I, SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE

MAN-MADE

SYNTHETIC ORGANS | LAB-GROWN MEAT | ENGINEERING LIFE | NUCLEAR FUSION | COL. DAVID SCOTT

I, SCIENCE

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I, SCIENCE

Welcome to the second issue of I, Science, in which we celebrate humankind and the immense range of objects and processes we have constructed: Man-Made!

Physicist Richard Feynman had a quotation written on his blackboard at the time of his death in 1988: "What I cannot create, I do not understand". This is yet another nod to Feynman's genius, as it is exactly how men and women look at the world. We ask questions of 'how' and 'why' and, in a bid to understand, replicate what we see around us.

At first glance, 'man-made' may bring to mind inventions such as the wheel, the car, and the computer, or the issues of genetic modification and human enhancement. These were some of our thoughts as we brainstormed ideas for issue 2. However, it has shown to be a deeper theme than we initially thought, and the wide range of contributions we received really emphasises the immense impact we humans have had on our planet.

Social aspects play a huge role in the human construction of science. Looking back on our issue's content before it went to print, we were struck by how many of our articles are steeped in social and cultural controversy. Designer babies, man-made animals, and man-made food were striking examples, and in the following pages we explore just how far humans can tweak the 'stuff' we are made of. Unfortunately – or perhaps unavoidably – we are also very effective in halting scientific research due to our cultural framework and social and moral values.

However, the flipside of this argument concerns technology. What is it about humans that makes us more than machines? Our own technology can often trump us, leaving us confused and right back at square one. In the case of recent faster-than-light neutrinos, the entire world was excited by the prospect of an error in Einstein's famous theory of relativity. This would mean overthrowing the entire theory and a rethink of our understanding of physics. After several retests and laboratories all around the world leaping to independently replicate CERN's experiment, a frustrating press release emerged in February of this year. The faster-than-light speeds achieved by the neutrinos may be a mistake. Exciting! The reason given for the error? Frustratingly, it might have all been down to a case of dodgy wiring. Have we reached a stage where we trust the tools we have built so much that it is affecting our science?

We can't claim to have the answers to these pertinent questions, but this magazine hopes to bring a range of articles to you that show how amazingly innovative and intelligent humankind is, despite our occasional mishaps. We hope you enjoy it!

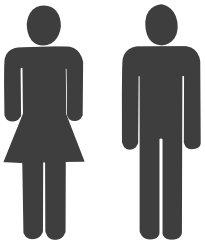
NICOLA & DOUGLAS

Note: The co-editor-in-chief for the previous issue, Jo Poole, had to pull out of the editorial team: thanks to Jo for lots of early input into the planning of this issue!

COVER FEATURE

MAN-MADE

INTRODUCTION ON PAGE 10



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NEWS FROM

IMPERIAL COLLEGE

NEW GENETIC LINK TO DIABETES DISCOVERED

LAURA TEMPLER

IMPERIAL SCIENTISTS FIND MELATONIN RECEPTOR MUTATIONS CAUSE AN INCREASED RISK OF DIABETES

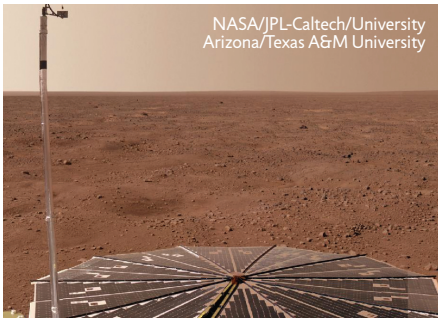
Researchers from Imperial College have identified mutations in a melatonin receptor that are associated with an increased risk of developing type 2 diabetes. This discovery is the result of research continued from work done in 2008 by the same group of scientists.

Melatonin is a chemical that controls the body's sleep cycles and temperature levels, as well as many other homeostatic mechanisms. It also regulates the release of insulin into the blood, and so disrupted levels of melatonin can cause health problems.

Work in 2008 showed mutations in the gene which codes for the melatonin receptor can increase the risk of type 2 diabetes. More recently, Professor Philippe Frogel of Imperial College led new research that analysed the gene in 7600 people which found 40 variants and identified 4 specific mutation sites. At these mutation sites the melatonin receptor was completely unable to respond to melatonin. Having a mutation at these sites also increased the risk of developing type 2 diabetes by a factor of six.

This research could be used in the future to accurately assess a person's risk of developing diabetes and lead to development of personalised treatments. Melatonin also regulates energy metabolism and body weight control within the body, so this research could have future implications for work on obesity treatments.

Flickr: ladytaz


NASA/JPL-Caltech/University Arizona/Texas A&M University

NASA STUDY SHOWS THE RED PLANET MAY NEVER HAVE HOSTED LIFE

MATTHEW PARKER

Analysis of soil samples has revealed that Mars is too arid to have ever sustained life. Samples collected by NASA in 2008 were studied to find content of microscopic clay particles. These are of interest as clays are formed by the chemical weathering of rocks with water.

Dr Pike, from the Department of Electrical and Electronic Engineering at Imperial, found the content of clay-sized particles made up less than 0.1% of the soils. This is similar to lunar soils, and compares with 50% on Earth. Even if all the particles were clay, it was estimated the soils must have been exposed to water for no more than 5000 years – too short a time to have developed life.

FORD SCHOLARSHIP PROGRAMME TO POWER IMPERIAL STUDENTS

DHARSHANI WEERASEKERA

Image: www.ford.co.uk

Ten Imperial students will participate in a £1 million scholarship programme funded by Ford of Britain. From 2012, the Ford Blue Oval Scholarship Programme aims to develop 100 of the UK's next generation of student engineers, scientists and innovators. It is donating £100,000 to each of 12 top universities, awarding ten undergraduate students £10,000 over the course of their engineering, science, manufacturing and technology degrees.

Universities and Science Minister, David Willetts, said of the programme "Ford is encouraging students to graduate with… core skills which are needed by the UK manufacturing sector to drive growth through innovation and research and development."

Imperial's Rector, Sir Keith O'Nions, stated: "I am delighted Ford has chosen to support Imperial students, and I applaud their initiative and foresightedness in working with universities."

EFFECTS OF MAGIC MUSHROOMS ILLUMINATED BY BRAIN IMAGING STUDIES

CARYS COOK

Famous author and psychedelic drug advocate Aldous Huxley once wrote, "There are things known and there are things unknown, and in between are the doors of perception". Two recent studies, led by Dr. Robin Carhart-Harris and Professor David Nutt from the Department of Medicine at Imperial College London, have revealed that hallucinogenic drugs can alter the activity of specific areas of the brain and therefore reduce our brain's own constraints on perception.

These two studies analysed how brain activity is affected by psilocybin, the active hallucinogenic ingredient found in magic mushrooms. By using functional magnetic resonance imaging (fMRI), which measures subtle changes in blood flow and blood oxygenation levels, the researchers were able to identify variations in brain activity of healthy volunteers who were given psilocybin intravenously.

Their results reveal that areas of the brain associated with depression and self-identity – the medial prefrontal cortex and posterior cingulate cortex – were characterised by decreased activity during exposure to psilocybin. The intensity of the effects experienced by the volunteers was positively correlated to a decrease in blood flow, suggesting that reduced activity in certain areas of the brain has a strong effect on perception.

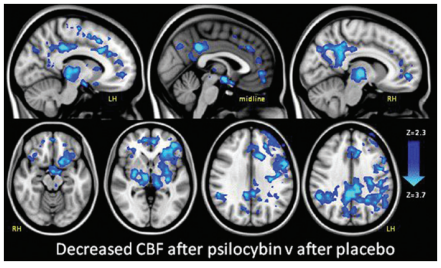


Image: Dr Robin Carhart-Harris & Prof David Nutt, Neuropsychopharmacology Unit, Imperial College London

Interestingly, volunteers reported long-lasting positive effects in their emotional well-being. Although further investigations are still needed, the findings of these studies suggest that psilocybin could be use as a therapeutic tool to treat depression and as an adjuvant to psychotherapy. Current UK drug laws, however, are an impediment to more widespread research.

BLACK HOLES COULD AID STAR FORMATION

MACIEJ MATUSZEWSKI

An international team including scientists from the Universities of Oxford and Tasmania – as well as Imperial's Dr Sugata Kaviraj – has found that black holes may not be the purely destructive objects we once considered them. Writing recently in the Monthly Notices of the Royal Astronomical Society, the team describe how it has long been known that the jets created by black holes at the centres of galaxies can disperse gas and prevent it from forming stars. Their findings, however, suggest that they might also have the opposite effect.

Using data from the Hubble Telescope's Wide Field Camera 3, the scientists studied the distribution of young stars in a gaseous filament in Centaurus A, a galaxy some 13 million light years away from the Milky Way. They found a large concentration of young stars at the end of the filament closest to the jet. Importantly, the stars appeared to have been formed at a similar time to the jet. The scientists theorise that this could be the result of the jet setting off shock waves through the gas – creating dense regions which collapsed to form stars.

> "WE MAY HAVE BLACK HOLES TO THANK FOR MANY OF THE STARS WE SEE IN THE NIGHT SKY TODAY"

While this effect has never been seen before, Dr Kaviraj believes that it could have been far more common in the early universe, when the existence of many dense gas clouds provided more opportunities for stellar formation. If this is the case, we may have black holes to thank for many of the stars we see in the night sky today.

