

# I, SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE



## THE MORAL ISSUE

# I, SCIENCE

**EDITORS-IN-CHIEF**  
ALEX GWYTHYR  
CONOR MCKEEVER

THE SCIENCE  
MAGAZINE OF  
IMPERIAL COLLEGE

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TOM BRAGG

**PRODUCTION MANAGER**  
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**PRODUCTION**  
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HEATHER JEFFERY  
ELISE RATTIGAN  
JESSIE DURK  
CLOUDY CARNEGIE

COVER ILLUSTRATION BY TRISTAN VARELA

I SCIENCE, FELIX OFFICE, BEIT QUADRANGLE,  
PRINCE CONSORT ROAD, LONDON, SW7 2BB

TEL: 020 7594 8072  
EMAIL: I.SCIENCE@IMPERIAL.AC.UK

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# I, SCIENCE



ello and welcome to the winter edition of I, Science – we hope you all had a smashing Christmas and New Year. This is our first issue as the new editors, so we'd like to take this chance to introduce ourselves and our lovely team. We also want to thank the outgoing editors, who helped us face the challenges of producing our very first issue, and whose hard work last year led to our website being nominated for a 2012 Guardian Student Media Award.

And so, down to business – this issue is all about morality in science. What ethical dilemmas do scientists face when doing research? On page 24, we look at the 'dual-use dilemma': is it our duty to publish results, even if they can be used for evil as well as good? Should we take the view of Wernher von Braun, that "science does not have a moral dimension. It is like a knife. If you give it to a surgeon or a murderer, each will use it differently"?

As science becomes more integrated into modern society,

questions of morality become increasingly important. The pharmaceutical industry plays host to many such concerns and on page 22, we look at the rise of 'orphan drugs' – a product of highly profitable medical research that only benefits a few sufferers every year.

We must be aware that with our scientific advances, and growing power to manipulate nature, comes an increasing responsibility to use our knowledge wisely. As Arthur C. Clarke noted: "As our own species is in the process of proving, one cannot have superior science and inferior morals. The combination is unstable and self-destructing." In our greed to consume our natural resources, we are quickly reaching a level of global climate change beyond the restorative powers of even our own mighty modern science.

And so we give you I, Science's own foray into the murky world of moral issues in science. We hope you enjoy the issue. ■

ALEX & CONOR



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# NEWS FROM

IMPERIAL COLLEGE



## PHENOME CLINIC PROMISES PERSONALISED CARE

Selecting the best treatments for patients on an individual basis is about to be made easier thanks to a new clinical centre at Imperial College. A range of state-of-the-art technologies will enable doctors to diagnose patients rapidly, whilst they are in clinic or even on the operating table.

The Imperial Clinical Phenome Centre, which will be based at St Mary's Hospital, is one of only two such centres in the world, both of which were developed at Imperial.

**“AN INTELLIGENT KNIFE WILL MAKE IT POSSIBLE TO DETECT CANCEROUS OR DISEASED TISSUE WHILST A PATIENT IS BEING OPERATED ON”**

At present, technologies that will be available at the centre are more commonly used in research than in a diagnostic setting. Now, novel techniques based on liquid chromatography, capillary electrophoresis, mass spectrometry and NMR spectroscopy will be used to analyse blood and urine to determine the severity of diseases.

The clinic will also host cutting-edge medical tools including an intelligent knife, which will make it possible to detect cancerous or diseased tissue whilst a patient is being operated on.

The combination of systems at the centre will allow doctors to follow disease progression and drug responses, making it easier to tailor treatment to an individual's needs.

**“THE COMBINATION OF SYSTEMS PRESENT AT THE CENTRE WILL MAKE IT EASIER TO TAILOR TREATMENT TO AN INDIVIDUAL'S NEEDS”**

Professor Jeremy Nicholson, Head of the Department of Surgery and Cancer at Imperial College London, said “These analytical technologies are now very mature and are immensely powerful for telling us about someone's physical condition and disease state.”

“Bringing them fully into the clinical setting will help doctors make a more informed diagnosis, choose the best treatment, and monitor patient progress more precisely.” ■

JENNY MITCHELL

## PHYSICS EQUATION FEATURED ON ROADSIDE BILLBOARDS



Featuring physics equations on advertising billboards might sound bizarre, but that's exactly the idea behind a recent installation: for two weeks in November, Londoners were treated to a pair of billboards depicting the Schrödinger equation. Located on Fulham Palace Road and Ladbrooke Grove, the billboards were part of a project to make people curious.

The project, aptly entitled 'Made Curious', seeks to show the public something intriguing in the hope they want to discover more. Artist Geraldine Cox and physicist Professor Terry Rudolph, both from Imperial College London, were responsible for the campaign, which received sponsorship from print and project management company Hi Rezz. They decided to collaborate to create something that would not only capture the curiosity of passers-by, but also increase the public awareness of science. Billboards were the perfect means for this, as they convey messages to large numbers of people in all walks of life.

**“THE PROJECT SEEKS TO SHOW THE PUBLIC SOMETHING INTRIGUING IN THE HOPE THEY WANT TO DISCOVER MORE”**

Cox and Rudolph chose the Schrödinger equation for its beauty, and wrote it in its concise form to highlight its simplicity. Furthermore, the equation has far-reaching applications in our technologically-based world: lasers, superconductors, solar cells, even GPS all rely on this equation.

Although the campaign has now ended, the website lives on in the hope that anyone – not just physicists – can have a piece of the Schrödinger puzzle. ■

JESSIE DURK

## TREE OF LIFE GETS THE GOOGLE MAPS TREATMENT

**S**cientists expect to have a first draft of the complete 'tree of life' within the next year. The tree will include approximately 2 million species, and in the hope of making it easier to visualize, an interactive website has incorporated software similar to that used in Google Maps.

**“SCIENTISTS EXPECT TO HAVE A FIRST DRAFT OF THE COMPLETE TREE OF LIFE WITHIN THE NEXT YEAR”**

A tree of life schematic describes the evolutionary relationship between organisms through use of a diagram: the trunk represents the earliest forms of life, while the many branches leading away symbolise the species that have subsequently evolved.

Attempts to physically represent this intricate diagram are restricted by page space and are often confusing and difficult to read. However the website 'OneZoom' overcomes this problem by utilising the near-unlimited space of the digital world. Created by Imperial's Dr James Rosindell in collaboration with Dr Luke Harmon from the University of Idaho, the website uses fractal map technology to create an easy to explore interface. The many branches and twigs can be panned across and zoomed in on, revealing more information about the organisms.

Using data from the Open Tree of Life Project, OneZoom is still under construction and currently only displays mammals and amphibians (and only 5000 species for each).

Dr Rosindell hopes that OneZoom will not only help scientists to visualize the tree of life and discover new patterns in nature, but also be used in engaging zoo and museum displays to teach people about the evolution and diversity of life. ■

ALEX GWYTHOR

## REMOTE-CONTROLLED ROBOTIC PILL

**I**mperial College researchers are developing a novel treatment for intestinal cancer using a remote-controlled pill. The pill, developed by Dr Tim Constandinou and his team, can be instructed exactly where and when to deliver its drugs, allowing it to directly target the small intestine. The small intestine is a particularly hard organ to reach, thus making it difficult to treat using conventional surgical methods. The robotic pill, however, could provide a simple method to treat cancers as well as ulcers.

**“THE ROBOTIC PILL COULD PROVIDE A SIMPLE METHOD TO TREAT CANCERS AS WELL AS ULCERS”**

The 30 mm by 11 mm pill has a built-in camera, a miniature needle and a remote-controlled anchor. The pill is swallowed and travels naturally down the gastrointestinal tract. When it reaches the small intestine, an operator can send a remote signal to the pill, triggering the anchor to hold the pill in position. The pill will then release a 1 ml dose of drugs via its miniature needle.

The Imperial College team is working in collaboration with IDC Models, the company that provides the technology required to build such a small pill. The prototype currently in development should be ready within a few months. The next step will be to test the prototype in animal models over a two-year period and, if that is successful, to proceed to clinical trials. Although it'll be a long wait before you see the robot pill being used in any hospitals, it nevertheless looks like a promising solution to improving the treatment of cancer and ulcers in the small intestine. ■

INDIA RENZIEHAUSEN



e-Magine Art, flickr

# WORLD NEWS

PICK OF THE BEST

## ON THE LOOKOUT FOR ASH DIEBACK

If you are often a guest of Britain's leafy countryside and happen to possess a portion of Sherlock's observational prowess, then you have a task of national importance: to report instances of ash dieback to any of the UK's tree health agencies.

Ash trees are the third most abundant species of broadleaf trees in the UK but many have now been infected with the ash dieback disease. This disease threatens the existence of 99% of ash trees in the country and a widespread outbreak would permanently alter the face of the British landscape and its wildlife.

Officials have been searching for infected trees throughout the UK in order to trace the progress of the disease and destroy

young sufferers to prevent further spread. Mature trees are left standing, however, as they are valuable to wildlife and can help in the search for naturally resistant varieties.

The disease – caused by the fungus *Chalara fraxinea* – has the following symptoms for you to look out for: wilting and black-brownish discoloration of the leaves; formation of small lens-shaped lesions on the bark of stems and branches; growth of fungus on leaf stalks; and 'dieback' of leaves, shoots and twigs, which means they die from root to tip.

Ash dieback was first noticed in the 1990s in some parts of Europe, but it was only in 2010 that the correct fungus species was identified. It is this species that is the cause of the current epidemic. ■

ARYAMAN SINGH



dichohecho, Flickr

## HIGHS AND LOWS FOR BBC SCIENCE COVERAGE

BBC East's recent decision to close down the much-loved radio show *The Naked Scientists* has stunned scientists and laymen alike. Ironically, the announcement came a week after the launch of Dara O Briain's *Science Club*, an hour-long science program for BBC Two.

*The Naked Scientists* has a very successful backstory. In 2008 it won the Kohn Medal for science communication, for which the show and podcast reached 114,000 people a month. Despite this, the BBC has decided the programme will cease to air in January 2013. The public response was loud enough to call Mick Rawsthorne, the BBC's head of regional and local programmes, to interview on Radio 4's *Feedback* program. He explained the cut was because *The Naked Scientists* did not "reflect local life, local communities or tell local stories".

*The Naked Scientists* have hit out against the BBC cutting the science budget by 87.5%. The team celebrate some positive decisions, such as the introduction of Dara O Briain's new show, which opened to generally positive reviews and reached 124,000 viewers. *Science Club* has a lively style with guests such as the venerable geneticist Steve Jones (who has, incidentally, also appeared on *The Naked Scientists*).

