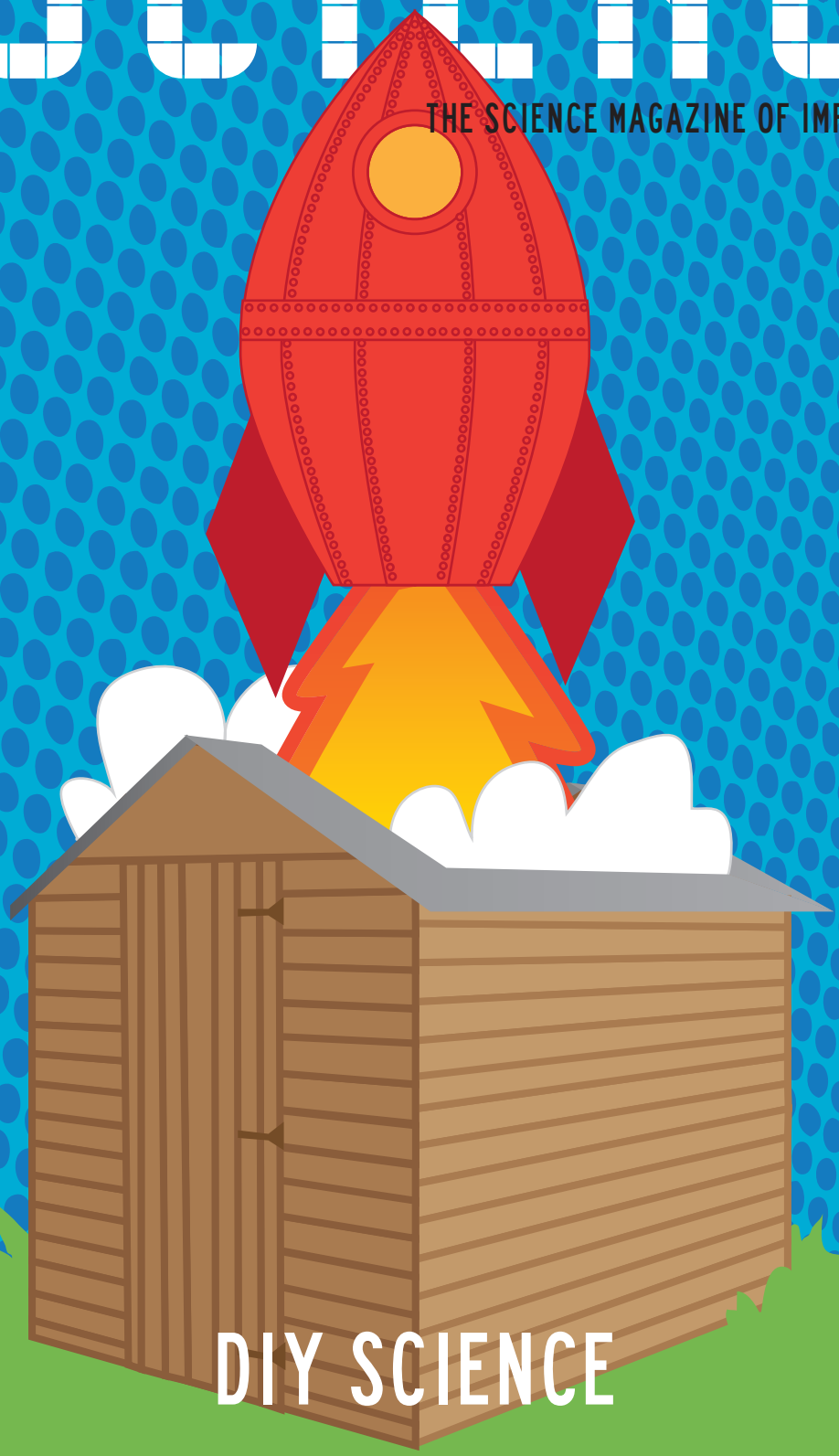
I, SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE



DIY SCIENCE

I, SCIENCE

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I, SCIENCE

Science wasn't born in the cold, sterile world of the modern laboratory. It was developed in the minds and actions of curious individuals and creative inventors. Early experiments were conducted in bedrooms, workshops and lightning storms. It was, after all, Thomas Edison who said, "To invent, you need a good imagination and a pile of junk."

And while modern science has now become associated with the heavily regulated world of industrial laboratories and tightly controlled research, there still exists a culture of the Do-It-Yourself scientist. And it appears to be growing.

In fact, London itself is home to a group of such individuals, known as biohackers. On page 12, we hear from Josh Howgego and Keeren Flora about the London Hackspace: home to amateur synthetic biologists who prefer to do their research out of the lab (in a former bathroom, to be exact). Could they lead us to the next major scientific breakthrough?

It's not beyond the realms of possibility – DIY scientists have made many important discoveries. On page 14, Christopher Yates looks at the pioneering individuals who experimented on themselves in order to test their theories. Where would we be without these brave (and maybe crazy) scientists?

Of course, we don't suggest you try their experiments at home: they could be dangerous. But does the adventurous nature of DIY science mean it should be stopped altogether? On page 18, Conor McKeever asks what might happen if we stifle this source of innovation.

Besides, 'traditional' science isn't as perfect as we like to think. As anyone who has worked in a lab will attest, it's not all rigour and precision – scientists are human, and they make mistakes. Jenny Mitchell investigated the trend of scientists confessing all on Twitter under the trending phenomenon #overlyhonestmethods. Can the hilarious comments tell us something serious about science? Turn to page 27 to find out.

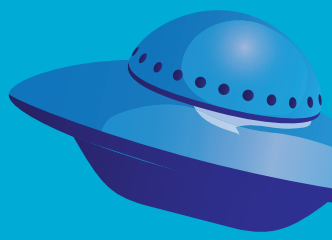
And so we leave you with *I, Science's* journey into the exciting world of DIY Science. We hope you enjoy the issue. ■

ALEX & CONOR

Here at I, Science we're always on the lookout for potential new contributors for both the magazine and the website.

If you are interested and would like to get involved as a writer, editor or illustrator please don't hesitate to get in contact. You can email us at i.science@imperial.ac.uk, tweet us @i_science_mag or contact us directly through our website www.isciencemag.co.uk.

CONTENTS



CITIZEN SCIENCE REVOLUTION | 9
Arianna Sorba explores how science can benefit from citizen participation.

HOW TO PRINT A GUN | 10
Rosemary Peters wonders if 3D printing might have hidden dangers.

LONDON HACKSPACE | 12
Josh Howgego and Keeren Flora bravely enter the world of the biohackers.

HUMAN GUINEA PIGS | 14
Christopher Yates describes how some scientists experiment on themselves.

CRIMINALIZING INNOVATION | 18
Conor McKeever asks whether strict regulations might strangle budding inventors.

IMPRACTICAL INVENTIONS | 20
A look at some of the most imaginative (if a little pointless) creations.

STARLITE'S POTENTIAL EXTINGUISHED | 22
Nick Kennedy tells the tantalising story of DIY scientist Maurice Ward and his mysterious creation.

THE DIY MENTALITY | 23
Julie Gould reports on Fran Scott's new vision for experimental procedure.

GIVE THE PEOPLE WHAT THEY WANT! | 24
Jonny Ritson interviews Dr Mark Mulligan about crowdsourcing and the demand for open access.

4 | IMPERIAL NEWS
Highlights from the College: bingeing bacteria, predicting pop, spotting sharks and speedy sequencing.

6 | WORLD NEWS
News from beyond Imperial: Richard's remains, cutting carbon, roaming rocks and metal men.

16 | SCIENCE BEHIND THE PHOTO
Peering into space with the Lovell Telescope at the Jodrell Bank Observatory.

26 | TO THE HIGHEST BIDDER
Laurence Pope explores why researchers are auctioning off the name of a cancer-eating virus.

27 | LAB CONFESSIONS
Jenny Mitchell describes the trend in confessing hilarious laboratory secrets.

28 | CHIMP GENIUS
Andy Roast tells us how chimpanzees have been outsmarting humans at a memory game.

29 | CALL OFF THE SEARCH
Laurence Pope gives us his opinion on why seeking out alien life might not be such a good idea.

30 | REVIEWS
Looking at some of the latest museum exhibitions, popular science books and DVDs.

NEWS FROM *IMPERIAL COLLEGE*


Imperial College

HOW BACTERIA DETECT AND INGEST DNA

Researchers have taken another step towards better understanding the method that some harmful bacteria use to become resistant to antibiotics. The discovery, published in the *Proceedings of the National Academy of Sciences*, could help prevent outbreaks of meningitis and septicaemia by keeping the bacteria that cause these diseases (*Neisseria meningitides*) susceptible to current antibiotic treatments.

One way bacteria develop antibiotic resistance is by taking up free DNA from their environment. By mixing the ingested DNA with its own DNA sequence, a bacterium can change its genetic code, potentially turning it into a bacterial strain more resistant to antibiotics. This process of sharing DNA through the environment is called natural transformation and is used by bacteria to share genetic traits.

Now, a new study has revealed more about the mechanism that bacteria use to detect and ingest the free DNA. The research, led by Dr Vladimir Pelicic, was carried out at Imperial College's Medical Research Council Centre for Molecular Bacteriology and Infection, which was set up in July 2012 with the aim of taking a multidisciplinary approach to combating disease-causing bacteria.

It was already known that on the surface of bacteria tiny tentacle-like structures called pili detect DNA molecules outside the cell using a special protein component. Dr Pelicic's research found that they preferentially bind certain DNA sequences using a newly discovered mechanism called an electropositive stripe.

Similar pili and proteins are found in hundreds of bacterial species, many of which cause diseases in humans. Dr Pelicic feels this research could become a successful new route to overcoming disease-causing bacteria. "The challenge now is to understand in greater detail the biology of these fascinating molecular machines, and – potentially – to exploit these findings to develop new drugs targeting them that would be effective against a very broad spectrum of bacteria."

TOM BRAGG

VOLUNTEERS NEEDED TO TRACE POP MUSIC'S EVOLUTIONARY TREE

Adele's genre of music is clearly very different to dubstep or indie, but do they all share a common ancestor? A new experiment, named Descent of Pop, aims to uncover patterns and paths in the evolution of popular music.

Biologists normally apply Charles Darwin's theory of evolution to biological systems in order to discover, for example, how humans evolved from early primates. Scientists from Imperial College and Queen Mary, University of London are now applying Darwinian theory to pop music.

"Paleontologists have charted the diversity of animal forms through time," says Professor Armand Leroi, one of the researchers working at Imperial. Professor Leroi wonders if the same processes can teach us about the music charts, "Did pop begin in uniformity and then explode into diversity?"

Evolution theory has been applied to music before, most notably during the DarwinTunes project, which Professor Leroi also helped create. In this experiment, a synthetic piece of music 'evolved' after members of the public selected random strings of music for their aesthetic quality. The Descent of Pop experiment now asks members of the public to help produce data that explores the evolutionary history of real-world music.

The researchers are looking for people to help sift through 30,000 music recordings to determine which are good or bad recordings and which sound most like each other. Dr Matthias Mauch, the lead researcher, from Queen Mary's Centre for Digital Music, is keen to sign up volunteers because "humans still outdo computers at spotting a bad recording, we need help from a lot of listeners."

Once the real-world data has been gathered, the team can analyse whether music styles change more swiftly now than they did in the 1970s, or whether music buyers in one year have an influence of what musicians will compose in the next year.

To sign up for the experiment visit descentofpop.eecs.qmul.ac.uk.

ANDY ROAST


Arturo deFrias

TOURIST PHOTOS TO BE USED IN SHARK CONSERVATION

Tourists who frequently photograph whale sharks whilst diving in the Maldives can now help scientists to monitor the movements of these giant creatures. Conservationists have long been keen to use publicly sourced images to help identify whale sharks, and now a study led by Tim Davies at Imperial College has demonstrated that amateur photographs are suitable for use in conservation work.

Whale sharks are the world's largest species of fish, with an average length of 9.7 metres. They are thought to be rare but their conservation status has long been uncertain. Davies' study, published in *Wildlife Research*, compared photographs taken by tourists with results from specific surveys undertaken by marine researchers.

