

Microscopical Realities and Fake News

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The award of Honorary Fellowship by Council in July 2017 brought with it a request for a lecture on my lifetime spent working with the living cell. It was the sight of minute forms of life during early childhood that matured into a commitment to research, and the legacy of the great pioneers was a continuing preoccupation. Those from earlier centuries included Hooke, Leeuwenhoek, Quekett, Carpenter and Hertwig; more recent inspirational luminaries whom I came to know personally included Jeremy Pickett-Heaps, Walter McCrone, John Delly and Dame Miriam Rothschild, and (at Cambridge) Archie Howie, Ellis Cosslett, Sir Andrew Huxley, John MacArthur, Joseph Needham, Sir John Meurig Thomas and Lord John Butterfield, to select just a few. The dawn of microscopical awareness marked the beginning of today's era of bioscience research, yet curiously the subject is unfamiliar to the public. Television programmes rarely venture into the microscopical realm, and the media fail to celebrate these insights – even though they are the most important in revealing to us the nature of life (2017).

Origins

The first organisms that attracted my attention were multicellular; creatures such as copepod water-fleas, the active larvae of mosquitoes, and cheese mites. As an infant I watched fascinated as adult *Culex* emerged from their aquatic pupae and launched themselves in to the air. I kept the water-spider *Argyroneta aquatica* in an aquarium at home, and observed trichopteran caddis-fly larvae constructing their homes, often studying them with a hand-lens – until I was thirteen. Then my grandfather passed onto us a small Victorian toy microscope, manufactured in Germany but with no maker's name. It gave inadequate images, certainly, but it was enough to carry my vision on

to the world of the single cell. I found it all endlessly diverting, and was surprised – not only by what I could observe – but by the apparent disinterest in the daily life of microorganisms that one could evince in everyone else. It is true today; though present-day investigators are transfixed by the quest for ever-great resolution, and informed by the reductionism of our age, few scientists step back to consider the microbe as organism and observe the way these curious creatures live their intricate little lives. As I have said before, it is as if we were transfixed by analysing the ink on the printed page, without every realising that this is a printed sonnet on a page that nobody troubles to read.

In my mid-teens I constructed a wooden camera to capture micrographs of what I observed, informally calling it Fred (an acronym deriving loosely from Photomicrographic Recording and Enlarging Device). There were later iterations, each more complex than the last, until the final home-made version which I described in my first published article on my microscopical research: “Fred Mk IV had to be seen to be believed. It had grown a long list of appendages and seemed to embody more labour-saving devices and fool-proof checking devices than I can possibly remember. A reflex mirror and ground-glass screen improvised from old photographic plates, a warning light when the mirror was raised, a ratchet on the shutter to check for double exposure ... as always, it created more work than it saved, but Fred Mk IV took some of my best shots down the microscope.” (1963)

During a year under Professor Scott Thompson at the Medical Research Council, I assiduously studied histology and amassed an extensive collection of microscopical preparations of a lengthy list of pathologies, patients gladly donating tissues for study. In my early twenties I was diverted by the microscopical mechanisms that allowed blood to coagulate (1965a & 2006), the study of early Devonian plants perfectly preserved in the flint beds of Rhynie in Scotland (1965b) and discovered



Figure 1. Lacquered brass microscopes, like the Leitz monocular instrument I used until fifty years ago, have since become curios. It provided an excellent, high-resolution image and could be fitted with a 35mm camera for still images, or an ex-WWII gun camera for cine.

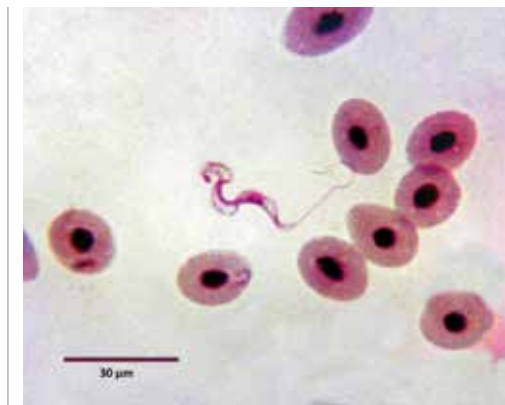


Figure 2. Among the early projects which attracted attention was a disease of freshwater fish. Microscopy of fresh blood, a technique rarely used at the time, revealed the flickering movement of the organisms which could then be Giemsa stained.

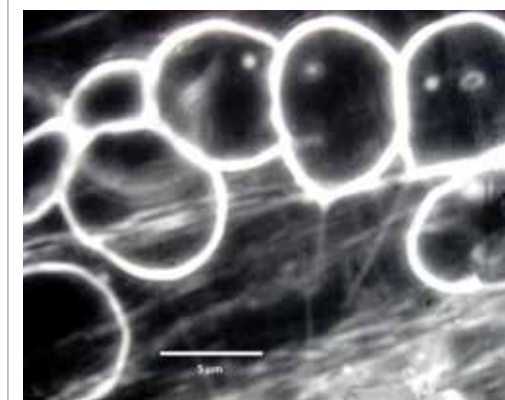


Figure 3. Studies of the dynamics human blood using a similar technique disclosed the means by which erythrocytes can be retained within the fibrinous reticulum during haemostasis. These submicroscopic threads can be visualised by dark-ground microscopy.

trypanosomes that were causing an outbreak of a mysterious disease of fish in a nearby lake (1960).