WORLD NEWS

PICK OF THE BEST

JOEL WINSTON

LIGHTING UP BRAIN BEHAVIOUR

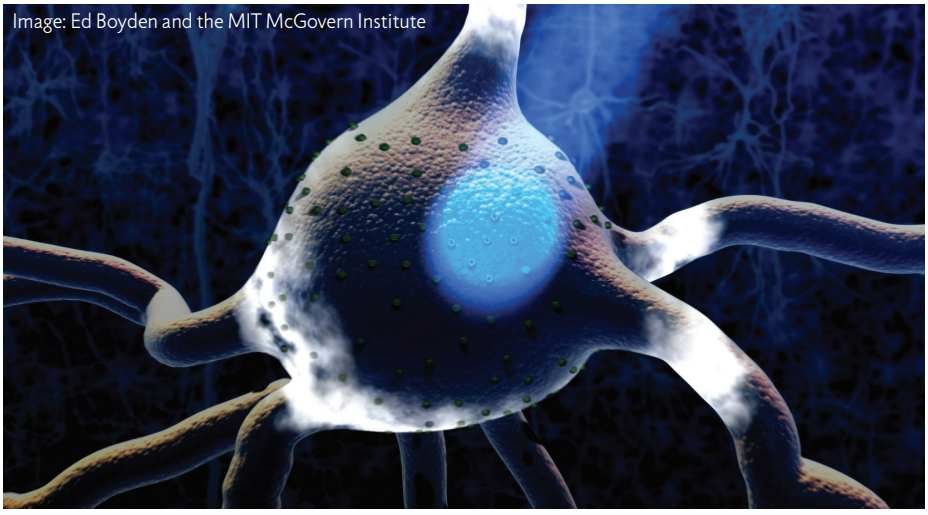


Image: Ed Boyden and the MIT McGovern Institute

A team of researchers at the Massachusetts Institute of Technology (MIT) has developed the technology to control circuits of the brain using light, revealing detailed insights into how behaviour is generated, and the potential for novel treatments for over a billion people worldwide suffering from brain disorders.

Conventional treatments for disorders such as epilepsy, strokes, chronic pain and Parkinson's disease often involve drugs that treat the entire brain and often produce side effects.

"The brain is a complex, densely wired, computer circuit, made out of cells of varying shapes, composition, and patterns of connectivity," explains Ed Boyden of the Synthetic Neurobiology Group at MIT. "Ideally we would be able to hone in on the precise brain circuits involved in disorders, and use those as new targets for drugs and neurosurgical procedures."

To find these specific neural targets, the group have developed 'optogenetic tools' that allow the manipulation of specific cells embedded within dense neural circuits with light.

"Certain proteins found in plants, bacteria and algae convert light into electrical power. Neurons compute using electricity," says Ed Boyden. "So by installing these proteins into specific cells in the brain, they then become controllable by light."

Using safe viral vectors, the team delivered genes that encode for light-sensitive proteins into neurons in mice, causing the proteins to form on the surface. They then delivered pulses of light via optical fibres inserted into the brain, which successfully activated or silenced the electrical activity of the targeted neurons. By observing the resulting behaviour of the mice, they could then determine how those neural circuits contributed to computations in the brain.

With this level of control, the team have been able to successfully change the behaviour of mice displaying symptoms of Post-Traumatic Stress Disorder, restore sight after certain forms of blindness, and reveal new neural pathways involved in learning behaviours.

The group are now turning their attention to developing more sophisticated ways of controlling large sets of neurons simultaneously, using three-dimensional light delivery devices that 'dial' information into the brain. Through these experiments, they hope to develop 'brain co-processors' that can analyse brain activity, and then optically feed an appropriate response into the brain in order to treat cognitive disorders.

BIRD FLU RESEARCH: BIOLOGICAL WEAPON OR BREAKTHROUGH?

JULIA ROBINSON

NORTH STAR SHRINKING:

FAMOUS STAR FACES AN UNCERTAIN FUTURE

LUCY VAN DORP

Concerns about the publication of two studies investigating the 'bird flu' strain of influenza have erupted into an emotive scientific debate on bioterrorism. The research, funded by the National Institute of Allergy and Infectious Diseases, examined the respiratory transmission of the highly pathogenic avian influenza H5N1, and involved a relatively low-tech method to mutate the bird flu virus in order to increase its airborne transmissibility between ferrets. Those opposed to the data being published believe that the information may be accessed by terrorists to make biological weapons. Virologists in New York have stated that this strain of influenza may be up to 30 times more deadly than the Spanish Flu which claimed over 50 million lives in 1918. In their eyes, publishing this data could pose a huge threat to our national security.

On the other side of the debate, however, it can be argued that those against the publishing of the research have been selective in their citing of literature, and that the supposed mortality rate of this avian flu strain is in fact a major exaggeration. Many have highlight the importance of scientific research being as transparent as possible. While the virus may be deadly, understanding the ways in which H5N1 and other viruses mutate is key to enabling scientists to take a more proactive role in controlling them.

Influenza pandemics have taken lives and challenged scientists for centuries. But as for where this research will take us now, it would seem the debate continues.

The North Star has been a crucial navigational tool for centuries, but new research suggests this familiar feature of the northern sky is slowly disappearing. Scientists at the University of Bonn have found that the famous star is shedding an Earth's mass-worth of gas every year. Also known as Polaris, the star always sits directly over the North Pole because it is aligned with the Earth's axis. Situated at the end of the Little Dipper's handle, the ability to locate the North Star means you don't need a compass to determine your location.

Light emitted from the North Star is not constant – it is instead a Cepheid Variable. This means the star becomes dimmer and brighter in a series of four-day pulsation cycles. This pulsation pattern is present during nuclear fusion, when the opposing forces of gravity acting inwards and radiation pushing outwards distort the outer gas layers to produce a pulsing light.

The team in Bonn found this pulsation cycle is slowing at a rate of about 4.5 seconds every year, indicating that Polaris is past the red giant stage of its lifetime and is burning helium at its core. Others argue that changes in the star's pulsation patterns are a regular occurrence and cannot be used to indicate the star's lifetime.

Whatever the outcome for Polaris, navigators need not fear. A new North Star is on the way: Gamma Cephei is set to align itself with the North Pole in about 1000 years time.

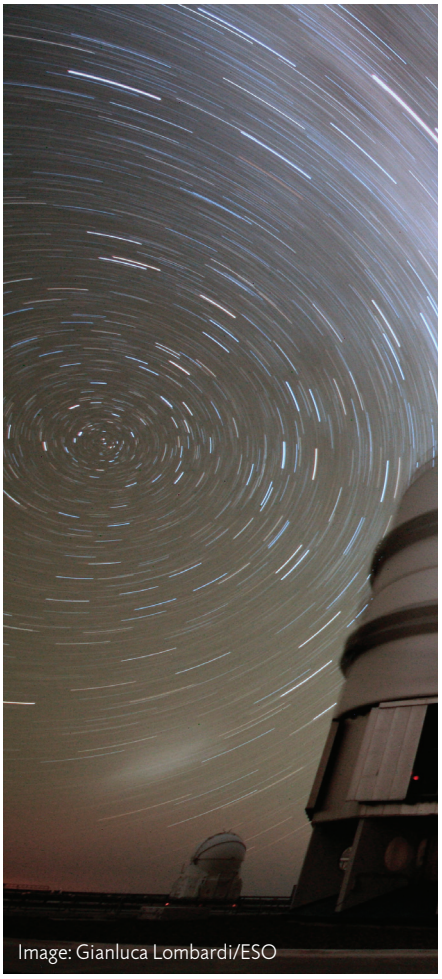


Image: Gianluca Lombardi/ESO

MAPPING THE MILKY WAY'S MAGNETIC FIELD

HARRIET JARLETT

Scientists have produced a map of the Milky Way's magnetic field to a higher level of precision than in previous studies. The research was carried out at the Naval Research Laboratory in Washington D.C., where researchers created their own database for observations. They then interpolated the results over areas where little data existed in order to produce the complete map.

Over 41,000 measurements were taken and analysed, resulting in one of the largest databases of its kind. It was this high density of material that resulted in the scientists being able to construct the unique all-sky map. Dr. Tracy Clarke, a member of the Naval Research Laboratory's research team, emphasised the enormity of the project: "The resulting database is equivalent to peppering the entire sky with sources separated by an angular distance of two full moons."

"MAPS LIKE THIS PROVIDE A UNIQUE INSIGHT INTO THE UNKNOWN ORIGIN OF MAGNETIC FIELDS"

The data points were measured using Faraday rotation, a process whereby polarized light changes its plane of polarization after passing through magnetic fields. Back on Earth, researchers can then study the intensity and direction of the light to determine the strength of the field it passed through. However, this data only provides information for a single pathway through the galaxy, which is why such a huge database was needed.

Maps like this provide a unique insight into the unknown origin of magnetic fields, which occur in all galaxies. Until now, scientists assumed magnetic fields were formed by processes of mechanical energy being converted into magnetic energy. This map provides a detailed look into the structure of the magnetic fields, and will help solve the puzzle of their beginnings.

BEHIND THE HEADLINES

***Nicola Guttridge** and **Jo Poole** unpick some of the most interesting science headlines from 2012 so far.*

BIG MEALS LINKED TO 'MEMORY LOSS' IN ELDERLY

This US study showed that mild cognitive impairment was more frequent in older persons regularly consuming an excess of 2000 calories a day. However they failed to consider the source of these calories – i.e. fat and sugar content, probably common in a higher calorie diet. Since mild cognitive impairment is linked to a degree of vascular disease, any risk factors for atherosclerosis (plaque formation), are relevant to age-related cognitive impairment e.g. high cholesterol and diabetes. Obesity is also a risk for cognitive impairment, and likely to be more prevalent in the higher calorific intake group. A further point is that excessively energy-laden diets tend to be vitamin deficient – there is a strong case for the role of antioxidants like vitamin C in defying general age-related cellular pathology, and vitamin B12 in particular has been strongly linked to reducing cognitive decline.

BBC, February 2012.

OPENING HOSPITAL WINDOWS WOULD REDUCE INFECTION

This claim was from an American who suggested that the presence of hospital superbugs might be due to the lack of benign bacteria in the sterile environment. This would be similar to 'good bacteria' in the gut helping keep some pretty nasty pathogens at bay. This conclusion is, sadly, a naive one. Firstly, one in three of us are carriers for MRSA without experiencing any negative consequences. In fact, most infections are caused by bacteria we normally carry on and around us. And secondly, our bodies are a sterile environment – with the exception of outer layers of skin and our digestive tract. Any bacteria in our bloodstream, or in the airways and guts of already-ill humans are immediately a threat, regardless of species. This is why hospital wards and theatres are kept sterile. Air convection currents would simply waft bacteria around onto sterile surfaces and wreak havoc.