A computer programme scanned hundreds of public images, including many from Flickr and YouTube, to look for the unique spot patterns, located behind the gills, which are used to identify different whale sharks. In 85% of cases individual whale sharks could be identified from public images. This is not far off the 100% identification rate attainable from the photographs taken by researchers.

"Globally, this outcome provides strong support for the scientific use of photographs taken by tourists for whale shark monitoring. Hopefully, this will give whale shark research around the world confidence in using this source of free data," said Davies. "In the Maldives in particular, where whale shark tourism is well established and very useful for collecting data from throughout the archipelago, our results suggest that whale shark monitoring effort should be focused on collecting tourist photographs."

The ECOCEAN project currently holds over 43,000 photographs of whale sharks. Davies hopes that more photos from future tourists will help to increase our understanding of the Maldivian whale shark population and allow researchers to better monitor its status. ■

ALICE HAZELTON

SPEEDY SYNTHETIC BIOLOGY

An improved rate of characterising DNA in synthetic biology, using a cell-free system, has reduced the time it takes to identify DNA sequences from a few days to a few hours.

Synthetic biology is a new field in science, which combines engineering with molecular biology. The aim is to engineer new or altered functions of biological systems for a multitude of purposes. In other words, creating microscopic biological factories that can complete tasks such as creating synthetic biofuels, detecting pathogens in the body or improving the delivery of medicines.

But this requires knowing which DNA molecules are programmed to do which specific tasks. Usually a living cell would be used as the host to look at how a certain DNA sequence works. This means allowing the cell to grow, inserting the DNA, and not interfering with the everyday processes of the living cell. However, this is a time consuming method, and only produces data after 48 hours.

Now, for the first time, Professor Paul Freemont and James Chappell, from the Centre for Synthetic Biology and Innovation at Imperial College, have used an *in vitro*, cell-free technique. "We wanted to break open the cell, take all the biochemical stuff out, and see if we could run our little genetic circuits in that mixture, without the need of growing cells," explained Professor Freemont.

By extracting the required biochemistry, the complexity of the living cell was removed, yet the data collected from the cell-free systems was still just as good as that obtained using living cells. This has reduced the time it takes to develop new 'parts' for the microscopic biological factories from two days to about six hours.

This new method means an increase in the efficiency in the characterisation of DNA, ultimately giving the synthetic biologists an opportunity to build larger catalogues of sequenced DNA to use for developing new, more intricate biological systems. ■

JULIE GOULD

WORLD NEWS

PICK OF THE BEST

Richard Ansett, Channel 4

LONG-LOST KING REMAINS

Scientists have recently confirmed that the skeleton discovered under a car park in Leicester is that of King Richard III. The finding has ended a 500 year-old mystery over the whereabouts of the king's remains after his death at the Battle of Bosworth in 1485.

The skeleton was discovered in September 2012 and has been subjected to extensive testing and analysis. Researchers found that some physical characteristics, including severe battle wounds and a curved back (scoliosis), can be attributed to the former king.

Genetic testing matched DNA from the skeleton to living descendants of Richard's sister, Anne of York, whilst radiocarbon dating techniques placed the time of death between 1455 and 1540. Physical analysis also revealed that the king died from head injuries, whilst other 'humiliation wounds' were inflicted after death.

The discovery of the skeleton has enabled scientists at the University of Dundee to build a facial reconstruction of the monarch. The team used CT scans and photographs of the skull, along with a computer programme, to produce a digital version of the head. The digital image was then brought to life using a 3D printing technique and an artist added the finishing touches, including prosthetic eyes, plastic skin and a wig.

As no portraits of Richard painted during his reign survive, the facial reconstruction relied almost entirely on the shape of the skull. Some features such as the shape and size of the ears required guesswork but others, including hairstyle, eye colour and skin tone, were based on posthumous paintings of the monarch.

The search for Richard was led by the University of Leicester in collaboration with Leicester City Council and The Richard III society. Members of the society have expressed their hope that the discovery of the skeleton, including the humiliation wounds, may change the long-held preconceptions of the king as a murderous tyrant. ■

REBECCA KNOWLSON

A GREENER FUTURE: US CARBON EMISSIONS LOWEST SINCE 1994

America's carbon dioxide emissions have dropped 13% over the past five years according to a report by Bloomberg New Energy Finance. The levels are now the lowest since 1994, suggesting the US is on its way to meeting President Obama's target of cutting emissions 17% from 2005 levels by 2020.

Several trends have contributed to this decline: energy usage has dropped 6.4% over the past five years; reliance on carbon-heavy oil and petroleum has decreased; and natural gas produced by hydraulic fracturing now supplies 31% of the country's electricity, which is 22% higher than in 2007.

What's more, the energy profile of the US is diversifying to include renewable sources such as solar, wind, hydro and geothermal energy. The report states that renewable energy represents the "largest single source of new capacity growth in 2012." In fact, the use of renewable energy sources over the last five years has increased at the same time from 8.3% to 12.1%.

The transport preferences of Americans are becoming more energy efficient with 488,000 hybrid and plug-in vehicles sold in 2012.

Total investment in US clean energy has grown by an outstanding 316% since 2004. These results are corroborated by a report out last year by the independent think tank Resources for the Future, which outlined three main causes: stronger regulation under the Clean Air Act, trends in higher fuel prices, and increases in energy efficiency from the use of natural gas and from subnational emission-reduction schemes.

Although the report suggests the US has taken a step in the right direction, the country is still the second-highest CO_2 emitter in the world. Furthermore, the GDP of the US has increased by just 3% since 2009. It therefore remains to be seen if these figures are sustainable in the long-term and how much of the reduction is attributable to the economic recession. ■

NATASCHA MEHRABI

COSMIC COINCIDENCE: TWO SPACE ROCKS AT ONCE

Travelling at a velocity approximately eight times faster than a speeding bullet, an asteroid zipped past the Earth on 15 February at 17,400 miles per hour.

The asteroid, 2012 DA14, flew within 17,200 miles of the Earth. That is 500 miles closer than TV, weather and communication satellites, or 14 times closer than the moon.

According to Donald Yeomans, an astronomer with NASA's Jet Propulsion Laboratory, this is the closest an asteroid of this size (nearly as large as an Olympic swimming pool) has come to the Earth in recorded history.

But while eyes were focussed on 2012 DA14, a meteor sneaked past the space-bound gaze of scientists and struck Chelyabinsk, Russia, just hours before 2012 DA14 was due to whizz by the Earth.

The meteor entered the Earth's atmosphere as a 17-metre wide fireball, releasing a sonic blast equivalent to force of detonating 20 nuclear bombs. The blast injured more than 1,200 people as it shattered windows – totalling one million square feet of glass – and damaged approximately 3,000 buildings.

There is no connection between the asteroid 2012 DA14 and the meteor, according to European Space Agency (ESA) experts, as the rocks were travelling in opposite directions past the Earth. It was just a cosmic coincidence.

However, in light of the number of people injured by the meteor and the fact that its approach went unnoticed, Nicolas Bobrinsky, the head of ESA's Space Situational Awareness for Europe, has called for Europe to strengthen its watch for dangerous space rocks.

"Around 99% of these big asteroids have already been spotted," Bobrinsky said, in an article published by Agence France-Presse on 21 February. "The real danger now comes from small asteroids, which are far more numerous."

ROSEMARY PETERS

MILLION DOLLAR MAN

Rex, the world's most complete bionic man, was recently unveiled as part of the 'Who Am I?' gallery at the Science Museum.

The London-based Shadow Robotics Company built Rex to have approximately two-thirds of a replicated human body. Even the company's managing director, Rich Walker, was surprised at the high percentage of replicated body parts.

Eighteen institutions – including universities and companies – lent artificial limbs and organs such as prosthetic hips, knees, feet and hands alongside an artificial retina, cochlea and heart.

Unfortunately, Rex is unable to eat or drink as he lacks a stomach and intestines, and no attempt was made to simulate a human brain. But he can have a simple conversation thanks to 'chatbot' artificial intelligence and a speech generator.

His head was modelled on Dr Bertolt Meyer, a psychologist from Zurich University, who was invited to create a bionic version of himself. His skull was reproduced using a high-definition CT scan and 3D printing.

Dr Meyer, who has a prosthetic arm, is concerned that new technologies are becoming so good that they may lead to elective prosthetics – where members of the public choose to swap healthy body parts for stronger and better artificial replacements. Dr Meyer feels this could result in commercial forces taking priority over medical need.

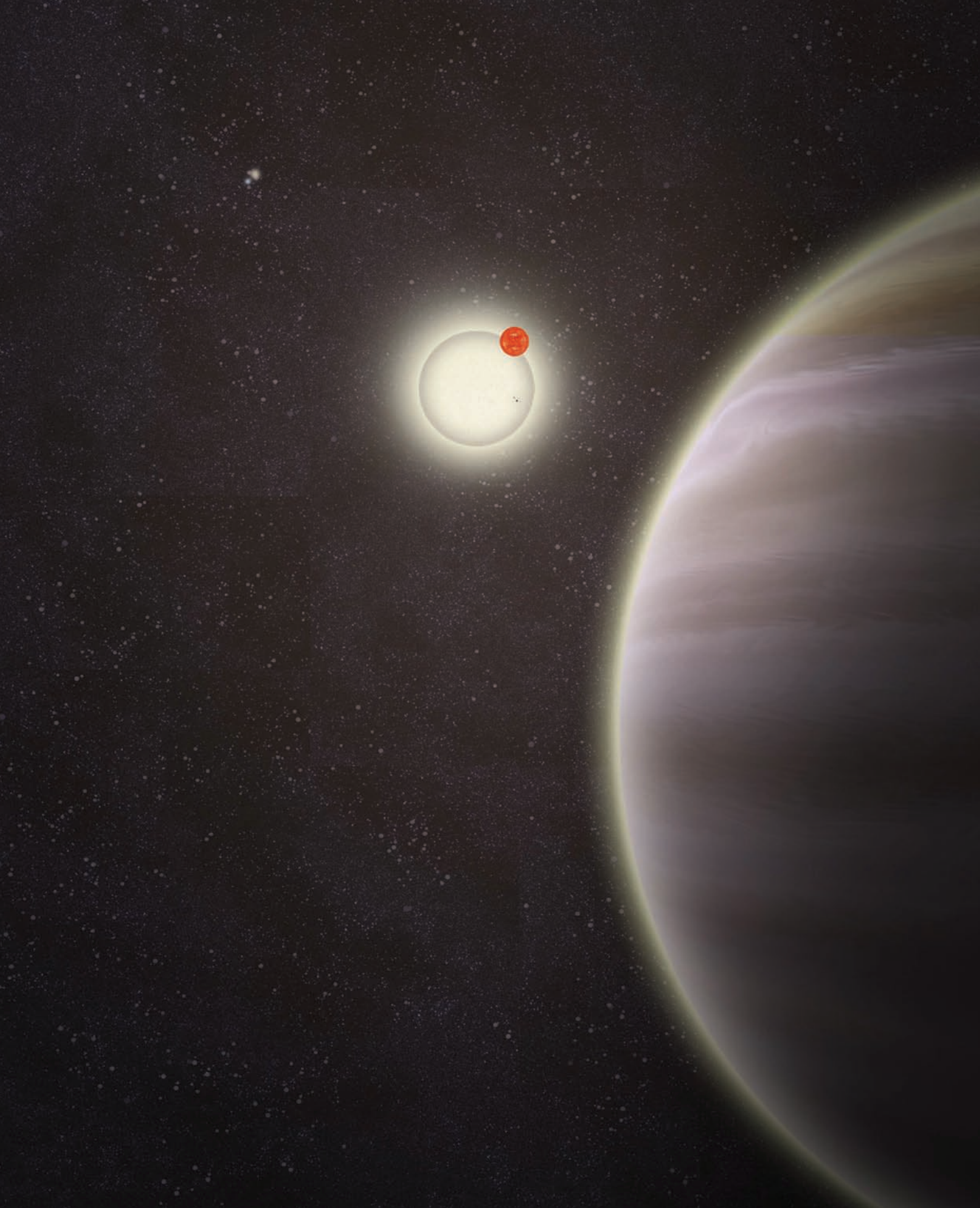
The Rex project cost $1 million (£665,000) and was a response from television company Darlow Smithson Productions to the question: "How close is bionic technology catching up with – and even exceeding – the capabilities of the human body?"