I studied cytology in *Endymion* and *Forficula* and obtained hauntingly clear images of mitotic chromosomes in autumnal corms of plants preparing themselves for the following spring; and investigated the Zygnemetales – a curiously complex chlorophyte family (1965c). I showed that the cytoplasmic bridles that suspend the nucleus of *Spirogyra* near the centre of the cell terminated in the peripheral chloroplasts, and demonstrated that the mucous layer that coats each cell could be visualised by fixing the cells to a slide and peeling the filament away. I identified *Lycopodium* spores in a

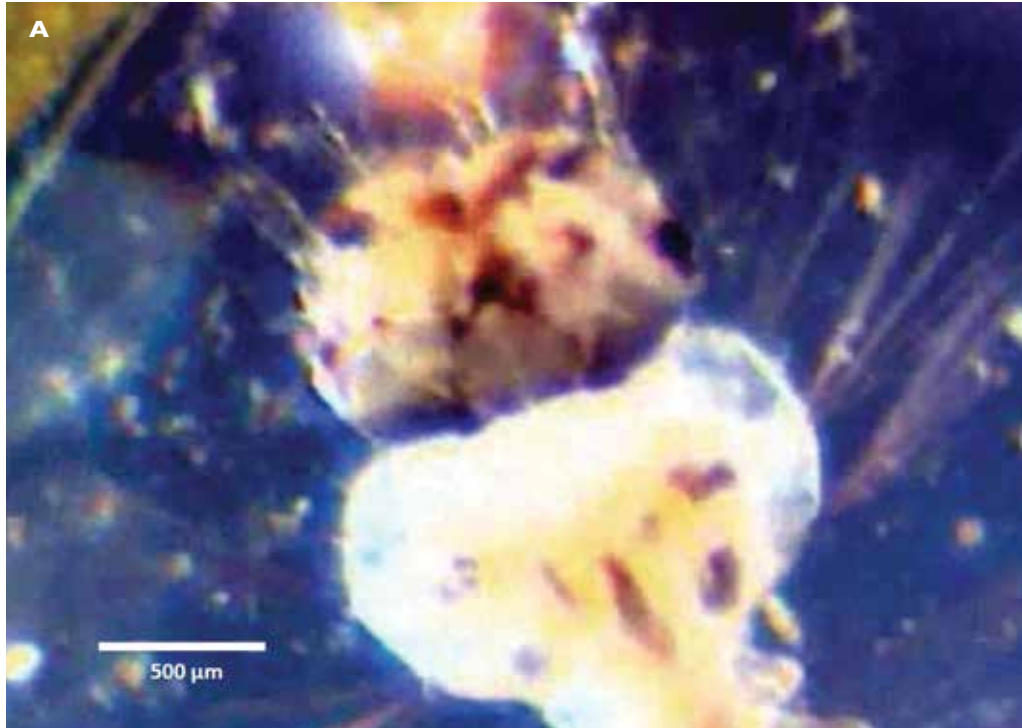


Figure 4. A) Early compound microscopes generate images that are highly chromatic and of low resolution. The appearance of the head and thorax of a living aquatic *Culex* larva, though a dynamic and vivid spectacle, cannot capture the fine structural details. B) Robert Hooke published detailed engravings of insect life in his celebrated book "Micrographia" in 1665. A paradox unnoticed by previous investigators is that this degree of resolution far exceeds anything that his compound microscope could provide. C) It was a single-lensed microscope which gave the high-resolution image that Hooke recorded. In the Preface to his book, Hooke provides a detailed description of how to make a simple microscope; this was later emulated in the Netherlands by van Leeuwenhoek.



smear submitted by a friend, and traced them back to the solid-phase lubricant on condoms (1990) and carefully categorised microscopical residues in virus-contaminated contaminated drinking-water so that I could identify their source (1988). I also identified ciliated vorticellid organisms as the agents responsible for purifying water in filter-beds. And behind all this lurked a continuing preoccupation with the way the pioneers made their remarkable observations (1966). This was an interest that would provide me with some of my most absorbing microscopical research (1971a).

Readers may be aware that not every subject I studied was microscopical: I prepared a forensic report on the death of the boxer Freddie Mills (Maxwell, 1965) and, when a twelfth-century skeleton was excavated by archaeologists (1970a), I was asked to examine it and found not only evidence of a frontal lobe excrescence (possibly from a tuberculous lesion) but detected traces of iron in a shattered rib, clear evidence of a vicious attack (1970b). In 1962 I attended my first annual meeting of the RMS at Balliol College, Oxford

University, and the microscopists I met inspired me to adapt a World War II 16mm cine camera to take movies down the microscope. I filmed the production of a small body – looking exactly like a platelet – ejected from a leucocyte (1968a) and, when there was an outbreak of pediculosis at the children's school, I filmed head lice stalking through snippets of human hair (1970c). For my haemostasis research, I captured the suspension of erythrocytes on submicroscopic fibrils (1969) composed of freshly-precipitated fibrin. Many of these adventures were featured in the popular press, in academic journals, reference books (1968b) and on television, while my skeleton investigations became a key section of a UNESCO textbook (1970b). These were exciting times.