There is now a widespread campaign to save *The Naked Scientists* (with #savethenakedscientists trending on twitter), which is backed by the MP for Cambridge, Julian Huppert, and other high profile bloggers who have offered to pay the £40 per week it costs the BBC to run the show. According to *The Naked Scientists*' Facebook page, the BBC is now reconsidering their decision. ■

ALICE JACQUES

## BRAZIL HOPES TO CLONE ENDANGERED SPECIES

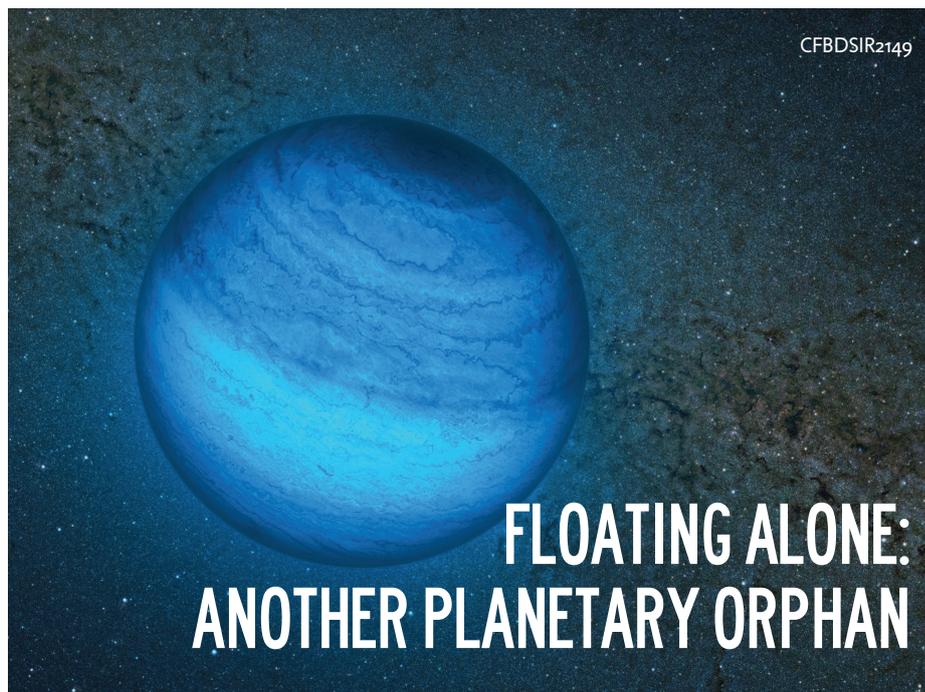
**C**onservationists in Brazil are exploring the possibility of cloning eight endangered species. The project is spearheaded by the Brasilia Zoological Garden, in partnership with Embrapa, the Brazilian government's agricultural research agency. Most of the species on the conservationists' wish list belong to the International Union for Conservation of Nature's Red List of Threatened Species. Those animals to be cloned include the black lion tamarin – the most endangered out of all the animals and the only one that lives exclusively in Brazil – as well as maned wolves and collared anteaters.

Animal cloning is not a new development, having already been successfully completed with many domesticated animals, such as cows and horses. One that received a lot of publicity was Dolly the sheep, a clone created at Edinburgh's Roslin Institute in 1996. However cloning technology is expensive and not very reliable, with a success rate of only 6%.

According to an Embrapa researcher, their aim is not for the cloned animals to replenish endangered wild populations. Instead the goal is to test cloning technology and captive breeding, ultimately providing zoos with more of these rare animals.

However, the project has already become a source of concern for many conservationists. These cloned animals could drastically reduce the genetic diversity and fitness of already dwindling wild populations if allowed to mix. Furthermore, there are worries that rare animal farming might encourage the illegal trade of animal parts and, perhaps most importantly, undermine the focus on wild habitat protection. ■

KARIN VALENCIA



## FLOATING ALONE: ANOTHER PLANETARY ORPHAN

**N**ot every planet is lucky enough to orbit a parent star. The recently discovered planet CFBDSIR2149 is one of the unlucky ones: a free roaming gas giant, 110-120 light years from Earth. Roaming planets aren't uncommon, but 2149 is the closest one to Earth currently identified.

2149 wasn't being deliberately sought after. The French and Canadian astronomers involved were looking for brown dwarfs: sub-stellar masses too big to be classified as planets, but too small to undergo fusion and become stars.

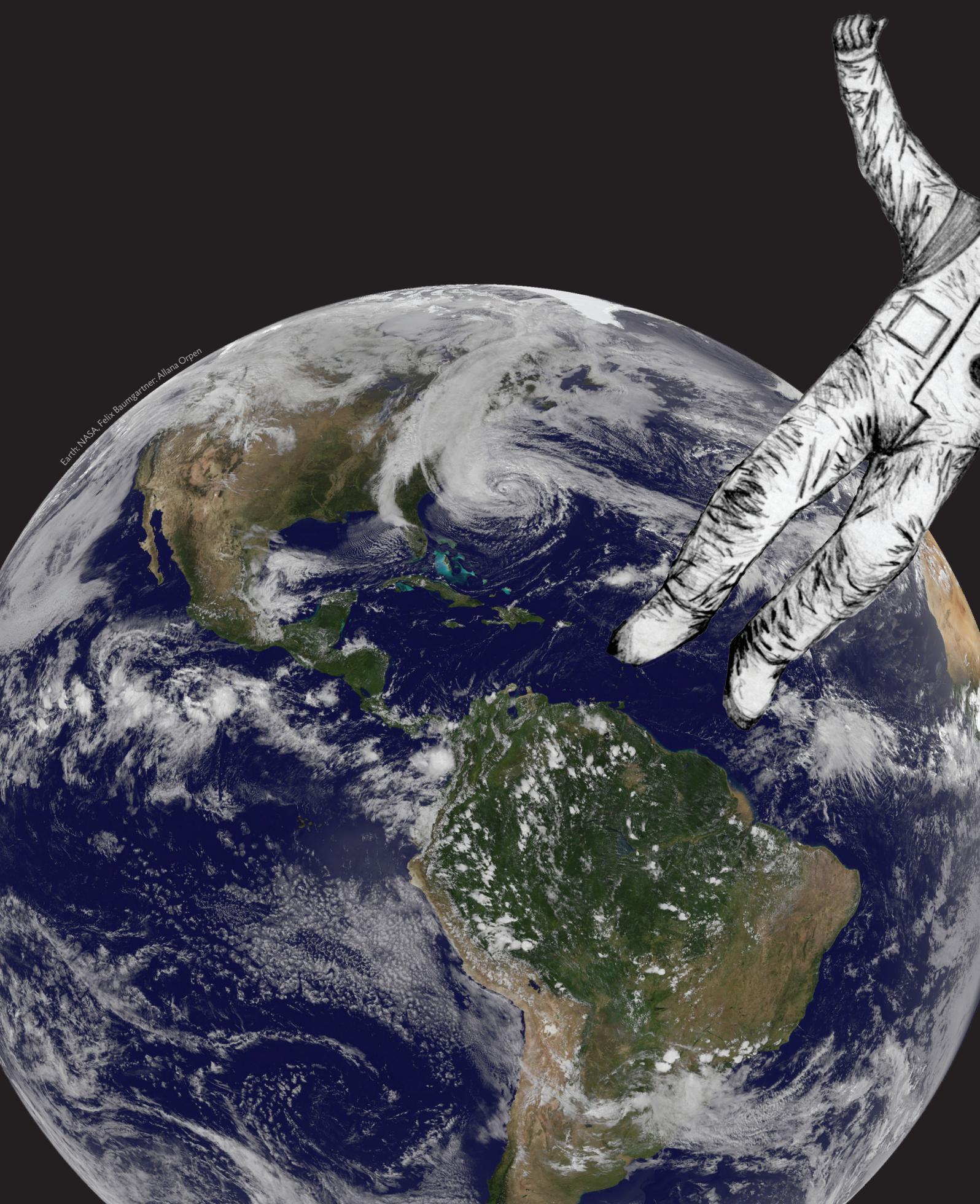
“**ROAMING PLANETS AREN'T UNCOMMON, BUT 2149 IS THE CLOSEST ONE TO EARTH CURRENTLY IDENTIFIED**”

2149 was initially thought to be a brown dwarf, but it was found to be relatively cool. Either it was a very old brown dwarf that had cooled off, or it was something else entirely. Further measurements revealed the planet to be travelling in the same direction and speed as the AB Doradus Moving Group, a young cluster of about 30 stars that are 50-120 million years old. Though it could just be coincidence, the odds are 87% that 2149 is part of the group, and therefore a young planet.

But how did 2149 come to be? Two explanations exist: either 2149 formed as a normal planet before being ejected from its original solar system, or it formed away from a parent star with too low a mass to achieve fusion.

At only 110-120 light years away, 2149 is open to closer study; most rogue planets are too far away to be accurately observed. It is already the best-studied rogue planet, with methane and water vapour signatures detected in its atmosphere. Future work will aim to identify more about the location of 2149 and the direction it is moving in. ■

LAURENCE POPE



Earth, NASA, Felix Baumgartner, Allana Orpen



# CAN RED BULL GIVE SCIENCE WINGS?

*Felix's space jump: incredible feat of ingenuity or simply a PR stunt?*  
**Maddy Staple** explores the consequences for science.

**O**n 14 October 2012, a man leapt from a capsule, fell 128,100 feet, broke the sound barrier, landed safely, and smashed numerous records along the way. Millions of people around the world watched him fall to Earth. His name was Felix Baumgartner.

As PR stunts go, it wasn't half bad. More than eight million people watched him live; he took over global media for a few days and became a household name. Red Bull was one of the biggest sponsors involved, and there's no doubt they were in it for the publicity.

Unsurprisingly, having invested seven years and millions of dollars, Red Bull took every opportunity to promote themselves. In the highlight video on YouTube, watched by more than 29 million people, their logo appears 26 times. That amount and quality of publicity is priceless – especially since association with this event fits perfectly with Red Bull's extreme-sports image.

The man himself, 'Fearless Felix', has become an icon. With his good-looking girlfriend and close relationship with his mother, he is a very family-friendly figure. Children in particular love him – he has hero quality. This was heightened by Red Bull, who built tension by reporting that he could die at any moment, recounting the tale of his mentor Joe Kittinger's spacesuit ripping, swelling his hand to twice its normal size. The whole event was captivating.

The PR capabilities of scientists can be somewhat varied. The results may be exciting and world changing, but can still be presented as a PowerPoint in Comic Sans. This event was the opposite. The concept

behind the jump was not complicated: man goes up very high, man jumps, man lands safely on the ground. But it had such window dressing that – just for a short while – it seemed the most exciting thing in the world.

