ESSAY

A microscopic reality tale

The earliest microscopes shed light on a once-invisible world. But, **Patricia Fara** explains, microscopists were uncertain about how well the images reflected reality — just as they are today.

In January 1665, Samuel Pepys followed up an afternoon with a prostitute by dining with the President of the Royal Society. On his way home, he called in at his bookseller and ordered an advance copy of Robert Hooke's book of the microscope. A couple of weeks later, Pepys collected his custom-bound volume and stayed up half the night absorbed in *Micrographia* — "the most ingenious book that ever I read in my life", he noted in his diary.

Pepys already owned a microscope, but he had never encountered images such as these. Like everybody who saw them, he was stunned by the intricate drawings of Hooke, who had modified a shop-bought instrument to reveal the minute details of insects and minerals, plants and feathers. For the first time, seventeenth-century gentlemen could closely inspect tiny yet only too familiar aspects of their daily lives — fleas, cheese mould, crystals of frozen urine, lice, nettle stings. In words whose punning eloquence complements his images, Hooke pointed out to his readers that a louse is "so proud and aspiring withal, that it fears not to trample on the best, and affects nothing so much as a Crown".

> **"For decades, biologists put themselves, not magnified specimens, in front of the lens."**

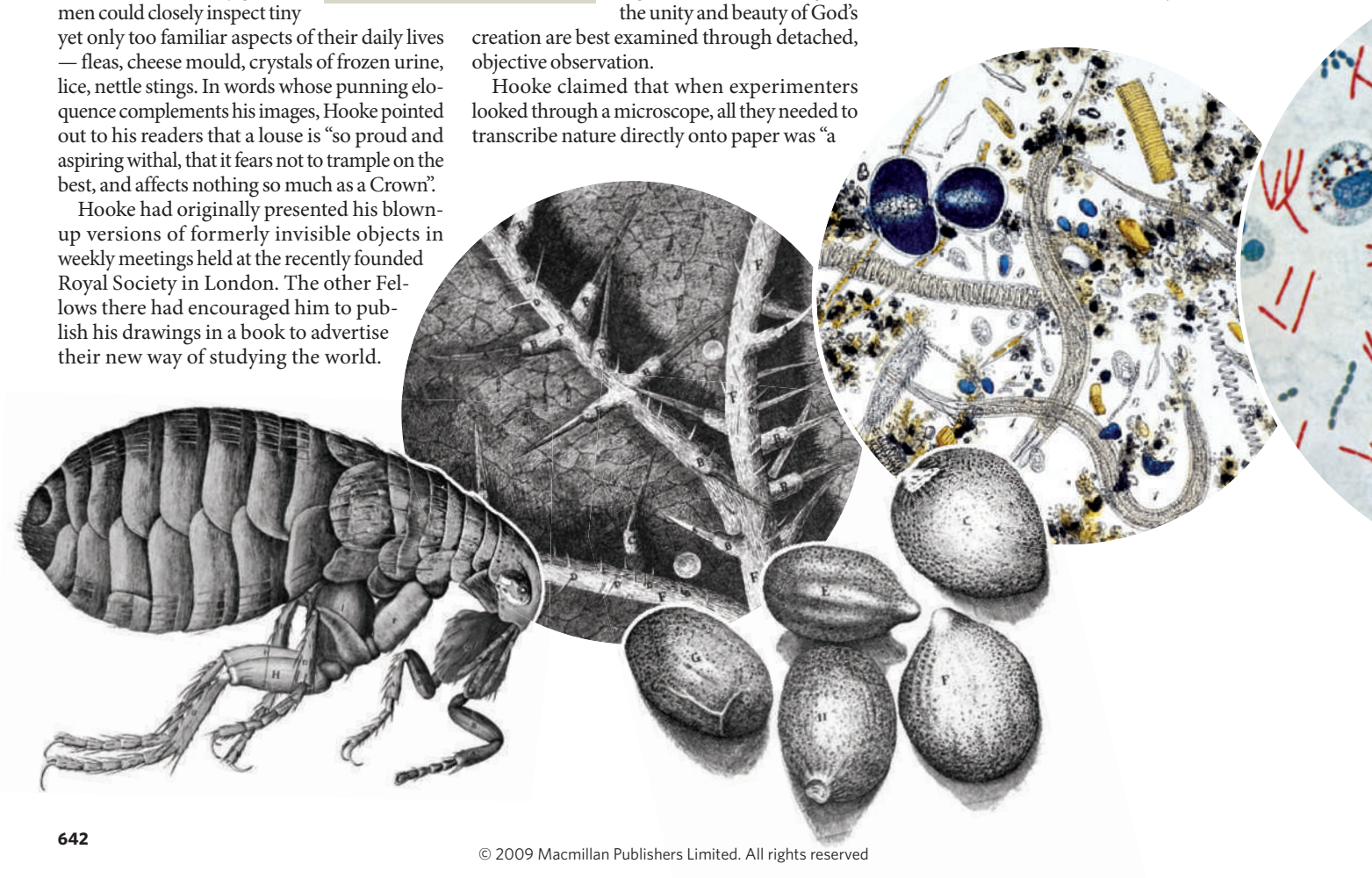
Hooke had originally presented his blown-up versions of formerly invisible objects in weekly meetings held at the recently founded Royal Society in London. The other Fellows there had encouraged him to publish his drawings in a book to advertise their new way of studying the world. They had adopted as their figurehead the late Francis Bacon, who had been squeezed out of his post as Lord Chancellor in 1621 on charges of corruption. With his political career ended, Bacon had been free to dedicate himself to philosophy. He had set out to reject Aristotle's theoretical approach and insisted that the best way to learn about God's world was through observation and experiment.

