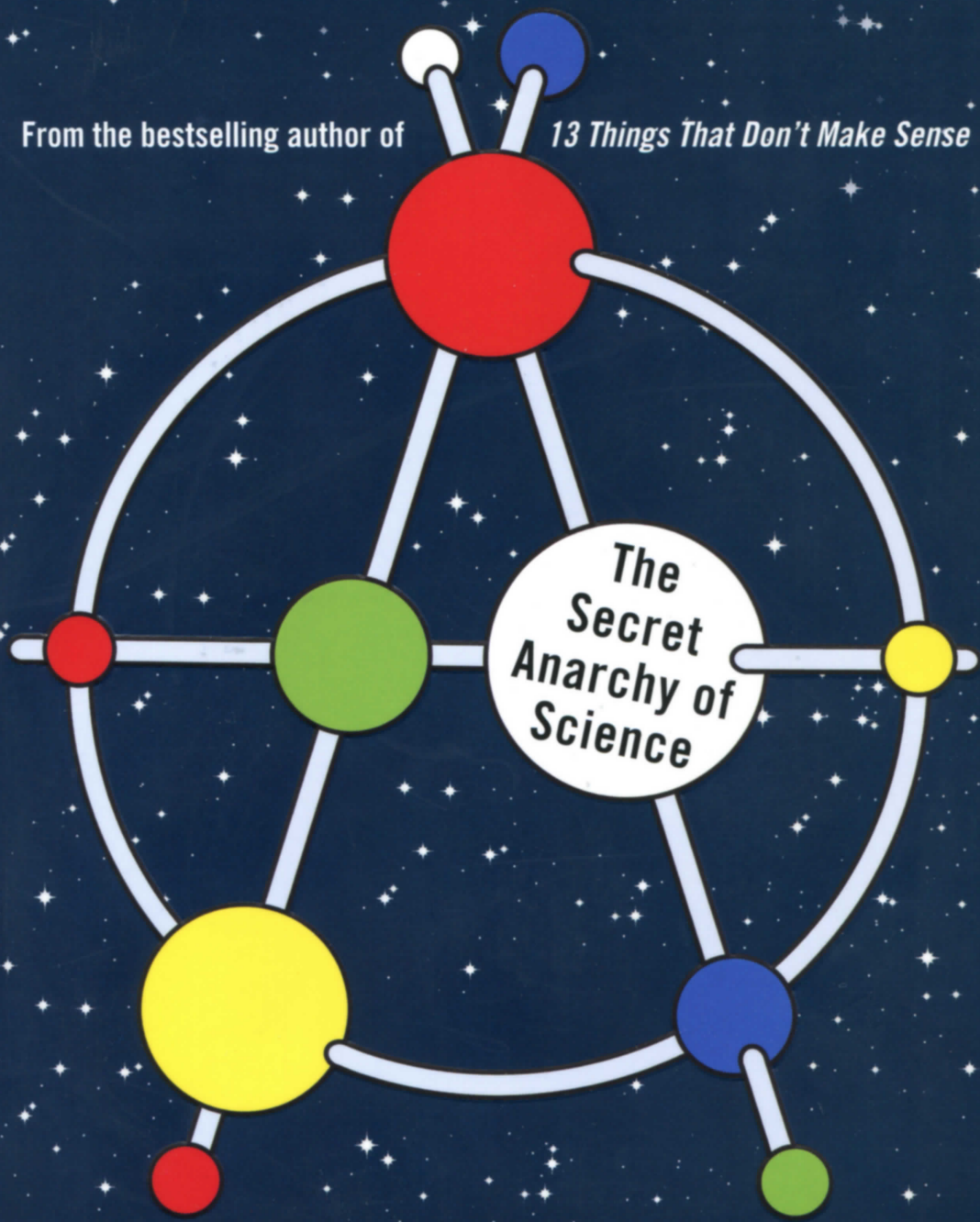


FREE RADICALS

From the bestselling author of

13 Things That Don't Make Sense



Michael Brooks

unravelling
DNA on
LSD?

'Brooks's take on science is not just ingenious, it's also hilarious' GEORGE LAMB

IN SCIENCE, ANYTHING GOES.

Why did Einstein cheat?