Red Bull doesn't have a duty to educate, yet this jump was truly accessible. Although the science behind getting Felix there and back was complicated, the premise was simple.

The science background was there too. The documentary *Space Dive* was well advertised and broadcast all over the world, and the public's interest was sustained enough for the science to be interesting and engaging.

I believe that technological development was a side effect to the greater goal of an edge-of-your-seat PR stunt. It was welcome. The mission was so successful that it is likely to inspire other big companies to do similar stunts.

As the world stands at the moment, companies like Red Bull can create missions, whilst governments freeze or cut back science funding. With more funding, technology can progress more quickly and generate new innovations. Unfortunately, unlike scientists, companies are not duty-bound to share knowledge. If a breakthrough is made, a sponsor could, theoretically, put pressure on the laboratory and suppress the information, keeping it a secret. The development might not ever reach the general public.

Felix captivated the world. Red Bull had their stunt. Now the focus is on science, and whether the presence of big corporations will aid or hinder it. ■

# FOETAL GENOME SEQUENCING: HOW MUCH DO WE WANT TO KNOW?

*Alice Jacques explores the practical and ethical implications of recent advances in prenatal testing.*

Last Summer, researchers led by Jacob Kitzman at the University of Washington sequenced the entire genome of a human foetus, triggering one of the most emotionally loaded debates of the year. The results promise a single non-invasive test to diagnose a broad range of genetic diseases as early as eight weeks into a pregnancy.

At the moment, expectant parents in an at-risk group can opt into amniocentesis or chorionic villus sampling; invasive tests that involve inserting a long needle through the abdomen, with a small risk of miscarriage. So why is the debate so loaded? Because despite the various reasons why pregnant women take the test, around 85% decide to abort if told they will have a child with disabilities.

Kitzman's team isolated the 10% of DNA in a mother's blood plasma that is her baby's, using a DNA sample from the father's saliva for comparison. The benefits of the new technique are threefold. Firstly, it does not entail the risk of miscarriage, which appears enormous to many expectant parents. Secondly, diagnoses could be made earlier in the pregnancy. Finally, this approach may be more reliable than the current tests, which throw up a significant number of misdiagnoses.

However, it is the one-time nature of the test that raises some doctors' concerns, specifically that it might mean poor quality advice for the parents. One NHS clinician

“TERMINATION DECISIONS COULD THEORETICALLY BE MADE ON GENDER, PATERNITY AND SEXUALITY”

described to me how she frequently pacifies frantic parents who have had news delivered from scan-performing experts, rather than condition-diagnosing experts, requiring her to dispel an image of their child who they think may never achieve psychological normality. Our current system continuously refines the high-risk category — mothers over 35, those with a family history of genetic illness, pregnancies with a backdrop of problematic fecundity — providing layers of preparation for parents. But this could be peeled away by a one-test system. Proper counselling should involve

more than a half-hour chat before the test, and provisions must be made to prepare the parents for a very difficult decision.

The American presidential election brought the issue of prenatal testing into the limelight. The Republican nominee Rick Santorum, who has a daughter with Edwards syndrome, attacked the Affordable Care Act's free testing policy as a “search and destroy mission” to “cull the ranks of the disabled in our society”. There is widespread and strong opinion that the availability of such testing contributes to, or even stems from, bad feelings towards the disabled in society. But there are opposing views even from within the American right. Sarah Palin was “grateful for all those months to prepare” for her son with Down's syndrome, and there are likely to be families who need the time to get together money and medical expertise. In a discussion on the popular parenting website Mumsnet, another woman spoke about her first child, who was born with a rare disorder that led to a short life full of pain. She told me it was not until she was pregnant with her second child that doctors realised the condition was genetic. She had an amniocentesis that identified a healthy foetus, and avoided a pregnancy filled with misgivings.

A rule of thumb is that the earlier the (invasive) test, the bigger the risk of miscarriage (3.5% of pregnancies are lost at 10 weeks; 0.3% at 20 weeks). Naturally then, many parents leave the decision as late as 20 weeks into the pregnancy, by which point their baby has grown hair,

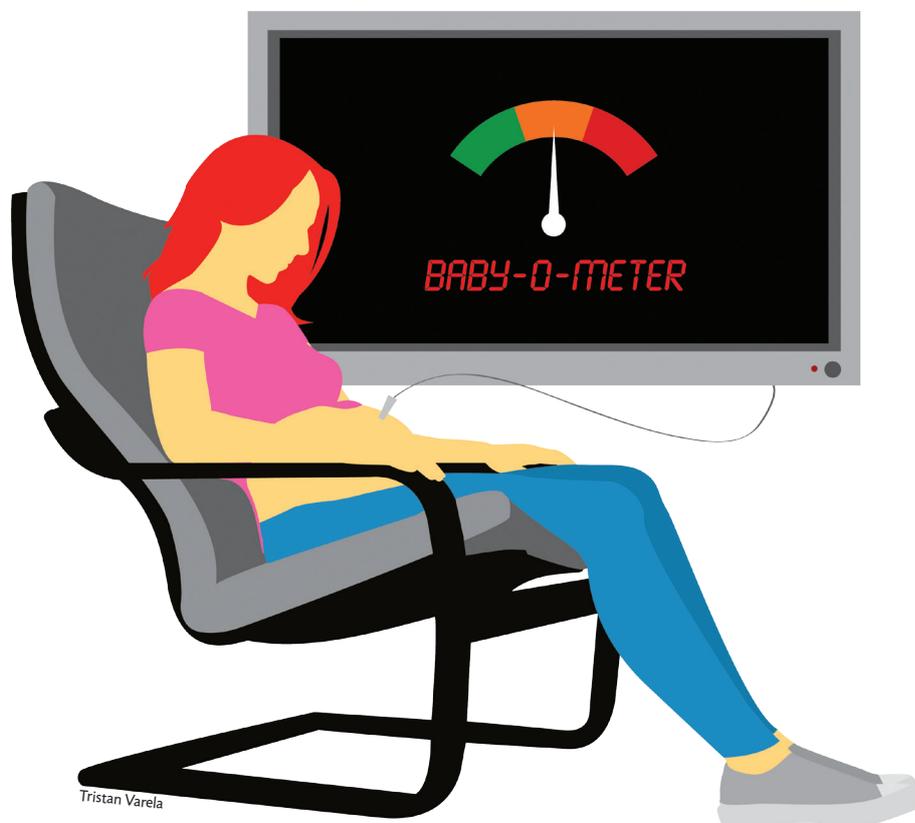
unique fingerprints and nails. The new, non-invasive tests would eliminate this risk — which mainly arises from amniotic fluid loss — meaning parents could choose when to test based solely on the potential outcome. This may seem inconsequential if the screen is only for preparation, but for those who might terminate the pregnancy based on the outcome, it is pivotal. Some religions make the choice clear. Despite the strong anti-abortion stance of Islam, Shi'a law posits that 'ensoulment' occurs up to 17 weeks into pregnancy, and abortion in dire need is permissible up to four months, so concerned Muslim parents need information as soon as possible. This hazily follows the dominant secular school of thought, which assigns a lower moral status to younger foetuses, perhaps making a later decision more difficult even for pro-choice parents. Interestingly though, a significant minority of Mumsnet denizens were concerned that having to make a decision so soon did not give mothers enough time to bond with their quickly growing child.

Hopefully these screening developments will go hand-in-hand with developments in treatment, such as *in utero* surgeries for spina bifida, allowing more pregnancies to result in the birth of a healthy child. For this, the zoomed-in resolution of the complete-genome tests can only help. It might even eradicate stories like that of a mother who had received a positive result for Down's syndrome, and spent the last three months of her pregnancy grieving the loss of the healthy child she had always imagined. She and her partner had prepared themselves as well as they could, even moving nearer a better-equipped hospital. Their daughter was born without the condition, and they

were left to reconcile themselves with their choices.

Another facet of better diagnostic resolution is being able to spot less debilitating or later-onset diseases, making selective abortion for less detrimental disabilities a concern. This leads the debate to eugenics, as seems inevitable for every discussion of prenatal testing. If the genome of a foetus is available to the parents,

termination decisions could theoretically be made on gender, paternity, and perhaps one day, sexuality. There is also talk of parents who are deaf preferentially aborting foetuses who are not, and 'screening-in' disabilities. It all leads us to the question, what is the moral authority of Nature these days? As our dominion over the natural order increases, has the debate caught up with it? And do we have the right to the child we want? ■



# MORE QUESTIONS THAN ANSWERS?

From *Brave New World* to *The Empire Strikes Back*, science fiction surrounds us, pervading all aspects of culture. Just because the settings can be alien, doesn't mean that the plots are. Time and again we see ethical questions rearing their heads in films and books: should clones have the same rights as everyone else? Are mind-altering drugs acceptable? Should we talk to aliens? Science can be billed as a solution to all our woes, but it often seems to raise more questions than it answers.

# SIX MORAL DILEMMAS

WRITTEN BY ALEX GWYTHYR, JADE CAWTHRAY, JOSH HOWGEGO

## CLONE WARS

Science fiction often visits the idea of clones: whether to create an army, supply spare body parts or just for some company. In creating our own clones, we thrust upon it incredibly high expectations: to act exactly like us, but at the same time, to do our bidding. Uncomfortably, this ignores the human right to self-determination. Terrifyingly, if this clone is our identical equal, who's to say we are in charge? Will they share equal rights to our possessions? Soon there could emerge racial tensions between original humans and clones. Not to mention the problem of overpopulation.

## TELEPORTATION: A WHOLE NEW YOU?

Teleportation would be an ideal tool for a fugitive; the ability to instantly appear anywhere in the world could be handy for lots of illegal activities (prison breaks would certainly become easier!) And that's ignoring the – frankly terrifying – privacy issues. Disturbingly, the process of teleportation also involves your atoms being disassembled at your original location and then reassembled at your destination using local atoms (kind of like sending a fax rather than a physical letter). Thus teleportation effectively makes a copy of you, while the original you is destroyed. Even after sidestepping the tricky question of whether this counts as murder or suicide, there still exists the problematic assumption that the new you will hold true to your original intentions.

## I, (EVIL?) ROBOT

We are already surrounded by machines that exist to serve us, but we are fast developing increasingly human-like robots. Are we comfortable with the idea of one day creating sophisticated android servants to follow their master's every command? As possessions they would effectively be slaves. As increasingly clever and self-aware androids (potentially with artificial intelligence) there would be a blurry distinction as to what basic rights they would enjoy. Whilst we might create emotionally neutral and uninhibited robo-slaves, what's to stop immoral owners from using their android to fulfil their evil intentions?