As I have reported in this journal previously, I left university before graduating and had set up my own laboratory to provide freedom to explore whatever avenues I wished – though the staff at Cardiff where I had started my studies, and at the National Museum of Wales, which housed an astonishing collection of Victorian microscopic preparations,

were always hospitable and sometimes sought my advice and assistance. For decades I was a member of Cardiff University Court, and was appointed a Fellow in 1986. At the Natural History Museum in London I was given access behind the scenes to their facilities; I had devoted my sixth-form project to *Osmunda regalis*, and Clive Jermy – an expert in the field at the Museum – was always ready to mentor my young enthusiasms. He showed me their copy of Robert Hooke's *Micrographia*, originally published in 1665. I turned the pages reverentially, little thinking I would own copies of my own one day. Although I was immediately impressed by the clarity of his observations, made through a crude microscope with cardboard body, I quickly realised that Hooke's studies revealed more detail than I could see through my microscope at home.

In due course I went on to resolve a fundamental paradox that others had overlooked: Hooke's published studies reveal details that his microscope could not resolve. The images in *Micrographia* were impossible. After studying his book in detail, I found in the unnumbered pages of his Preface a definitive description of how to manufacture a single-lensed microscope which Hooke insisted could "magnify and make some Objects more distinct" than a compound instrument, and my experiments with these simple microscopes proved that they alone could resolve the details Hooke showed in his plates. This solved the problem. Hooke's studies had been made with these diminutive instruments, and not by the impressive compound microscope made by Christopher Cock for which Hooke became renowned. Hooke's design was the inspiration that led to Leeuwenhoek taking up the task.

These enthusiasms needed to be communicated to others, and had I begun lecturing on microscopy when I was a schoolboy. I was writing a newspaper column even before I was a student, and brought microbes into the list whenever I could; while presenting my lectures took me to venues ranging from the Royal Society's lecture rooms

in Burlington House to Imperial College, London, where I gave my first lecture to the Inter/Micro conference. The BBC approached me several times to join them as a full-time broadcaster, but this was not compatible with an ongoing commitment to research. In 1965 I was invited to broadcast some documentaries for BBC Wales and, since I was not prepared to join them, it was agreed that I should compile them as an independent producer (Anon 1865). Nothing like this had happened before, and the announcer proclaimed that the programmes had been "prepared and presented by Brian J Ford" – the most diplomatic form of wording. This pioneered the concept of external production for the Corporation (now a crucial component of its operation) and, of course, I was able to bring the microbial world into my production.

In my thirties, I launched a proposal for the legal regulation of biohazards in articles for the *New Law Journal* (1971b) and *Nature* (1974). My proposition was supported by reports in newspapers including the *Guardian* and *The Times* (Berlins and Wright 1971) and I took part in the BBC television programme *Panorama* with a startled Ludovic Kennedy, where I produced a vial of typhoid from a well-wrapped container and explained that there was nothing to prevent my doing so if the bacteria were in my pocket, whereas – had they been in my gall-bladder instead – I could have immediately been detained. Legislation for the judicious handling of pathogens was soon drawn up (1974) and now this control of biohazards exists world-wide. I wrote of the dangers, at the time scarcely perceived, of crocidolite asbestos (1971c) and lectured at Cambridge on the widespread neglect of microscopical science by the media and the public, which became the topic for a leading article I published in *Nature* (1974). There was much sympathy for my viewpoint, and I had made some small inroads in my television presentations. I was presenting a weekly science report for ITV in Bristol and, whenever I could find space for them, there were microbes in the mix. I illustrated these

reports with micrographs, in the hope of making the viewers more familiar with what we all take for granted.

Addressing the Wider World

I had discussed many of these ideas in my American lectures and they acquired an international audience when I embarked on my first round-world lecture tour. It involved 38 stopovers in dozens of countries and took two months. There were diplomatic receptions, presentations, laboratory visits; I had recently produced a film on cancer research and the Council of Scientific and Industrial Research in New Delhi were keen for me to discuss it. This involved transporting the film, weighing several kilograms in a metal can the size of a bicycle wheel, right around the world. India suffers frequent cuts, known in the United States (where they prefer three syllables in place of one) as "outages" and in India (where they like to give such events a positive spin) as "load shedding". Every ten or fifteen minutes the power would fail and the projector ground to a halt. It was important to stand by for this and carry on the narrative in lecture form, until suddenly with a groan and a flicker or two, the projector would lurch back into life and the film would resume for its next randomly-chosen section until the electricity failed again. I also lectured on public engagement in science and discussed it at length on state television, while reporters eagerly wrote accounts for the popular press (1978a). In Singapore I lectured at Raffles College (1978b) where Sir Stamford Raffles was regarded as an imperialist who had ravaged SE Asia; last time I spoke there, a few years ago, his bust was back in the foyer and garlanded with flowers. Raffles had been restored to a position of honour, recognised for bringing education and commerce to a sparsely-populated corner of the world. Since my first visit in 1978, when modern Singapore was just emerging, I have frequently returned to give public presentations at the Singapore Science Centre. By the time I reached Australia on that first world tour I was ready to present a keynote speech

on the unrecognised role of microorganisms in purifying drinking water (1978c) and made my first broadcasts on Australian television. Later I went on to explore the Pacific islands – fascinating places to which I would return in later years when I was invited as guest speaker aboard cruise liners. Those audiences are always fascinated when I reveal to them the microbial world that surrounds us all.

