Small wonders
The invention of microscopy

Felicity Henderson

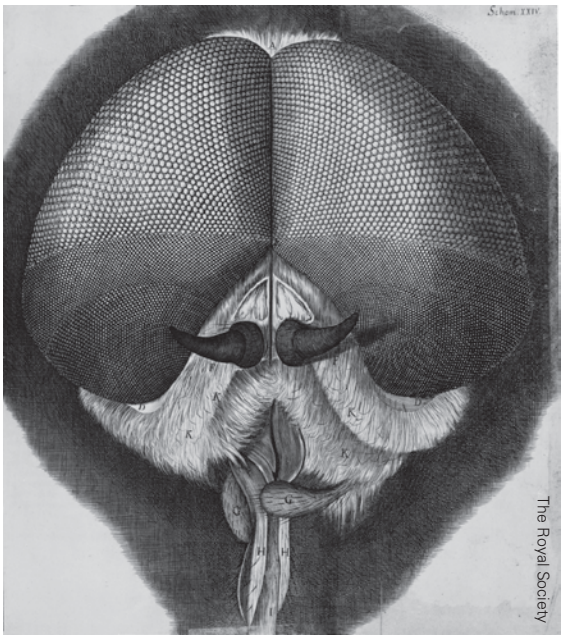
Key words
microscope
Royal Society
cells
lens

Summer, 1665. London was hot, dirty and smelly – and so were Londoners. They rarely changed their clothes, and the bathroom hadn't been invented yet. Fleas and lice lived in houses, beds and hair – they were hard to see, but their bites were a constant annoyance.

One man was investigating these tiny animals more closely. Robert Hooke was one of London's best early scientists, making discoveries in chemistry, geology, engineering, medicine and many other areas (Hooke's Law of elasticity is named after him – see the previous issue of CATALYST).

Hooke was fascinated by the miniature world that existed beyond human sight. He designed an improved microscope, and used it to study anything he could find: snowflakes, the tip of a needle, mould on bread, flies, lice and fleas, and a full-stop on a printed page.

These were all common, everyday things – most people wouldn't give them a second thought. But through the microscope, they were transformed into something mysterious, wonderful, and perhaps even beautiful. Hooke was excited to find that snowflakes grew in regular, hexagonal shapes, each one different from the next. A razor's edge that seemed perfectly smooth was actually marked with impurities and nicks. A fly's eye contained a multitude of tiny facets, allowing it to look in many directions at once.



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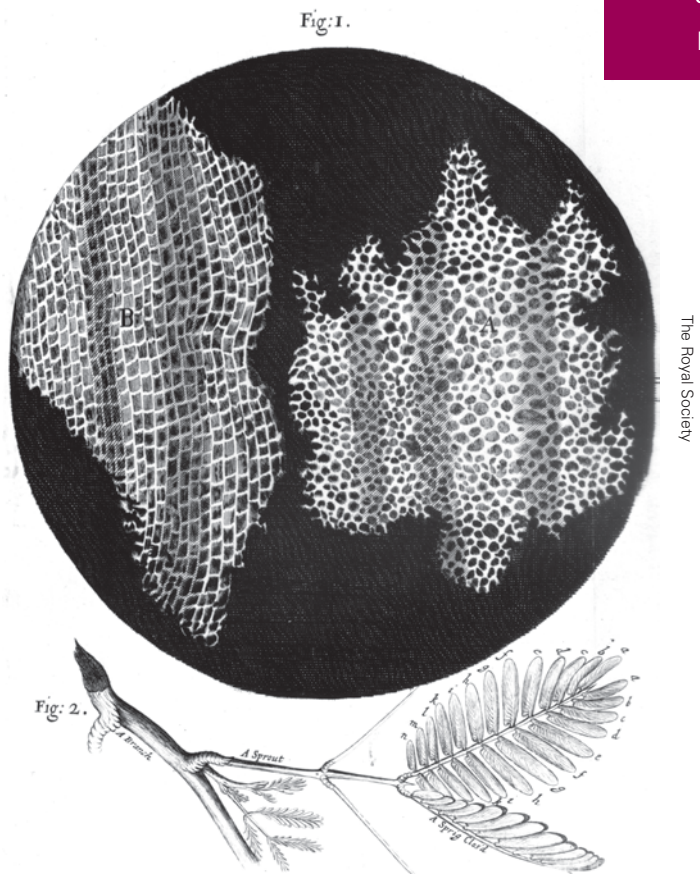
Hooke's image of a fly's eyes, from Micrographia *(1665)*