Guardian, February 2012.

CHILD ABUSE MAY STUNT EMOTIONAL GROWTH

Being physically, verbally or sexually abused as a child may be to blame for a variety of mental and emotional disorders in adulthood, claims a paper published in the journal *Proceedings of the National Academy of Sciences* and subsequently reported on in *The Guardian.* Such abuse can lead to a multitude of psychiatric disorders, including major depression, post-traumatic stress disorder, and schizophrenia. The study is by no means conclusive – the test sample included 193 subjects, 62% of whom were female and 72% of whom were white, all aged between 18 and 25. However, the 'exposure to abuse' factor was heavily reliant on the individual's recollection of their childhood experiences – introducing 'recall bias', where those more susceptible to emotional issues such as depression would be more likely to report abuse. In fairness, *The Guardian* mentioned this last detail in its coverage.

DOI: 10.1073/pnas.1115396109

MALE SEX DRIVE CAUSES HOSTILITY

This study concluded that males' tendency to guard their females (and thereby their routes of genetic perpetuation) leads to aggression, whereas women preferred to 'tend and befriend' to maximise offspring survival. In nearly all higher animal species, fighting is traditionally a way to assert a male's dominance, fertility and mating rights. It is a frequent motivation in club brawls, homicides and the overwrought scenes of films, theatre and soaps. There is no doubting that testosterone, a prime feeder of male fertility and behaviour, primes aggression. However, fighting also occurs for other reasons: food, territory, entertainment and other sexually unrelated disputes. And we must be careful not to over-extrapolate our 'animal instincts' – animals probably lack our capacity for reflection. It is unlikely any primate species could cohabit as peacefully in the sheer density humans do.

Independent, January 2012

COULD WE SOON BE USING MIND-CONTROLLED MISSILES?

A Royal Society report on the potential applications of neuroscience research has warned that scientists should be wary of law enforcement and the military using their work in the future. The Guardian picked up on this, and reported on the potential weaponisation of neuroscience manifesting itself in the form of "soldiers controlling weapons with minds". While the report does refer to neural interface systems being able to "provide a connection between an individual's nervous system and a specific hardware or software system", the idea of mind-controlled missiles is an exaggerated one. However, both the report and the news article are mainly concerned with performance enhancement, analysis and identification of risk-taking behaviour, and the ethical and legal issues behind the utilisation of such research – overall, despite a little sensationalism to get the ideal headline, the article is a fair representation of the paper itself.

Royal Society. ISBN: 978-0-85403-938-8.

DYING OF A BROKEN HEART

Many of us are familiar with heartbreak, and indeed for some, it may seem as though life is no longer worth living. There are even reports of heartbreak inducing immediate heart attacks that are simply diagnosed as 'myocardial infarctions'. In fact, grief-induced heart attacks have a mechanism all their own: large bursts of adrenaline and other catecholamines are released in response to the stress of an emotional event. Cells of the ventricles respond differently to their neighbours, classically bulging in a manner similar to the Tako tsubo octopus traps, for which the syndrome is named – Takotsubo's syndrome. This can lead to acute heart failure, long-term fatal changes to the pumping rhythm and even ventricular rupture. As oestrogen and other hormones present throughout a woman's fertile years help protect the heart from stressful events, the syndrome is thought to be more common among postmenopausal women. Otherwise, childbirth might be too risky to contemplate!

DOI:10.1016/j.jcmg.2010.01.009

FANCY A CUPPA? WAIT 3 MINUTES – IT'S BETTER FOR YOU

In a recent BBC video, "Tea expert" Dr Tim Bond spoke about brewing time. He claimed that a "seven-minute brew time has three times as many anti-oxidants as the three-minute brew", and that increasing brewing time from the 40-second average consumer brew up to 3 minutes doubles the anti-oxidant levels. He light-heartedly added that if you give the teabag a "helpful little squeeze" at the end, you'll get "the last few anti-oxidants into the cup". The humour in his statement is all very well, but is it misleading? Flavonoids are thought to have antioxidant, anti-inflammatory and anti-proliferative properties, and drinking black tea may lower the risk of coronary heart disease and type 2 diabetes. However, the mechanism by which it does this is largely speculative – the research we believe the video to be based on states that "it would be useful to gather information on preparation methods, such as brew time, which would influence flavonoid exposure" – but no more specifics.

DOI: 10.1111/j.1467-3010.2011.01937.x

ONLINE OFFLINE

Here's what's been happening at www.isciencemag.co.uk

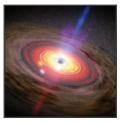
MOST HITS

DON'T BLAME IT ON THE GULF STREAM | BIT.LY/YWB9ZC | LUKE SHELDON

Laying bare the science behind our harsh winters.

BADGER, BADGER, BADGER | BIT.LY/ZAOGHZ | JOEL WINSTON

Cute and controversial: our 'Science vs Politics' blogger picks apart the government's policy on culling.



PHOTOGRAPHING A BLACK HOLE | BIT.LY/W3F4Z6 | NICOLA GUTTRIDGE

Our 'Space for Thought' blogger on the Event Horizon Telescope that is set to test Einstein's theory of relativity.

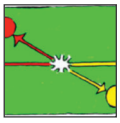
PODCAST: KINETICA ART FAIR | BIT.LY/AKMVLE | PETER LARKIN

Clicks, burrs, whirrs, and whistles: a dispatch from where art meets cutting-edge tech by our 'Don't Mention the Tiny Robots' blogger.

DOES SIZE MATTER? | BIT.LY/ZC3JMC | VICTORIA CHARLTON

Our 'Science Means Business' blogger looks at the economies of scale behind mega-shipping.

FEATURE HIGHLIGHTS



THE ARROW OF TIME | BIT.LY/XD119M | JACK JELFS

A hand-illustrated account of the thermodynamic "arrow of time" in physics (and to a lesser extent, in snooker).

SCIENCE BEHIND THE PHOTO: SHUTTLE LANDINGS | BIT.LY/ZEVFBN | NICOLA GUTTRIDGE

A stunning but poignant image taken during the 33rd and final landing of Atlantis in July of 2011 – the final US shuttle mission.

INTERVIEW WITH A DEEP-SEA BIOLOGIST | BIT.LY/WY74YH | JUAN CASASBUENAS

"We are the aliens." An extended version of the interview behind last issue's Exploring the Deep feature.

SECRET SCIENTIST: SUZANNE LEE | BIT.LY/ZELRUT | BRITISH SCIENCE ASSOCIATION

The first of a series on secret scientists looks at a fashion designer who grows her clothes.

VIDEO: GM FROM SCRATCH | BIT.LY/ABDRPF | SEE DESCRIPTION

Genetic modification explained in less than three beautifully-paced minutes by Pen Hill, Lucy van Dorp, Sam Cavenagh, Vanna Barber, and Luis Mulet Planelles

WHAT'S IN IT FOR YOU?

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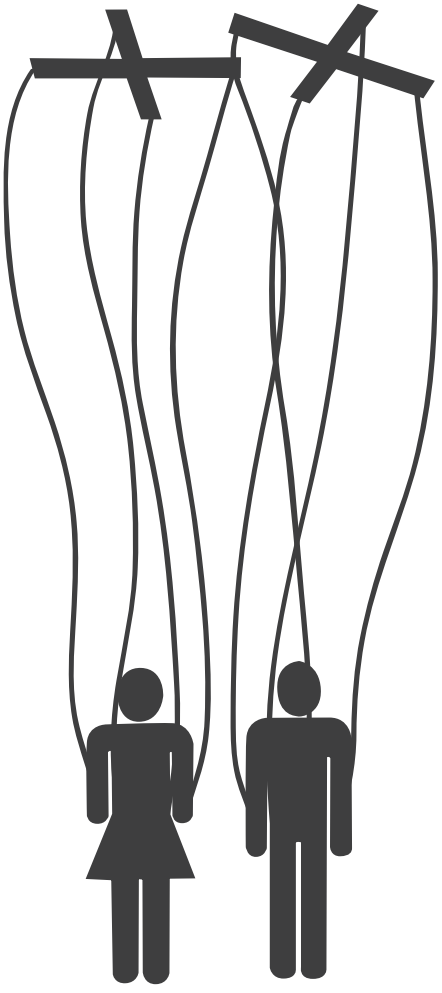
MAN-MADE

"What I cannot create, I do not understand."
– Richard Feynman



We live in a man-made world. There is a good chance that everything within your sight right now has been manufactured, except – though perhaps only for now – the people. Machines for every purpose, buildings filled with clutter, paved and plastic surfaces, commodities of all kinds, dogs, clothes, and haircuts. Artefacts, every one. Away from industrialised cities, agriculture has been carving out its landscape for millennia. We have covered the Earth and filled the skies with human constructs, remaking the world to suit our myriad needs. Changes we have made to the Earth can be seen from space, and telescopes show us what we have left behind on the moon.

We have manipulated atoms to write the initials of corporations and synthesised an artificial genome. Here too, Craig Venter's team left their mark, etching their names into the fabric of life. They announced they had encoded in their genome those famous words of Feynman quoted above – found on his blackboard after his death in 1988 – and a line from James Joyce: "To live, to err, to fall, to triumph, to recreate life out of life." When told they had misquoted Feynman's words and used Joyce's without permission Venter, master craftsman, simply promised to resynthesise a corrected version. To err is human, but so is to triumph.