# IN SCIENCE FICTION

## TIME TRAVEL FOR DUMMIES

Widely addressed in science fiction, from Arnold Schwarzenegger to H. G. Wells, time travel throws up some interesting moral issues. Especially the huge amount of power and responsibility afforded to anyone able to travel through time and alter the future by changing past events. Moreover, due to the difficulty in predicting exactly how your adjustments will pan out, quantum leaps could be incredibly dangerous. Whose interests are served? How much is to be changed? Is it acceptable if past-you (or present-you?) kills future-you? Besides the mind-bending complexity, it's definitely a moral maze.

## SOUNDS LIKE EUGENICS

Genetic engineering offers the potential to fashion the perfect human being, eradicating any inherited genetic flaws. It's an attractive-sounding proposition: the opportunity to stack the odds in your favour in the 'nature versus nurture' gamble. But breeding perfect humans would create an entirely new social class. Taking discrimination to new levels, the class you belong to will not be determined by skin colour, income or social status, but the make-up of your genes. Creating a super-race of humans has been discussed before, although often not by the most morally sound kinds of people.

## WHAT A 'WALL-E'

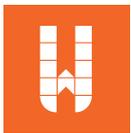
In the Disney Pixar film *WALL-E*, humans have been living on a spaceship for 700 years, waiting for robots to find signs of plant regeneration on the earth they have –covered in rubbish. The spaceship is a fully automated system which utilises sleek and efficient robots to do everything for the humans. Although seemingly happy, our species has become confined to 'hover chairs', and have become disgustingly obese as a result. Physical contact is not necessary thanks to personalized holographic displays which mediate all activities. In short, we don't have to lift a finger. But is that a good thing?



Claire Lynn

# POLYGRAPHS: ARE THEY TELLING THE TRUTH?

*Polygraph tests are used across many industries and are often relied on during police investigations. Conor McKeever asks whether they are reliable.*



When Bill Wegerle came home to find his wife murdered in their bed, his world fell apart. To make it worse, he became the prime suspect in her murder and, without an alibi, no one would believe his innocence. In a bid to clear his name, he agreed to a police polygraph test, but failed. Twice. By the time he was finally exonerated, in light of new evidence, it was too late – Bill and his children had spent twenty years living as social outcasts, damned by the very machine that should have saved them.

This might seem to be an anomalous case, but it's not – time and time again, polygraphs have shown themselves to be undeserving of the nickname 'lie detector.' Take the case of Ana Montes, a Cuban spy who successfully worked at the US Defence Intelligence Agency for over 25 years despite their regular polygraph tests. Or Floyd Fay, who was sentenced to life in prison following a failed lie detector test, and only released when new DNA evidence came to light.

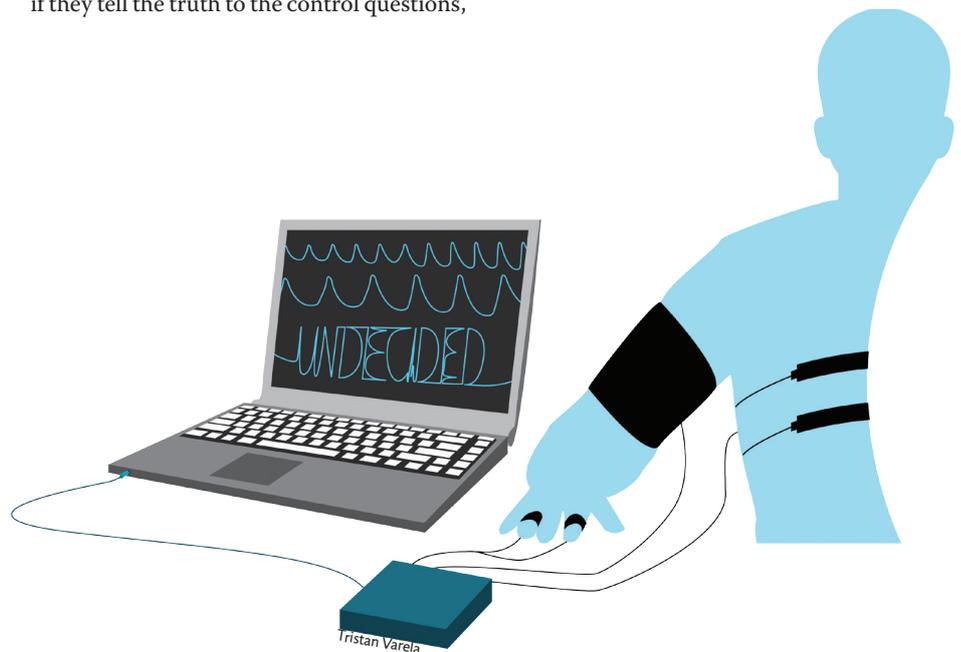
The problem lies in how the test works: it is based on the assumption that when we lie, we become increasingly emotionally aroused. The polygraph test measures changes in heart rate, blood pressure and skin conductance, which are the body's physiological responses to arousal, so when an interviewer asks control questions followed by case-relevant questions, the two physiological responses can be

compared. An 'innocent' person shows more of a response to control questions, things unrelated to the crime that someone is likely to lie about, such as "Have you ever stolen anything?" A 'liar', on the other hand, shows more of a response to case-relevant questions.

However, there are many reasons why an innocent person might show a heightened response to the case-relevant questions. They may be scared their answer won't be believed, or know something about the crime without having committed it. In fact, if they tell the truth to the control questions,

they will have an unexpectedly low control response, making them appear liars.

As for the guilty person trying to beat the test, relevant techniques are easy to find. These include heightening responses to control questions through physical pain or mental stimulation, or lowering responses to relevant questions through meditation. Floyd Fay spent his time in prison reading up about polygraph tests and coaching his fellow inmates to beat the test. With just 15 minutes of training, 23 out of 27 prisoners could beat it.



What's more, the test results are analysed by the polygraph operator, making them vulnerable to subjective errors. In one such case, David Westerfield of San Diego failed a polygraph test after the examiner decided his alibi was unbelievable and took measures to 'compensate' – deviating from the agreed questions, raising the room temperature, and adjusting the machine sensitivity when the readings were too low.

Pre-existing biases can also sway the result, as the American investigative news programme 60 Minutes cleverly demonstrated. Using a photography magazine as a front, it hired four polygraphers to investigate an alleged case of theft. Each examiner was given the same four suspects to interview and, before the tests started, told that one of the four was most likely to be the thief. Despite the fact the hunch-suspect was different every time, the tests of each of the four polygraphers 'proved' the suspect they were given as the hunch-suspect was the thief. Of course, there had been no theft, and all four suspects were actors – the polygraphers had simply looked for reasons to justify their suspicions. Can we trust that, in a real-life situation, when the person being tested is already under suspicion, these biases won't re-emerge?

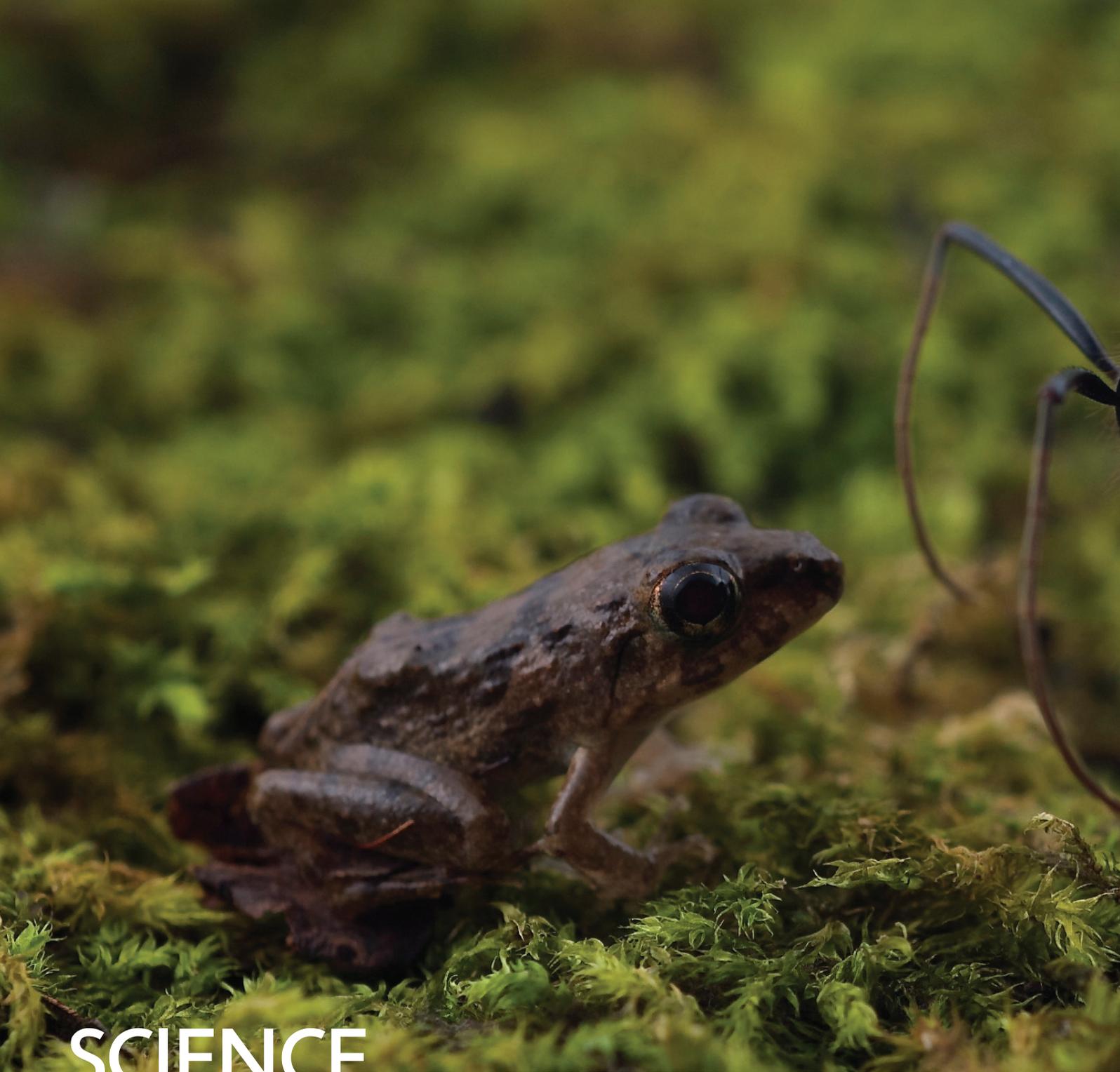
Given these problems, it's not surprising that a 1997 survey of psychologists estimated the polygraph's accuracy to be around 61% – not much better than chance. If we consider the case of a company with 10,000 employees, ten of whom are spies, then six spies and 3,896 innocent people would be accused of spying. Such a result is next to useless. Yet in America, 17

states allow polygraph evidence in court, and private employers can polygraph test their employees as part of an internal investigation. In the UK, the government plans to introduce mandatory polygraph testing for sex offenders in the hope that this will reduce re-offending rates.