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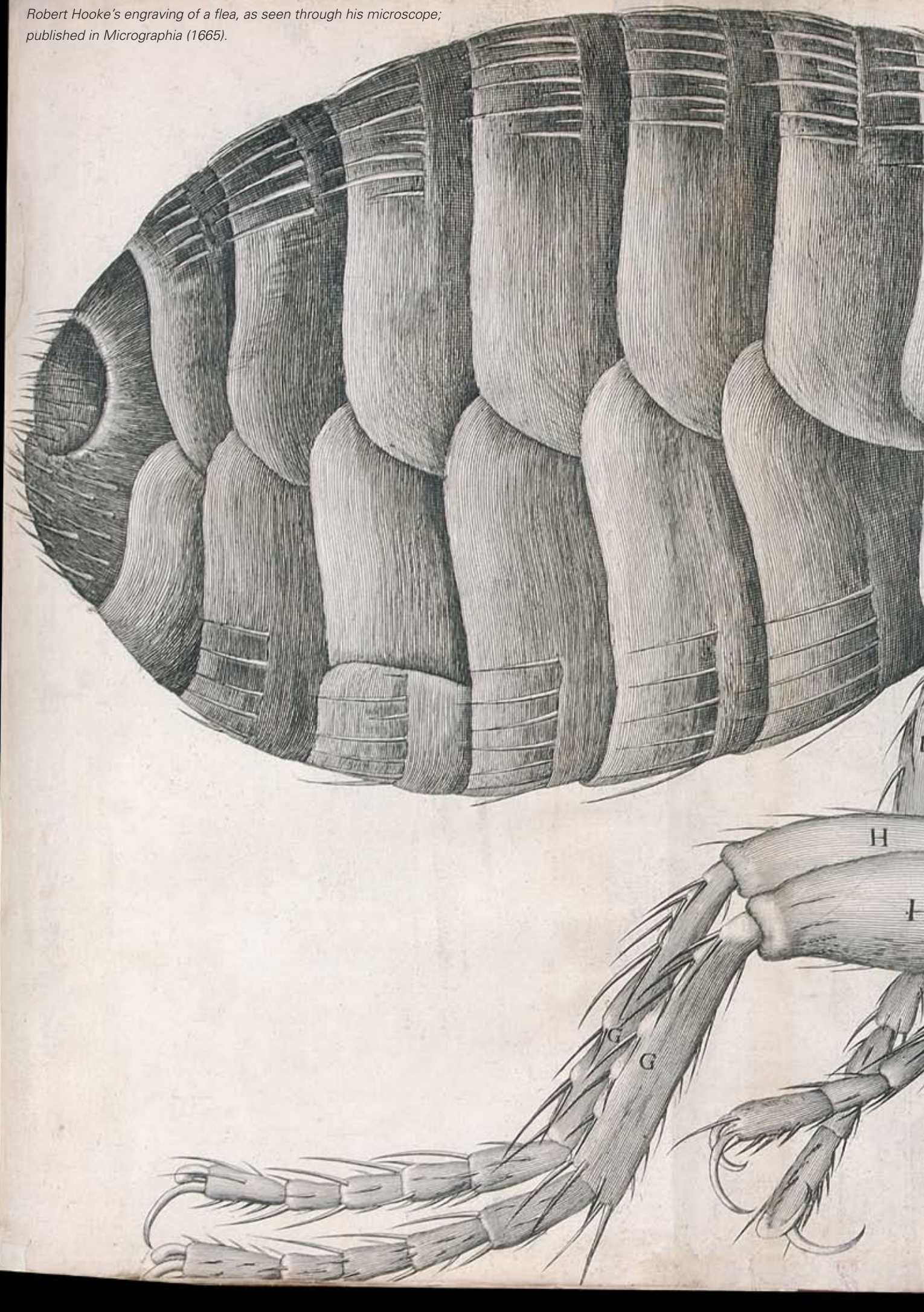
Hooke's drawing of cells in a slice of cork, from Micrographia (1665)