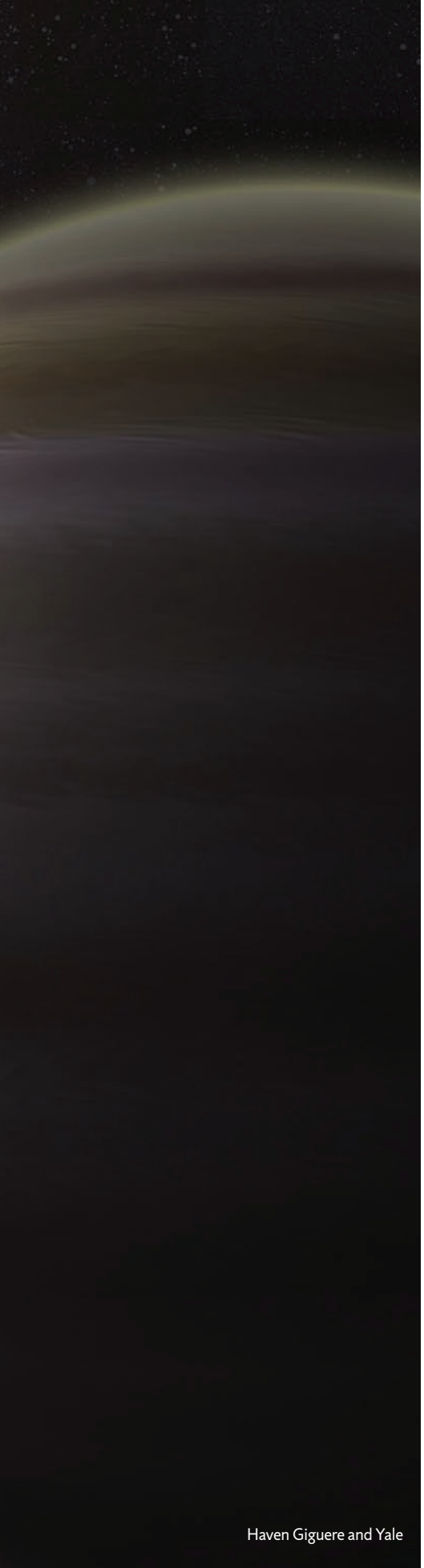
The project's success is impressive but scientists have stressed there is a long way to go before complete replication can be realised. For example, we are still a long way from prostheses that relay sensory information the way a human body does.

Rex will be on display at the Science Museum until 11 March, before jetting off to the Smithsonian Museum in Washington DC.

JESSICA LOWRIE

Dave King, Channel 4





Haven Giguere and Yale

WE'RE SCIENTISTS, ONE AND ALL

Citizen science is becoming an extremely popular method of data analysis. ***Arianna Sorba*** *gets excited about the results.*

For centuries, scientific research was conducted almost exclusively by an elite few. Hidden away from the general public, determined individuals spent their entire lives looking up telescopes or down microscopes, observing and calculating in an attempt to understand our mysterious universe. Ordinary men and women were kept mostly in the dark about such experiments, until some major discovery was made – and suddenly the scientists would get chatty. But now a new age is dawning for scientific research. And it involves everyone.

'Citizen science' is the term used to describe a revolutionary new way of analysing data. The premise is simple: get lots and lots of people to look at something, and a few of them are bound to spot something special. Advances in technology mean that, especially in fields like astronomy, huge volumes of experimental data can be gathered at a phenomenal rate, but the computing power available to analyse it all doesn't match up. Meanwhile, across the globe, millions of people are online, looking for ways to spend their time. Ordinary people who, regardless of their scientific background, have that magnificent skill that computers can't master – pattern recognition. As it turns out, this human capability, of finding order out of chaos, noticing signals that are just a little bit unusual, suits an extraordinarily large number of scientific projects; from classifying bat calls to searching images of tissues for cancer cells.

Planet Hunters is one such project and its business is booming. Initially set up at Yale University in 2010, there are now over 200,000 people from all over the world involved in the project. Volunteers are asked to take a look at the 'light curves' of the thousands of stars recorded by the Kepler satellite telescope, and search for the dips or changes in intensity that are the tell-tale signs of orbiting exoplanets. After enough people have flared up a particular star, the Planet Hunters team take another look at it with the Keck telescope in Hawaii, and try to make further measurements of quantities like velocity and mass of the possible planet, in order to figure out what's going on.

The citizen science approach suited this kind of research perfectly and the team's first major success came just a few months ago. In October 2012, the planet hunters discovered their very first exoplanet. Named PH1, after the project, the individual volunteers who first spotted the unusual light signal were even made co-authors of the paper, submitted to the *Astrophysical Journal*, which detailed its discovery. Three more research papers have also been submitted that detail the overall success on the project. 2013 has brought yet more data, better software, and new possibilities of discovery for the team. "But the entire goal, let's be clear, of looking for exoplanets, is not finding exoplanets," says Debra Fischer, a founder of the Planet Hunters project. "We want to find life."

What makes projects like these so successful is not just the amazing processing power of human collaboration. They are also, by their very nature, outreach projects. Ordinary people with perhaps no scientific background are becoming involved, educated, and above all, excited, by some tiny aspect of all that science has to offer, be it the light from stars or the details of the ocean floor. Anyone can be a citizen scientist. These projects let people know, science is not just for men in laboratories – it's for everyone. ■

3D PRINTERS:

USEFUL, CONVENIENT... AND DANGEROUS?

Rapidly gaining popularity around the world, 3D printers are showing the potential to instigate a revolution in home manufacturing. But ***Rosemary Peters*** *asks, do they have inherent dangers?*

From knee replacements to chocolate bars; from jewellery to cars; when it comes to 3D printing, if you can design it, you can print it.

Over the last 10 years, additive manufacturing, or '3D printing' as it has become more affectionately known, has begun to step out of the manufacturing world and take up residence in many people's homes. As 3D printers trek across the globe in various forms and sizes, the printing process itself remains the same: an object is created by laying down thin, successive layers of material such as glass, polymers, metal, plastics or ceramics.

3D printing has become extremely popular with those with a do-it-yourself mentality. In fact, 3D printing enthusiasts believe that in the next few years, instead of running to the shops for a household item, you'll simply design the object yourself, or download a template file, then print it at home. Printers designed to be used at home, like the 'Makerbot' or 'RepRap', are already commercially available.

Though it may seem premature to suggest that 3D printers will be in every household or business in a few years' time – printer prices currently range from £300 to £15,000 – one fact remains: 3D printing is quickly gaining in popularity. According to a survey by the *Journal of Peer Production* in 2012, the 3D printing community has grown at a rate of 20–40% every year since 2005. In a recent article about the 3D printer phenomenon, the *New York Times* noted that "their rise has been compared to that of personal computers in the 1980s."

> "PEOPLE ARE CAPABLE OF IMAGINING SOME PRETTY DANGEROUS (EVEN ILLEGAL) THINGS"

As the number of 3D printers grows, it is likely that so too will the number of digital design files being uploaded to open source websites like Thingiverse and Google's 3D Warehouse. As users continue to upload designs to these sites, the chances for patent and copyright infringement will also rise, believes Dr Phill Dickens, Professor of Manufacturing Technology at Loughborough University. "In the end, who owns the intellectual property?" Dickens asked a room of students and professors at an Imperial College lecture. "Furthermore, who is responsible if something goes wrong? There are lots of business and social issues that we just haven't worked out yet because we haven't really thought about it very much – but we will have to soon."

The question of who owns the design for a 3D-printed object may not, however, be as thorny an issue as what the object is. While the vast majority of home 3D printing is currently being used to design and build innocuous items like kettle lids, manufacturers celebrate the fact that the only limit is your imagination. And it's this 'limit' of what can be printed that underscores a potential issue, because people are capable of imagining some pretty dangerous (even illegal) items.

One example that has recently gained international attention is the 3D printing of gun parts. Regardless of the legal status of guns, it goes without saying that a gun in the wrong hands can be very dangerous. The idea that 3D printing could one day enable anyone to download the design files needed to print the pieces and assemble a gun at home is a prospect that deserves attention.

In July 2012, Michael Guslick, posting under the name HaveBlue on a gun forum called ar15.com, successfully designed, printed and tested the lower receiver of a .22 calibre AR-15 assault rifle made out of ABS plastic (the plastic used to make Lego) using a Stratasys 3D printer. The lower receiver is the body of the gun and is the most regulated of gun components.

"It's had over 200 rounds of .22 through it so far and [it] runs great!" Guslick posted

under photos of a gun with his lower receiver.

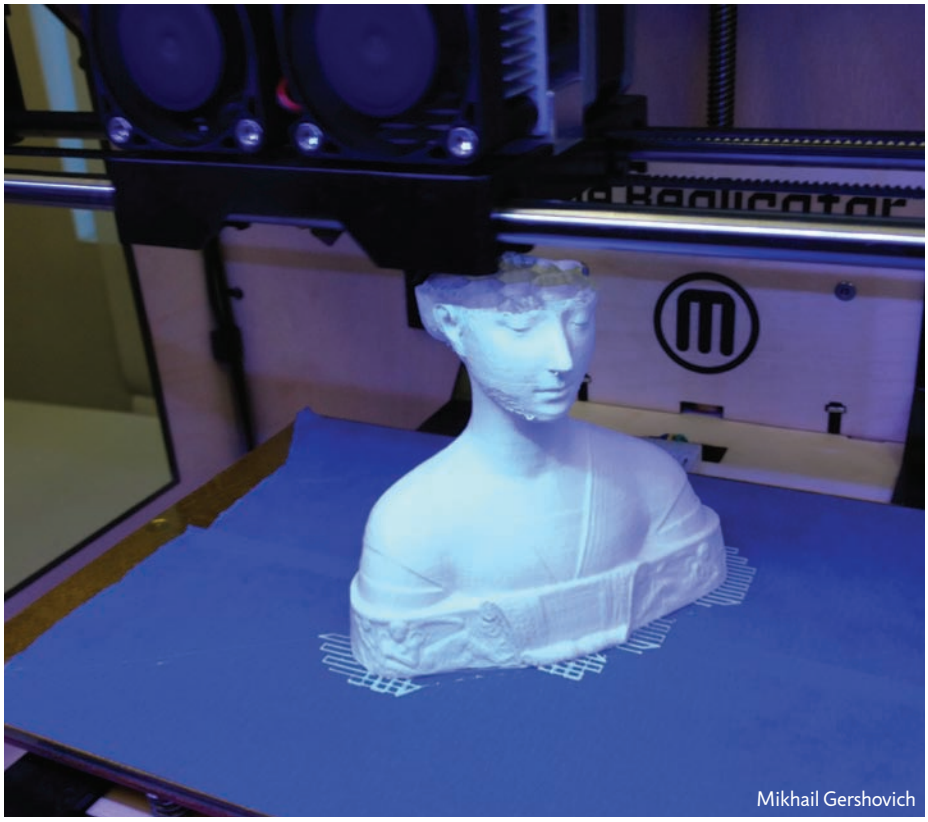
Guslick uploaded the design files for the lower receiver to Thingiverse. Until a website overhaul in late December, Guslick's design shared database space with hundreds of files for firearm parts of several semiautomatic rifles and handguns.

These sorts of files have started to gain even more attention recently as the designs Guslick released are for the same AR-15 assault rifle that was used by Adam Lanza in December 2012 to massacre 20 children and eight adults in Newton, Connecticut, USA. Furthermore, the printable gun components have stirred up controversy because when these parts are combined with gun parts that can be purchased online, a person might be able to put together a lethal weapon without having to cross any legal barriers or even need identification. Moreover, these guns could be made undetectable by security scanners, especially if main components like the lower receiver are made of plastic.

Cody Wilson, a law student from the University of Texas, set up Defense Distributed, a group with one main objective: to produce and publish a design file for a completely 3D printable gun. Wilson calls this gun-in-progress a "Wiki Weapon" and is currently working with a team to make a functioning magazine for the gun.