Scientists have colluded in the most successful cover-up of modern times. They present themselves as cool, logical and level-headed, when the truth is that they will do anything – take drugs, follow mystical visions, lie and even cheat – to make a discovery. They are often more interested in starting revolutions than playing by the rules.

Who scammed the Pope?

In *Free Radicals*, bestselling author Michael Brooks reveals the extreme lengths some of our most celebrated scientists are willing to go to, from fraud and suppressing evidence to reckless, unethical experiments, in order to make new discoveries and bring them to the world's attention.

This thrilling exploration of our greatest scientific breakthroughs proves that some rules were meant to be broken.

'Brooks is an exemplary science writer. His explanations have the sort of clarity you often yearn for when you read about science, but rarely find' *DAILY TELEGRAPH*

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Who called

Free Radicals

**THE SECRET
ANARCHY OF
SCIENCE**

MICHAEL BROOKS

MICHAEL BROOKS, who holds a PhD in quantum physics, is a consultant at *New Scientist* magazine and writes a weekly column for the *New Statesman*. His writing has appeared in the *Guardian*, the *Independent*, the *Observer*, *Times Higher Education* and many other newspapers and magazines. He has lectured at New York University, The American Museum of Natural History and Cambridge University. His first book, *13 Things That Don't Make Sense* was translated into eight languages. www.michaelbrooks.org

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That is the essence of science: ask an impertinent question,
and you are on the way to a pertinent answer.

Jacob Bronowski

PROLOGUE

It is 5.15 pm on 23 March 2003. In a brightly lit auditorium in Davis, California, Harvard cosmologist Lisa Randall is trying to give a talk about her research. The audience contains some of the greatest scientific minds on the planet, even some Nobel laureates, but no one is paying Randall any attention. Even she is having trouble concentrating. Her eyes flick repeatedly from her notes to the front row of the audience. There, on the far right of the auditorium, Stephen Hawking is being given his tea-time soup. It's quite a sight.

Earlier in the day Hawking gave a sparkling talk, crammed with witty asides and acerbic commentaries on the state of science. It was delivered via his speech synthesiser, with that hallmark monotony; Hawking is paralysed by motor neuron disease and simply cannot speak for himself. Eating is similarly problematic.

His nurses are trying their best to avoid a spectacle, but it is difficult. The spoon won't quite go into his mouth, and the soup dribbles down his chin. It is unquestionably distracting: not one of these fine minds has the capacity to ignore the goings-on in the front row and focus exclusively on Randall's talk. Discomfiting as

this scenario is, there is an upside. Here, in this strange moment of their lofty, cerebral lives, it has become clear, just for a moment, that these scientists are very human beings.

The humanity of scientists – and what that really means – is what this book is about. For more than fifty years, scientists have been involved in a cover-up that is arguably one of the most successful of modern times. It has succeeded because even the scientists haven't understood what has been going on.

After the Second World War, science was given a makeover. It was turned into a brand – in the same way that Coca-Cola, Apple Computers, Disney and McDonald's are brands. The brand identity of science is reinforced with adjectives such as logical, responsible, trustworthy, predictable, dependable, gentlemanly, straight, boring, unexciting, objective, rational. Not in thrall to passions or emotion. A safe pair of hands. In summary: unhuman.

The creation and protection of this brand – the perpetuating of the myth of the rational, logical scientist who follows a clearly understood Scientific Method – has coloured everything in science. It affects the way it is done, the way we teach it, the way we fund it, its presentation in the media, the way its quality control structures – in particular, peer review – work (or don't work), the expectation we have of science's impact on society, and the way the public engages with science (and scientists with the public) and regards scientists' pronouncements as authoritative. We have been engaging with a caricature of science, not the real thing. But science is so vital to our future that it must now be set free from its branding. It is time to reveal science as the anarchic, creative, radical endeavour it has always been.

Science's domination of today's world belies the fact that it is a relative newcomer as a profession – perhaps one of the newest.

Before the Second World War, jobs in science were largely ivory tower affairs reserved for the few. However, the global conflict showed that scientists were capable of changing the fates of nations. During those difficult years, science provided governments and their armies with penicillin, radar and – of course – the atomic bomb, among myriad other innovations. Those in power quickly realised that science was a good investment: if there should be another war, then whoever had the best scientists would win. Physicists were 'the Merlins of the Cold War', as Michael Schrage has put it: 'their wizardry could tip the balance of the superpowers in the twinkling of a quark'.