Of course, nothing would be possible without tools. The making of tools – whether stone axes or computers – is the precursor to making everything else. Our development as a species has gone hand in hand with making and without tools, without artefacts, would we even be human? But with great power comes great responsibility, as the old adage goes. Though popularised as Uncle Ben's advice to Stan Lee's young Spiderman, the sentiment goes back at least to Voltaire, the Enlightenment, and the birth of modern science. Today, with the capabilities to remake not only our world but ourselves, are we mature enough to show restraint if – or when – it is needed?

"Practising responsibly requires some humility," says Dr Megan Palmer, Deputy Director of Practices at the Synthetic Biology Engineering Research Centre (SynBERC) – one of many institutions promoting responsible research along science's new fronts. For Palmer, responsibility "involves recognizing that we are always operating under limited and imperfect information, and striving to identify and address areas of uncertainty in both the benefits and risks of technologies." Perhaps we should then add to Feynman's words: "What I can create, it is my duty to understand."

MORTAL DEVICES

Jo Poole asks whether humans really can be repaired like machines.

It is true that however well we look after our health, from diet and exercise to vaccination, all organisms are subject to progressive changes. These arise via both extrinsic devices such as radiation and toxic chemicals, and intrinsic factors like the chemical stability of component molecules and the organisms themselves. Frankly, we are designed to die; it ensures that the best genes survive and controls competition for food and resources.

In otherwise healthy individuals, the final common road to dying is organ failure. Like machine parts they wear out, losing their youthful ability to repair. Then there are the more acute organ changes that precipitate death, such as trauma. In end-stage illness the only curative measure is transplant.

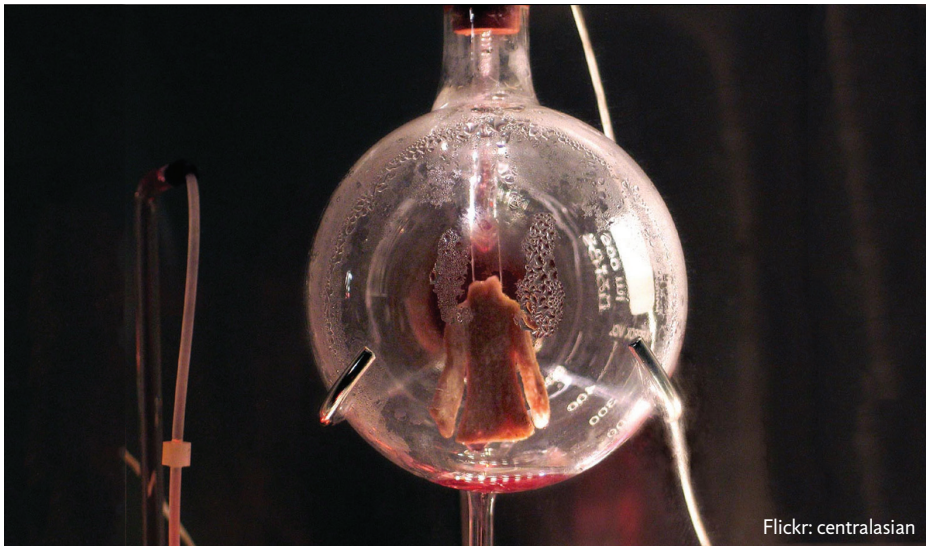
Mentioned in texts over 2000 years ago, transplants are surprisingly ancient. However, the first successful transplant was a cornea in 1905. The next – kidneys between identical twins – was fifty years later. The issue of rejection was first addressed in the 1940s and sufficient immunosuppressants discovered in the 1970s. In the intervening years hundreds of transplants were carried out, but all perished in the post-transplant days and months. The first successful heart-lung transplant was in 1981 and the field has grown exponentially since, including the live birth of a baby from a transplanted ovary in 2008 and a full face transplant in 2010. However, donor-transplants will never be suitable as large-scale therapy: donors are too few and the complications of immunosuppression severe.

REPLACE NOT REPAIR

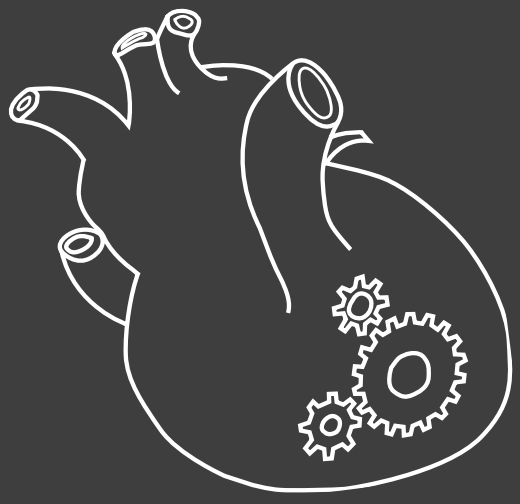
As Leland Kaiser predicted in 1992, "a future form of medicine that will interrupt chronic disease and repair or replace failing organ systems" is now coming to pass. Regenerative medicine based on stem cell research and tissue engineering is essentially building new body parts from scratch. Since the new parts have been genetically tailored to match the recipient, problems with rejection will be minimal. This technology is already being used in clinic.

Normal skin and tissue consists of cells embedded in a network of different fibres and chemicals including growth factors and signalling molecules. One such molecule is heparan sulphate, which has been used to help seal defects that cause herniation and promote regeneration of muscle chunks lost through trauma. The simple addition of heparan sulphate over wounds dramatically improves healing.

If cells are the various musicians in an orchestra, the extracellular matrix (ECM) is



Flickr: centralasian



a bevy of conductors organising them into glorious symphonies. For many years research has focussed on stem cells when the real magic lies in the matrix between.

"IT WOULD BE FANTASTIC TO HAND A TWENTY-YEAR-OLD STAB VICTIM NEW LUNGS"

Since discovering the power of this matrix, tissue engineering has exploded. In one case, a donor windpipe was cleansed of cells leaving the scaffold matrix behind, which was then seeded with stem cells from a young boy. The cells adhered and differentiated into tracheal tissue, and the whole complex was transplanted into the boy where subsequent biopsies demonstrated new blood vessels had entered and nourished the transplant. No rejection took place since ECM contains no immune markers. Further to this, pig bladder matrices seeded with stem cells have been successfully used in moulds to produce artificial bladders subsequently used in humans.

Some of the most exciting prospects in organ replacement are burgeoning alongside the advent of 3D printing; ECM and different cell types can be loaded into cartridges and printed onto any mould. Beating rodent hearts have been produced this way and while the technology is new it holds tangible potential.

However, medicine is perhaps the most ethically controversial fields of science because its remit includes life, death and everything in between. It would be fantastic to hand a twenty-year-old stab victim new lungs, or give a young woman with polycystic ovaries a new chance at conception. But would we give a ninety year old with heart failure a new heart? They've paid their taxes. A further ninety years of incontinence would be untenable, so we could replace their bladder. Aching joints could be renewed. Hair transplants would erase grey hairs, collagen erase wrinkles, we could replace any organ that harboured cancer.

But no matter what level of medical proficiency society reaches, we simply cannot regrow the brain. It is not a mechanical tissue; its function relies solely on the connections made, wired up in response to real-time events. The brain could be compared to the London Underground, with stations as brain cells and lines as signals. To get from Wimbledon to Earl's Court, one must pick a station on the District line. If Wimbledon were destroyed and rebuilt, it would be useless without being plugged back in to this line. You could plug it into the Central line but that would confuse everyone, and in a brain of this age, the rest of the Underground is unwilling to cooperate. Unfortunately for us, in the brain analogy, Wimbledon is connected to a few thousand different lines and by the time we've rebuilt that, Earl's Court would disappear. If you consider how much disruption line closures have on the Underground, you should have some understanding of what happens to neural circuits in the aging brain.

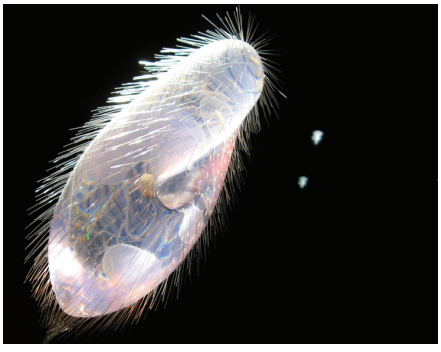
"WILL WE SIMPLY BE MAKING HUMAN DOLLS?"

Thus we may well be able to extend life, but at what expense? Will we simply be making human dolls, beautiful mannequins with fading memories and reduced interaction and awareness? And if doctors can't write "natural causes" on death certificates, what will they have to write instead – euthanasia?

ENGINEERING LIFE: *Apps, genomes and*

Douglas Heaven explores how synthetic biology and computer science can work in tandem to engineer the human genome.

In May 2010, the J Craig Venter Institute held a press conference to announce the creation of a synthetic bacterial species. After 15 years of work, Craig Venter's team, led by Nobel laureate Hamilton Smith, had managed to synthesise the entire genome of a bacterium and insert it into a recipient cell. "This is the first self-replicating species we've had on the planet whose parent is a computer," said Venter. "It's also the first species to have its own website encoded in its genetic code."



"It is my belief that the basic knowledge that we're providing to the world will have a profound impact on the human condition and the treatments for disease and our view of our place on the biological continuum..." J. Craig. Venter.
Flickr: photonquantique

WATERMARKING THE GENOME

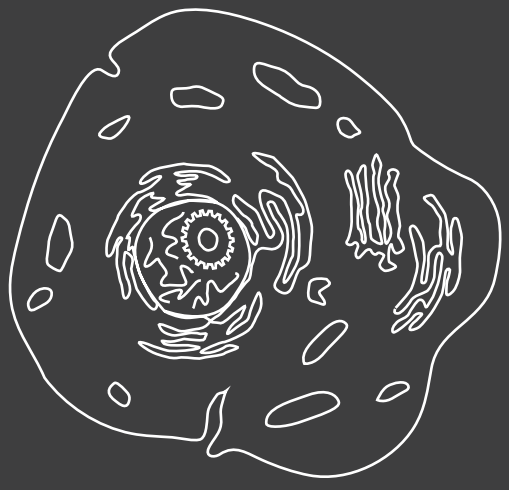
When Venter described the sequence of technical breakthroughs leading to this result – transplanting a chromosome from one bacterium to another, synthesising the Mycoplasma genitalium genome, growing artificial chromosomes in yeast, adding 'watermarks' such as a web address to synthetic DNA to make it distinguishable from naturally-contaminated DNA – there was a single question from the crowd of reporters. "Could you explain, in layman's terms, how significant a breakthrough this is?"