In his writings, Bacon had stressed the Bible's message that humans are fallen creatures with defective vision; their comprehension is, he wrote, clouded by imagination. Attempting to overcome people's intrinsic weaknesses, Hooke invented devices for augmenting the senses — hearing and smell as well as sight. Indeed, *Micrographia* is an extended argument demonstrating that the unity and beauty of God's creation are best examined through detached, objective observation.

Hooke claimed that when experimenters looked through a microscope, all they needed to transcribe nature directly onto paper was "a *sincere Hand*, and a *faithful Eye*, to examine, and to record, the things themselves as they appear". To reinforce Bacon's biblical message of human fallibility, his first plate exposed the imperfections in objects produced by humans: under his microscope, a honed razor looked jagged, a needle's point became blunted, and a full-stop lost its sharp edge.

Seeing is believing

Yet in practice Hooke found that "a *sincere Hand*, and a *faithful Eye*" were not enough to capture Nature exactly as she is. For one thing, microscope images were often ambiguous, so attempts to decipher them were shaped by individual expertise and personal interpretation. "The Eyes of a Fly in one kind of light appear almost like a Lattice, drill'd through with abundance of small holes," Hooke remarked; "In the Sunshine they look like a



WELLCOME LIBRARY, LONDON;

Surface cover'd with golden Nails; in another posture, like a Surface cover'd with Pyramids; in another with Cones." An observer needed a fine instrument, but also the skill to judge when it was yielding the right answers.

Hooke realized that further problems were introduced when he tried to reproduce what he saw on paper. *Micrographia*'s readers were removed from the original specimens by two intermediaries: Hooke himself and his engravers, whom he tetchily accused of making inaccurate copies. And unlike the colourful microscopic world that he observed through his lens, Hooke's illustrations were in black and white, mostly free-floating on the page rather than confined within the circular boundary of an eyepiece.

It is easy to assume that with better technology, Hooke and those who read his book might have come closer to seeing things as they truly are. But no straight line of progress links him with modern microscopists.

Hooke's eighteenth-century successors were so concerned with divine perfection that they often portrayed not the natural specimens they saw in front of them, but imagined versions that improved on observed reality. For instance, a particular ant under examination might have a missing leg or a deformed head, but illustrators would mentally combine all the ants they had ever seen to depict an ideal ant, as though they were trying to capture the essence of antness. Their approach was similar to that of anatomists of the same period, whose drawings of female skeletons were given particularly wide pelvises (thought necessary for child-bearing), while those of males were given especially large skulls.