Such cases of people starting to print their own guns have put lawmakers and law enforcement agents in a tough position. While law enforcement agencies can potentially work with websites such as Thingiverse to have them self-regulate designs that appear on their site, they cannot regulate everything that appears on the Internet. For example, after Thingiverse removed files for firearm pieces from its website, Defense Distributed started DEFCAD.org, a website dedicated to hosting files for printing firearms, rifles, pistols and grenades. And no amount of regulation can prevent a person from designing and printing pieces of guns on their own 3D printer.

There are a lot of benefits from 3D printing's rising popularity. There are also bound to be some tough issues, like gun regulation, that will arise. These are problems that may be easiest to grapple with now – before the dream of having a 3D printer in every home is made a reality. ■


Mikhail Gershovich

BIOHACKERS, UNMASKED

Josh Howgego and Keeren Flora encounter some 'citizen scientists' in their natural environment: a bunker in Hoxton.

Raphael Kim

On a cold Wednesday evening in January, we showed up at Hoxton station and ventured out to look for 'unit 24' in the complex of industrial buildings across the road. The sounds of night-time in East London were all around us. When we found our destination, Cremer Business Centre, it looked like a fairly run-down sort of place. A security guard passed by and we asked him which way to unit 24. "Hackspace?" he asked. We nodded, and he pointed us to a door with peeling paint marked 'fire escape'. "Take the stairs to level two," he said.

Up the stairs, we emerged onto an unenclosed walkway with a series of green double doors set along it at intervals. Glancing over the handrail to our right, we saw a yard with an assortment of rubbish and bits of rotting machinery lying abandoned in it. Three doors along, we found the place; the entrance marked with a bright red home-made door bell. It spoke something in electronic tones to us when we pressed it, but almost immediately a bearded man in a Slayer hoodie opened the door and warmly invited us in.

We had arrived at London Hackspace, a place that seems to have captured something of the anti-capitalist zeitgeist of the twenty-tens. The space houses a community of 'hackers', who work on technological projects in their spare time. It started out with computers, but the do-it-yourself synthetic biology section – the 'biohackers' – have recently been growing in popularity. The popularity of events like the annual iGEM (International Genetically Engineered Machine) competition also shows how DIY synthetic biology is increasingly fashionable. The competition to design a useful machine using synthetic biology attracted165 teams in 2011, including some DIY biologists. So a small but increasing section of the public likes doing synthetic biology in their spare time. But who are they, and what was it that attracted them to this unrefined lock-up in Hoxton? We were there to find out.

When we said that, yes, we were here for the biohackers meeting, Slayer Hoodie pointed us to a back office where we joined the rest of the meeting. In total there were about eleven other new recruits sitting in the room (see 'Meet the Biohackers'), and only three fully enrolled biohackers. All were very friendly and we were soon invited on a tour of the building. Most of the space was given over to the community's other hacking activities: to computing and engineering projects. Members pay a subscription fee that varies depending on what sorts of activities they want to do. The biohackers have just one small, windowless room for a laboratory. It had enough room for three people to stand in, shoulder to shoulder, and it was lit with an artificially bright white light to aid visibility. "It used to be a toilet when we first got the site," explained Will, one of the few regulars. "But that's a bonus really, because it's got a sink. That is something we need."

Space is not the only thing that the biohackers lack. They also have few instruments. Their centrifuge was bought for £100 with pooled money. Other bits and pieces, like their electrophoresis kit, were donated, or brought along by one of the members who is an academic biologist at a London university.

Raphael Kim

They also have a limited supply of reagents; their biggest expense – except perhaps for sterile pipette tips. They use an enzyme called *Taq* to run polymerase chain reaction (PCR) protocols that replicate DNA, but they can't afford to run such things too often. The hackers spent quite a while debating whether to run a demo PCR for us newbies, since it would mean completely using up their remaining supplies of *Taq*.

Richard, an old-hand in the group, told us about his vision for the future. At the moment the hackers are still teaching themselves the basics, he said: "It's a matter of personal interest for us". But he hopes one day they will be able to do some full-on synthetic biology. "I would like for us to be self-sustaining," he said. "To be able to bio-synthesise all our own reagents, so we don't have to spend money buying them from chemical companies."

Once we had seen the basics we began to feel a bit redundant. We had to rotate out of the tiny lab so all the potential new members could take turns observing. The members spoke longingly of the Hackspace's plans to buy another property nearby, about twice the size of the current one, where the biohackers hope they can glean a little more bench space.

For the time being the biohackers are limited in space and funds, but with new members and a new building on the horizon, that could soon change. It is our fellow new recruits who will shape this future. Who knows what they might be capable of soon? ■

MEET THE BIOHACKERS

Some names have been changed to protect the biohackers' privacy.

Raphael

Studied Design Interactions at the Royal College of Art, a course that takes technology (whether it be biotechnology, computing, or electronics) and uses innovative design to communicate its implications for our society. During his course Raphael set up an impromptu lab in his studio and used whatever equipment was to hand to culture bacteria from the studio floor, in a project he called 'Tangible'. He is now a regular member of biohackers looking to develop his next project.

Will

Regular member of 10 months. Before that Will had not done any science since school. Since then he has learnt the principles of molecular biology and how to run a PCR. Small steps, perhaps, by Imperial standards, but pretty impressive for someone whose last experience of science was at GCSE level.

Jacqueline

An art student from London College of Communication. A newbie at Biohackers, she wants to use the skills of the members to help her develop a piece of 'bio-art'. When we met, she was keen on the idea of growing patterns of bacteria on giant pieces on agar. The work would slowly decay away as the bacteria colonies grow.

Richard

Regular Biohacker Richard has the most molecular biology experience of the group, plus a vision for the future of the Biohackers. Spearheading the plans to upgrade to a larger lab, he also hopes to make the lab self sufficient by developing bacteria to bio-synthesise some of the reagents they need.

Louise

A recent MSc graduate currently volunteering in a lab in London. She was attracted to the idea of coming up with her own research ideas and working on anything she liked. Institutional stresses can often stifle such "blue sky" research, in her experience.

SELF-EXPERIMENTING SCIENTISTS

Some scientists have gone to dramatic lengths to test their theories. ***Christopher Yates*** *discusses what motivates these scientists to become their own experimental guinea pigs.*

What do HG Wells's Invisible Man, Spider-Man's foe The Lizard and Sir Isaac Newton all have in common? Despite sounding like the start of a bad joke, there is a serious answer – self-experimentation.

Sir Isaac Newton is famous for his work on gravity and mathematics, but he was also interested in optics and the workings of the eye. In one of the earliest recorded examples of self-experimentation, he "tooke a bodkin [sewing needle] and put it betwixt my eye and ye bone as neare to ye backside of my eye as I could." It's unclear exactly what he hoped to achieve with this, but it goes without saying that this shouldn't be tried at home!

> STUBBINS FFIRTH BREATHED IN FUMES FROM THE VOMIT OF INFECTED PATIENTS, SMEARED IT INTO CUTS IN HIS SKIN, POURED IT INTO HIS EYES AND EVEN DRANK IT

In medical sciences, one way of proving that a disease is caused by a certain virus is to infect an animal with that virus and see if it develops the disease. Alternatively, if there are no animals available, you could use yourself. At least, that seems to have been the mentality of some scientists, such as the wonderfully named Stubbins Ffirth. He was determined to prove his theory that yellow fever could not be transmitted between people. He breathed in fumes from the vomit of infected patients, smeared it into cuts in his skin, poured it into his eyes and even drank it. Shockingly, despite being wrong, he didn't develop yellow fever, perhaps because the patients were past the infectious stage of the disease.

In 1984, Barry Marshall also went to great lengths to investigate a disease. Working as a gastroenterologist at Royal Perth Hospital, Australia, Marshall was investigating the cause of stomach ulcers. At the time, most people believed that ulcers were caused by stress or spicy food, and anti-ulcer drugs, which only treated the symptoms, were a real money-spinner for pharmaceutical companies.

However Marshall and his co-worker Robin Warren believed it was in fact a bacterium called *Helicobacter pylori (H. pylori)* that caused these ulcers, as well as gastritis (stomach inflammation). They extracted *H. pylori* bacteria from the stomachs of ulcer sufferers and then grew cultures of the bacterium to use in tests. Unfortunately, they were unable to infect piglets with the bacteria to prove their theory, so Marshall took the direct approach and swallowed a sample of *H. pylori* himself. Within three days, he was nauseous. An examination just eight days after his noxious drink showed he had developed gastritis. This discovery was fantastic news as it meant gastritis and ulcers could be cured simply using antibiotics.

It isn't just medical doctors who do weird and wonderful things to themselves in the name of science. In 2002, Kevin Warwick, Professor of Cybernetics at the University of Reading, had an implant inserted into a nerve in his arm. This implant enabled electronic signals to be sent between him and a computer. When the computer was connected to a robotic arm, he was able to control its movement, even when the arm was the other side of the Atlantic Ocean. In a later experiment, his wife also had electrodes inserted and they were able to send signals between one another in a form of non-verbal, electronic communication.

> KEVIN WARWICK HAD AN IMPLANT INSERTED INTO HIS ARM MAKING HIM ABLE TO CONTROL A ROBOTIC ARM – EVEN WHEN THE ARM WAS THE OTHER SIDE OF THE ATLANTIC OCEAN


JD Hancock

Engineer Kevin Warwick has experimented on himself, trying to become the first cyborg

Warwick views these experiments as the first step towards creating cyborgs – humans with electronic improvements. He envisages implants allowing communication with computers and each other, potentially giving humans amazing new abilities.

So why do people submit themselves to these experiments? In his autobiography – *I, Cyborg* – Kevin Warwick describes his emotions going into the experiment as a mixture of fear and excitement, but also talks about his strong desire to be the first person to take the plunge and become a cyborg. Others, such as Stubbins Ffirth, have done it to prove a point, whereas Barry Marshall did it because he needed experiments on a human in order to make people pay attention and ultimately help develop effective treatments.

Ralph Steinman had a more pressing reason for experimenting on himself. In the 1970s, he discovered dendritic cells, which are involved in recognition and targeting of infections for attack by the immune system. Because of the important role of dendritic cells in aiming the immune system, experimental vaccines have been developed which cause them to target cancer cells or cells infected with HIV.

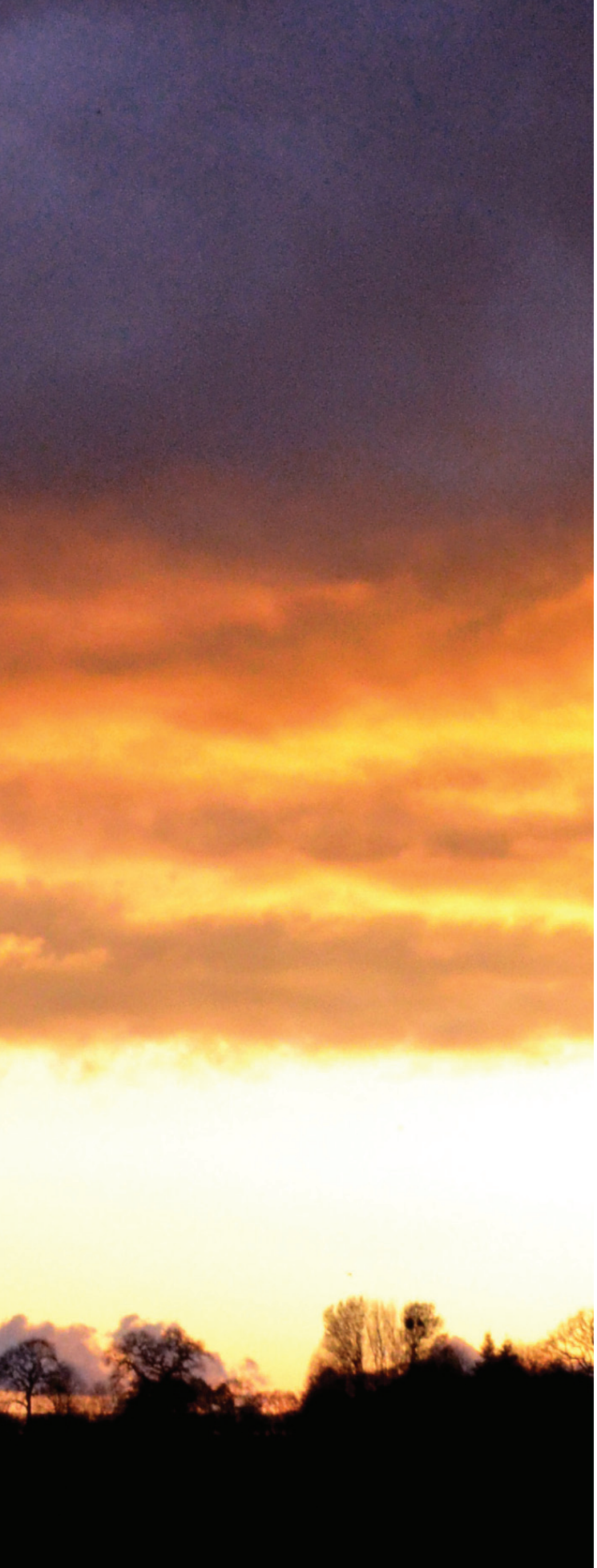
In 2007, Steinman was diagnosed with pancreatic cancer. The survival rate for pancreatic cancer is very low, with just 20% of patients surviving for a year after diagnosis. However, he was able to use the experimental vaccines developed by his colleagues and survived for a further four years. Sadly, he died in September 2011, just three days before he was awarded the Nobel Prize.