What followed, according to historian Steven Shapin, was the 'professionalisation and routinisation of science as a remunerated job'. So, with the prospect of secure funding, steady jobs and even good pensions, scientists set about making themselves look worthy of the investment. The first task was to solve their image problem.

At the end of the Second World War, when this process began, scientists were mistrusted. Though their power was enticing to governments, it was also disturbing. 'The Stone Age may return on the gleaming wings of Science,' warned Winston Churchill, 'and what might now shower immeasurable material blessings upon mankind may even bring about its total destruction.'

Another of Churchill's pronouncements makes science's dilemma plain:

It is arguable whether the human race have been gainers by the march of science beyond the steam engine. Electricity opens a field of infinite conveniences to ever greater numbers, but they may well have to pay dearly for them. But anyhow in my thought I stop short of the internal combustion engine which has made the world so much smaller.

Still more must we fear the consequences of entrusting a human race so little different from their predecessors of the so-called barbarous ages such awful agencies as the atomic bomb. Give me the horse.

The fear of science's power is almost palpable. Penicillin and radar had helped the Allies survive the conflict, but it was the scientists' cataclysmic unleashing of atomic energy that won it. And it was the scientific mind that produced the rockets that had rained down on London, causing such devastation and misery. Tales about the inhumanity of science were leaking out too: reports of scientists conducting gruesome and inhuman experiments in the German concentration camps, and of Japanese medical research on prisoners of war. Churchill would also have known of Allied scientists testing nerve gas and mustard gas on their own soldiers.

The scientists' first move was to dissipate the unease the public felt about science's power and sense of responsibility; science would henceforth serve the people. Science projected itself as responsible and safe: a careful, measured discipline involving sensible, level-headed people not given to dangerous passions. As the renowned biologist and broadcaster Jacob Bronowski put it just a few years after Hiroshima, the scientist became 'the monk of our age, timid, thwarted, anxious to be asked to help'.

It was a deliberate policy: whenever British scientists of the post-war era allowed television cameras into their laboratories, for example, the message was upbeat and optimistic, 'very much the image of science that the high-ups in the Royal Society wanted to put across', as Tim Boon, chief curator of London's Science Museum, has put it. Television drama, on the other hand, free from the influence of senior scientists, showed a much more distrustful attitude. 'You scientists,' rages a character in a 1960s drama, 'you kill half the world, and the other half can't live without you.'

Once the scientists' subservience was established, all they had to do was convince governments and the public that science had at its disposal a safe, efficient, controllable Method that, given enough resources, they could use to create a better world. It helped that science works so well. By 1957, 96 per cent of Americans said they agreed with the statement that 'science and technology are making our lives healthier, easier and more comfortable'.

The scientists too allowed themselves to be fooled by the cover-up. They became convinced that they were the heirs to a noble and dispassionate tradition, and that the brand values of science were carefully nurtured and passed down the scientific generations. According to the US Office of Technology Assessment, the average science professor trains around twenty PhD scientists. All are, almost unconsciously, taught to play by a set of rules that will perpetuate the myth of the responsible, level-headed, trustworthy scientist.

One of the few senior scientists to have dared to expose the spin was the British biologist and Nobel laureate Peter Medawar. Scientists, he admitted, 'actively misrepresent' themselves. The famed scientific routine of deductions based on experiments that were themselves based on logical hypotheses 'are simply the postures we choose to be seen in when the curtain goes up and the public sees us', Medawar said. 'The illusion is shattered if we ask what goes on behind the scenes.'

So what *does* go on behind the scenes? The most concise description was given by the Austrian-born physicist turned philosopher Paul Feyerabend. In 1975, Feyerabend published a book called *Against Method* in which he set out a shocking idea. When it comes to pushing at the frontiers of knowledge, there is only one rule, he said: Anything Goes. Science is anarchy.