Hooke made an important discovery when he inspected a thin slice of cork. He noticed that the wood was made of many tiny individual compartments bunched together. He called these compartments 'cells' (thinking they looked like a honeycomb). We now know that cells are the fundamental unit of all life.

Hooke's great achievement was not just to see these things for the first time, but to show them to others. His book, *Micrographia*, published in 1665, was filled with beautiful, intricate drawings. They made the microscopic world visible to non-scientists for the first time, and people have been fascinated by it ever since.

On pages 10-11 you can see Hooke's drawing of a flea. The original engraving is considerably larger than these pages although the flea itself was only about 3 mm in length.

Robert Hooke's engraving of a flea, as seen through his microscope; published in Micrographia (1665).



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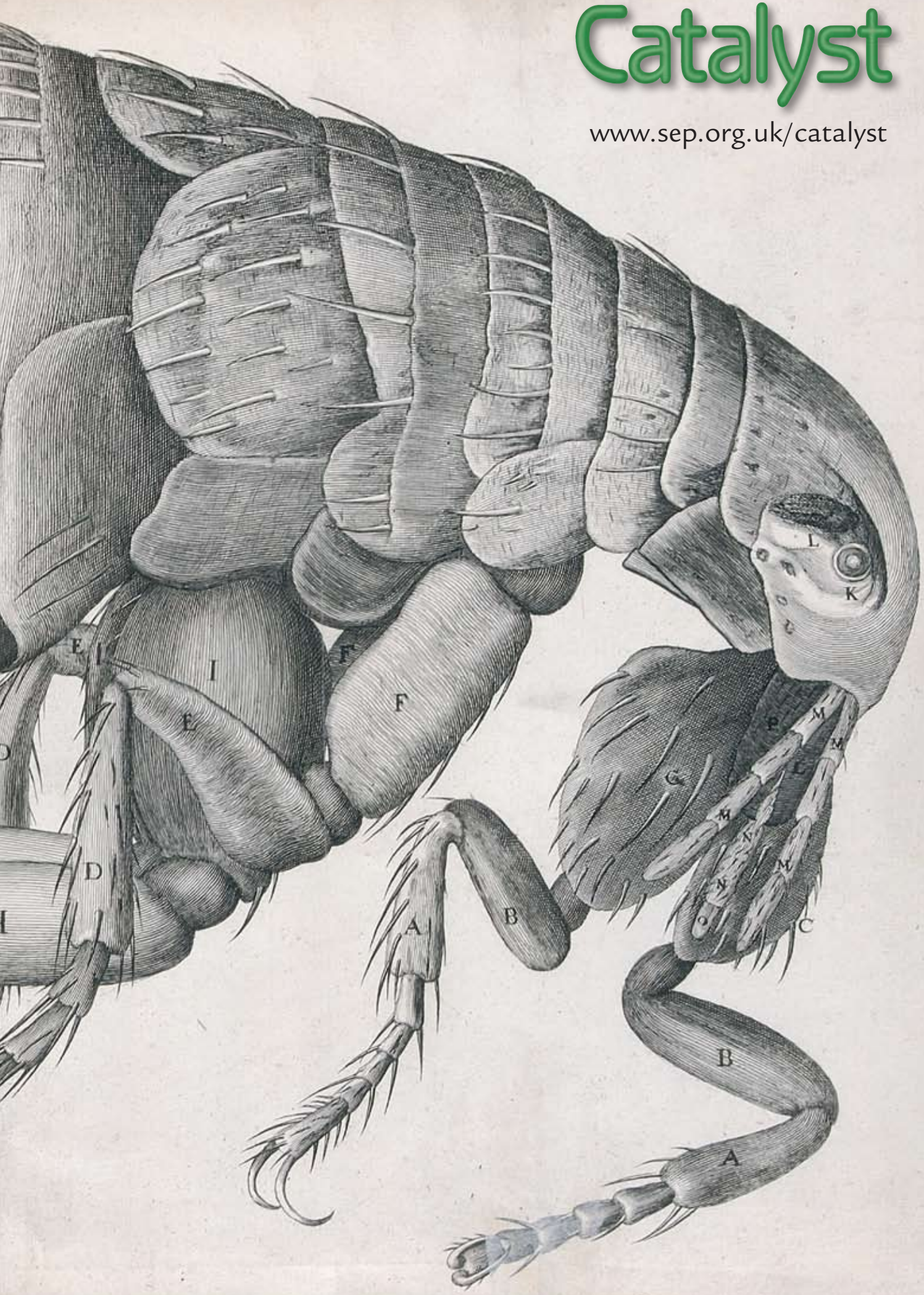
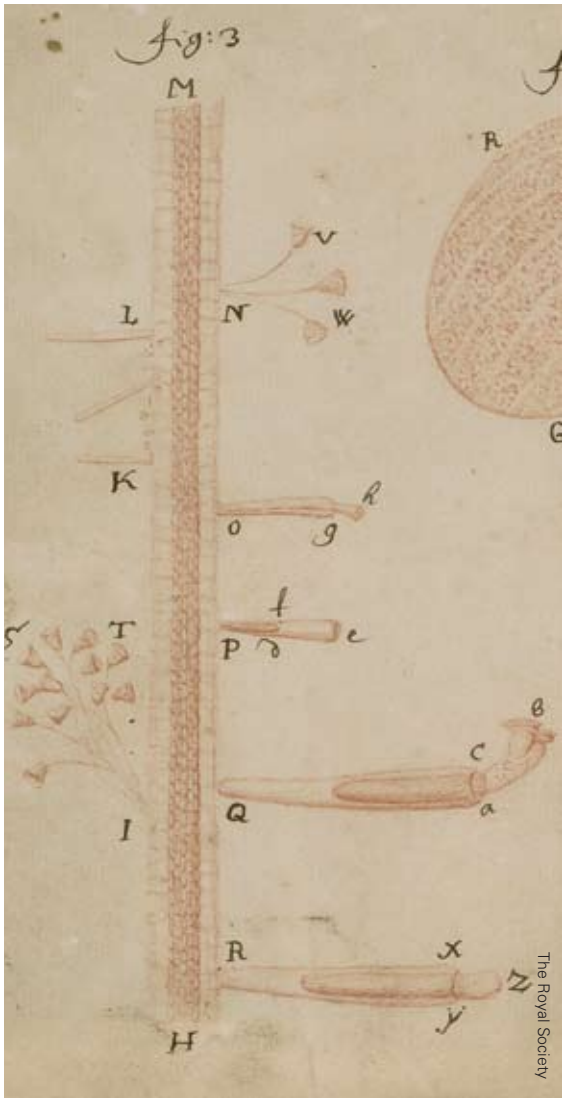


The Royal Society of London for Improving Natural Knowledge

Robert Hooke was employed by the Royal Society, Britain's first scientific institution. It was founded in 1660 by a group of men who wanted to understand more about the natural world. At the time, most 'natural knowledge' had been passed down from ancient philosophers such as Aristotle. The Fellows of the Royal Society wanted to test this knowledge for themselves, using personal observations and experiments to prove or disprove ancient theories. They were among the first to do what we would call 'science' today. Find out more about the Royal Society and its history at royalsociety.org.

