea that animals had once been 'of a much bigger stature', because this exceeded the dimensions of Noah's Ark.[139] Hooke, in contrast, drew big conclusions out

[135]*Posthumous Works*, p. 408 (15 February 1688). See also: 410. One of the many books that Hooke owned that discussed these floods (i.e. of Ogyges and Deucalion) was: Walter Raleigh, *The History of the World* (London: Walter Burre, 1614), pp. 99–103.
[136]*Posthumous Works*, p. 411 (29 February 1688).
[137]*Posthumous Works*, p. 335 (8 December 1686 to 19 January 1687).
[138]Thomas Sprat, *History of the Royal Society [...]* (London: John Martyn, 1667), p. 251.
[139]Wilkins, *Essay*, p. 62, 163.

of fossil stones. Their size questioned Noah's Flood as an unique event. It also showed how animals had been exceedingly big.[140] Hence Hooke's remarkable claim that ancient creatures could differ from their 'dwarfish Progeny' in a way that was 'so considerable, as that if we could have seen both together, we should not have judged them of the same Species'.

The reason why Hooke didn't draw more explicit connections between current animals and their fossil counterparts was that neither observation nor experiment could establish these connections as matters of fact. They remained conjectures. 'If it should be found', Hooke had written in the *Micrographia*, 'that [insects], or any other animate body, have no immediate similar Parent, I have in another place set down a conjectural *Hypothesis* whereby those *Phaenonema* may likely enough be solv'd'.[141] The puzzling '*Phaenomena*' arose when one couldn't point to an antecedent parent. Hooke's 'conjectural *Hypothesis*' offered a solution: either the previous parent was surprisingly different due to variation or it no longer existed due to extinction. Thus Hooke hoped that his readers – despite the scanty evidence – might still end up with 'a satisfactory account of the cause of those creatures, whose original seems yet so obscure'.[142] An obscure cause – the prime parent or 'original' – explained a visible effect: the current offspring in its various forms. The obscurity arose because it was hard to recover the original first parent. Fossils, then, helped fill some of the gaps in this murky past. Fossils such as the 'petrify'd crab' were the physical remains of an ancient ancestor. Perhaps even of a prime parent.

It was in the *Micrographia* that Hooke first used genealogy as a method to reconstruct Nature's past. Even *insects* had family trees, with roots that struck into the very beginning and branches that sprouted up to the present. Insects, Hooke contended, 'may be innobled with a Pedigree as ancient as the first creation, and farr exceed the greatest beings in their numerous Genealogies'.[143] 'Innobled' indeed. Insects were still widely viewed as the imperfect products of putrefaction. This story of their lowly origins – of being endlessly recreated out of rotting matter – implied that these tiny creatures didn't have a proper history of their own. By granting insects a genealogy, Hooke endowed them with a distinguishing mark of human nobility – an age-old lineage – and secured them a spot at the beginning of the Earth's timeline. Thus the smallest creatures of natural history acquired a *history*, one that made them just as sizeable as the rest.

[140]For a further contrast between Hooke and Wilkins, see William Poole, 'Heterodoxy and Sinology. Isaac Vosius, Robert Hooke and the early Royal Society's Use of Sinology', in *The Intellectual Consequences of Religious Heterodoxy 1600–1750*, ed. by Sarah Mortimer and John Robertson (Leiden: Brill, 2012), pp. 135–54, here: 151.
[141]*Micrographia*, p. 207.
[142]*Ibid.*
[143]*Ibid.*

6. Conclusion

As Hooke began to magnify tiny animals under the microscope, he was pushing natural history into new directions. Insects had already been studied beforehand by naturalists like Gesner, Wotton and Aldrovandi, who began to compile what was known about these creatures. Later, Hooke's colleagues at the Royal Society developed elaborate systems of classification and description for spiders and other animals. The advent of the microscope greatly enhanced the effort to amass an empirical inventory. The Dutch trio of Goedart, Swammerdam and van Leeuwenhoek observed (more extensively than Hooke ever did) the various ways in which insects developed from larvae into adults.[144] Yet while Hooke utilized these empirical methods, he initiated a shift from *natural* history – collecting and describing Nature's productions – to natural *history*: reconstructing their origins. For Hooke began to stress that insects were the products of ancient genealogies, to conjecture how their forms were the results of the Earth's history.

The preface of the *Micrographia* celebrated the kind of knowledge that did not build on 'any Strength of Imagination' but on 'a sincere Hand and a faithful Eye'.[145] Yet Hooke *imagined* a past that no microscope had shown him. Insects traced back to 'obscure' parents at the beginning of time and were connected through genealogical trees. The microscope did not reveal to Hooke that a variety of insects could be arranged into a genealogy in the way that it did reveal to him that a piece of cork was riddled with tiny holes. It was the careful acts of anatomical comparison that enabled him to establish similarities between insects and – in some cases – make the inference to shared parentage. But while he asserted that the existence of Adamitic insects was 'probable', he readily acknowledged that he had 'not yet been so farr certify'd by Observations as to conclude any thing, either positively or negatively, concerning it'.[146] That raises the question: if empirical observations did not adjudicate between truth or falsehood, how (and why) did Hooke even come to conjecture about genealogies?

Hooke's story begins inside the halls of the Royal Society. He had wanted to challenge the prevailing view that many insects arose *spontaneously* out of rotting matter. Under the microscope he scrutinized their intricate forms. Commonalities, he argued, weren't produced by a random or 'spontaneous' process, but by a common parent, a 'prime parent'. Hooke explained descent and variation in the realm of insects by importing concepts from human genealogy. Insects had family trees with different branches like humans. They also counted crabs and lobsters among their ranks. And at the beginning of the

[144]See Brian Ogilvie, 'Order of Insects: Insect Species and Metamorphosis between Renaissance and Enlightenment', in *The Life Sciences in Early Modern Philosophy*, ed. by Ohad Nachtomy and Justin Smith (Oxford: Oxford University Press, 2014), pp. 222–46.
[145]*Micrographia*, sig. a2v.
[146]*Micrographia*, p. 207.

Earth – as fossils suggested – Nature's tiniest creatures were so big that one did not need a microscope to see them. In the conventional wisdom insects were as insignificant as they were small. Under Hooke's magnifying lens they were restored. Insects, so it was believed, arose *endlessly* out of the dirt, without a history they could claim as their own. Hooke established their claim on the past – a past – through an ancient lineage. This constituted a new form of sight. One in which observable patterns became traces of Nature's history.

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