Although it makes for exciting science, there are a few problems with self-experimentation. In addition to the many legal and ethical issues if the experiment goes wrong, results in only one patient could be down to chance. This is why medical experiments are usually performed on larger groups of people, because by repeating the experiment on a large group of people any differences are more likely to be relevant.

Another problem is due to the placebo effect. When developing a drug, it is compared to either a sugar-pill placebo or the best current alternative. Subjects are randomly divided into two groups and assigned a treatment. If the subject knows they have not been given the drug, they are less likely to show effects than someone given the placebo without knowing. Because of this, experiments are usually 'double-blind', with neither the experimenter nor the subject knowing who is in each group. If the experimenter is also the subject, they will know exactly what they are taking. On the other hand, a self-experiment may help convince people to allow a larger-scale experiment to take place.

Throughout history, many scientists have put their well-being on the line for the greater good. Even in the modern world, where most experiments on humans are carried out on large groups, there is often a need for someone to go first. Who should that be? If a scientist isn't willing to put themselves through an experiment, perhaps they should think twice about asking others to do the same. ■

"IN ADDITION TO THE MANY LEGAL AND ETHICAL ISSUES IF THE EXPERIMENT GOES WRONG, RESULTS IN ONLY ONE PATIENT COULD BE DOWN TO CHANCE"



SCIENCE BEHIND THE PHOTO

At 76 metres in diameter, the Lovell Telescope at Jodrell Bank can be seen for miles around the Cheshire plains. This was once the largest steerable radio telescope in the world and while it has now dropped to third place, it is still impressive enough for Placebo to film a music video there.

For centuries, astronomers have probed the heavens with ever more complex telescopes. A rule of thumb is "the larger the telescope, the better", since a larger sensor can record images to greater levels of detail.

The Lovell Telescope does not detect visible light, but instead receives radio wavelengths, making it an obvious choice during the early days of space exploration. The dish tracked Sputnik – the first artificial satellite – and during the 'Space Race' America used the dish for their own space projects.

But Jodrell Bank hasn't just been used to detect man-made signals; many important astronomical discoveries have been made by observing the radio spectrum. The observation of quasi-stellar objects, or quasars, was one such discovery in which the Lovell Telescope was instrumental. To make this observation, data from many radio telescopes at the Jodrell Bank site were combined, providing a greater resolution image.

Although the Lovell Telescope is no longer the largest in the world, its popularity is resurging. By employing methods similar to those used to discover quasars, Lovell will be linked with radio receivers from around the world to create the so-called Square Kilometre Array (SKA). This combined data essentially allows scientists to build a radio telescope with a massive area, providing even clearer images of the cosmos. At over fifty years old, the inception of the SKA project means Jodrell Bank can remain useful for many more years to come. ■

PHOTO AND TEXT BY ANDY ROAST

SCIENTIST OR TERRORIST?

Our world has become all too aware of the threat of terrorism. ***Conor McKeever*** *asks, will the rise of the nanny state restrict our potential to invent?*

Imperial College

Picture the scene: you glance out of your kitchen window to see your neighbour making his way towards his shed. He opens the door, turns on a light and instantly a rudimentary laboratory is revealed. On a table, a jumble of wires, powders and liquids lie in anticipation and even from this distance, the ominous icon of a biohazard symbol shimmers in the fluorescent light. He returns into view, clutching a timer; its display casts a green pall across his features.

Should you call the police?

Just 50 years ago, this description might have conjured up the idea of a DIY scientist at work in his garden shed, but in a post-9/11 world, it's much more likely the man would be accused of terrorism. This dramatic change in attitude has led to increasingly restrictive laws governing chemicals and scientific equipment. In Texas, for example, it's now necessary to have a licence just to purchase beakers and conical flasks. While such barriers might simply inconvenience someone determined to cause havoc, they will be incredibly effective at discouraging potential amateur scientists.

An obvious example is the rise and fall of the home chemistry set. At their peak in the mid-20th century, chemistry sets could include all manner of chemicals, from sodium and lithium, to sulphur and potassium nitrate. Now the closest children can get to real chemistry is a set designed to make sweets or perfumes; sodium and lithium are restricted due to their use in methamphetamine production, while potassium nitrate and sulphur can be used to make explosives. If this trend continues, children will become so far removed from science that they will lose all interest in it.

In fact, evidence suggests this change is already happening. In 2000, the *Journal of Chemical Education* published a study into 'chemistry anxiety' amongst American high school students. Having so little hands-on scientific experience, huge numbers of children reported having a fear of "chemicals" and "lighting the Bunsen burner". This apparent chemophobia translates into less scientifically-literate university students; one lecturer suggested his students had become "more passive" and "less versatile in the lab" over the years. Some potential consequences could also go unreported; many famous scientists – among them Mario Molina, who probed the link between CFCs and the ozone hole – were inspired to take up science by their home chemistry sets.

Of course, there is a legitimate element of health and safety in these choices; most people would agree that the radioactive uranium powder once found in chemistry sets should continue to be banned. And this can extend to adult DIY scientists: some restrictions are necessary to keep them (and the surrounding public) safe. In 2011, a man named Paul Moran was jailed after he accidentally set light to his block of flats; he had been trying to turn his faeces into gold when his experiment caught light.

But at the same time we must be careful not to stifle a source of innovation. We owe much of our modern world to DIY scientists.

Take Charles Goodyear. He spent over a decade of his life working in his kitchen, trying to improve on the process for making rubber; brittle in cold weather and sticky in the heat, the material was unsuitable for any large-scale applications. But following Goodyear's discovery of vulcanization, the success of the automobile industry, today worth over $5bn annually, was possible.

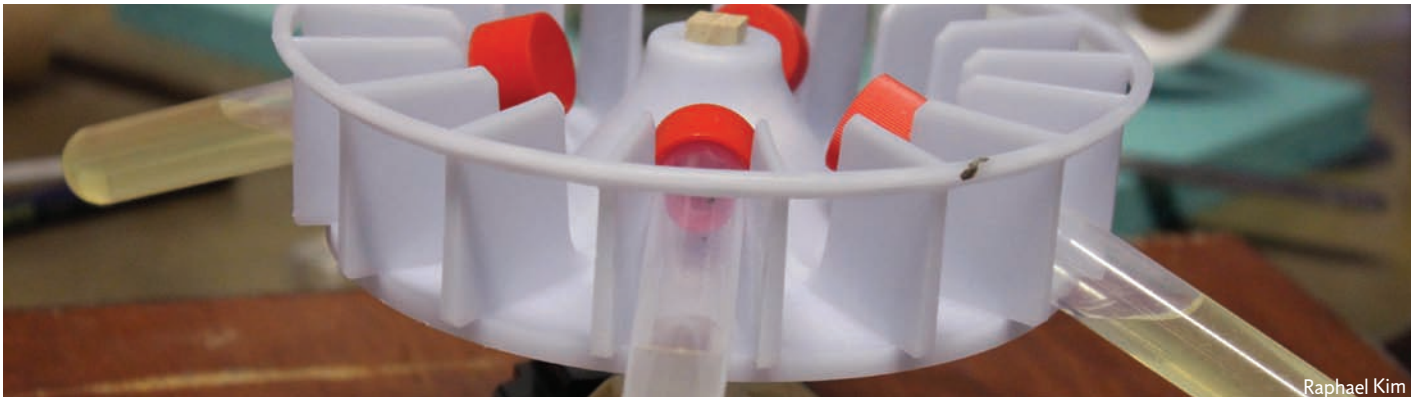
Or James Spangler, a janitor in an Ohio department store, who was fed up of choking whenever he used his mechanised carpet sweeper. He attached a fan, and a pillowcase as a dust collector, and invented the modern-day vacuum cleaner.

Had regulations been much stricter, these men might not have made the innovations they did, changing the world we know entirely. But denying access to equipment can also have a worrying knock-on effect: it implies that DIY scientists are suspicious and untrustworthy – a message that causes problems for even the most law-abiding scientists.

In August 2008, the fire brigade was called to the house of Victor Deeb, a DIY scientist in a small town in Massachusetts. Although the fire was quickly extinguished, when the firemen examined the rest of his house, they immediately called for backup. In Deeb's basement they had found hundreds of bottles of chemicals and suspected the worst. In fact, he had been developing an alternative to BPA – a chemical, commonly found in beverage cans, that's suspected of causing hormonal disruption in humans – and none of his chemicals were even poisonous. Despite this, the police launched an investigation and confiscated his work. When they were unable to find anything incriminating, they not only left his notes out in the rain, but also proceeded to sue him for the cost of the removal.

If regulations continue as they are, incidents like this are only going to become more common. The Internet has created a surge in people joining DIY science communities, with groups like biohackers (amateur synthetic biologists) and makers (engineering and technology enthusiasts) suddenly able to collaborate on a global scale. This makes the call for a change in strategy ever more urgent. We can't have millions of people unwittingly become criminals because they want a better understanding of chemistry.

A final mention should go to perhaps the most important DIY scientist of all: Edward Jenner. His interest in a variety of sciences, from geology to ornithology, could merit him a place amongst the modern day DIY scientists, but it was his contribution to medicine that made him remarkable. He pioneered the concept of vaccination, a process that has since saved millions of lives, after noticing that milkmaids who caught cowpox were generally immune to smallpox. Despite his medical training, this idea was not developed in a lab, or purely through theoretical discussions with other intellectuals (in fact, many of his peers ignored or ridiculed his idea), but in his village surgery. Jenner's DIY science has made the world an immeasurably better place – surely that's worth the risk. ■



Raphael Kim

TOP 6 'CREATIVE' DIY INVENTIONS

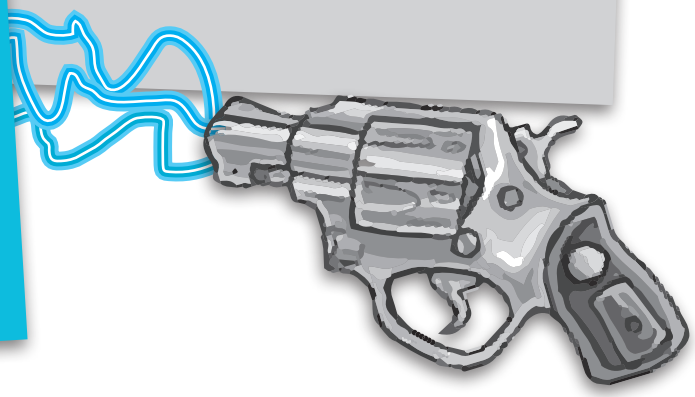
There's no doubting the creative ingenuity and innovative resourcefulness that goes into Do-It-Yourself science projects. However, while many of the home-built technologies are designed with clear practical applications in mind, there are some innovators who prefer to let their creative sides run wild. Here are six of some of the more adventurous designs, crafted by individuals who refuse to be held back by such boring norms as 'functionality' or 'practicality'. By ***Alex Gwyther*** *and* ***Tom Bragg.***

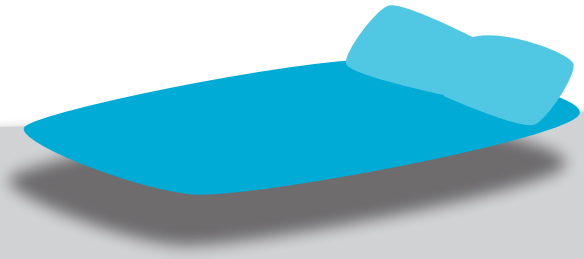
THE CHEESE-CONTROLLED CAR

Conor O'Neill, a particularly resourceful father, was determined to give his children a memorable Christmas present. Starting with an i-Racer – a Bluetooth-equipped toy car that can be controlled by an Android phone – O'Neill toiled through some tricky coding to link up his Raspberry Pi computer as a controller. Not stopping there, the determined dad incorporated a MaKey MaKey invention kit: a system that allows the user to convert everyday objects into inputs for a computing device. Thus the cheese-controlled car was born: five pieces of cheese acting as buttons, connected to a Raspberry Pi, controlling a car over Bluetooth. And as if cheese wasn't enough, O'Neill was also able to use grapes and a Barbie doll as controlling mechanisms.