So, the reason for polygraph use? Confessions. If a person believes that they have failed the test (this is often suggested to them by the interviewer), then they are more likely to confess to the crime. But consider the implications of this; because a small number of cases yield results, wrongful convictions and pardons seem like acceptable 'collateral damage.' This is a seriously unethical way to approach crime solving. What's more, it means that institutional lying becomes a legally acceptable way to get the truth.

Yet the most dangerous problem is this: the confession approach only works if the person believes in the accuracy of polygraph tests. It's hard to get a confession from someone who knows you're bluffing. And how long will it be before people start to beat the test? Given the sheer volume of information out there about polygraphs, it is only a matter of time. If we blindly trust a machine that fails in nearly 40% of cases, then why not also allow juries to convict someone on the basis that he or she 'looked a bit shifty', rather than considering the evidence that proves it 'beyond reasonable doubt'? Better still, just flip a coin. Overall you're bound to be right half the time. It's time to expose the fact that lie detectors do not actually 'tell the truth, the whole truth and nothing but the truth' but only someone's interpretation of the truth. ■

**“IT IS BASED  
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# SCIENCE BEHIND THE PHOTO

The number of ants living on Earth at any one time is inconceivable. Their adults alone are thought to number 1,000,000,000,000,000 individuals: almost one hundred and fifty thousand times the number of humans alive today.

The Malaysian giant forest ant *Camponotus gigas* is a contender for the

title of largest ant on Earth. The biggest of its workers are approximately 2.5 cm in length, with their heads reaching almost 1 cm across. Despite these impressive statistics, almost all of the diet of this colossus amongst insects is made up of honeydew, a sugary secretion produced by aphids and their relatives. The giant ants nest underground but send foraging



workers out every night at dusk, when they can climb up to 80 m into the canopy to feed. So high is their feeding ground that the ants create satellite nests in the canopy to further protect their territory. Whilst foraging, the largest workers take part in 'ritual' battles when they encounter ants of the same species. Rather than allowing clashes to escalate into full-blown violence,

they box with their front legs to defuse the conflict: their territories are so large, and their numbers so small, that the cost of losing ants to non-ritual battles is simply too high.

Despite its formidable appearance, the giant ant is a gentle creature, unaggressive towards humans and incapable of stinging.

The frog is a juvenile grass frog (possibly *Fejervarya limnocharis*), commonly found in temporary water sources such as puddles and ditches. This photo was taken in rainforest in Sabah, Borneo, a habitat critically threatened by logging and conversion to agriculture. ■

PHOTO AND TEXT BY TIM COCKERILL

# LANDFILL THROUGH A MORAL LENS

*Urgent action needs to be taken to reduce the amount of waste in landfill. Tom Bragg takes a look at the ethical reasons for waste reduction.*



Tascha Mehrabi



hundred years ago, when resources were scarce, it was costly to replace essentials like clothes or furniture.

Broken items would be stripped for parts, and only when there were no other uses for the constituent materials would they be discarded. But since the second half of the 20th century, consumer products have become so cheap that there is now no incentive to reuse materials when an item needs replacing.

During this long-running consumption boom, did anyone question whether it was right to pull resources from the ground, turn them into cheap goods, then guiltlessly discard and forget about them? No – the economic benefits of shelving the problem meant that such questions were ignored and saved for another day. Now, landfill in the UK is filling up fast, with some estimating there will be no space left as early as 2016.

In response, the Government's Department for Environment, Food and Rural Affairs wants to move towards a 'zero waste' society over the coming years. Their plans have reduced the percentage of household waste going into landfill from 90% in 2000 to 60% in 2011. The water industry now treats 66% of sewage sludge by anaerobic digestion, which helped generate 1 TWh of electricity in 2010. The reasons for this ongoing clean-up are the numerous economic and environmental problems associated with landfill usage, but

there is also an important moral imperative to stop this uncontrolled natural resource exploitation.

In the 17th century, the ethicist Benedict Spinoza equated a life of virtue with a life lived in accordance with our rational nature. In line with Spinoza therefore, if it is moral for us to pile waste into landfill, it must also be rational. Let's use the production of a simple plastic chair to discuss whether or not we're behaving rationally and therefore virtuously. To produce the plastic chair from unused material, a barrel of oil is first drawn from the seabed up a long pipe and transported to shore in a tanker. It then undergoes processing before being transported to a subsidiary company, where more processing is carried out. Eventually, the end manufacturer shapes the plastic into a chair, screws on four metallic legs and sells it to a furniture store. The whole procedure is an amazing feat of ingenuity.

When the chair is no longer needed, one option is to throw it into landfill, while another is to unscrew the legs and reprocess the plastic seat and metal legs. Obtaining plastic this second way is clearly much simpler than the first, because there is no need to extract oil from the seabed, and it involves far less processing and transportation. The majority of plastic chair-making companies, however, do it the first way. Why? You'll be told it's because systems are already in place for the oil-extraction method, which makes it cheaper,

despite requiring more effort. But if we have created a plastic chair-making system through the complex oil-extraction process, we must be able to create another system, using the simpler recycling method. On an industrial scale, this process would require even less money and effort than it does now. The real reason we're reluctant to embrace a recycled plastics industry is that reusing material doesn't prove to ourselves our own ingenuity. By the rules that drive the economy, this reluctance isn't rational and therefore, according to Spinoza, isn't moral.

Another source for moral guidance on this issue comes from the 19th century philosopher, John Stuart Mill. His theory of utilitarianism said that it is moral to act in a way that brings the greatest happiness to the greatest number. An economist will tell you that extracting natural resources to produce every new product will lead to the greatest happiness for the greatest number because it produces cheap objects, which drives the economy, thus making everyone richer.

But like a number of contemporary considerations, this fails to account for the

next generation. In our short-sightedness we might deplete all available resources – an especially poignant argument against landfilling rare earth metals used in the production of electronics. Also, contaminants from landfill pollute surface water, groundwater and soil, thus causing problems for future generations. Finally, there is no logical link between natural resource extraction and economic activity; no one is going to stop buying chairs if oil pumping from refineries is stopped; chairs will still sell if they are made from recycled plastic.

Governments can easily create a system where it's cheaper to manufacture goods from recycled plastic by taxing goods made from non-recycled plastic. But they don't because of this unmoving wedge in the mind that says the objects around us must be imbued with ingenuity. Their position is as immoral as the economist's recourse to a utilitarian argument to defend excessive natural resource extraction. The greatest happiness will come from efficiently using resources and minimising waste. This is even more obvious when the utilitarian argument is coupled with

Anscombe's Consequentialist theory from the mid-20th century, which argues that the consequences of a person's actions are the ultimate moral judge.

Drawing on the theories of Spinoza, Mill and Anscombe, we can see that there is a moral argument for reducing waste. The UK government is responding to some degree, for instance by increasing the tax on landfill deposits by £8 per year from £56 per tonne of rubbish in 2011/12, to £80 in 2014/15, however, little is being done at the manufacturing stage. Why are so many products still on the shelves, like disposable nappies, that are made from composite materials that can't be recycled? Why is it still cheaper to buy products made from extracted materials than from recycled materials? The government is dragging its heels in taking the problem to the manufacturers' doors and not providing enough support for either new materials research or the young recycling industry. The ethical wisdom of Mill might help manufacturers recognize that: "Everyone who receives the protection of society owes a return for the benefit." ■



# DRUGS POLICY: NOT AS EASY AS ABC

*A new report on UK drug policy is refreshingly different, writes Jonny Ritson.*

**I**n October 2012, the UK Drugs Policy Commission published a report, six years in the making, into the country's current approach to illegal drugs. It highlights a growing desire in society to move towards a more evidence-based approach to policy-making. Entitled 'A fresh approach to drugs', it proposes making possession a civil rather than a criminal offence, and suggests focusing remedial efforts on harm reduction so that users can be supported to adopt more responsible behaviours instead of being criminalised and stigmatised.

The report is highly critical of the antiquated, and largely arbitrary, 'ABC' system of drug classification drawn up in 1971. Under this system, 42,000 people were sentenced to drug offences in 2011, with a further 160,000 issued warnings for cannabis possession. Given the body of evidence in the literature on the relative impacts of drugs, it seems somewhat ill-conceived that magic mushrooms, the least harmful of drugs to user and society, are categorised with heroin and crack, two powerfully addictive substances. It seems that the only similarity in the damage caused by taking mushrooms and crack is the prison sentence that can be brought against the user, and the criminal record that will follow them for years to come.

One of the key successes of the report is that it recognises the prevalence of drug use (36.4% of people in England and Wales take illegal drugs) and the potential impact

## “NOT ALL THE EFFECTS OF DRUGS ARE NEGATIVE”

of criminal records on so large a group. It also discusses the need for policy makers to accept that not all the effects of drugs are negative; frequently young adults will use drugs and simply grow out of it. In this respect the report echoes one of Bill Hicks' famous rants where he says "I have taken drugs before and [...] I had a real good time. Sorry. Didn't murder anybody, didn't rape anybody, didn't rob anybody". Refreshing, too, is the report's discussion on why there is a difference in our minds between 'drugs' and state-sanctioned drugs like alcohol and nicotine; in terms of harm there is no clear-cut distinction.

Response to the report has been, regrettably, predictable. Although many media outlets communicated the findings, they could not resist pulling out eye-catching quotes, ironically underlining the issues of an alarmist media which the report itself warns against. The *Independent*, *Daily Telegraph* and *Huffington Post* all opted for headlines picking up on the report comparing drug use with junk food or

gambling – sadly reminiscent of the horse-riding comment that led to the vilification and mockery of Professor David Nutt in the press.

Outside the media, responses have been mixed. The Green Party, which campaigns for the decriminalisation of small drugs offences, welcomed the findings, with MP Caroline Lucas calling for "policy based on evidence about what reduces harms, rather than one driven by moral judgements". This is a common theme in current drugs policy; the assumed moral values of society are imposed via criminal sanctions on users. Interesting questions are raised when we consider that a third of us are taking illegal drugs; so where has this assumed morality come from and is using drugs inherently wrong?

The answer will depend on your frame of reference – many religions, for example, prohibit the use of alcohol. What if my religion allows or encourages the use of psychoactive substances, or what if I have no religion at all? Should beliefs like these be given influence over policy in a modern, secular society?

There seems to be an underlying theme here. Should the use of drugs be a personal choice or should the government have control over what you do? The latter is a troubling idea for people from all over the political spectrum. This is further complicated by the fact many of the 'wrongs' of taking drugs – such as exploitation during production and the crimes committed to

feed addictions – are caused or exacerbated by the fact that drugs are illegal in the first place.