Microscopy matters. The microscope is the only scientific instrument that is used in every field of scientific investigation (even astronomers use sub-micron tolerances for their optics, and scrutinize high-magnification images of interplanetary dust). Reporters love microscopy, but have often told me how their enthusiastic reports are spiked in favour of the latest celebrity break-up or political embarrassment. Physicists spend huge sums of money on promotion and are far better at public relations. When the Large Hadron Collider (LHC) was launched, there were vast numbers of press announcements sent out and it made news around the world. There were endless high-level press visits, and the BBC even renamed their entire schedule "big bang day". The LHC was the setting for the BBC's *Afternoon Play* (Lidster 2008) that day entitled "Lost Souls" (a promotional campaign only slightly compromised when a later BBC News bulletin printed it as the "hardon" collider). It is often suggested that physics is the queen of the sciences, though this term was traditionally applied to theology and it was the German mathematician Carl Friedrich Gauss (1777–1855) who dubbed mathematics as "the Queen of the Sciences" in 1856. Biology transcends physics and microscopical biology defines life. Physics is simple by comparison and much of it, unlike the hard science that we observe, is invented by its practitioners and used to impress the public with hyperbole. Microscopy, by contrast, deals with realities rather than dreams. Regrettably, few British editors or television producers are biology graduates with microscopy experience, and – while physics and astronomy feature extensively in television documentaries –

our subject is rarely dealt with satisfactorily in our media.

In my late twenties I had decided it would be timely to bring together the disparate disciplines of food production, spoilage, hygiene and nutrition in a textbook entitled *Microbiology and Food* (1970) which was enthusiastically discussed in the press (even being reviewed in journals like *New Scientist*). Three years later saw my book *The Revealing Lens* (1973a) trigger extraordinary interest – it was widely reviewed and discussed in dozens of publications including *The Times*, the *New Scientist* and the *School Science Review*. That same year my *Optical Microscope Manual* (1973b) was reviewed by many publications including *The Times Higher Education Supplement* and *The Microscope*, and this magazine's illustrious predecessor, *Proceedings of the Royal Microscopical Society*. When I published *Microbe Power* (1976) it was extensively reported with the usual reviews supplemented by reports in the popular press such as the *Daily Mirror* and the *Daily Mail*, and featured widely in broadcasts including the BBC's *Today* programme.

For all this sense of support and enthusiasm, featuring microbial life on television proved to be difficult. I demonstrated the living cell on the BBC television series (Vorderman & Fells 1990) entitled *Take Nobody's Word For It* (a title translated from the Royal Society's motto, *nullius in verba*) and I brought microbes into the discussion whenever I could when the BBC had given me my own Saturday programme, *Science Now on Radio Four*. I frequently appeared in programmes discussing health, and food, even computers; but British producers remained unwilling to launch a full-blown television series devoted to the microbe world. This was not true of other nations; I have explained my work with microscopes in films for Korean and Chinese networks, and have appeared on Channel News Asia from Singapore with videos of microbes performing antics as I spoke (Anon 2008). Britain was loth to follow.

Microbes in the Media

Programmes that brought the realities of the microscopical world were so conspicuously absent from television that I resolved to see if the subject was ripe for production. I spoke to Mark Thompson when he was the Chief Executive of Channel Four television, and we met to discuss the idea of some programmes on the living cell. Thompson thought the idea was exciting. When he became director-General of the BBC he felt he was well placed to see the idea come to fruition so I prepared a formal proposal and he passed it to a commissioning editor, George Entwistle. He remained silent for months until Thompson pressed him to follow it up. Entwistle then wrote to say that he was not impressed. He stated that the BBC would certainly not broadcast a series on the cell; and if they considered a single programme, it would have to be produced independently. This was disappointing, though not a surprise.

A few months later, after presenting a lecture at Cambridge University, an enthusiastic young producer approached me and asked if we could discuss a series on microscopical life for a television series, and I agreed that he should look into it. Two weeks later, he called me from Birmingham: "They tell me the BBC have just been here," he said, "filming interviews for a television series called *The Cell*." The programmes made their debut in 2009 and they covered the areas I had proposed – including Leeuwenhoek's investigations with single-lensed microscopes (1982) and Robert Brown's revelation of the nucleus (1992). I had managed to demonstrate that the images Leeuwenhoek's single lens could generate were of astonishing quality, and Brown's seemingly primitive microscope could provide remarkably detailed insights into the structure of a cell. I had obtained exquisite video micrographs of actively swimming protozoa using a lens ground for me by Es Reid in Cambridge and no larger than the head of a pin. The BBC's version was filmed in the Netherlands with a replica Leeuwenhoek microscope, but it managed only to



Figure 5. A) Single lenses demand meticulous adjustment. In a BBC television documentary, a replica simple microscope was used to record aquatic microorganisms, though this indistinct result is little improved on what can be perceived with the naked eye. B) A lens magnifying 60x and ground for the author by Es Reid of Cambridge allows us to demonstrate the capacity of a single lens to resolve detail. We can observe the active cirri and cytoplasmic inclusions of an active *Stylonicchia* grazing among chlorophyte algae.

show a blurred image resolving no more than can be discerned by the naked eye (Rutherford 2009).

We all smiled when the presenter, Adam Rutherford, teased the attitude of the “old duffers” at the Royal Society, because he had overlooked one small point – at the time the microscope was being discussed, those distinguished seventeenth-century Fellows were about the same age as Rutherford was when the programmes went out. They asked an expert on Brown’s research, David Mabberley of Oxford University, to demonstrate cell nucleus with the microscope but could not capture it clearly. Rutherford presented a sample of his own semen and conscientiously stuck to his script, speaking about the sperm swimming along with whip-like tails; but the technical team could not resolve any. There is a vogue for imagining that people with little experience can quickly master some alien speciality, but this does not work for microscopy. That takes time and experience, and currently there is no television programme that features the microbial universe which we all take for granted.