TESLA GUN

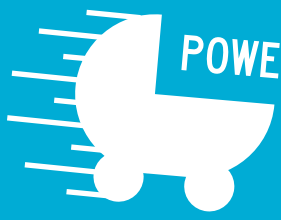
By using mainly scavenged parts, Robert Flickenger managed to construct his own fully-functional 20,000-volt Tesla coil gun for only £500. He created the body of the gun by melting down aluminium scrap metal and pouring it into a mould of a plastic Nerf toy gun. The current, provided by a lithium ion battery from an electric screwdriver, is repeatedly doubled inside the gun using a transformer from an old television and additional circuitry, while a fan from an old computer server helps to cool the spark gap. He proudly debuted the lightning-blasting gun at his wedding reception.





LEVITATING BED

Reddit user 'mememetatata' built himself an incredible floating bed from a simple wooden frame, hockey puck-sized neodymium super magnets and steel cables to hold the bed in place. Neodymium is a rare earth metal and the strongest permanent magnet known; apparently, the hardest part of the build was prying apart two magnets that had become stuck together during shipping. Although this is a fully functioning bed, it is made impractical by its maximum weight of 110 kg (so only enough for one person) and its obvious exclusivity to users devoid of any piercings.

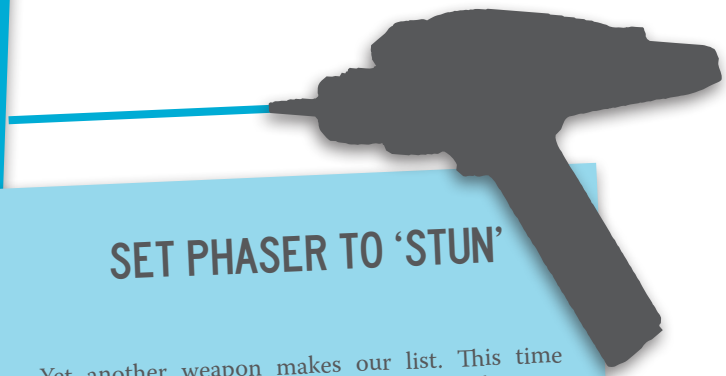


POWER PRAM

Father-to-be Colin Furze turned his attention to baby transportation as soon as he discovered his girlfriend was pregnant. The result was a petrol-powered, twin-exhaust baby carriage that reached 53 mph at a local racetrack: the first world record of its kind. Built around a 125 cc motorbike engine, the pram comes with a built-in wheeled platform and handlebar controls for the parent, and a steel roll cage cot for the child. But it's only housed plastic dolls so far: Furze says his new-born son Jake won't be included in any record-breaking baby rallying just yet.

MACHETE-SHOOTING SLINGSHOT

Jörg Sprave is a slingshot enthusiast like no other, creating some of the deadliest-looking contraptions you never could have dreamed of. His masterpiece: a slingshot that fires machetes. Custom made in the shape of a rifle, it sports a trigger for firing the weapon, and an exceptionally strong rubber band to hold the modified machetes in place. Although this mega-weapon does indeed work – driving the machete up to its hilt in the target – short of a zombie-apocalypse there isn't much practical use for it. Not to mention its unwieldy ammunition makes it both slow to reload and very expensive. Unless you plan on retrieving a lot of machetes out of zombie corpses.



SET PHASER TO 'STUN'

Yet another weapon makes our list. This time a handheld *Star Trek* phaser gun that shoots a continuous blue laser beam from the barrel, and even imitates the oscillating, futuristic noise when fired. To build it, the inventor picked up a PlayStation 3 laser assembly and wired it into a *Star Trek* plastic phaser toy. He had to exchange the AA battery holder with a 9-volt holder to deliver maximum charge to the Blu-ray diode. Although the sound comes from the in-built speakers of the original toy, the new beam can blast through the tough membrane of an inflated balloon at the distance of a garage length. Cardassians beware!

THE SECRET LIFE OF STARLITE

***Nick Kennedy** looks back on the remarkable story of the mysterious Starlite, and how we may never know its full potential.*

In 1993, an episode of *Tomorrow's World* (the once popular BBC science and technology television programme) opened with a close-up of an intense blue flame heating an egg. The welding torch was working hard against the egg's shell, producing temperatures of 1200 °C, yet the egg appears normal and unscorched. The presenter leaves it under the torch's glare for a few more minutes, then extinguishes the flame and picks the egg up. He flashes us a knowing smile, and cracks it into a glass bowl. It is completely raw.

The egg had been coated in Starlite, a complex polymer of 21 ingredients that is incredibly resistant to heat, even surviving nuclear blasts and temperatures of 10,000 °C. It is lightweight, releases no toxic fumes when heated, and can come as a liquid, paste, or solid moulded into any form. In short, it is remarkable. But the truly remarkable thing about Starlite is its discovery.

> "THE FORMER HAIRDRESSER FROM HARTLEPOOL ACCOMPLISHED SOMETHING MILITARY ORGANISATIONS HAD SPENT MANY YEARS AND MILLIONS OF POUNDS TRYING TO CREATE"

Maurice Ward invented Starlite over 25 years ago but neither went to university nor had any formal scientific training. He'd once worked for a chemical company, but only as a forklift truck driver, and for the majority of his life he made a living as a hairdresser in a quiet Yorkshire town. Yet he was an inventor. In his spare time he experimented with chemicals in his workshop to develop new hair dyes.

Then, on 22 August 1985, the Manchester flight disaster occurred. As a Corfu-bound plane prepared for take-off its engine caught fire and 55 passengers died. Not from burns, but from inhaling toxic smoke. At that time aeroplanes were not required to have fireproof panels. Ward felt that such a disaster could have been avoided and this prompted him to create a fire-resistant plastic that would not release toxic fumes when burned.

By Easter the following year, he hit upon his first major success and took the new material to be tested by a friend who worked in a chemical factory. It withstood their tests, but the factory boss did not want to be bothered and told Ward to leave. Disheartened, Ward threw his creation in a cupboard where it remained for several years. Nevertheless, he continued to concoct complex compounds in a food blender and test them under a blowtorch flame. Eventually, Starlite was born.

But without a science degree, Ward struggled to get people to take him seriously. So he began to demonstrate the wonders of Starlite himself. *Tomorrow's World* noticed Ward's enthusiasm and his appearance on the show became a pivotal point in Starlite's story. Starlite quickly gained the attention of the public and scientific scepticism began to wane. The former hairdresser from Hartlepool had accomplished something military organisations had spent many years and millions of pounds trying to create: a non-toxic plastic that did not burn. Soon, however, Starlite would exceed even its creator's expectations.

The Atomic Weapons Establishment in the UK tested its resistance to extreme heat, which the polymer survived unscathed. NATO's test centre then exposed it to simulated nuclear blasts of 70 kilocalorie forces (the equivalent of 70 Hiroshima explosions).

Ward was bombarded with offers from companies wanting to buy Starlite, but he became more and more reluctant to let the recipe go. He refused to sell it to Boeing for less than a multi-million pound sum. He refused to get it patented in fear of someone stealing the recipe. He refused to send further samples away to be tested. Sadly, in 2011, with Starlite's composition very much still a mystery, Maurice Ward died.

Several years later and still nobody has come forward demonstrating knowledge of Starlite's fabrication process. Although a tribute to the power of DIY scientists, it is a sad realisation that the secrets of this potentially revolutionary material may have died with its creator. ■

FRAN SCOTT: DIY SCIENTIST

*Can science communication benefit from the DIY revolution? **Julie Gould** asks unconventional scientist Fran Scott if the two fields are really all that different.*

When I met Fran Scott and picked small wooden splinters from her jumper, I could tell she wasn't your ordinary science communicator. She develops scientific demonstration for various outlets including TV, radio and books. Simply put, she makes big things that go BANG, SPLASH or ZZAPPP!

But these demonstrations don't just make noises; they have an underlying message to them.

Doing science yourself is something that Fran is passionate about. From a young age, she used to try to replicate demonstrations from science books, but this didn't always go according to plan: "It would say do this and do that, and you do exactly as it said, and it wouldn't work," she explains. "And I took it as 'I can't do that', rather than 'it's not working.'"

So now Fran has taken it into her own hands to build new demos, and redesign the old ones so that they work for everyone. I was curious to see if there were any similarities between making things that go bang and designing a scientific experiment.

A scientific experiment follows several steps. First there's the theory, then the predictions based on that theory. Following this, data sets are collected and analysed before conclusions are made, and finally the results are peer-reviewed and published.

In Fran's case, she has been designing a Van de Graaff electrostatic generator. The Van de Graaff, with its distinctive metal dome, is a common sight in labs and classrooms. However this is one you can produce with everyday materials that "really require you to understand the science before you can make it work."

So, theory: check!

Step two is about making predictions: "I look at objects, not what they are intended for, but what they could be used for." So Fran has to be able to predict which materials would be able to do the job. And she finds most of them in her local supermarket.

The Van de Graaff contains a rubber belt running across two rollers, which need to be different materials. Fran has been working with pencils wrapped in PVC electrical tape for the top roller, and Teflon tape for the bottom roller.

The dome, which accumulates electrical charge, needs to be large, round and metallic, with a hole in the bottom. This could be made from a casserole pot, a stainless steel salad bowl, or a football wrapped in aluminium foil with a bit cut away from the bottom.

Predictions: check!

Next is assembly and testing, which comes with all the frustrations of a scientific experiment: "Nine times out of ten, they don't work," Fran says. "Or they do, but something else has gone wrong."

Data collection: check!

Once Fran has finalised her demonstrations, she 'publishes' them by demonstrating them to an audience. This could be compared to peer review: if the audience likes it, great! If not, it's back to the drawing board.

Publication: check!

These demonstrations may not be designed to discover new science, or create new technologies only available to the trained scientists. However they do allow anyone near a supermarket to have a go at some DIY science. ■


Fran Scott

CITIZEN SCIENCE DEMANDS OPEN ACCESS

***Jonny Ritson** talks to Dr Mark Mulligan about the value of crowdsourcing and the demand for open access journals.*

> MUCH RESEARCH IS PUBLICLY FUNDED, SO WHY SHOULD THE PUBLIC HAVE TO PAY ONCE FOR RESEARCH TO BE UNDERTAKEN AND AGAIN FOR ACCESS TO THE RESULTS?

Crowdsourcing has brought fresh impetus to scientific discovery both in terms of raw processing power and in public engagement. Anyone with a computer can get involved in projects ranging from mapping galaxies to logging visits to their bird feeder. What would have once been a PhD student's dreary summer of collecting raw data, is now an opportunity for anyone with a bit of spare time to get involved, even in a small way, with a genuine research problem.