While Robert Hooke was at work in London, a Dutchman living in Delft was making exciting discoveries of his own. Antoni van Leeuwenhoek (pronounced Lay-wen-hook) used a very small, very powerful lens. It was simple, just a single tiny drop of glass made at home by Leeuwenhoek himself.

Leeuwenhoek used his lenses to study a huge range of natural objects, from animal tissue and plant structures to saliva, vinegar and blood. He was the first to systematically investigate the tiny eel-like creatures he found swimming in drops of water and other liquids. Today we would know them as bacteria and other protozoa.



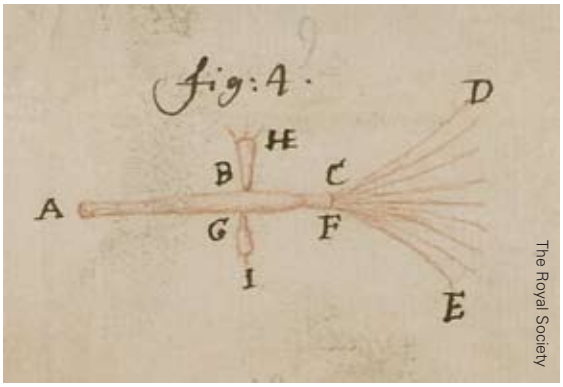
A strip of pondweed (MH in the figure) with 'animalcules' attached, from Leeuwenhoek's letter to the Royal Society in December 1702. The organisms have been identified as Vorticella (NVW), Carchesium or Zoothanium (IST), and the rotifer Limnius ceratophylli (RXY and cba).

On the opposite page, Felicity compares the microscopes used by Leeuwenhoek and Hooke.

Leeuwenhoek wrote to the Royal Society with news of his discoveries, but it took Robert Hooke a long time to reproduce his results. When he did, he was amazed, saying,

I was very much surprised at this so wonderful a spectacle, having never seen any living creature comparable to these for smallness.

He showed the little animals to the other Fellows, who were equally surprised. Sadly, it took almost 200 years – and millions of deaths from cholera, dysentery and typhoid – before scientists understood the significance of the creatures swimming in their drinking water.



A drawing of a Hydra species, first described by Leeuwenhoek in his letter to the Royal Society in 1702.

Spontaneous generation

Leeuwenhoek discussed his discoveries with another Dutch microscopist, Jan Swammerdam. Although he trained as a doctor, Swammerdam was particularly interested in insects. He dissected them at every stage of development, from larvae to adult, and showed that the same insects underwent a series of developmental stages. He also investigated insect reproductive organs. His research provided evidence against the long-standing theory of 'spontaneous generation'. This theory suggested that insects (and some small animals) simply appeared out of rotting vegetation rather than being the offspring of parents.

Swammerdam dissected a queen bee and other insects and was able to see microscopic eggs inside their bodies. He argued that all animals, no matter how small, came from eggs like the ones he had seen. He was correct, but the theory of spontaneous generation was only finally proved wrong in an experiment by Louis Pasteur in the 19th century.

Hooke, Leeuwenhoek and Swammerdam were all fascinated by the microscopic world, but they didn't just want to see it – they wanted to understand it, and they wanted to describe it to other people. They knew that if they could explain structures and processes that existed on a small scale, they would have the key to understanding more complex organisms. Scientists have built on their work ever since.