There was one major opportunity when the Royal Society celebrated their 350th anniversary and a BBC programme was planned to mark the occasion. Their intention was to show how what the first microscopists had seen of their specimens, and Giles Harrison, the producer, wondered whether I could start by providing information on Leeuwenhoek, and said he might enquire if I’d be happy to be involved on screen. When he added that he “wanted to feature Leeuwenhoek and the major discoveries he made” it made me think. Although I had often spoken of the clarity of those lenses, and had obtained many still images, I realised that this would require video, and so I set aside a week to set up a system that could capture the fleeting images those tiny instruments can create as video sequences. It was an entrancing experience: Hooke’s crisp view of the cells in cork was captured, we saw Leeuwenhoek’s view of drifting blood cells, and Brown’s penetrating gaze at the

orchid nucleus. In all 150 sequences were prepared that documented in detail what the pioneers could see. In the end, the BBC decided they would not be featuring Leeuwenhoek after all. The final programme assured the audience that cells could not be studied until the nineteenth century, when it was discovered how they might be fixed and stained. No matter – we had been given the stimulus to acquire a unique collection of videos, which vividly demonstrate the astonishing clarity of a single-lens microscope; and meanwhile the BBC programme, presented by Michael Mosley and entitled *The Story of Science*, provided several quotable examples with which to illustrate my lectures (Mosley 2010).

Similarly, when the BBC planned a series presented by Richard Hammond and entitled *Invisible Worlds* they sent their researcher Simon Cronin to spend a day with me, asking for some “inspired ideas” for their programme, though some months later end he wrote to say they had been told to scale back the ambition of their show. In the event, Richard Hammond’s programme on the microscopic world included a fascinating demonstration of micro-writing on a hair, showed us the dust mite *Dermatophagoides* and a few tardigrades, with a brief sequence of *Turbatrix aceti*, the vinegar eel-worm, but did not include any signs of a living cell (Hammond 2010).

An Era of Misrepresentation

The microbial world is missing from the litany of nature documentaries. There is an on-line catalogue of every creature the BBC could locate: “Find Your Favourite Animals”, their site is called. The candidates range from mammals and birds past sea anemones and jellyfish through sea urchins and worms – but it stops before we reached anything microscopic (website 2018). A television programme about microbes in recycling never actually showed them; when extremophile bacterial colonies were demonstrated in Mexican caves we saw the colonies, but not the organisms; and when a series called *The Planets* showed a greenish desert