Feyerabend was soon declared the 'worst enemy of science', and for good reason. His argument was deliberately provocative and

mischievous, and he took it to the furthest extremes: witchcraft was just as valid a way of gathering knowledge, he once contended. But his point still stands. When we look behind the curtain, science is astonishing.

To make a breakthrough or to stay on top, scientists take drugs, they follow crazy dreams, they experiment on themselves and on one another, and occasionally they die in the process. They fight – sometimes physically, but mostly in intellectual battles. They try to entrap one another, standing in their colleagues' way to block progress and maintain the lead. They break all the rules of polite society, trampling on the sacred, showing a total disregard for authority. They commit fraud or deceive or manipulate others in order to get to the truth about how the world works. They conjure up seemingly ridiculous ideas, then fight tooth and nail to show that the ideas are not only far from ridiculous, but exactly how things really are. Some challenge the interests of government and business, occasionally sacrificing their reputations for the greater good. Science is peppered with successes that defy rational explanation, and failures that seem even more illogical. There are moments of euphoria and – just once in ten thousand working lifetimes – world-changing success.

This is not the 'wacky' science, the crazy things that happen on the fringes of research. This is the mainstream. These anarchies are behind many of the Nobel Prizes of the last few decades – the decades that have given us such powerful insights into what the universe is, how it works and how we fit into its schemes. It really does seem that, in science, anything goes.

And this is no modern phenomenon. Science has always been this way, because this is how it works. Isaac Newton, for instance, was cavalier with scientific truth, and cared nothing for the accepted rules of engagement. His writings contain passages that his biographers have declared to be 'nothing short of deliberate

fraud'. He routinely made discoveries then kept them to himself, taunting his colleagues about his 'secret knowledge'.

Newton is known for humbly declaring that he had achieved his great breakthroughs by 'standing on the shoulders of giants'. Though this may be true in part, it is largely humbug. Newton was hardly humble, and it would be just as true to say that he achieved greatness by stamping on the shoulders of giants. When others, such as Robert Hooke and Gottfried Leibniz, made breakthroughs in fields he was also researching, Newton fought ferociously to deny them credit for their work. Though his reputation has been polished for centuries – he is the 'scientist's scientist' – Newton was not someone you would want to put in charge of science today; in later life he suffered episodes of madness and became obsessed with the Old Testament Book of Daniel, writing a commentary on it that he considered his greatest work. Hardly the model of scientific level-headedness.

Albert Einstein, who is widely considered to be the greatest scientist in history after Newton, provides another classic and shocking example of the reality behind scientific progress. Einstein relied on mystical insights – insights that his mathematics was not good enough to prove. His papers are riddled with errors and convenient omissions – though they were lazy fudges rather than, as with Newton, deliberate frauds. Einstein repeatedly failed to take account of known facts when formulating his ideas. He bristled at reviewers' criticisms of his papers. More than once he argued that any data found to be in conflict with his beautiful ideas should be ignored. He took credit for the $E = mc^2$ equation even though he wasn't the first to suggest it. Neither did he ever manage to prove it, despite eight published attempts: it was left to other, better mathematicians to set the world's most famous equation on the firm footing it has today.

History, they say, is written by the winners. Perhaps that's why

Galileo Galilei is also known as a hero, not a fraud. His *Dialogue Concerning the Two Chief Systems of the World*, banned for two centuries by the Catholic Church because it provides a bedrock for the heliocentric universe, is riddled with glaring errors. Though this monograph earned him a life sentence under house arrest, Galileo was no martyr to the truth: in many places, his science simply does not stand up. Given the man's obvious brilliance, historians now concede that his errors are an attempt at fraud resulting from obsession. Galileo was so convinced that the Earth moved round the Sun that he wasn't prepared to let the difficulties of making a watertight argument get in the way.

As we will see in the pages that follow, the tradition of scientific anarchy continues right up to the present day – though today's anarchies are much better concealed. But the purpose of this book is not just to present a string of entertaining anecdotes about scientific 'misbehaviour'. Its purpose is to show how scientists get the job done, and to argue that our misplaced expectations of science are preventing further discovery. This brand identity is not how science *really* is, and the disparity between the public image of science and the way breakthroughs are actually made matters more than most people realise or care to acknowledge. Scientists are starting to accept the straitjacket of the robot-researcher as if it were a standard-issue lab coat, necessary for the job. The fact is, you can't do good science in a straitjacket. This book is a call for more scientific anarchy, and for the creation of a culture in which it can thrive. After all, our future may depend on it.