Intelligent debate on drugs policy has been extremely difficult, as politicians are loath to appear soft on crime and many media sources see decriminalisation as indicative of declining moral values. A key recommendation is to remove the political and criminal angle from drugs policy and instead make it a health and civil issue – take responsibility away from the Home Office and give it instead to the health service. Let an independent body set statutory policy. If these measures were taken, evidence-based policies could be pursued without any political party being involved, hopefully allowing some progress.

The Home Office, in response to the suggestion that responsibility for such policy-making be taken from them, has

**THERE IS AN AIR OF FATALISM FROM KNOWING THEIR IDEAS ARE LIKELY TO BE IGNORED**



claimed “our ambitious approach to tackling drugs is the right one”. Therein lies the problem. Having just read an 89-page report stressing the lack of long-term thinking, research and evidence-based policy, it is mildly amusing to hear the Home Office declare business as usual. Throughout the report the exasperated tone of the authors is evident. Frequently they offer examples of successful policies of harm-reduction and decriminalisation that have worked in Portugal, Switzerland and the Czech Republic, yet there is an air of fatalism from knowing their ideas are likely to be ignored. Perhaps if enough people take notice, we might start to see fewer policies based on some idea of a national

morality and instead move towards a scientifically based framework which might actually, well, work.

Is the UK ready for these types of strategies? Colorado and Washington have just voted to legalise cannabis use, adding to the growing number of countries and states moving away from a criminally enforced abstinence approach to one based on harm reduction. This report points to a new way: what if we accepted that some people are going to take drugs no matter what we do? Why not just make sure they don't injure themselves or their futures while they're doing it? Now that would be a fresh approach. ■

# PHARMACEUTICAL INDUSTRY ADOPTS ORPHAN DRUGS

*Josh Howgego discusses how research into treating rare diseases is gaining popularity and questions the future for these 'orphan drugs'.*

In the autumn of 2012, a paper was published in the journal *ACS Nano* that proposed a model for understanding how a rare condition called argyria comes about. The condition is caused by chronic exposure to silver salts and is particularly nasty, as it turns the skin a distressing blue colour. It characteristically occurs in the few people who ill-advisedly guzzle down 'health tonics' containing colloidal silver.

The new work was motivated by worries over the environmental fate of silver nanoparticles. These are now ubiquitous in modern life – found in everything from bandages to cleaning sprays – due to their antimicrobial properties. The new

information about argyria was a happy bonus for the researchers. Since so few people suffer from the condition, it would be hard to imagine a funding body or pharmaceutical company ever investing in a full-scale search to find a treatment. To put it in terms of crude economics, the tiny size of the client base would make it a bad business move.

But surprisingly, so-called 'orphan drugs' – formulations that treat uncommon medical conditions, from rare genetic diseases to bites from obscure species of snake – are riding a wave of financial and clinical success at the moment.

According to a report by Thomson Reuters, the compound annual growth

**“ORPHAN DRUGS  
ARE RIDING  
A WAVE OF  
FINANCIAL AND  
CLINICAL SUCCESS”**

rate of orphan drugs increased by 25.8% between 2001 and 2010. Sounds like a lot? It really is, especially given the huge problems that the industry faces in general: in that same period, the non-orphan drug market contracted by 20.1%.

So why the disparity? One reason is the way drugs are licensed. In most cases a pharmaceutical drug can be patented for a set number of years (this varies depending on country of sale, among other factors). During that time the developer has exclusive rights to the active ingredients – the drug molecules – they have developed. But from day one their competitors can start working out how to make the same molecule more cheaply and efficiently. That means that soon after the patent expires, usually 10 years or so, the market will be flooded with



Frupus, Flickr

'generic' competition: the same drug sold under another name by a competitor. In some ways that's great; cheaper drugs that have stood the test of time sound attractive. But in practice it means there is wariness from drug giants about how much to invest in researching a drug. If they begin to think they can't recoup burgeoning levels of investment in the first 10 years, they are prone to pull out.

Pfizer, a large drug company, developed a cholesterol-lowering drug called Lipitor – the most profitable drug ever – some time ago. But it began facing competition from generic copies in November 2011. Even before then, the company had been cutting costs by closing offices and research centres around the world. In August 2012 they announced they would be pulling the plug on most of their research into Alzheimer's disease. One of their clinical trials had failed, and the company evidently decided the cost-benefit ratio didn't make sense anymore.

Orphan drugs are attractive to pharmaceutical and biotech companies since they have added protection from generic drugs plus a host of other financial bonuses attached to them. It all started in 1983 when the US introduced the Orphan Drug Act. Similar acts were passed in Australia and Singapore in the 90s, and finally one in Europe in 2000. These acts provided tax incentives to orphan drug manufacturers. But more than that, they offered 'marketing exclusivity' on top of the patent system, which in practice prevents the drugs from being copied for longer. The acts also mean that in some cases drugs only need to undergo shorter and smaller

than average clinical trials. Applications for state approval can be fast-tracked too.

There are, of course, some difficulties with orphan drugs. For instance, it may be more difficult to find patients to participate in clinical trials – there are fewer of them, and they are spread out across countries – so organising logistics is not easy.

But this doesn't seem to be putting companies off. The Reuters report says that, in 2010, the industry's most expensive drug, Soliris, brought in a total of \$541 million in total sales. Only between 4000 and 6000 people have the disease it treats – paroxysmal nocturnal haemoglobinuria, a rare and life-threatening blood disease – but the drug costs more than \$409,000 per year so the money soon adds up.

Not only do patients pay more for orphan drugs, but they jump at the chance to do so. Most non-orphan drugs have some sort of

**“ORPHAN DRUGS HAVE ADDED PROTECTION FROM GENERIC DRUGS, PLUS A HOST OF OTHER FINANCIAL BONUSES”**

**“NOT ONLY DO PATIENTS PAY MORE FOR ORPHAN DRUGS, BUT THEY JUMP AT THE CHANCE TO DO SO”**

lag time before the public get used to them and start using them. But patients who have a life-threatening disease with only one treatment option are understandably desperate.

So should we be optimistic about the future of orphan drugs? We've seen evidence of government legislation prompting research into drugs for people who would otherwise have been overlooked. That's a reason to celebrate; there are drugs where before there was despair.

But at what price? We would be naïve to think that pharmaceutical companies champion orphans for reasons other than because they turn a good profit. None of the individual scientists are bad, or immoral, it's just that the money for drug research and development must come from somewhere. So of course we should be pleased that orphan drugs are taking off. But we shouldn't forget that 5.4 million people in the United States are living with Alzheimer's. They may not be orphans, but they're still worth caring about. ■

# A RECIPE FOR BIOTERRORISM?

*A year after the publication of breakthrough bird flu research was delayed due to bioterrorism concerns, Jenny Mitchell explores the dual-use dilemma of continued research.*

In December 2011, Ron Fouchier, a virologist at Erasmus Medical Centre in Rotterdam, inadvertently sparked international controversy after submitting a research paper for publication. The paper explained the method he had used to mutate a highly lethal strain of bird flu, H5N1. His research suggested that H5N1 was only 5 mutations away from being able to pass through the air from person to person (rather than the typical bird-to-human transmission).

On the face of it, this research looked to be a major breakthrough in the understanding of bird flu transmission. That was until a US biosecurity committee declared the research too dangerous to publish – calling for it, and another similar paper, to be censored. Media interest ensued and concerns over the security of research into such highly lethal viruses began to surface.

Since the current H5N1 outbreak began in 2003, 345 of the 584 confirmed cases have been fatal, giving H5N1 a potential mortality rate of 59%. These high mortality rates have been the focus of debate surrounding the continuation of research using the lethal strain of bird flu virus. It is feared that the description of mutations necessary for the virus to spread from person to person could be used by bioterrorists to create a 'superweapon'.

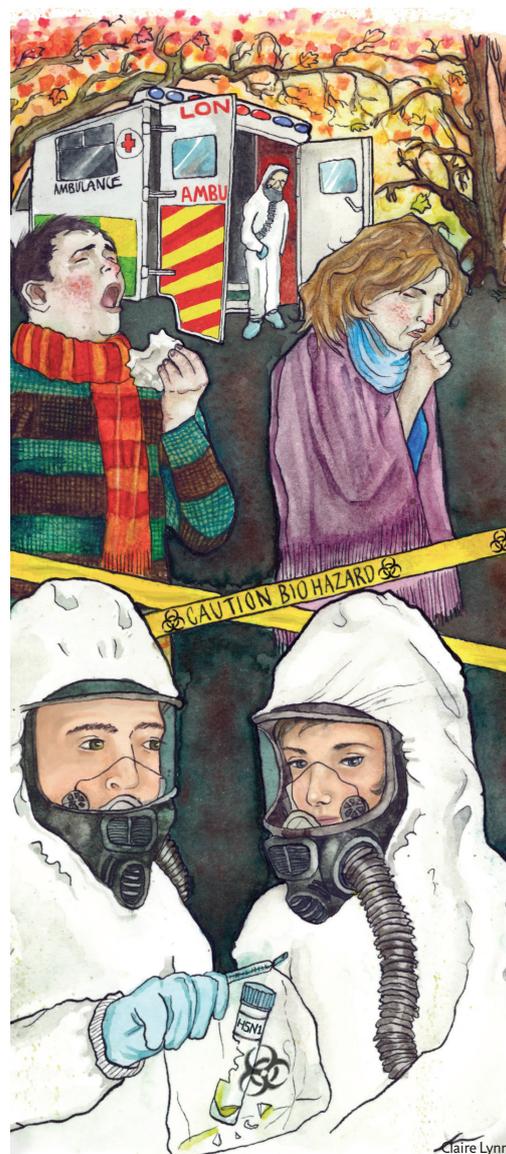
However, Wendy Barclay, the chair in Influenza Virology at Imperial College London, is concerned by the possible ramifications of such a censorship: "I don't

agree that science should be censored, how do you know that by not telling somebody something, you're not preventing the next breakthrough? The point of science is that we use our combined brains together, we share our knowledge."

Both papers involved in this dispute have now been published in full. But scientists have recognised the need to address public and governmental concern surrounding the dangers involved in studying highly pathogenic viruses. However, the debate over who, if anyone, should be allowed to carry on with this possibly harmful research has left scientific investigation into the potentially lethal virus strain virtually at a standstill.

And according to Professor Barclay, there may be dangerous consequences associated with this voluntary moratorium on investigations into bird flu: "This science has been on hold for almost a year, and that's a terribly long time in the world of science. Certainly the virus hasn't been on hold for a year, it hasn't stopped circulating in South East Asia, it hasn't stopped mutating and it hasn't become any less of a pandemic threat."