> **"Even for scientists, clarity seems to trump neutrality."**

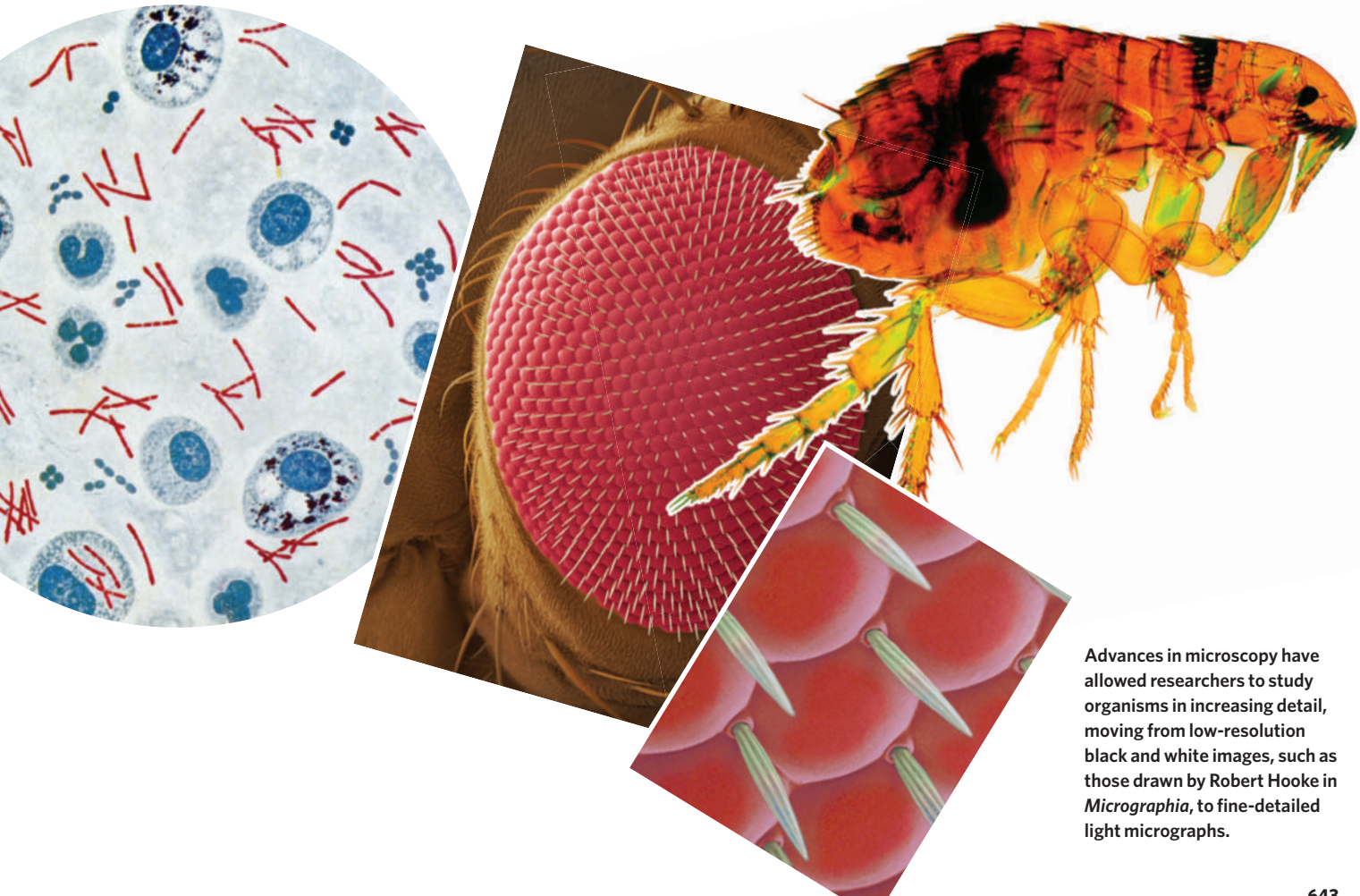
Around the middle of the nineteenth century, biological fashion swung the other way: the rallying call now became 'Let Nature speak for herself.' Scientists began to insist that a faithful record should be made of the individual specimen under observation, including all its defects. By developing new types of microscope with vastly enhanced accuracy, they hoped to eliminate the subjectivity entailed in personal judgements.

But like Hooke two centuries earlier, experimenters found it impossible to eliminate human involvement. On the contrary, as their instruments became more complicated, they had to intervene more. Under a stronger lens, less of the object could be seen at one time, which meant that more expertise was needed to identify the image and be confident that it represented external reality. Also, specimens now had to be carefully prepared, mounted and stained. Just as Hooke had to consider how his fly eyes were illuminated, so later microscopists had to ensure that light or dark spots were not instrumental artefacts.