On 20 November 2009, the world woke up to the 'climategate' scandal. Activists sceptical of scientists' claims about climate change had hacked into the email system of the University of

East Anglia. They managed to download a set of communications which, the activists claimed, showed that scientists had manipulated climate data to strengthen the case for global warming.

The ensuing investigation eventually cleared the scientists involved of any scientific misdemeanours, but there were serious official misgivings about some of the scientists' attitudes and obstructiveness towards those trying to get hold of their data. And the damage, it seemed, was done. In February 2010, a poll commissioned by the BBC showed that the number of adults who did not think global warming was happening had increased by 10 per cent since the previous November. This was 'very disappointing', Bob Watson, the UK's chief environmental scientist, told BBC News. 'Trust has been damaged,' German climate scientist Hans von Storch told the *Guardian* in July 2010. 'People now find it conceivable that scientists cheat and manipulate.'

The thing is, this doesn't actually explain the BBC poll results. Close inspection reveals that most people who had changed their views as a direct result of climategate had become *more* convinced of global warming, not less.

The downturn in public acceptance of climate change was most likely a consequence of a harsh British winter. A study carried out in March by Stanford University researchers revealed that any impact of climategate on public opinion had already disappeared. This was confirmed in June, when polls on both sides of the Atlantic showed that February's increase in climate scepticism had died away.

The only tangible outcome of climategate was positive. People who were unsure about whether to trust scientists got a glimpse of scientists being human – and thought that was OK. In fact it was more than OK, as the net allegiance change in the BBC poll shows. Contrary to everything scientists might have feared, exposing their irrationality, their humanity, even their craftiness and hot tempers, makes the public more receptive to the revelations of

science, not less. People can not only *take* the truth about science, they actually *prefer* it.

It seems that scientists may have perpetrated one of the most misguided cover-ups in history. The trouble is, it will be painful to undo because it has served some scientists rather well.

The educated Western mind venerates science to the point of mysticism: its proponents are the new high priests. And scientists do little to discourage that reverence. In his 1951 book *The Common Sense of Science*, Bronowski went so far as to admit that scientists actively welcome it. Scientists 'have enjoyed acting the mysterious stranger, the powerful voice without emotion, the expert and the god,' he wrote. A famous example of this comes at the end of Hawking's extraordinary book, *A Brief History of Time*. He talks about the revelations we are seeking from science. Get to where we want to go, he says, and we will 'know the mind of God.'

The scientists with Hawking in the Davis auditorium are closer to knowing the mind of God than most. The meeting was convened to discuss the implications of a new set of results from one of NASA's orbiting telescopes: the Wilkinson Microwave Anisotropy Probe, or WMAP. WMAP is a satellite equipped with state-of-the-art instrumentation and backed up by thousands of researchers who use the world's biggest computers to dissect its data. But its function can be summed up pretty simply: it is a pair of cosmic bat ears.

Just as bats listen for echoes to tell them what is in their surroundings, WMAP listens for echoes – in the form of heat radiation – from the early universe to tell us what was there. We are blind to the first moments of creation because they took place too long ago. But we can still pick up the echoes, and these echoes are clear enough to give us insights into the beginning of everything.

They tell us, for instance, when and how the first atoms formed, and that in turn is enough to tell us when the first subatomic particles formed, and when the forces of nature first appeared, right back to an infinitesimal fraction of time after the Big Bang itself. Thanks to the WMAP probe, and other experiments like it, we have worked out pretty much the entire history of the universe. After more than four centuries of arguments based on speculations and prejudice, we now have data. We are living in the Golden Age of cosmology.

Because of that, we might be forgiven for looking around in awe at this assembly of the 'expert and the god'. These are, after all, the people who have given us an astonishing perspective on the universe, a perspective that humans have dreamed of since the time of the ancient Greeks. However, their story serves as a useful primer for what we are about to learn about science. Don't be fooled into thinking that their discoveries are part of a smooth progression in our knowledge.