Although the public is more engaged with the acquisition of data they still face a problem in getting to the results; one-off access to a single peer-reviewed journal article costs around $25. Considering much scientific research is publicly funded, and the peer review process is conducted gratis by researchers, many academics are calling loudly for citizens to be freed from the knowledge hegemony of the major journals. The public should not have to pay once for research to be undertaken and then again for it to be communicated to them; so the argument goes. With this increasing demand there is perhaps a chance to re-mould the publishing process and remove the accusations of bias and manipulation that have dogged the traditional model of journals as 'gatekeepers' to scientific knowledge.

These are certainly issues that need addressing. Numerous reviews in journals such as the *British Medical Journal* have found systemic evidence of publication bias, and with funding sources becoming increasingly scarce and dependent on visible outcomes, scientists are turning to less traditional and more open methods of publicising themselves. A blog and a Twitter profile can generate far more publicity for a department in the public eye than journal articles that will never be read.

> ANYONE WITH A COMPUTER CAN GET INVOLVED IN PROJECTS RANGING FROM MAPPING GALAXIES TO LOGGING VISITS TO THEIR BIRD FEEDER

So could open access really challenge traditional publishing or will the respectability and prestige of *Nature* and *Science* always dominate? And how useful is crowdsourcing – are there any disadvantages to entrusting research to these new 'citizen scientists'? *I, Science* spoke to an expert in the field to gain some insights.

Dr Mark Mulligan is a Reader in Geography at King's College London and has used crowdsourcing on a range of projects, from digitising the locations of mines and dams, to policy support tools. He is also the founding editor of the open access e-journal *Advances in Environmental Monitoring and Modelling*. He talks here about the practicalities of using crowdsourcing, issues involving quality control as well as the future for peer review and open-access journals.

Could you outline a project where you've used crowdsourcing?

I have been involved in a number of such projects, including the development of a global database of mines using a Geo-wiki tool that we developed in Google Earth and, more recently, crowdsourcing the validation of environmental models by making them very easy to apply to real world problems at sites throughout the world.

Was there a lot of interest?

There was actually relatively little interest in the dams project. Partly because it was developed in the early days of the technology (2006) and, being based in Google Earth, was not as easy to use as it could be. Most of the 36,000 dams in the database were digitised by a group of my PhD students and myself. The web-based models are more widely used, since they solve a problem for the users by providing information for conservation, water resources and other environmental projects. We have more than 1,000 users of the Co$ting Nature ecosystem services modelling tool and the WaterWorld water resources tool. And these users – members of conservation NGOs, international development organisation, academics and students – help us to improve the associated datasets, models and systems by testing them against their own on-the-ground knowledge of the sites to which they are applied.

Did you come across any issues of quality control?

Even the specialists and dedicated PhD students developing the dams database still had to carry out a significant process of comparison and quality control. Any dataset that has more than one collector is open to differences in interpretation and thus inconsistency. Crowdsourced data cannot usually be used 'as is' but require a strong validation step.

Do you see crowdsourcing as a way to engage with the public or is it preaching to the converted?

A bit of both. There are notable successes in crowdsourcing as an engagement process. Our geodata portal provides a range of environmental datasets to a wide audience because these geographic data are visualised in Google Earth and Google Maps so that users do not have to be specialists in Geographical Information Systems in order to use and understand them. As a result we have a wide range of users, from folks at NASA through to artists and school children.

You are a founding editor of an open access journal. Do you see crowdsourcing playing more of a role in peer review in the future?

Yes I hope so. I would like to see scientific publications both more accessible to a wide range of audiences and also peer reviewed by a broad community of interested stakeholders rather than two or three anonymous reviewers. I would like to see journals evolve so that they 'publish' online all papers that they receive that pass basic editorial and communication effectiveness checks.

As it is, much research – some of which later turns out to be useful and correct – remains unpublished because it does not agree with the consensus views of the reviewers. Thus there are inbuilt disincentives on some types of innovation because of the associated difficulties in getting the work published. ■

OPEN ACCESS

FAMOUS FUNDING

Cash-strapped researchers have turned to an unusual source of income to fund their trials. ***Laurence Pope*** *asks, is this the future of science funding?*

As far as names go Ad5[CgA-E1A-miR122] PTD (Ad5 for short) is neither catchy nor all that memorable. But, should someone stump up enough cash, to the tune of £1 million, their name would replace this rather unwieldy mouthful.

And why would anyone want this seemingly pointless honour? Ad5 is an oncolytic adenovirus, manipulated by a Swedish research team to specifically target and kill neuroendocrine tumours, a pancreatic version of which killed Steve Jobs. So far the virus has only undergone pre-clinical trials in mice, though the results are promising. The money would be used to push the virus into Phase 1 clinical trials in humans; an expensive process that the Swedish team can't afford with their current financial support. Their funding issue reached the ears of English author Alexander Masters, and, with his support, the story of the Ad5 virus went… well, viral.

Several issues are raised by this tale, though one of the most pertinent is scientific funding. Superficially the exchange seems innocent enough. The scientists get their money; the virus enters clinical trials; while a rich person gets named after the modified virus. The whole thing might not even succeed in Phase 1 trials, and the Paris Hilton/David Beckham/Kim Kardashian virus ends up relegated to the footnotes of obscure Scandinavian journals. Big deal.

Scientific funding in the current economic climate is inarguably tight. Money is not a resource that is being freely splashed about, and more and more specialised research groups are fighting over dwindling cash piles. Is it therefore wrong for scientists to stick a price tag on their work and offer those rich enough the opportunity to have their names pinned onto drugs or other cures? Maybe not, but it's a non-trivial question.

In order to earn funding scientists would have to sensationalise their work to some degree, hyping up the benefits of their research to draw in people with more money than scientific expertise. Already the Ad5 virus suffers from this to some degree, being described using such phrases as "a cancer-eating virus" and even "assassin". While it is true that even those applying for grant proposals need to put some positive spin on their work, it would require far more to draw in hesitant philanthropes. Enter unscrupulous scientists with wildly overblown claims, and there is the worrying thought that science's image would be further distorted in the public's eyes as a process that sucks in money without providing results. Thus, further dampening support for currently existing, publically funded research grants.

People want results, and if stumping up so much cash, they would inevitably gravitate towards those scientists 'promising' cures. It is a tricky issue. Regrettably science tends to suffer during hard times, but funding by individuals seeking some form of recognition ought not to be seized upon, lest a trend is set. The storm, as they say, must be weathered. But who knows. Maybe, several decades down the line I'll be sitting in a hospital, waiting for my injection of Donald Trump. Perhaps then I'll change my mind. ■

Imperial College

"Blood samples were spun at 1500rpm because the centrifuge made a scary noise at higher speeds."

#OVERLYHONESTMETHODS

RDECOM; flickr

Scientists have been using Twitter to speak candidly about their 'un-scientific method'. ***Jenny Mitchell*** *asks what this means for the public's perception of science.*

Science: objective, quantitative and rigorous. Or maybe not. This January, a neuroscience postdoc initiated a Twitter hashtag that challenged the way many see the scientific process. Her first tweet went: "incubation lasted three days because this is how long the undergrad forgot the experiment in the fridge #overlyhonestmethods." It was a frank exposé of the human element of scientific study. The hashtag #overlyhonestmethods has now become a platform for scientists to confess irregularities in their precise protocols and dispel the conventional errorless image of science.

The ensuing tweets have provided a comical insight into laboratory life. If you have ever wondered why scientists chose a certain method of study, or where the timings for their experiments came from, this hashtag will explain. But some tweets seem to show science to be imprecise, fabricated or even due to downright luck. So what does this say about a discipline that is meant to be, well, disciplined?

The tweets show that the scientific method isn't perfect, which seems fair enough. Scientists (for the most part) are humans and everyone's objectivity can take a battering at times. Just as many of us don't like Mondays, it would appear that science has its off days too: "Experimental results are reproducible – on Thursdays". What is unusual is that the scientists tweeting #overlyhonestmethods aren't hiding behind the wall of infallibility; instead they want us to recognise that science is imperfect.

Many of the tweets poke fun at the workings of competitive laboratories. The Lewis-Sigler Institute for Integrative Genomics at Princeton University confessed that: "We used jargon instead of plain English to prove that a decade of grad school and postdoc made us smart." Another twitter user showed that 'office politics' can spring up in labs too: "Our paper lacks post-2010 references as it's taken the co-authors that long to agree on where to submit the final draft."

Making the workings of science more transparent is an important goal, especially in the current economic climate. With the government pouring money into scientific research – recently awarding £885 million to graphene researchers based at the University of Manchester – there is certainly an argument to be made that the scientific community should be more accountable, or at least more open with, the taxpayer.

> "A COMICAL INSIGHT INTO LABORATORY LIFE"

However, as much as this hashtag provides an interesting view of scientists as fallible and sometimes downright nonsensical human beings, it is unlikely to make science any more approachable. For instance, although many may relate to one tweet that: "The experiment was left for the precise time that it took for us to get a cup of tea," it could be argued that the real issues surrounding science and its place within our society are still being missed.

Whether helpful or simply humorous, the #overlyhonestmethods hashtag has at least managed to confirm something that we have long known to be the case: Blu-Tack really is the most useful thing, ever. "Sample was agitated overnight by sticking the Eppendorf onto the vortex mixer with Blu-Tack." Other forms of adhesive are available but clearly Blu-Tack is the most scientific. ■

THE CHIMP THAT LEARNED TO COUNT

Are we really the most intelligent creatures on Earth? ***Andy Roast*** *discovers one area where chimps have the upper hand.*

Ayumu sits in front of a computer screen that displays the numbers from one to nine. His job is to sort these numbers into the correct order, and he does this to receive a bonus. Within a fraction of a second, the numbers are shrouded by white squares, so Ayumu must memorise the positions of the numbers. It sounds like a pointless and mundane office job, but in fact Ayumu is a chimpanzee.

Over the past few decades, researchers have begun to blur the perception that we are more intelligent than apes. Some have discovered, for example, that chimpanzees can use a switch to regulate periods of light and dark in a room (in order to sleep), crack open nuts with tools, and even recognise symbols. Indeed in this latter category, chimpanzees seem to show greater skill than humans.

The Ai project, currently headed by Professor Tetsuro Matsuzawa from Kyoto University, Japan, was set up to explore how chimpanzees understand symbols. It began in 1978, when scientists recruited a few chimpanzees, including a female called Ai, and taught them to recognise symbols. Positive reinforcement, in the form of a chime and pieces of apple, successfully 'trained' Ai and the other primates to recognise and order the numbers one to nine on a computer screen.

> "DON'T CHALLENGE A TEENAGE CHIMP TO A MEMORY GAME"

The story does not stop there. In an experiment measuring chimp memory, white squares masked the symbols after the first number had been picked. Matsuzawa's team noted that Ayumu, Ai's son, was better than his mother at remembering the positions of the numbers. In a further test, the numbers were shown for only a fraction of a second (just 210 milliseconds), before being masked by the white square. Again, Ayumu showed the greatest affinity among his primate peers for recognising the symbols, correctly remembering their positions and ordering them.