Article of faith

Photography, which was introduced in the early 1800s, was initially hailed as a direct recording technique that would eliminate human error and subjective interpretation — a veritable *Pencil of Nature*, as photographer William Henry Fox Talbot titled his self-promotional book (published in instalments

WELLCOME LIBRARY, LONDON; A. WESTON/WELLCOME IMAGES; C. POWER/SPL; M. I. WALKER, WELLCOME IMAGES



Advances in microscopy have allowed researchers to study organisms in increasing detail, moving from low-resolution black and white images, such as those drawn by Robert Hooke in *Micrographia*, to fine-detailed light micrographs.

Microscopes have got more sophisticated, but have they brought us closer to seeing Nature as she really is?

SCIENCE MUSEUM/SSPL; WELLCOME LIBRARY, LONDON; AKG-IMAGES

between 1844 and 1846). "No human hand has hitherto traced such lines as these," enthused the physicist Michael Faraday, an early campaigner for the use of photography in science; "What man may hereafter do, now that dame Nature has become his drawing mistress, it is impossible to predict."

But all this excitement didn't bear much fruit for microscopy, at least initially. For decades, biologists kept cameras out of their laboratories, and put themselves, not magnified specimens, in front of the lens by posing for publicity shots in artists' studios. In retrospect, this turn to self-portraiture may seem surprising, but scientists were keen to establish their public standing.

Even when cameras did begin to be used in laboratories, bitter arguments ensued among researchers about the pros and cons of using cameras as objective recorders. Many scientists felt that if people could believe they saw spirits returning from the dead in photographs, then the technology could hardly be relied on to reveal the truth of the microscopic world. Long exposure times made it difficult to capture things that moved, and uncertainties were introduced by lens imperfections or fluid splashes and the lack of colour. Moreover, it was impossible to make accurate measurements of the specimens photographed because development processes often shrank or stretched the photographic paper.

Printing limitations also meant that photographs had to be hand-copied as engravings before they could be mass-published, thereby allowing human involvement to creep back in. Engravers could highlight crucial features that were hard to pick out in blurred photographs packed with detail — but when does clarifying an image become distortion?

By the beginning of the twentieth century, mechanical reproduction of the images seen through the eyepieces of microscopes had won favour over drawings. "If a microscopist really did need a drawing," wrote the German researcher Erwin Christeller in his 1927 histological atlas of disease, then he should assign the task to an untrained technician, the closest approximation to a mechanical device. Mechanization spelt progress, and microscopes became increasingly sophisticated, revealing aspects of the natural world that had previously belonged to the domain of conjecture.

Hooke would have been thrilled by the three-dimensional images generated by today's electron microscopes showing the minutest striations on insect carapaces, yet his goal of eliminating human intervention has remained elusive. Don Fawcett, a pioneer in electron microscopy, stressed that technical progress depends on an inherent preference for order that cannot be factually demonstrated. It is "an article of faith", he wrote in an essay in the mid 1960s, "that an image which is sharp, coherent, orderly, fine textured and generally aesthetically pleasing is more likely to be true than one which is coarse, disorderly and indistinct". Even for scientists, clarity seems to trump neutrality.

As non-optical microscopes probe ever deeper into the once invisible world, viewers are further and further removed from reality. Nowadays, they are separated from the object itself by complex processes that transform electrical signals into visual representations made with artificial colours. If Bacon were confronted by the electronic image of a virus, he might well object that science suffers from what he called "Idols of the Tribe" — those errors of perception arising from a limited human mind that are "like an enchanted glass". ■

Patricia Fara is senior tutor of Clare College, University of Cambridge CB2 1TL, UK. Her most recent book is *Science: A Four Thousand Year History* (Oxford University Press, 2009).
e-mail: pf10006@cam.ac.uk

FURTHER READING
Hooke, R. *Micrographia, or Some Physiological Descriptions of Minute Bodies* (Cosimo Classics, 2007 reduced facsimile of 1665 edition).
Bennett, J., Cooper, M., Hunter, M. & Jardine, L. *London's Leonardo: The Life and Work of Robert Hooke* (Oxford Univ. Press, 2003).
Tucker, J. *Nature Exposed: Photography as Witness in Victorian Science* (Johns Hopkins Univ. Press, 2005).
Jones, C. & Galison, P. (eds) *Picturing Science Reproducing Art* (Routledge, 1998).
Interactive website of Cambridge's Whipple Museum for the History of Science: www.hps.cam.ac.uk/whipple/explorecollections

See also pages 615 and 629, and online at http://tinyurl.com/microspecial.