The H5N1 debate is an excellent example of the ethical tightrope negotiated by science. On one side lies public and governmental uncertainty, whilst on the other lies research aiming to limit the potential impact of the virus. Whilst it is true that research conducted using H5N1 could pose a risk to public safety, in stopping the research are we increasing the risk of future pandemics? ■



Claire Lynn

# CONTINUING TO DECODE THE HUMAN GENOME

*Christopher Yates practices his ACTGs at the Wellcome Collection, and explains how the sequencing of the whole human genome may not be as complete as you think.*



Russ London, flickr

**A**t the Wellcome Collection near Euston, the human genome sequence is printed in multiple volumes, filling an entire bookcase. On opening a book I read line after line of ACTG but can't make any sense of it. What is this book and what do these letters mean?

The Human Genome Project Consortium published the first draft sequence of a human genome in 2001 but it contained many gaps and there was uncertainty about the order of sequences in some areas, particularly in repetitive parts. Thanks to improved technologies, many of these gaps have been filled in and several 'whole genomes' have been sequenced. This means there isn't really any single 'human genome sequence'. The sequence which comes closest is the reference genome, the current release of which is known as GRCh37. This is assembled by the Genome Reference Consortium and is not the genome of a single person, but based on a consensus between four individuals from Buffalo, New York. In most cases it contains a single sequence at each chromosomal location.

This reference genome is not meant to be an 'average' genome, but is designed as a map to show the location of genes and other genomic regions relative to one another. Along with improved sequencing technology and assembly software, the reference genome is part of the reason the time taken to sequence genomes has dropped from years to days. This opens the door for genomes to be sequenced in a clinical setting as an alternative to genetic tests in diagnosis, or to determine the best treatment for a patient.

**“CODING GENES ACCOUNT FOR JUST 2% OF THE GENETIC MATERIAL, MEANING THERE IS 98% LEFT TO DECIPHER”**

Some of the largest remaining gaps in the reference genome are caused by heterochromatin: a tightly packaged form

of DNA that is involved in silencing genes and in chromosome structure. While most known genes are in euchromatic (loosely packed) regions, around 10% of the genome is heterochromatic and cannot be sequenced with current technologies. Work is ongoing to develop technologies that can read this hidden sequence and begin to reveal its secrets.

So what lies ahead for the human genome? GRCh38 is due to be released this summer with even more of the gaps filled in and improved accuracy in chromosome coordinates, but one area still to explore is the function of the different parts of the genome. Traditional protein-coding genes account for just 2% of the genetic material, meaning there is 98% left to decipher. The ENCODE (Encyclopaedia of DNA Elements) project aims to do that, using high-throughput techniques to find out which areas of the genomes are associated with certain proteins and functions. Their first results have just been published and show a wide variety of functionality across the genome, but there are many mysteries still to be solved about how our genes determine who we are. ■

# NUCLEAR IN A VOLATILE ENVIRONMENT?

*Jade Cawthray considers the future of the UK nuclear industry in the aftermath of the Fukushima disaster*



apanese engineering group Hitachi has purchased the UK nuclear energy company Horizon from its German owners E.ON and RWE,

in a “100-year commitment” to the UK. There are plans to build between four and six new plants at Horizon’s Wylfa and Oldbury sites, supplying an estimated 14 million homes with electricity over 60 years. Over 12,000 jobs will be generated during the construction process, after which 2,000 permanent jobs will be available across the sites. In addition, energy supplier EDF has started the consultation process for two new plants at Sizewell, which will generate enough energy for approximately 5 million homes. In the context of our current economic difficulties the opportunities sound promising. But with increasingly volatile weather patterns approaching, is nuclear the best investment for the UK?

## “EIGHT OF THE UK’S NINE OPERATIONAL NUCLEAR REACTORS WILL CLOSE BY 2023”

Nuclear fission is a highly productive form of energy generation, with one atom producing 15 million times the energy available from carbon combustion, and no carbon emissions released at the electricity generation stage of the process. Currently nine operational nuclear reactors in the UK supply 16% of our energy demand. However, eight will be shut down by 2023 (in addition to 30% of oil- and gas-fuelled power stations by 2015), leaving an energy gap of 20-30GW. At the same time the UK government is legally bound to reduce carbon emissions by 26% by 2020, and it is estimated that the new investment in nuclear power will reduce our emissions by 7–14%. The government recognises nuclear as a key feature of a low-carbon energy mix – fulfilling the increasing energy demands of the UK whilst meeting our carbon reduction commitments.

Since the Fukushima crisis, the EU has called for safety improvements at all plants within its member states. Although a natural disaster along the lines of the earthquake and tsunami which caused the Fukushima catastrophe are an unlikely risk for us, super-storm Sandy in the USA led to the shutdown of three nuclear plants in New York and New Jersey, due to loss of power and high water levels. Scenarios such as these could potentially impact the UK. Erica Thompson, a research postgraduate at Imperial College London, is studying how climate models can be used reliably in decision making. She explained that due to its multitude of meteorological phenomena, the UK is one of the most uncertain regions for climate projections. However, what does seem certain is a future rise in sea levels and summer temperatures. This could pose a risk to the nuclear industry in particular, as power stations struggle to keep cool during the summer and are therefore usually situated by the coast in order to gain easy access to water for their cooling systems.

Erica Thompson explained that there is “no such thing as bad weather, only unsuitable clothing” – stressing that nuclear power plants need to be suitably ‘dressed’ to be resilient to the risks of our changing climate. At an Energy and Climate Change Committee meeting at the House of Commons, Dr Andy Hall, acting chief nuclear inspector at the Office for Nuclear Regulation (ONR), explained how there has been an improvement in new designs of power stations – including those proposed by Hitachi – that now take into account external hazards such as weather. However, ONR’s chief operating officer, John Jenkins, added that many of the features, such as back-up generators, were for recovery post-event.

After the Fukushima disaster, Germany decided that nuclear power was too risky and opted for a nuclear phase-out plan, calling for an immediate shutdown of nuclear reactors built before 1980, with all plants to be closed by 2022. Interestingly, the phase-out programme coincided with a reduction in Germany’s carbon emissions. Keith Barnham, Emeritus Professor of Physics at Imperial College, has shown that Germany has already

## HISTORY OF UK NUCLEAR POWER

- The United Kingdom Atomic Energy Authority (UKAEA) started in 1954 with the purpose of developing nuclear energy in the UK
- Calder Hall was the first station to be connected to the national grid on August 27, 1956
- The public enquiry surrounding the building of the Sizewell B plant in 1987 took four years and produced documents running to 16 million words
- UK Nuclear Energy peaked in 1997 when it provided 26% of the energy mix.
- Since then nuclear plants have closed at Chapelcross, Bradwell, Sizewell A and the original at Calder Hall

installed more wind power than the UK’s nuclear capacity, and is installing the wind equivalent of one nuclear reactor every year. But while it has been proven possible by Germany, wind power is not a faultless technology. Many people in the UK find it aesthetically invasive, and some German citizens have claimed that the density of turbines in some areas creates noise and spinning shadows, which can cause headaches and nausea.

## “RISING SEA LEVELS COULD POSE A RISK TO NUCLEAR PLANTS”

The question of whether nuclear is right for the UK is a complex debate that is being coordinated by the Energy and Climate Change Committee. The Electricity Market Reform bill has a big part to play, as does the consultation process for the communities adjacent to proposed sites. But with such a solid commitment from Hitachi, it seems inevitable that nuclear will continue to be a part of the UK energy mix. ■



# NASA'S MOST AMBITIOUS MISSION YET

NASA's Marshall Space Flight Center, Flickr

*The next decade could play host to some exciting developments in space exploration. **Sotirios Karamitsos** writes about NASA's plans to send astronauts to lunar space stations and beyond.*



Over the past year, NASA has been considering the possibility of launching a deep-space outpost beyond the Moon. Now, following the end of the United States presidential election, the agency looks likely to reveal details about its plans for manned missions beyond low-Earth orbit.

Under President Barack Obama's instructions, NASA has been working on the long-term goal of sending a manned mission to an asteroid. According to John Logsdon, space policy expert and Professor Emeritus at George Washington University, the space agency had been in contact with the Obama administration before the election about the details of the expedition. It did not, however, reveal any specifics in case Mitt Romney was elected, as his policies included a restructuring and reassessment of NASA's priorities.

The 'foundational elements' of the mission, the Space Launch System, a heavy-lift rocket, and Orion, a multi-purpose crew capsule,

are currently under development and are scheduled to take off in 2021. This expedition, named Exploration Mission 2, will be manned, as opposed to Exploration Flight Test 1, meant as a trial of the capabilities of the equipment and planned for 2017. Exploration Mission 2's goal is not to reach an asteroid, but to set up an outpost at the second Earth-Moon liberation point (EML-2). There, the gravitational forces between the Earth and the Moon are balanced such that there is no net attraction to either body: in theory, the outpost could stay there indefinitely.

At about a million kilometres from the far side of the Moon, a station at EML-2 will mark the farthest point from Earth that humans have travelled to. Exploration Mission 2 will also be the first manned mission to the Moon since Apollo 17's visit in 1972. NASA's Deputy Administrator, Lori Garver, states that Congress has been apprised of the scope of the mission, and underlines that the presence of a manned station at EML-2 is a stepping-stone towards missions to various destinations beyond lunar space. These destinations could

include asteroids by 2025 and even the moons of Mars or Mars itself by the 2030s.

**A MANNED STATION AT EML-2 COULD BE USED AS A STEPPING-STONE TOWARDS VARIOUS DESTINATIONS, INCLUDING ASTEROIDS AND EVEN MARS.**

According to Logsdon, the expedition to launch an EML-2 station does not pose a significant strain on NASA's budget, especially in light of the benefits to be gained by its establishment. Apart from being a gateway to a host of destinations, the station would enable advances in numerous areas, ranging from investigations in radiation shielding outside the Van Allen belt, to the assembly and maintenance of telescopes and satellites. Garver appears enthusiastic, stating that NASA is "going back to the moon, attempting a first-ever mission to send humans to an asteroid and actively developing a plan to take Americans to Mars". ■

# L'AQUILA AND THE DILEMMAS OF RISK COMMUNICATION

*Science is a risky business: all measurements have inherent errors associated with them, and future events can never be predicted with 100% accuracy. But as more areas of society become intertwined with science, experts are being called upon to communicate their scientific insights quickly and clearly, but accurately – including the uncertainties. That won't be easy, but it should be possible, says **Brigitte Nerlich**.*



any articles have been written about the case of the three seismologists, two engineers, one volcanologist and the public official who were sentenced in L'Aquila, Italy, to be jailed for six years. These members of the National Commission for the Forecast and Prevention of Major Risks were found guilty of manslaughter for 'falsely' reassuring or 'over'-reassuring people in the Italian town of L'Aquila about the likelihood of a major earthquake at the end of March 2009. Soon after their conclusion that the risk of an earthquake was minimal, the town was struck by a major earthquake and more than 300 people died. Prosecutors and victims' relatives claimed that 29 of those who died would have left their houses if they hadn't felt reassured by the authorities, and that these lives could therefore have been saved.