WMAP examines the details of microwave radiation known as the cosmic microwave background, or CMB. The first prediction that a Big Bang would fill the universe with this type of radiation was made in 1948, just after the end of the Second World War. And it was forgotten almost as soon as it was made.

At that time, most people didn't believe there was a start to the universe. To the majority of physicists, the universe simply existed, and always had. What's more, the new theory about microwave radiation was born out of a combination of particle physics and astronomy, and, although plenty of people knew about either particle physics *or* astronomy, almost nobody was well versed in both. As if that wasn't enough of a problem, looking for this radiation would require microwave knowhow – and that was still a specialist area. That's why it took two decades and a set of lucky breaks to work out the history of the universe.

In 1963, a couple of astronomers based at Bell Laboratories in New Jersey found the CMB radiation by accident. Arno Penzias and Robert Wilson had been given a microwave detector in the form of a 15-metre long, 6-metre wide horn antenna to investigate why distant galaxies were emitting radio waves. Their first task was to identify the amount of noise in the detector, to make sure that any signal could be properly identified. As it turned out, there was an annoying amount of noise – far more than they had expected. They tried everything to get rid of it, even going as far as shooting the pigeons that were nesting in the horn antenna and removing the accumulated droppings.

Eventually, while at a conference in Montreal, one of them mentioned the problem to another astronomer, Bernard Burke. Burke thought nothing of it until he happened to be sent a paper by some Princeton astrophysicists. The Princeton group were suggesting that if the Big Bang really had occurred, the universe ought to be filled with microwave radiation. It was Burke's job to decide whether the idea merited publication – whether it was novel, and whether the idea stood up. He failed on the first call: he didn't make the connection with the same prediction made nearly twenty years earlier. However, Burke did make a connection with the troublesome noise in Penzias and Wilson's microwave detector. He put the Princeton theorists and the Bell Labs researchers in touch with one another. The result of that collaboration became front page news in the *New York Times*, and earned Penzias and Wilson a Nobel Prize.

Brand Science presents itself as if it takes a series of cool and logical (but brilliant) steps, a graceful flow of ideas from concept to irrefutable proof. That is a long way from the truth. 'Nearly all scientific research leads nowhere – or, if it does lead somewhere,

not in the direction it started off,' Peter Medawar once wrote in a typically off-message pronouncement.

Scientists have a habit of airbrushing science's greatest moments to smooth out the human wrinkles and flaws in the process of discovery. Ultimately, though, scientists did themselves a disservice when they dehumanised their field. No wonder we have had such trouble keeping schoolchildren interested in science.

Education is just the tip of the iceberg. It is also no wonder that governments ignore the advice of scientists with impunity: they have been reliably informed that scientists are meek and unlikely to kick up a fuss. And the scientists, keen to perpetuate the myth of the scientist as public servant, play right along. No wonder the media don't give these scientists much space or airtime: who wants to be presented with dry facts by people who are just not like the rest of us? No wonder science has never been a part of popular culture: for generations, people have been persuaded that science is not like anything else humans get up to. No wonder scientific progress is slow: most scientists have spent their entire careers convinced they shouldn't do anything dangerous or too different from whatever is going on in the laboratory next door. They also know full well that they would fail to get funding or ethical approval if they dared to break out of the straitjacket.

It is time to embrace the reality about science, and discard the fantasy – before it is too late. We are building a civilisation on the foundations of science, placing our faith in its ability to support our hopes and deliver our needs. So far, scientists have been lucky: their cover-up has not resulted in the disastrous lack of trust it could have engendered if exposed in a malicious sting. That luck won't last for ever, though. Perhaps Daniel Sarewitz has put it best. 'The leap of faith that spans the chasm between laboratory and reality must be replaced with a bridge,' he says, 'lest ... we look down and realise that there is nothing underneath our feet.'

The work of science is too precious, and – in this age of approaching environmental crisis – too urgent, to allow that to happen. But safe in the knowledge that the public can cope with truly human scientists, and empowered by the realisation that people no longer fear science, we can set scientists free to work in the way that gives them their best chance of making progress. As the first step towards this, we are now going to peek behind the curtain and take an honest look at the lengths to which scientists have to go in order to make a breakthrough. Be warned: like Stephen Hawking's tea-time routine, it's quite a spectacle.