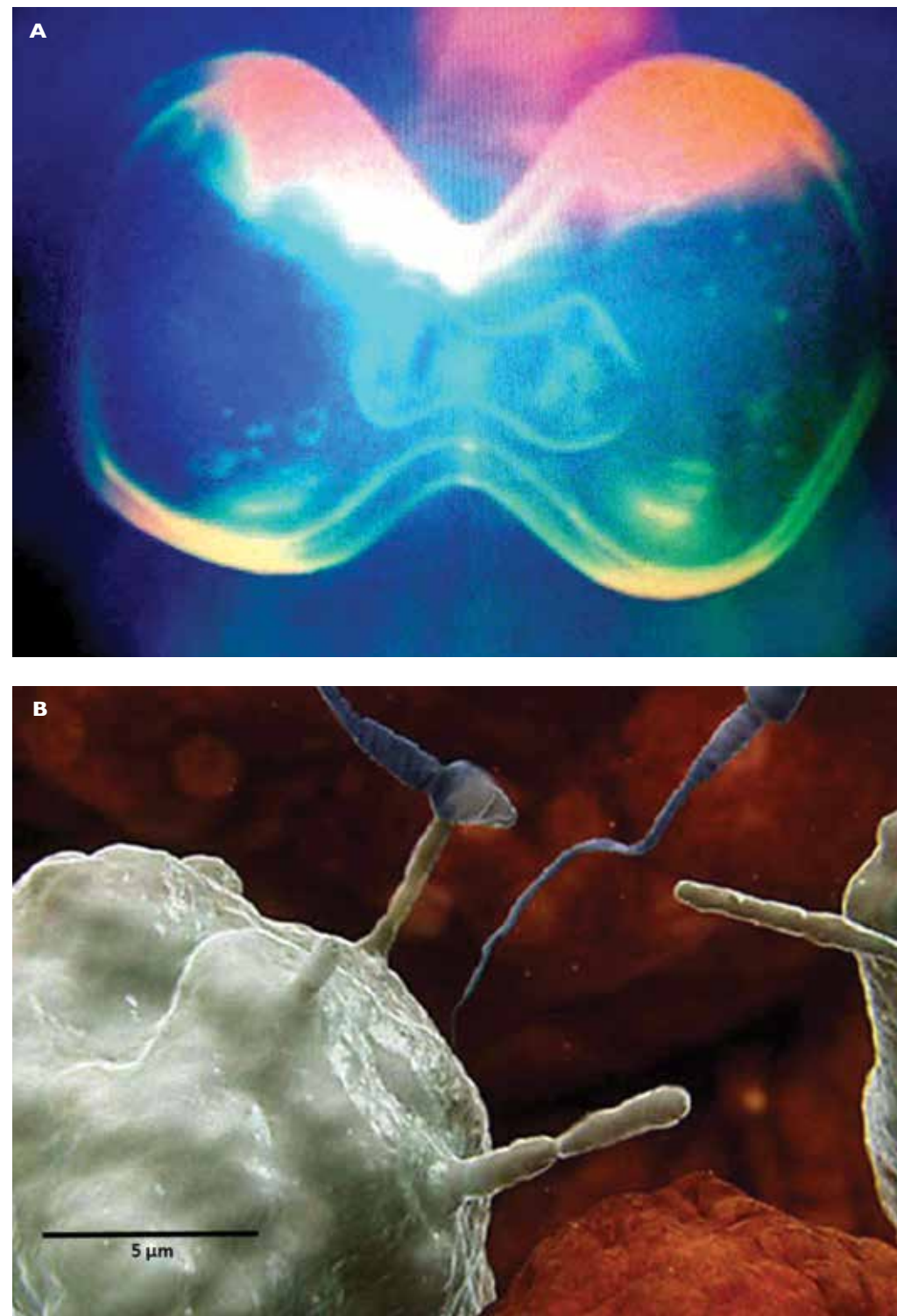


Figure 6. A) The title sequence of the BBC television series “The Cell” featured a computer graphic of a dividing cell, in which the cytoplasmic intricacy of life is replaced by smooth bubbles. The public are inevitably given the impression that these simplifications represent reality. B) Computer simulations were also used to illustrate a series on the human body presented by Michael Mosley. Scanning electron micrographs of gold-sputtered sperm were provided for the artists, and leucocytes rendered literally, as “white cells”.

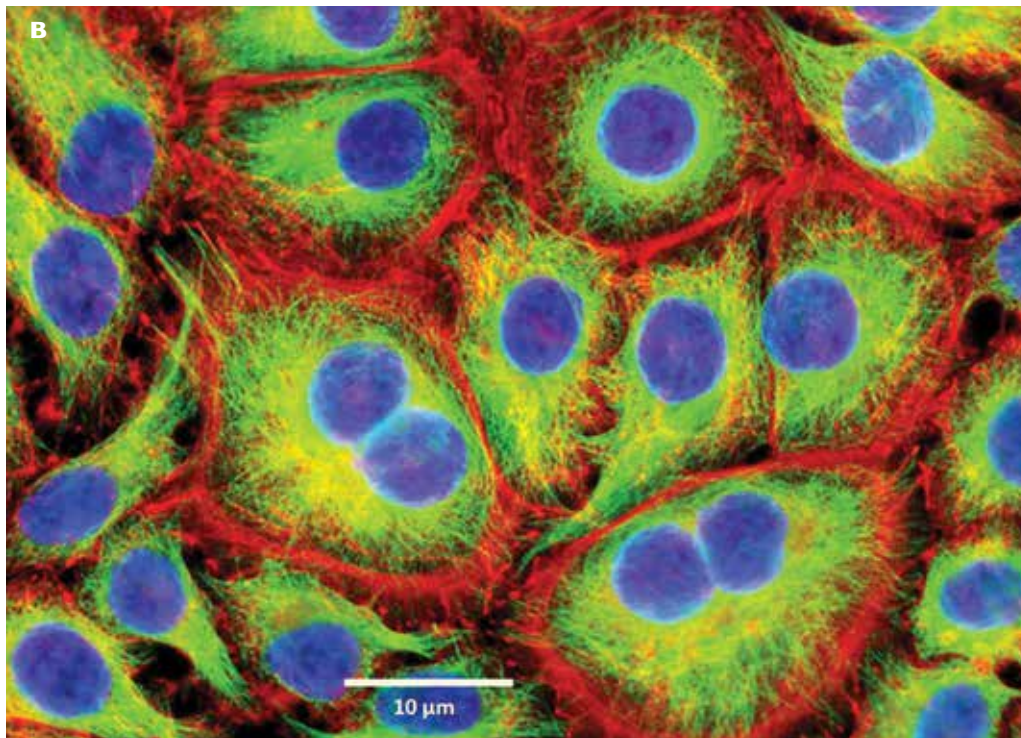
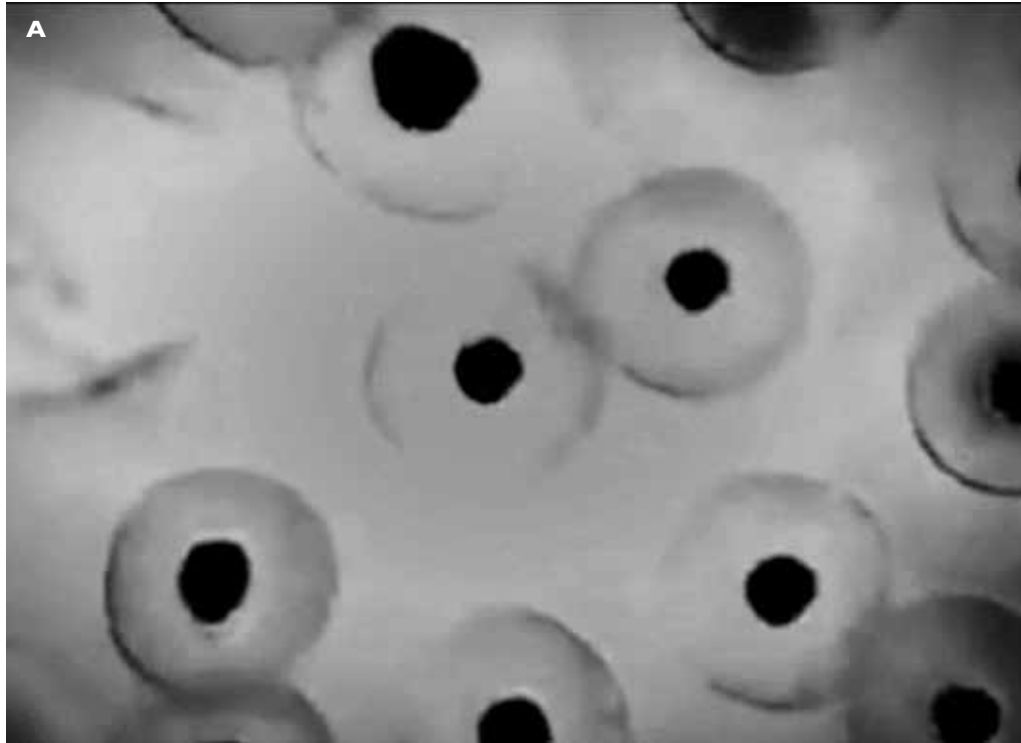