It's a question I put to Dr. Tom Ellis, a synthetic biologist from Imperial College London's Department of Bioengineering. For him, biological science and biotechnology are turning into an information science. "Think of the human genome as a vast amount of data," he says. "Now we're sequencing the genome of a new organism almost every day." Admittedly, these are mostly bacteria with relatively small genomes, but the amount of data appearing is still staggering. "Biology is now an information-rich subject," says Ellis. "Really information rich."

"WE'RE SEQUENCING THE GENOME OF A NEW ORGANISM ALMOST EVERY DAY"

Unsurprisingly, the common analogy is one of computation. "One of the major tenets of synthetic genomics," says Smith in *Creating Synthetic Life*, a documentary made for the Discovery Channel, "is that the genome, the chromosome of the cell, is the software – the operating system of the cell – and the cytoplasm is simply the hardware that allows a genome to express itself." This computational analogy can only be pushed so far, since DNA itself – the software – is physical: "You've got an operating system which is also part of the hardware", Ellis notes. But it's compelling, nonetheless.

"Synthetic biology is building new subroutines to run on the operating system," he says. We can put subroutines in a more

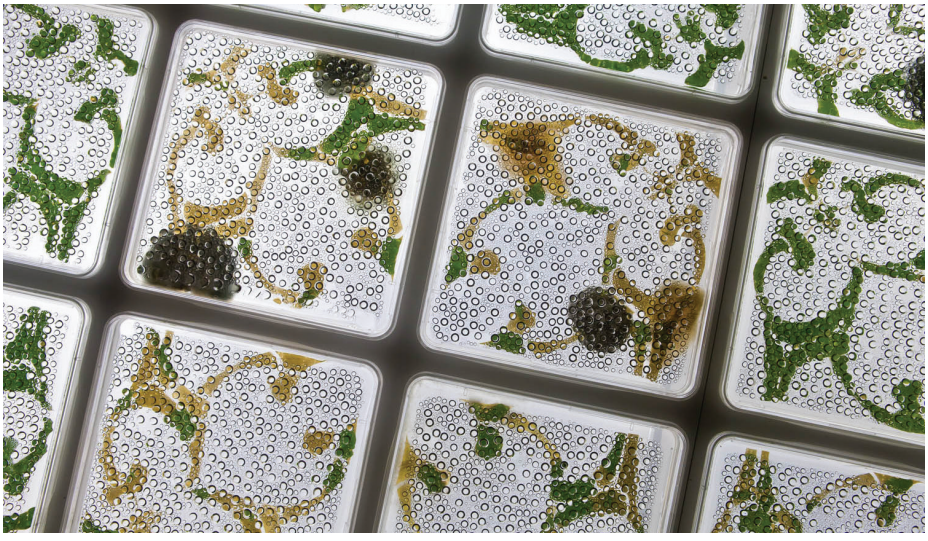


familiar context by slightly adapting Smith's metaphor and thinking of them as apps, with the cell as a phone and the genome representing an operating system such as iOS or Android. Such apps are currently modest constructions, but researchers are "building up to entire programs that you can load and even subroutines that can then be engineered to run within those programs," he says. "We're getting up to that sort of complexity now."

CELLS AS APPS?

"The majority of synthetic biologists are working on the design of effectively small software apps that will boot up and run within the genome," says Ellis. "What Venter showed is that all the materials are there to be able to write the entire operating system." But, importantly, he didn't rewrite it from scratch. Imagine a hacker copies the code for an operating system and adds something at the end – perhaps just a comment with their name. "That's what Venter's done – copied the entire genome and in just a few places put watermarks to say this isn't the original one, this is the one with our change," he says. "Do they understand the program, the operating system? Not really. Not yet. But they want to."

Many institutions are working towards standardisation – in terms of data, how specific biological parts should be defined, and how parts are measured – that will bring an even greater level of engineering maturity to the field. "At the moment the computing analogies function to galvanise people into action," says Dr Darren Nesbeth of University College London's Biochemical Engineering Department. "Right now, most biological labs in the world pretty much do things in a bespoke manner. If people constructed biological devices using the same standardised language, then there are benefits to that in terms of what people can do."



This photo of tobacco plant leaves by Kristof Vrancken was part of an exhibition 'Alter Nature: We Can' that showed at the Z33 art centre, Hasselt during 2010/11. Growth Pattern consists of a 2.5 x 2.5m grid in which 64 Petri dishes contain tobacco plant leaves cut in specific shapes. Flickr: z33be

BESPOKE BIOLOGY

Standardisation will further support the establishment of repositories of biological components such as the BioBricks Foundation, which maintains a catalogue of parts and devices. "Hopefully, we'll get to the stage where you can have an algorithm which tells you all of the rules for where things should go if you build up an entire genome from scratch," Ellis says. "And then from that point, someone like Venter could sit down with the parts list he wants and create a cell that had a completely synthesised genome based just on parts."

"The actual definition of synthetic biology is quite hard to pin down," he tells me. "But the simplest way you could put it is that it's about applying engineering principles to biology."

The more I think about what this prosaic statement actually means, the more I'm struck by its audacity. ■

MATHS AND IMAGINARY

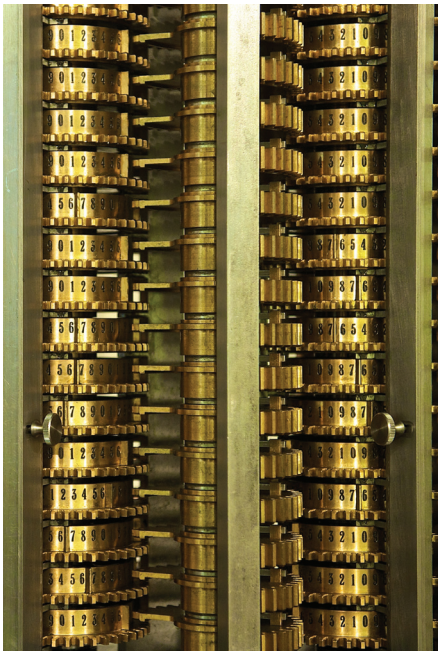
Programming is a skill that allows us to develop and personalise the functions of computers – and anyone can learn to harness it, argues **Michael Cook**

One of my favourite editions of historical webcomic *Hark! A Vagrant!* is about Ada Lovelace, daughter of renowned poet Lord Byron and a gifted mathematician. In the comic, Ada's mother hides the young girl from a passing poet, for fear that she might be tempted into her father's wild life. Purportedly, it was her mother's fear that led to Ada's rigorous mathematical education, something that caused her to achieve notoriety as the world's first computer programmer. This achievement was even more impressive due to the simple fact that computers didn't actually exist yet.

SPOT THE DIFFERENCE

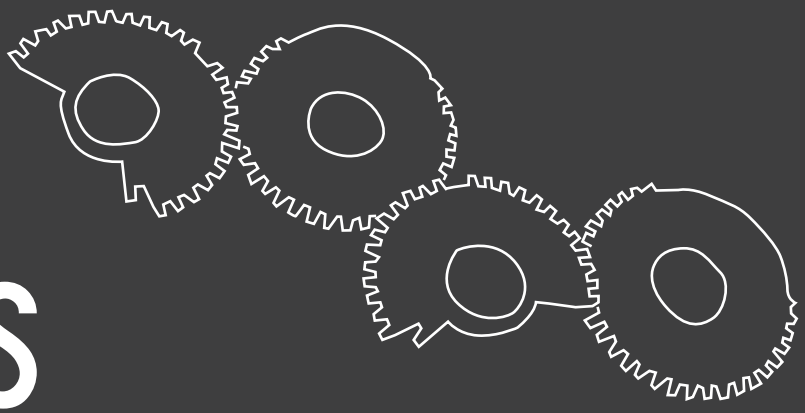
When mathematician and inventor Charles Babbage failed to construct his Difference Engine for computing logarithm tables in the 1800s, he drew up designs for an even more complex machine that could be programmed through punch cards – the Analytical Engine. Lovelace was one of the few people who understood Babbage's idea, and wrote what amounts today to a computer program for calculating Bernoulli numbers for a machine that didn't even exist. As any computer scientist will attest, some days it is hard enough writing code for a machine that is right in front of you. It wasn't until 1991 that Babbage's Difference Machine was finally built, and although his Analytical Engine is yet to be fully built, Ada's algorithm has been verified as correct.

The programming aspect of a computer is what makes it such an invaluable tool to human beings. Tools are a key part of our society and are crucial to our rise as a species, but most tools are developed for specific uses – from crude stone axes right through to Geiger counters and plasma cutters. Unlike these specific tools, computers are designed to understand very small instructions, allowing us to build up layers of complexity resulting in three-dimensional simulation, international communication and artificial intelligence. Without programming, modern technology is just a series of single-use items, no more remarkable than a clay bowl.



Charles Babbage's difference engine
Flickr: Larry Johnson

MACHINES



"IT IS HARD ENOUGH WRITING CODE FOR A MACHINE THAT IS RIGHT IN FRONT OF YOU"

Despite this immense flexibility and power found in every computer, only a very small proportion of our society are able to make the most of it. The majority of us use our computers for a very limited range of purposes. We play games someone else made, we check our email using protocols and encryption algorithms someone else designed and we print our photos only after letting someone else's application touch them up automatically. For all the wonder and potential inside the grey metal boxes we carry everywhere with us, we are quite happy to treat them as a Swiss Army knife – multipurpose, but limited to what its designer intended it for. It's a curious situation, but one that might be changing.