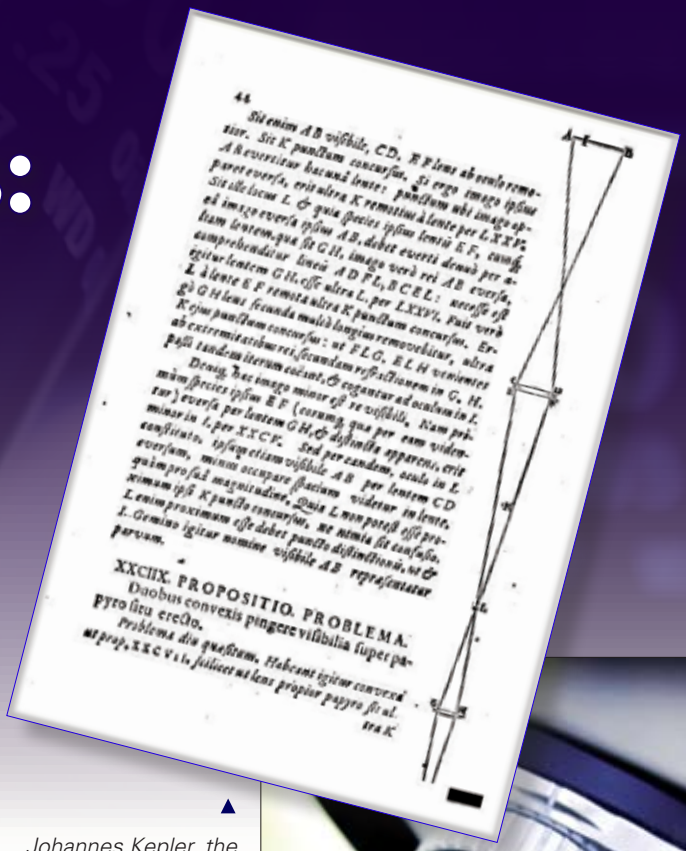
Dr Felicity Henderson is a researcher at the Royal Society Centre for the History of Science

Microscopes:
Simple or Compound?

Hooke and Leeuwenhoek were both using microscopes, but they were very different instruments.

- **Leeuwenhoek** used a 'simple' microscope, with a single lens – just a tiny drop of glass about five millimetres in diameter. He mounted the lens in a thin piece of metal – like a very small magnifying glass.
- **Hooke's** microscope was a much larger, 'compound' instrument. It used three lenses: a small double-convex eye-lens at the top, then a large plano-convex field-lens, and another double-convex lens with a short focal length at the bottom of the tube.

Which was better? Some of Leeuwenhoek's simple microscopes could magnify objects more than 250 times, but Hooke's compound microscopes only magnified somewhere between 20 and 50 times. Leeuwenhoek's instruments were more powerful, so why did Hooke not use one? He knew how to make and use a simple lens, but he chose not to. They had to be held very close to the eye, and Hooke was concerned that he would damage his eyesight if he used a simple microscope regularly.



Johannes Kepler, the astronomer, was also interested in microscopy. Above is his publication in which he explained (in Latin) how a compound microscope works, complete with a ray diagram.

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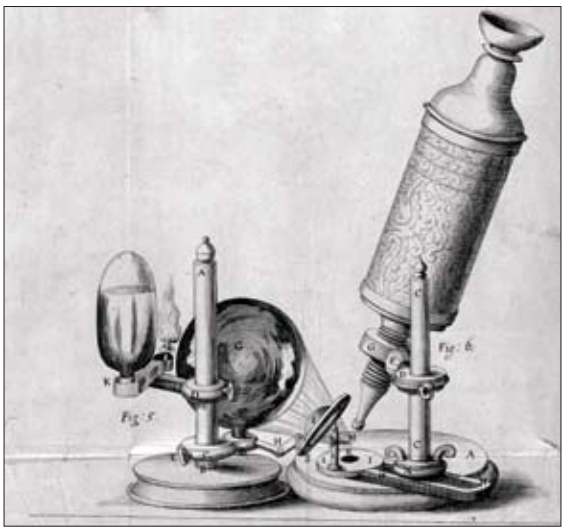
A modern lab microscope usually has a choice of objective lenses which gives a choice of magnifications.



A drawing of Hooke's microscope, from Micrographia (1665). He used a glass globe filled with water to focus light from a small flame onto the specimen, to counteract the darkened images caused by lens aberrations.

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A replica of Leeuwenhoek's simple microscope. Specimens were fixed to the sharp point and viewed through a tiny lens mounted in the small hole.