Figure 7. A) The most recent BBC series to refer to living cells is “The Human Body, Secrets of Your Life Revealed” produced by Andrew Cohen in October 2017. Most of the cells are replaced by computer graphics, though the audience are assured that these are images of life. B) Molecular Expressions on <http://micro.magnet.fsu.edu/> remind us of the intricacies of the living cell, which the public rarely, if ever, see. These examples are HeLa cells in culture that have been fluorescent-labelled for tubulin and counterstained for DNA and actin.

rock in America, where blue-green algae could be found, the viewers never saw them down the microscope. A games designer named Will Wright introduced his new computer game *Spore*, giving players a single cell to start playing an evolutionary contest. His digital image of a cell had a tiny eyespot, but Wright explained: “I actually realise that cells don’t have eyes, but it helps to make it cute.” No eyes? Many chlorophyte algae have eyespots with a refractive lens and a curved retinal cup; indeed, when you are studying euglenophytes or *Uroglena* it is tempting to imagine that they are looking back at the microscopist.

Whenever the microscopical realm impinges on a television programme these days, optical micrographs are missing. Producers rely on scanning electron images if they show cells at all though they usually resort to computer-generated imagery (CGI). If you enter the word living cell into Google and search for images, you will find very few images that portray living cells – almost all are cartoons or CGI images. The television series *Inside The Human Body* was produced in 2011 by the BBC and was presented by Michael Mosley. The cells are all CGI renditions based on SEM pictures. Lucid, sinuous swimming sperm cells are transformed into bent rusty wires, translucent phagocytes become rough blobs of white dough. Why this misrepresentation? The solid appearance of the phagocytes is easy to explain: to the graphic artists they were identified as “white cells” and so they were portrayed as – white (Mosley 2011).

This series was followed in 2012 by the BBC series *Miniature Britain*, presented by my respected colleague George McGavin, in which living cells – which should have been the stars – failed to appear (McGavin 2012). McGavin’s commentary was bright and brisk, with his inimitable blend of avuncular insight with boyish enthusiasm, but the visuals could not match him. The most promising sequence featured an attempt to capture marine microbes with a fine plankton net. We all watched it

excitedly – but the climax took the form of videos showing dirt particles, and little else. The producer had to overlay three separate sequences together in a vague attempt to fill the screen with interest. Sharp-eyed microscopists might have recognised a blurred glimpse of *Scenedesmus*, out of focus among the gritty particles, but the joy of the microbial world never emerged.

The most recent of the genre is *The Human Body: Secrets of Your Life Revealed*, first broadcast on 21 October 2017 (van Tulleken 2017). One of the presenters, Chris van Tulleken, assured viewers: “The human body is full of mysteries, only just beginning to be revealed. We are able to explore the human body in a level of detail that was unimaginable even a few years ago. It’s a new age of exploration.” The reality gave viewers CGI versions of living cells, looking as vital as a doodle on a napkin. Their muscle section looks like a stack of logs, lacking all the voluptuous detail of striated muscle we observe through our microscopes. A grossly simplified version of a living cell had served to introduce *The Cell*, and resonances of this conventional CGI interpretation – a circular body with a blob in the middle, to represent the nucleus – also played a conspicuous role in this series. There are such vivid images waiting for an audience, and the computerised versions that producers present inform viewers of microscopical life no more than *The Simpsons* might be taken as a documentary on American family life.

Current Misconceptions

When we look at the birth of microscopy, the importance of the single-lens microscope has long been misunderstood. It was immensely exciting to transmute my fascination for the pioneers into new discoveries; I had recognised the impossibility of Robert Hooke making his observations with his compound microscope and had reprised many of his revelations; and had discovered the precise method for making a Leeuwenhoek microscope hidden in his writings. After my discovery of Leeuwenhoek’s

original specimens – they had been lost to science for over 300 years (1981a, 1981b) – not only could I delve into Leeuwenhoek's methods of workings but recently, in the space of a single year, I was asked to authenticate two previously unknown microscopes that he had constructed (2015a, 2015b). No new examples had been found for centuries; now two hitherto unknown Leeuwenhoek microscopes had dramatically come to light and the revelation featured on national television. One of the microscopes was given to me to examine and analyse in detail (its discovery was reported in *Nature*). This instrument was casually sent to me from Spain to Cambridge in the mail – bear in mind that the last time one of his microscopes sold on the open market it cost the purchaser half a million dollars (Anon, 2009). I had even been able to restore Robert Brown's microscope at the Linnean Society to working condition, and had discovered exactly how it was used. The micrographs it provided gave breathtaking images, both of the cell nucleus, but also revealed the phenomenon of Brownian Motion which he had meticulously described. This too was published in *Nature* and finally laid to rest the idea that his microscope was incapable of high power microscopy (1992).