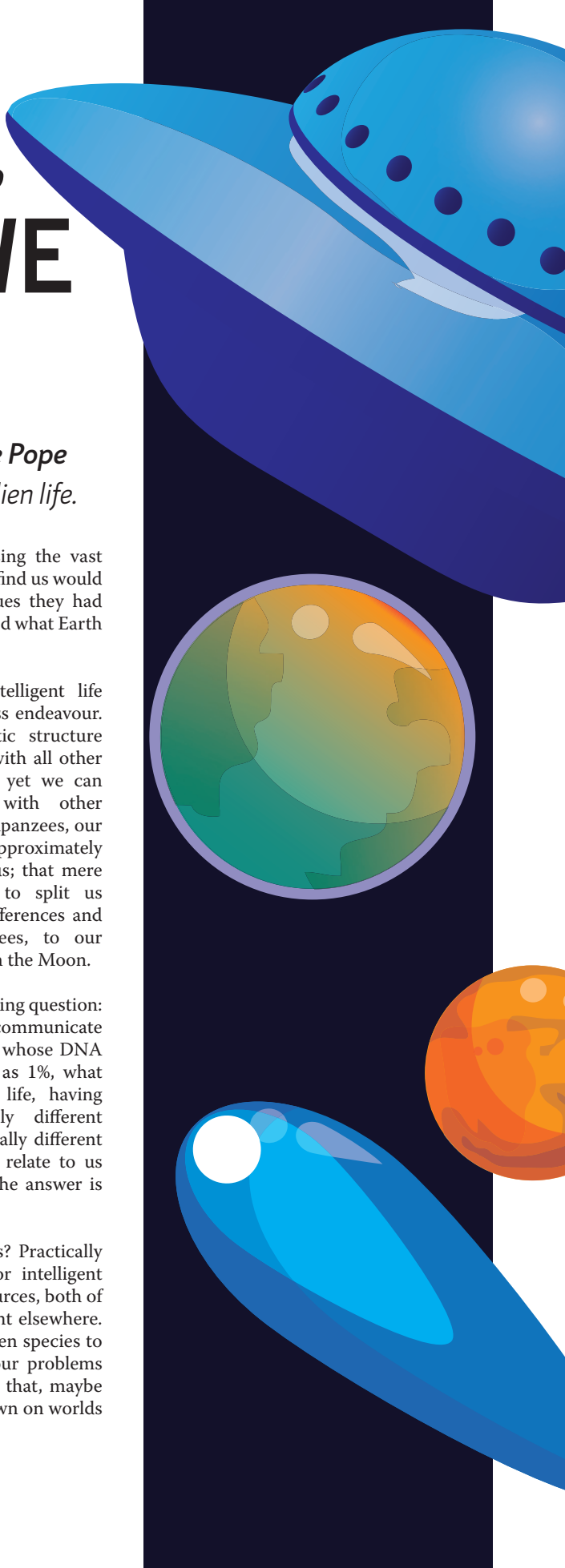
The researchers went further and decided to test Ayumu's symbol recognition and memory skills against human participants. Perhaps unsurprisingly, human performance dropped as the time allowed for observation of the symbols decreased. However, Ayumu's performance remained roughly constant – he was able to recognise and remember the symbols' positions after just 210 milliseconds, observation time.

The researchers explain that this is due to eidetic imagery; the ability to retain a complex image at a high level of detail. Human children are able to do this, but we lose this ability as we age. In contrast, young chimps such as Ayumu seem to retain their ability for much longer, surpassing most humans. We often think of ourselves as mentally superior to primates, but clearly you should never challenge a teenage chimp to a memory game – the odds are biologically stacked against you. ■

Raul Lieberwirth

IT'S LIFE, JIM, BUT NOT AS WE KNOW IT

Forget your UFO hunting and exoplanet probes; ***Laurence Pope*** *gives us his opinion on why we shouldn't be searching for alien life.*



Science fiction has conjured up a plethora of fictional alien species, from the harmless likes of E.T. to the positively barbaric xenomorphs of the *Alien* series. The possibility of life existing outside of Earth, especially intelligent life, has fascinated both scientists and non-scientists for generations. But, should we really be searching for it?

Whilst there's not yet definite proof that life exists outside of Earth it's almost a mathematical certainty. It has been estimated that there are more than 170 billion galaxies in the observable Universe. Given the millions and billions of stars and planets contained within each one it's more likely than not that some form of life exists in a far-flung galaxy.

It has been claimed by many, including theoretical physicist Stephen Hawking, that searching for intelligent life is a dangerous endeavour. The argument goes that any species finding us or being alerted to our presence would arrive to plunder our planet for resources, be they mineral, organic or human. Or maybe they'd pop over just to wipe us out, *Independence Day* style. But why would they bother?

Earth is no longer a goldmine of resources. Humankind is accepting that Earth's natural resources are in decline, and we're looking out to space to meet our needs, through asteroid strip-mining for example. An alien 'resource acquisition team' would probably mark Earth as 'spent', especially considering the vast number of other, resource-laden planets and celestial bodies in the Universe. Any species capable of crossing the vast distances of space and time to find us would have solved any resource issues they had long ago, and would hardly need what Earth has to offer.

If anything, contacting intelligent life elsewhere would be a pointless endeavour. We share a common genetic structure and building block (carbon) with all other Earth-bound organisms, and yet we can only converse intelligibly with other members of our species. Chimpanzees, our closest living relatives, share approximately 95-99% identical DNA with us; that mere 1-5% difference is enough to split us apart and account for our differences and accomplishments. Chimpanzees, to our knowledge, have not landed on the Moon.

This raises a thought-provoking question: if we cannot meaningfully communicate with chimpanzees, organisms whose DNA differs from ours by as little as 1%, what is the likelihood intelligent life, having developed on a completely different planet under potentially radically different conditions, would be able to relate to us in any way, shape or form? The answer is probably way below 1%.

So where does this leave us? Practically speaking, alone. Searching for intelligent life is a waste of time and resources, both of which could be far better spent elsewhere. We can't rely on a superior alien species to swoop down and fix up all our problems – that's our job. If we can do that, maybe we'll be the ones swooping down on worlds unknown. ■

REVIEWS

DRIVEN TO THE BRINK

*Reflecting on extinction and the difficult questions of conservation, **Alanna Orpen** reviews the Natural History Museum's new exhibition.*

In the past, volcanic eruptions, asteroids, noxious gases and climate upheavals were the main exterminators, causing the last five mass extinctions. Now, the world's diversity and environment are threatened by a single species. Could our impact really cause greater damage than a meteorite impact or a volcanic eruption? 'Extinction: Not the End of the World?' at the Natural History Museum raises the alarm, warning that if we continue to exploit nature and eliminate species at the current rate, we'll soon find out.

Stunning photographs and film footage, real life specimens and interactive installations all immerse the visitor in a three-dimensional encounter, actively exploring the meaning of extinction. Visitors are engaged by stories of modern extinctions or stimulated by arresting quotes from a range of people, from prominent scientists to playwrights, including Edward Wilson and William Shakespeare.

The exhibition presents the story of extinction chronologically, which is a sensible and logical approach for tackling the topic. It lays the foundation by providing an initial understanding of what extinction is, before delving into the past to examine the causes of major extinction events. This fulfils visitors' expectations of seeing the textbook extinct species of dinosaurs, dodos and passenger pigeons. Then, an examination of current human activity and an assessment of our impact on the planet, taking the exhibition beyond simply educational and informative, to arousing critical reflection.

The exhibit raises interesting points, addressing the controversial questions and the difficult decisions facing conservationists today. For example, the tiger has become a status symbol of endangered species, but with the increasing cost to protect it, should the money be better spent on other species that provide greater benefit to us? Such questions are scattered throughout the exhibition, stimulating personal contemplation and encouraging public debate.

Displays are accompanied by detailed accounts of the conservation actions of scientists. The hour is urgent and nature's heroes are trying desperately to protect the world's diversity. But financial, political and cultural factors are obstacles in the race for survival. Case studies, such as the tragic tale of the Baiji Dolphin, reveal the devastating fate awaiting accidental victims of human activity because of lack of political interest and funding.

Some of extinctions' usual suspects are displayed in the invasive species line-up: dogs, cats, rabbits, grey squirrels and black rats, all convicted of devastating indigenous wildlife by driving native species to extinction.

The use of such dramatised displays appears to be the exhibition's favoured tactic. Elsewhere, a giant tuna floats above a large tin can accompanied by the slogan 'Out of sight, out of mind' – a stark reminder of how our day-to-day lives impact species survival. Although seemingly distant, we cannot afford to be oblivious to our harmfully high demands. But could such didactic material persuade us to limit our consumption of the fish?

The exhibition comprehensibly and directly tackles the subject of extinction head on, whilst purposefully articulating the need to change our idleness, encouraging visitors to become active agents in conservation. The exhibition ends with a creative display of hope: a 'wishing tree' invites visitors to sit and peacefully consider the facts before pinning up their own bright leaf of aspirations to a colourful bloom of personal reflections. ■

Extinction: Not the End of the World? is set to run until 8 September 2013 and costs £4.50 for students and £9 for adults.

geekcalendar; flickr

OUT OF AFRICA

Africa: Eye to Eye with the Unknown
Michael Bright
Quercus (2012)

Africa, the BBC's most daring and technologically advanced nature series to date, gave millions of viewers an insight into some of the most incredible feats of the natural world. Transporting us into a magical world of film, it captured the strangest and rarest creatures, showed unprecedented animal behaviours, and astounded with awe-inspiring landscapes. With the release of the new book (of the same name), this journey into the depths of Africa does not have to end.

Through the use of amazing photography and accompanying texts (written by the BBC's Natural History Unit producer Michael Bright), the book continues our spectacular voyage through the five unique regions of Africa. The visuals and texts in themselves are astounding, but these are only the beginning: the book, like the series, uses the best in modern technology, incorporating augmented reality into its pages.

All the reader has to do is download the free QuercusEye app, point their smartphone or web-enabled tablet at the select images and then sit back and watch in awe as they come to life. Witness the drama of lizards stalking their prey on the backs of lions, male giraffes fighting to the end, and beetles that will risk everything for love. It's even possible to learn more about the filming techniques used during the ground-breaking documentary.

With new videos being released constantly, the fun and learning just keep coming. The book is available now, so join the journey and experience the amazing continent that is AFRICA. ■

ANNIE MACKINDER

BRAIN TRAINING

Mastermind: How to Think Like Sherlock Holmes
Maria Konnikova
Canongate Books Ltd (2013)

With two blockbuster movies in five years, the original novels still in the top 100 most read books, and the last BBC series attracting over 9 million viewers, it seems as a nation we've gone a little Sherlock mad. Now, with the launch of Maria Konnikova's book *Mastermind*, not only do we find out more about our favourite pipe smoking detective, we learn to think like him too.

From the onset it's clear Konnikova is an avid fan of Sherlock Holmes. Her constant references to memorable passages show how the detective embodies an ever-present mindfulness, and she explains these examples using neuroscience and psychological theory.

One of Konnikova's key points is that the brain operates using two contrasting systems: 'System Holmes' and 'System Watson'. System Holmes is rational, deliberate, objective and conscientious, while in contrast, System Watson is quick to action, likely to stereotype, judgmental and mostly unconscious. The systems reflect the key characteristics of the famous male double act.

Although the majority of people use System Watson, Konnikova tells us we can change and become like Holmes, and she backs up this claim with a number of well-known psychological theories. And once I got over my offence at being labelled a 'Watson', I must say I enjoyed reading the book.

Any bibliophile will appreciate Konnikova's passion for Holmes and her excitement at the idea of being able to replicate his thought processes, although I'd recommend this book to anyone who wants to be more aware of how our brains work and the logic behind our decisions. Though I warn you: be prepared to be stereotyped as a System Watson. ■

ANNIE MACKINDER

DELIGHTED BY DOCUMENTARY

National Geographic 125 Years DVD
National Geographic (2013)

If you are looking for a variety pack of documentary delight, then look no further than the *National Geographic 125 Years* DVD. It will keep you thoroughly entertained for 5 hours, and give you a sense of achievement upon completion.

The first of the eight documentaries in the set is 'Machu Picchu Decoded'. This documentary is framed from the viewpoint of the archaeologists and scientists investigating the ancient hill-top city, and is as much about their methods and experiences, as it is about the history of Machu Picchu itself.

Three wildlife documentaries are included as part of the compilation. Instead of short snippets of perfectly crafted footage of a variety of exciting animals doing exciting things, the documentaries focus on the scientific endeavour of the people who study animals in the wild.

A strong human-interest angle is core to the other episodes as well. 'Secrets of the Titanic', although a little dated, accompanies the investigators on their voyage to first discover the ship's wreck. And 'Inside the Vatican' meets the many people who keep the world's smallest country ticking over.

One thing to bear in mind before you set out to buy the DVD is that it won't be much good on mute. Some documentaries provide swathes of impressive footage that can be appreciated independently from the narration. But in this DVD set, the documentaries rely heavily on strong spoken narrative.. This is absolutely fine if you intend to sit down and give the DVD a thorough watch. But if you're looking for background viewing, you should probably stick to an Attenborough classic. ■

DAVID LAWRENCE