This verdict has started a process of rethinking what it means to make predications, engage in risk and uncertainty communication, and give scientific advice in high-risk situations involving public confusion about risk and uncertainty. This is a highly complex affair and one fraught with almost irresolvable dilemmas. Here I can only highlight some of them.

Scientists are generally exhorted to be open and honest about uncertainties. This is difficult in situations where certainty is what people expect to hear. So how can scientists navigate between the Scylla of being open

about uncertainty and the Charybdis of public and political expectations regarding pronouncements of certainty, as well as, and perhaps more importantly, between the rock of scare mongering and the hard place of 'complacency mongering'? There are quite a few obstacles in the way.

**“MAKING PREDICTIONS IS NOT JUST A MATTER OF RIGHT AND WRONG”**

Making predictions is not just a matter of being right or wrong. There are two kinds of 'right' and two kinds of 'wrong', all with different costs and benefits. You can predict that something will happen and be right or wrong or you can predict that it won't happen and again be right or wrong. These are called true positives, false positives, true negatives and false negatives, respectively. The real problem is that these things trade off against each other so that more true positives can only be made at the risk of false positives and more true negatives can only be made at the risk of false negatives. There is no simple way 'just to be right'. Scientists are generally trained to think that false positives should be avoided, while false negatives are relatively harmless. (In an experimental lab you do not publish a finding until the evidence is conclusive. Meanwhile there is no finding and nothing to say). But in real world

terms this can mean not giving a warning because the danger is not proven, when in fact the warning would have been helpful. If your sole aim were to avoid false alarms you would never give any warnings. And if your sole aim were never to miss a real danger you would issue warnings every day. Neither of these situations is satisfactory and all the real options involve a mixture of both disadvantages.

So what can scientists do about communicating risk in such a profoundly dilemmatic situation when, in addition, the communication of risk is full of complex political and communicative pitfalls and slippages, as was the case in L'Aquila?

After the L'Aquila verdict, David Spiegelhalter, Winton Professor for the Public Understanding of Risk at the University of Cambridge, provided some advice about how one may be able to proceed. The most important points he makes are, to slightly paraphrase: (1) Never give advice unless confident that the findings will be communicated either by yourself or a trusted professional source, using a pre-determined plan and appropriate, carefully chosen language that acknowledges uncertainty and does not either prematurely reassure or induce unreasonable concern. (2) Do not engage in informal communication using social media on that issue. (3) Ensure proper indemnity arrangements are in place.

Peter Sandman and Jody Lanard, two experts on risk communication, also provided some good advice. They stress that it is important to "alert scientists to their obligation to inform the public candidly about uncertain risks, instead of giving in to the temptation to over-reassure." They go on to say: "To get the job done, experts have to proclaim their uncertainty, insisting aggressively that they're not at all sure about the things they're not sure about."

These are some signposts and lighthouses that might allow scientists to navigate the dangerous seas of risk communication, but it will always be difficult. ■

**Brigitte Nerlich** is Professor of Science, Language and Society at the University of Nottingham, UK. She studies the debates that surround important contemporary scientific topics like emerging diseases and climate change, with a special emphasis on the use of metaphors. She blogs at <http://blogs.nottingham.ac.uk/makingsciencepublic/> and tweets as @BNERlich.

# REVIEWS

## WELCOME TO THE WEB LAB

How does the internet work? **Sotirios Karamitsos** finds out at a new exhibition by Google at the Science Museum.

**T**ucked away downstairs in the Science Museum, Chrome Web Lab, an interactive series of exhibits by Google, is a hands-on exposition of the inner workings of the Internet, consisting of five interactive experiments that focus on different aspects of the World Wide Web.

Upon arrival, visitors are presented with a personal Lab Tag, while the first exhibit, 'Universal Orchestra', greets them with the sound of vibraphones, marimbas and drums – all of which can be programmed by visitors as well as online guests (who visit [chromeweb.com](http://chromeweb.com)). Just nearby, 'Teleporter' offers the chance to watch a live feed from Hamburg, Cape Town, or North Carolina via web-enabled periscopes. Next

are the 'Sketchbots' – the Web Lab's most publicised experiment – which involves visitors having their pictures taken and watching in amazement, as the image is edited, step-by-step, before finally being drawn in sand by a robotic arm.

Another exhibit, 'Data Tracer', displays an assortment of pictures hosted by different servers around the world, allowing visitors to uncover the locations of the images and highlighting the tremendous speeds with which data can be transmitted across the Internet. Finally, 'Lab Tag Explorer' allows guests to peruse the database of contributions made by previous visitors to the Web Lab; each Lab Tag acting as a save card, allowing the results of any creative tinkering with the experiments to be viewed online.

Each experiment asks a different question – "How can we see something that isn't here?" "How is data transferred across the globe?" – and is accompanied by a short video explaining the mechanism which drives them. 'Universal Orchestra' showcases the potential that two-way communication offers for remote collaboration, 'Teleporter' explains the process of compression and its importance in the transmission of data, while the 'Sketchbots' are an example of the link between software and the physical world. It can seem, at times, that the short videos bite off more than they can chew: attempting to incorporate a large amount of information into a two-minute film, all the while trying to keep it accessible to the general public. Yet they remain clear and enlightening for the most part.

Offering a range of familiar examples of what web technology is able to achieve and illuminating the processes behind them, Web Lab leaves the impression of an informative exhibition that deals with an increasingly important part of modern life in a remarkably lucid and attractive way. ■

**Chrome Web Lab is set to run until 20 June 2013 and can be found on the Lower Ground Floor of the Science Museum, London. Admission is free.**



## ALCHEMY EXPLORED

The 'Signs, Symbols, Secrets' exhibition at the Science Museum was born out of the discovery last year of one of the 23 legendary Ripley Scrolls in the museum's archives. These intricately decorated tapestries are named in honour of the alchemist George Ripley, and are thought to be based on a lost original scroll from the 15th century. They were believed to contain the secrets leading to the creation of alchemy's most highly prized goal – the Philosophers Stone – in their rich imagery and verse.

Hidden away in the top floor galleries, the exhibition comprises a collection of alchemical artefacts from the Science Museum Library and Archives. These objects range from beautifully illustrated 16th century treatises to tools from alchemical workshops. Opposite the cabinets of treasures we find a detailed examination of the symbolism found within the texts and alchemy is weaved into a historical narrative. The exhibition certainly manages to give a comprehensive insight into the meaning that might be extracted from alchemical texts and goes some way towards explaining its mysterious appeal. However, for a collection aiming to review the intersection of art and science within this protoscience, the two end up feeling slightly disconnected.

The bulk of the exhibition is really intended to provide a context for the Ripley Scroll, found at the back of the exhibition gallery. This piece is certainly impressive and the accompanying descriptions of the hand-painted images go some way to showing why alchemy once served as a crossroads of arts, philosophy and mysticism.

If your knowledge of all things alchemical is limited to recollections of the first instalment of Harry Potter, this exhibition provides a useful overview of the ancient belief system that fascinated many bright minds in the 16th and 17th centuries. If, on the other hand, you are hoping for something more interactive (where the Science Museum normally excels) or focused on the artistic merits, you may leave disappointed. ■

***Signs, Symbols, Secrets runs until 30 April 2013. Admission is free.***

ALEKS BERDITCHEVSKAIA

## PREDICTING MEGAQUAKES

*The Million Death Quake*  
Roger Musson  
Palgrave Macmillan (2012)

A post-apocalyptic opening scene sets the tone for this charmingly macabre read by Roger Musson, the British Geological Survey's Chief Spokesman. The book covers all the key aspects of earthquake prediction in an engaging, conversational style, and is peppered with details that would be useful for a pub quiz. For instance, I now know the name of the only seismologist to have appeared on a postage stamp (Andrija Mohorovičić) – that's got to come in handy one day.

There are also rumblings of a delicious maliciousness throughout the book, such as a carefully articulated argument for the seismologist's superior right to time travel, should it ever become possible; they would have the ability to save lives, after all. This puts an interesting twist on a serious message: earthquakes have a shocking, unpredictable, unpreventable nature that completely undermines the modern notion of science's capabilities. The seismologist's best predictive tool is still the past, which seems about as reliable for earthquakes as for banks (it's gone wrong before, it probably will again, but we don't know much more than that).

Yet this dark humour doesn't detract from the seriousness of this topic. Throughout the book, Musson reveals just how underprepared and underfunded some of the world's politicians and builders are for the next generation of earthquakes. According to him, these earthquakes will greet an overpopulated and poorly-built urban metropolis and leave us with destruction on a scale we can currently only imagine. ■

Alice Jacques

## REMEMBERING THE STORM

*Strong in the Rain*  
By Lucy Birmingham and David McNeill  
Palgrave Macmillan (2012)

On 11 March 2011, a 9.0 magnitude earthquake struck Japan. *Strong in the Rain* describes the devastation caused by the earthquake and the following tsunami from the perspectives of those that lived through it.

Starting with the authors' own description of the earthquake in Tokyo, the book goes on to follow six different individuals through their experiences of the catastrophe. These stories are used to anchor the narrative, which examines various aspects of the immediate and medium-term responses.

Many aspects of the Japanese Government's preparedness and reaction are greatly criticised, along with their actions in conjunction with Tepco (the company that owns the Fukushima plant) surrounding the events at Fukushima. Journalists – both foreign and national – have their roles examined in great detail, exposing problems with both groups' coverage of events. Though in some parts these analyses are slightly drawn out, they are all clear and accessible; a particularly commendable feat when discussing nuclear reactors.

In general, the book works exceptionally well; the voices are well selected and provide diverse commentary on events from a good range of perspectives (from a fisherman to a local Mayor). The commentary also tends to take on a very matter-of-fact tone, which, rather than detracting from the emotion of the situation, actually adds to it.

The structure of the book makes, what would otherwise be a heavy analysis of events, organisations and people surrounding the Fukushima story come alive. The honest commentary of those impacted, their resilience, bravery and practical approach to the events shines through, creating an exceedingly emotive tale. This book is a beautiful testament to the heroism of numerous individuals and the resolve of a nation to persevere in the face of such catastrophe. ■

CATHERINE POWELL