To commemorate its 350th anniversary, the Royal Society commissioned a commemorative volume written by Bill Bryson, who described Leeuwenhoek's microscopes as "tiny wooden paddles with a little bubble of glass embedded in them" (Bryson 2010). Similarly, when Jim Khalili demonstrated Brownian Motion on television, he assured his viewers that Brown had observed pollen grains "jiggling about" (Al-Khalili 2007). As we know, pollen grains are thousands of times too large to be thus set in motion, and the particles that Brown observed to be agitated lie *within* the pollen. To illustrate the point, viewers were shown pollen grains in a state of agitation and, because they do not exist in nature, the producers prepared CGI images of pollen grains that did what Khalili expected them to do. Old legends die hard. As an adviser

to *Encyclopaedia Britannica*, it took me many years before they would agree to correct their incorrect account of Brownian Motion, and most textbooks still contain that inaccurate account. Reference books do not rely on academic publications in the real world for their information; they copy details from each other. It can take centuries before new findings replace the mistaken views that have been bequeathed to us from the past.

Informed Responses

Reviewers have often recorded a sense of disappointment in the programmes we see on television. In the *Sunday Times*, the late A. A. Gill, reviewed *The Cell* by saying "The story of the cell is also the story of microscopes, and looking down microscopes is not great telly." He concluded: "The story of cells actually is interesting, it's simply not very exciting, and no amount of wishful thinking is going to make it so," (Gill 2009). This is the predictable response of someone who has never had the chance to observe living cells, but has seen only television documentaries. In an interview on the Jonathan Ross chat-show, physicist Brian Cox mentioned evidence for the existence of water on Jupiter's satellite Europa, and Ross asked: "Will there be fish in there, and crocodiles?" Cox replied: "Many people think there'll be at least microbes around." Ross was unimpressed: "All right; that's fine. Now listen, never mind that," he demanded. "Microbes don't count ..." A flustered Cox tried to insist: "Microbes would be a start," but Ross ended the exchange by shouting: "No microbes!" (Cox 2010). His words exemplify the mantra for television programmes on life.

Yet, when the public see what microbes can do, the antipathy vanishes in a flash. On a *QI* programme, the host Stephen Fry presented vivid images of shell-building amoebae for the first time on television. The panel of comedians were immediately entranced. "That is actually quite interesting," said Eddie Izzard in a rare show of enthusiasm. "Hooray!" triumphed Fry. "We've never heard that before," Alan Davies

interjected, and Izzard added: "Why have we never heard of that before?" "We've never mentioned that," Davies insisted. Bill Bailey said, sagely, "It's a conspiracy to keep this information from us," (Fry 2010). It's certainly no conspiracy – but it is the current vogue. The BBC's unparalleled reputation for memorable nature programmes does not extend to the world of the cell. To the public, living cells exist only as cartoon images created by computer artists. You might as well believe that re-runs of *Spitting Image* are genuine party political broadcasts.

Successes in Videomicrography

The videos that many of the Society's fellows are obtaining are often stunning, and I could cite so many examples of astonishing results that put mine to shame. In Australia, I have spent hours with Jeremy Pickett-Heaps who has taken the most stunningly beautiful films of microbes and has had extensive experience of the microscopy of living microorganisms. Sometimes, remarkable results are obtained by academics you'd not imagine to be involved; you might not expect to find microbiology as a focus of interest at the Department of Applied Mathematics and Theoretical Physics at Cambridge University, but my colleague Ray Goldstein has shown me their astonishingly detailed videos of *Chlamydomonas* performing perfect breast-stroke with its diminutive flagellae, and he is currently studying the eversion of early *Volvox* colonies. These are all such enticing projects, and the public would find them irresistible. When I was involved with a project that resulted in giving a free QX3 digital microscope to every state school in England, I compiled a comprehensive experimental manual for the young users. Although it was appreciated, one of the most frequent comments afterwards was to lament the lack of relevant programmes on television.

We know that we are composed of living cells, survive on food made of them, can see diseases cured and wounds heal when cells are at work, and

know we will die because of the way cells behave; these are the single most crucial concept a modern audience needs to understand, yet few members of the public know what they are. If anyone is planning a new school syllabus, or a science schedule for a broadcast network, this should be a prime candidate for inclusion. The media have always skated over the microscopic world, and the public lack the essential knowledge they need. Although we live in a world of science, that most important and accessible discipline – the study of the single cell – is a field about which the public know little. We need microscopy for everyone, and this should be a top priority for us all.

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Biography

Professor Brian J Ford was elected a fellow in 1962 and an honorary fellow in 2017. He is one of the best-known microscopists and most of his 30-odd books have discussed microscopy, ranging from monographs and textbooks to popular works. He is an authority on the creation of images by early microscopes, and has been described in *Nature* as "the world's leading expert on the topic." He is a fellow of Cardiff University, an honorary member of Keynes College at the University of Kent, a former fellow at the Open University, and is currently a dining member of the senior combination room at Gonville & Caius College, Cambridge University. In 1981 Professor Ford discovered the original specimens sent to London by Leeuwenhoek in 1674, and he has recently identified two previously unknown Leeuwenhoek microscopes. He has lectured on microscopical research since his teens and is a popular guest speaker around the world. Brian Ford recently celebrated presenting his 100th lecture at the same conference – Inter/Micro in Chicago. He has featured on television for more than 50 years, and in his plenary address at mmc2017 in Manchester he lamented the lack of documentaries that deal with microscopy.