TEACHING TECHNOLOGY

Many governments are now announcing a greater emphasis on teaching schoolchildren to program and to understand computer science, which might lead to an upcoming generation that are not only users of code, but creators as well – people who can adjust and tweak and create software that solves problems unique to them, in a way they want them to be solved. This paints an optimistic picture of the future – where everyone has the knowledge to protect themselves from exploitation online and to create and share solutions to niche problems that might not be commerciall viable to solve today.

What happens to the generation caught in the middle, though? We often laugh (or at least wryly smile) at the generations before us for being less tech-savvy, unable to send text messages or avoid viruses online. Yet we are about to be succeeded by a generation that will not only have their own gadgets that we won't understand – they'll be controlling them in a way we won't understand either.

"PROGRAMMING CAN BE MUCH SIMPLER THAN IT IS PORTRAYED TO BE"

Fortunately, there are organisations online that don't think it is too late to turn this around, the most passionate of which are Code Year and Codecademy, two websites running with the grand aim of teaching programming to everyone, regardless of skill or savviness. The former, Code Year, runs weekly tutorials teaching programming from the ground up, using pleasing interactive lessons that let you write real code, see it running and get immediate feedback. It is an incredible service, offered for free, that thousands of people around the world are now taking part in (and it is not too late to start either – you can catch up with their previous lessons too).

The message Code Year tries to get across is that programming can be much simpler than it is portrayed to be, that it is not some dark art as it was in the days of Ada Lovelace and the imaginary machines she wrote algorithms for. Today, programming isn't all maths and imaginary machines – you are carrying all the tools you need around with you. Take advantage of it.

Part of a Kate Beaton comic entitled 'Young Ada Lovelace'.


MADE IN HONG KONG
SQUARE
M2GH
CHUBB
ROLSECURE
TELFORD
EURO LOCKS
ROSS
Tri-Circle
264
MADE IN CHINA
RST
MADE IN ENGLAND
102
192
267 10
27
YALE
CHUBB
Yale
BIRD
TRADE MARK

SCIENCE BEHIND THE PHOTO

WORDS AND PHOTOGRAPHY BY PETER LARKIN

For nearly as long as we have been creating objects of value, we have been developing ways to keep them safe. Being a relatively untrusting species has meant that we have invested a significant amount of time developing security measures to keep our belongings out of the hands of other people. Apart from simply hiding objects or constantly looking after them, a method was required to secure objects from the prying hands of our neighbours. The result was the lock and key.

The first locks to be created were made from wood and thought to be in use around 4000 years ago. They worked in a way that is not too dissimilar from the locks and keys we currently use, employing a series of pins that drop into a corresponding series of openings in a bolt. Whilst the lock and key hasn't always stopped the most determined of thieves, they have done a pretty good job of keeping us and our valuables safe so far.

But as we move further into the Digital Age, the emphasis in security has moved on from protecting tangible objects to securing the zeroes and ones that make up our digital assets. Not only have digital products such as music and film been the target of digital piracy, but sensitive information stored digitally has also come under threat, and is a growing area of concern for individuals and organisations alike.

RSA, one of the main algorithms used for cryptography, is essentially the digital equivalent of the padlock. It is based on the factoring problem – the supposed difficulty of factoring the result of two large prime numbers multiplied together. The product of the two prime numbers is known as a public key and can be used by anyone to encrypt a digital file. However, only the person with the private key – which contains the original prime numbers – can decrypt the file. The principal of RSA was recently thrown into question by researchers in Switzerland who have discovered a way to uncover the original prime numbers for a small fraction of public keys, putting around 200,000 embedded devices, such as routers, at risk.

The next big hope for digital cryptography is the exploitation of the effects of quantum mechanics to provide unconditional security. The use of quantum mechanics guarantees that any attempt to read quantum data disturbs that data, putting out the alert that the data has been interfered with. But quantum cryptography may not be as infallible as once thought. Researchers in Canada have recently shown that, in practice, quantum hacking could go undetected at the level the quantum keys are distributed.

It seems that as long as our digital systems rapidly continue to become more complex, digital security will have to adapt quickly and may struggle to keep up. ■

LOOKING OUT

Of all the man-made instruments we have invented over the years, the telescope and the microscope are perhaps two of the most influential. ***Nicola Guttridge*** *describes the history of these two scientific lenses that enable us to see the very tiny and the very large in incredible detail.*

Galileo cannot take sole credit for inventing the telescope – he apparently took the idea from a Dutch spectacle maker and the design was later much improved by Newton's addition of mirrors – but he was the first to turn it towards the heavens and use it as an astronomical tool.

Through this he observed sunspots, lunar craters, Jupiter, Saturn, Venus, and the stars of the Milky Way. He was limited only by the resolving power of his early telescope, and came painfully close to discoveries such as Saturn's rings, which he viewed as 'bumps' on either side of the planet. His observations undermined many ideas of the day including the geocentric Ptolemaic model, the idea that there were only a small number of fixed stars in the sky, and Aristotelian concepts of perfect unchanging spheres.

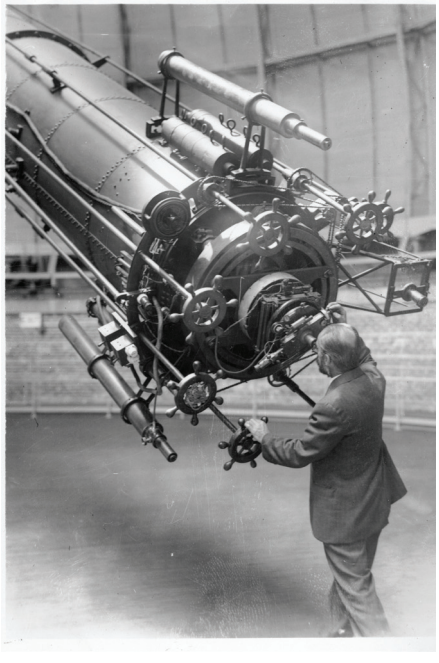
However, it is not only telescopic resolution that limits our stargazing. Ground-based telescopes suffer from a lot of optical problems. Due to the Earth's atmosphere, images obtained are distorted, and certain wavelengths of light are weakened. The next logical step was to launch a telescope into space, which NASA did with the Orbiting Astronomical Observatory in 1968. Space telescopes are very impressive pieces of kit, combining the delicate precision of the inner components with the robust outer casing for survival in space. However, maintenance and repair is very expensive and dangerous, as NASA found after the launch of Hubble. Carried into space aboard a space shuttle in 1990, NASA scientists and engineers soon discovered that the primary mirror had been ground incorrectly, rendering it almost useless. A servicing mission in 1993 managed to restore the telescope to its planned capabilities, but acted as a warning over the potential problems with space-based telescopes.

Despite the embarrassing slip-up during the making of Hubble, it has had a huge impact on our knowledge of the universe. Its photographs, including the most famous 'deep field' and 'ultra deep field' images, are not only goldmines of information but are also astoundingly beautiful.

We even focus on areas of our own exploration. Recent images of Apollo lunar landing sites taken by NASA's Lunar Reconnaissance Orbiter are extremely detailed. It is even possible to make out the tracks made by Neil Armstrong as he shuffled away from the lander to place the flag on the moon's surface, power cables trailing across lunar rock, or the marks left in the soil after the astronauts attempted a quick game of golf during the Apollo 14 mission.

Advancements like this enable us to investigate the human history of discovery and are the most effective in capturing our imagination. The telescope brings the astronomically distant within sight, reducing the vastness of the universe to a human scale.

George A. Van Biesbroeck (1880-1974), astronomer at Yerkes Observatory observing Mars when it approached close to the Earth in 1926, and using a 40 inch refracting telescope, the largest of its kind in the world. Image credit: Smithsonian Institution Archives



LOOKING IN

Zoologist Elizabeth T. Kinney sitting by her microscope at the University of Pittsburgh. Image credit: Smithsonian Institution Archives

There are several defining experiments in the memory of any GCSE science student; the unmistakable smell of Bunsen burners, the horrific-yet-hypnotic moment when the teacher inflates a pair of pig's lungs with a straw (and, fingers crossed, remembers not to inhale), and, perhaps one of the most fascinating: preparing microscope slides of onion cells and cheek swabs.

Experiments such as this do not do the technology justice; the idea that it is possible to peer into the very heart of a biological cell – in the case of cheek swabs, our own cells – is astounding. The humble microscope is often overlooked, but it allows scientists to see things that are otherwise invisible to the naked eye. It also brings an important personal aspect to scientific research; photographing a star is incredibly inspiring, but outer space can seem very abstract. Theories based on microscopic objects are rife, especially in fields like cell biology and organic chemistry, and so the ability to view them is vital.

The optical compound microscope, developed in the early 1600s and initially named the "little eye", was in itself an impressive feat of human engineering. However, it has since led to the invention of highly complex fluoromicroscopy and darkfield, X-ray, SEM and STM microscopes over the course of around 400 years. Microscopic discoveries have had a far-reaching impact into fields such as bio-replication, where the minute structures visible on insect corneas are used to research the possibility of mass-production of commercial lenses and solar cells. Observations of Brownian motion and cell division helped to prove the existence of the atom, and to further the support for Darwinian evolution.

However, it is not just science that was changed by the invention of the microscope – philosophy and culture were also greatly affected. When the microscope was being developed, disease was attributed to angry Gods and life was thought to be created and destroyed according to the whims of a life force or greater being. In the 1670s and 80s, amateur scientist Leeuwenhoek was the first to observe single-celled organisms that he labelled 'little animals' through a homemade microscope, noting that they "had a very strong and swift motion, and shot through the water like a pike". The Royal Society dismissed his claims for a number of years, but Leeuwenhoek had seen bacteria, something that would lead humans to accurately classify, treat, and prevent disease and infection.

This impact is nowhere near ceasing, with exciting developments within electron microscopy. Electron microscopes emerged in the 1930s and possess a greater resolving power than optical ones as they use a beam of small electrons to resolve their images. These electrons have wavelengths that are approximately 100,000 times shorter than visible light and so can achieve useful magnification of x10,000,000, compared to a much lower x2,000 for photons. A very useful application of such microscopes is for 3D imaging, something optical microscopes are unable to achieve due to their lack of depth of field.

The microscope is the inspiring result of human thought, engineering and skill, and has helped to further countless scientific disciplines since its invention – viewing the very small has proven to be a very big achievement.

MAN-MADE FOOD

From GM crops to lab-grown meat, we have the ability to alter and manipulate our food – but will it make its way to our plates? ***Sacha Thorpe*** *questions our attitudes towards technologically modified food.*

For some time, Churchill's prediction in the 1930s that "we shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium" seemed somewhat fantastical. However, the first signs of lab-grown meat are now beginning to surface.

The US charity, People for the Ethical Treatment of Animals (PETA), have offered a $1 million reward for the first edible lab-grown chicken breast – and researchers at the University of Maastrich are confident they will be able to produce an artificial burger by the end of 2012. Two methods currently exist to produce in-vitro meat. One is to attach satellite cells from muscle tissue to a scaffold to differentiate into myofibers. The other is to introduce skeletal muscle explants into a culture medium. In both cases, the cells multiply to form a strip of meat of exactly the same cellular composition as its natural counterpart.

This might seem a bit Frankenstein-like, but scientists have hailed the numerous benefits of such meat. In theory, large quantities could be produced from a single donor animal, allowing a much more efficient use of the Earth's resources and space, and a reduction in pollution related to rearing livestock. Researchers believe the process could consume 35 to 60% less energy and 98% less land than current meat production. Add to that the possibility of reducing fat content, avoiding food-borne pathogens, and an end to suffering for animals – hence PETA's interest – and the future seems very bright indeed.

However, will consumers accept meat from a lab? Those who have seen the lab-grown meat have reported something colourless, tasteless and lacking texture. A quick glance at commentaries circulating online is enough to illustrate the fact that people seem to have a natural aversion towards meat which isn't really meat. This 'yuck' factor also derives from the aversion towards the scientific manipulation of nature, especially when it comes to food. The parallels with attitudes towards another type of man-made food, GM crops, are evident. As with lab-grown meat, GM crops have been lauded as the solution to world hunger due to the possibilities of introducing resistant plants to countries where failed harvests are frequent. However, consumers have been hard to win over. Why is

this? One reason is unease regarding the potential risk which consumers believe GM foods carry for both the environment and consumer. Whatever the justification for growing meat in the lab, the public seem to see the risks as outweighing the benefits.

Another public concern with GM foods has been the fear of a monopoly of the technologies by large multi-national companies. This could also be a worry in relation to lab-grown meat. Can they be trusted with the foods of the future? The potential to solve the food crisis and environment claimed by the technologies may be hard to reconcile with a profit-making enterprise.

The GM story shows that tampering with food is not readily trusted by consumers – even though ever since the advent of agriculture, all crops and livestock have been to some extent 'man-made' through selective breeding. One possibility would be to focus more on upgraded selective breeding through Marker-Assisted Selection (MAS), where genomic studies are used to determine which genes are associated with particular traits. This would produce varieties that are more finely tuned to a particular environment without drawing on the more 'Frankenstein' end of GM. Enhancing an existing process in this way might be more easily accepted by consumers.

Churchill presumably saw his prediction in a positive light; however, the implementation of man-made food has turned out to be a complex process with social, economic and environmental consequences. Without public trust, the transfer of a feat of technology from the lab to the public table has proved problematic for GM foods, and is likely to be just as difficult for man-made meat.

Image: Pacific Northwest National Laboratory

WRITTEN BY JENNIFER WHYNTIE

SIX GREAT INNOVATIONS

1 PROFESSOR STEPHEN COWLEY: AT THE FOREFRONT OF FUSION

Professor Stephen Cowley, CEO of the UK's Atomic Energy Authority, imagines that the first electricity-producing fusion power plant could be built in Europe during the 2030s. It seems we are often told that usable fusion technology is about thirty years away. However, ITER, the world's largest fusion reactor to date, is set to start operating in 2019. The project is funded by a global collaboration of agencies, with China, the EU, India, Japan, Korea, Russia and the United States all on board. Perhaps we could be closer to a source of the longest-lasting, cleanest power possible than ever before.

2 CATALYTIC CLOTHING: BREAKS DOWN POLLUTANTS WHILE-YOU-WEAR

Combining their knowledge of fabric and chemistry, the team led by fashion professor Helen Storey and science professor Tony Ryan have created jeans impregnated with a photocatalyst. Using energy from sunlight and water in air, the clothes break down common airborne pollutants, such as nitrous oxides and volatile organic compounds, as the wearer moves around. One square metre of coated fabric can take out 0.5g of NOx per day. This means that if the goods prove popular, they could measurably improve air quality in the world's cities. Items could be on sale in two years time.

3 PROFESSOR ED BOYDEN: BRAIN ENGINEERING

You might have seen the head of MIT's Synthetic Neurobiology group on Adam Rutherford's recent BBC Horizon episode. His team have elegantly coated specific brain cells in mice with light receptors from photosensitive algae. When blue light, delivered to the mouse in a choice chamber, hits the modified dopamine neurones, they activate. This delivers a shot of the reward chemical to the mouse's brain, causing it to repeat the behaviour that gave it the dose, effectively stimulating learning. The technology has potential applications in reducing post-traumatic stress disorder, and could even remedy certain common forms of blindness.

4 PROFESSOR ALEXANDER SEIFALIAN: REPLACEMENT ORGANS

Last July, a windpipe created by Professor Alexander Seifalian became the first synthetic organ to be transplanted into a human. The professor and his team at University College London produced the section of trachea using a specially-shaped section of their patented nanocomposite "plastic-like" scaffold. They seeded this with the patient's own stem cells, then grew the organ in a bioreactor. Professor Seiifalian is now working as part of a team hoping to make the world's first synthetic voice box. Clinical trials for this transplant begin next year.

5 THE WYSS INSTITUTE: REVOLUTIONARY TECHNOLOGY INSPIRED BY NATURE

This cross-disciplinary institute contains some of Boston's finest minds from, amongst distinguished others, the Harvard Schools. They aim to discover more about engineering within nature and use these principles to create revolutionary technology. Inspired by the Nepenthes pitcher plant, they have created SLIPS: Slippery Liquid-Infused Porous Surfaces. This inexpensive material is ultra-repellent; impervious to tricky substances such as blood, wax and ice. Self-cleaning and self-healing, it could lessen the enormous number of unwanted interactions between liquids and surfaces. These include reducing microbial growth on medical kit, and lowering drag in transport systems.

6 DR VICTORIA COKER: BACTERIA THAT CLEAN UP AFTER US

Geomicrobiologist Dr Victoria Coker plans to use her L'Oréal Women in Science Fellowship to support research into high-resolution mapping of the fate of toxic and radioactive metals in environmentally relevant materials. Using state of the art Scanning Transmission X-ray Microscopy, Dr Coker will examine bacteria that break down metals as part of their metabolism. She hopes to discover the role that these bacteria could have in managing our environmental legacy. Her findings may help us to deal with toxic metal contamination and offer new ways to make nuclear legacy materials safe.

BABIES TO ORDER?

Imagine you've stumbled across a website that promises you a 'perfect' blonde-haired, blue-eyed baby. Is it too good to be true? This is what ***Lucy Van Dorp*** *found when she investigated GenoChoice, a spoof website set up to test public reaction to the issue of human genomics*

I can't help but feel ill at ease as I tick off the characteristics I want for my online child: sex, eye colour, hair colour, intelligence, and so on. Simply put, it seems that for a tidy sum anyone can have the 'perfect' blonde-haired, blue-eyed child, free from genetic abnormalities. OK, so GenoChoice is a spoof website, but nevertheless it poses some interesting questions. How long will it be before this kind of website becomes a reality? Do we really want a society of citizens designed to be whatever we deem as genetically 'optimal'? And what is the scientific reality, aside from the media hype?

"DO WE REALLY WANT A SOCIETY OF CITIZENS DESIGNED TO BE WHATEVER WE DEEM AS GENETICALLY 'OPTIMAL'?"

To some extent, babies are already being designed. It is already possible to select an embryo's sex, have it screened for genetic disorders or choose an embryo that is a match for an ill sibling. These are all achieved using a technique known as pre-implantation genetic diagnosis (PGD). Such a technique allows couples who may otherwise pass on a debilitating hereditary disease the opportunity to have healthy children.

PGD is only capable of choosing between embryos with genetic profiles inherited from their parents. It is all very well ordering a designer baby with the brain of Stephen Hawking and the body of Kate Moss, but if the parents don't have those qualities it simply can't happen. It's currently not even clear to what degree traits such as beauty or intelligence are genetically determined. However, real 'designer babies' might one day become possible through advanced genetic engineering. One possibility is the use of synthetic chromosomes which have been engineered to carry beneficial genes. These chromosomes can be inserted into the cells of early stage embryos to produce a child with traits entirely independent of those of its parents.

So what are the objections? For many, the use of PGD sets an alarming precedent. Opponents argue that it is only a matter of time before societal pressures dictate selection preferences such as intelligence, athletic ability and good looks, rather than those for disease status, sex and genetic compatibility. This could lead to children being commoditised and the human race becoming one of unblemished stereotypes free from diversity and disability. For proponents, PGD holds promise of a society free of genetic disorders in which parents with heritable diseases have the opportunity to halt the progress of a disease that may have plagued the family line for generations.

PGD and associated technologies can and probably will be used to create designer babies. PGD is already being used outside of the UK to select for gender and consequently there has been a rise in so-called 'IVF tourism'. The medical potential presents both an exciting opportunity and a threat. In the right hands, the technology offers society freedom from some of the most debilitating genetic disorders, and techniques are constantly improving. But poorly governed – as it is in many countries outside of the UK – the consequences of such a technology may not bear thinking about.


Image: D. Sharon Pruitt

WHAT IS PRE-IMPLANTATION GENETIC DIAGNOSIS (PGD)?

A mother-to-be undergoes In Vitro Fertilisation (IVF) treatment, in which an unfertilised egg is removed from her and fertilised in a petri dish with sperm from her partner. At the eight cell stage, cells are removed and tested, and only normal embryos are transferred back into the mother's womb.

PHARMING:

The New Farming?

Biotechnology allows us to create some extraordinary animals. ***Sarah Byrne*** *asks whether the principles behind these novel techniques are as new as we think.*

Goats that produce spider-silk in their milk, cows lactating insulin, pigs growing human corneas for transplantation. These are some of the strange animals that can be seen around farmyards and labs. Using techniques such as transgenics – inserting genes from one species into the genome of another – and stem cell technology, we increasingly have the ability to design animals according to our needs. Sometimes called 'pharming' when used to produce drugs, this technology sounds futuristic. But the concept of man-made animals goes back many thousands of years, to when we first started to domesticate the species around us.

Domestication is far more than just capturing and 'taming' wild animals. After many centuries of selective breeding, most domestic animals are now entirely different species from their wild ancestors, with both their physical characteristics and behaviour changed beyond all recognition. We have used them for food, or for their milk or fur or skin, put them to work alongside us through centuries of agriculture and industry; they have even lived with us in our homes as friends and companions. We have been creating designer animals for a long time.

This raises the question of whether we have a special responsibility towards these animals, for their welfare and their very existence. Some might argue that, as we created these animals, they are ours to dispose of as we wish, that the moral obligations we might feel to conserve and protect wildlife do not apply here. But this would not sit well with most of us, especially when it involves more intelligent animals. So there are ethical questions to answer.

The trait we insert or select for may be harmful or unpleasant for the animals themselves; we might ask to what extent this is justified. What is increasingly accepted as wrong when done for trivial cosmetic reasons – show dogs with legs so fashionably deformed they can barely walk, or with such adorably snub-nosed faces that they struggle to breathe – becomes far less clear-cut when the trait has some practical purpose which benefits us, such as dairy cows bred for maximum milk yields despite the discomfort and strain on their bodies. And even less so when we are talking about life-changing, life-saving products such as insulin or organs for transplant.

Additionally, the unavoidable fact is that having created new animals, we are stuck with them. What should we do with them? We can't set them free, release them back to their natural habitat – because they don't have one. The only option is to look after them.

The ethical issues are not new, but the recent developments perhaps sharpen the need to think about them. And in doing so, it may be worth considering whether there are lessons we can learn from the past. ■

SELECTIVE BREEDING

- May require many generations to get desired result
- Breeding only between members of the same or related species
- Impossible to target single gene, often unintended/additional consequences
- Used for thousands of years

GENETIC ENGINEERING

- Changes can be made in a single generation
- Transfer of genes from another species
- Changes can be targeted to a single gene
- Relatively new technology

NUCLEAR FUSION

***Rich Millar** investigates the possibilities of nuclear fusion and how its development is shaping international scientific cooperation.*

For centuries, humans have looked up at the sun, shining brightly in the sky, wondering what it really is. In ancient times, it was thought of as a God, a creator, shining benevolently over us. Some of the first scientists even thought that the Sun was a huge fire burning away above the Earth. It was only relatively recently, with the discovery of quantum mechanics, that we have been able to understand exactly what the Sun is and how it shines. As we pass from an age of scientific discovery to an age of scientific mastery, we approach a new phase of our understanding of the Sun and, with it, the ability to harness its awesome power on Earth.

The currently accepted theory of how the sun shines is that of nuclear fusion. Imagine firing two north ends of really strong magnets straight toward each other; as all good physics students will remember, the magnets repel each other, slowing down as they near each other before finally stopping, and moving away again. This is an example of the electromagnetic repulsion that needs to be overcome when two similarly charged objects approach each other. The reason stars burn so brightly is because their cores are hot enough to overcome this coulomb barrier. This allows the hydrogen nuclei in the plasma that makes up the body of the star to move close enough to make physical contact and, consequently, fuse together. Energy released in this process then radiates out across space in the form of light and heat.

The challenge of achieving fusion on Earth corresponds to achieving and sustaining these star-like conditions. One way of doing this is via a machine called a Tokamak. A Tokamak is a large doughnut-shaped chamber in which a plasma of hydrogen nuclei is confined using large magnets and then heated by firing electromagnetic beams into the chamber. The plasma is heated in this way until it reaches a temperature high enough to overcome the coulomb barrier and allow fusion to occur. The temperature required to achieve this is approximately 100 million degrees Celsius. The heat produced as a result of this reaction is then used to heat water and subsequently generate electricity in the same way as in conventional power stations.

The International Thermonuclear Experimental Reactor (ITER) is a worldwide collaboration dedicated to building the world's largest and most advanced Tokamak experiment. It is the first attempt to demonstrate a working fusion power plant. The reactor is being constructed at a site in the south of France and should become operational by the end of the decade. ITER marks a new pinnacle in scientific cooperation too. It is funded by seven separate entities, including the EU, USA and China, with the results and benefits available to all. It has been hailed as the ideal model for large-scale scientific collaboration projects and as a model for international cooperation in this globalised but mistrustful age.

Without a doubt, fusion energy will play a large role in energy production for generations to come. Producing no harmful by-products and with no chance of dangerous large-scale industrial disasters, nuclear fusion has the advantage over our current energy solutions: fossil fuels and nuclear fission. The deuterium fuel of the fusion, which is harvested from sea water, is plentiful enough in the Earth's oceans to supply the current and growing energy requirements for millions of years to come.

In a world of expanding energy demands and countless new man-made technologies, imagine what could be achieved with access to a clean, safe and essentially unlimited source of energy. The world would never be the same again.

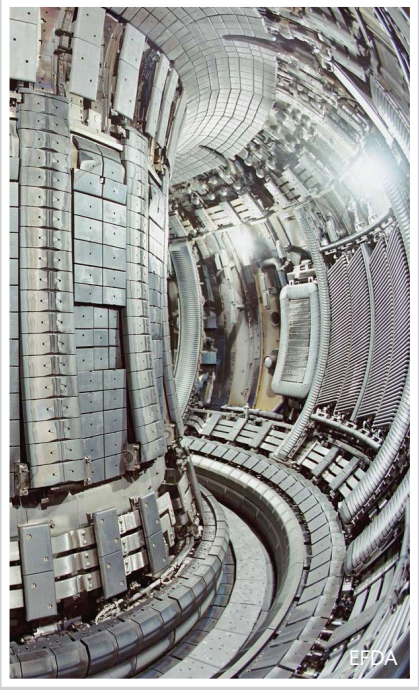

Flickr: Tomorrow Never Knows

> "IMAGINE WHAT COULD BE ACHIEVED WITH ACCESS TO A CLEAN, SAFE AND ESSENTIALLY UNLIMITED SOURCE OF ENERGY"

> THIS WAS NO ORDINARY ISLAND...IT WAS A PATCH MADE SOLELY FROM TRASH

THE GREAT PACIFIC GARBAGE PATCH

Where does the future lie for the recycling of plastic pollutants in the world's oceans? ***Juan Casasbuenas*** *explains the microplastic threat and how it may lead us to build a habitable 'plastic island' at the heart of the Pacific.*


EPDA

In 1997, Captain J. Moore was returning home from a sailing race when he discovered a new island in the middle of the Pacific. However, this was no ordinary island. It was a patch made solely from floating trash: the Great Pacific Garbage Patch. This gyre of marine litter in the North Pacific Ocean is a result of marine debris being gathered by the ocean's currents and trapped in the middle of the ocean by a relentless vortex. Although its size is believed to be equivalent to the size of France, this massive accumulation of mainly plastic remains largely undetected. There are similar patches like this in all of the world's oceans and they represent a huge environmental threat.

We usually associate the environmental threat of plastics with images of marine animals being trapped or choked by large pieces of waste. Increasingly, though, research is showing that we should be seriously concerned about plastics that are invisible to the naked eye, known as microplastics. In January, a paper in the journal *Environmental Science and Technology* showed that microplastics make up 80% of the plastic polluting the environment, and that the highest proportions of microscopic pieces can be found in all samples of coastal sea water taken from different places worldwide.

The origin of these tiny pieces can be from industrial processes, the breakdown of bigger pieces of plastic, or even from synthetic fibres when we wash our clothes. There are already indications that microplastic debris is entering the food chain and persisting in animal cells, causing toxicity. Given its persistence, there are concerns that humans will ultimately be affected.

Some of the solutions to this problem seem to lie in the realm of fantasy. For example, Dutch eco-architects WHIM want to upcycle the Great Pacific Garbage Patch by cleaning it up and turning it into a habitable landmass. Another idea is to harvest all of the plastic in the ocean and turn it into oil through an expensive process known as pyrolysis. At the moment, both are technically and logistically impossible due to the massive size of these garbage patches.

The only realistic solution is preventing plastic from reaching our oceans in the first place. Only 10% of plastic trash is recycled because it is so hard to sort. However, as Mike Biddle illustrated in a TED lecture at the end of last year, the technology does exist to build plants that can sort and recycle all plastics. Another great example of a step in the right direction is the new 'Waste Electrical and Electronic Equipment' legislation; this overhauled law passed by the European Parliament in January will force large electronic retailers to take back broken or obsolete gadgets and recycle them. These are the types of initiatives we need to at least slow down the huge influx of trash into our oceans.

INTERVIEW WITH AN ASTRONAUT
COLONEL DAVID SCOTT

I, Science's ***Nicola Guttridge*** *interviewed ex-NASA Astronaut* ***Colonel David Scott****, who made his first flight into space as pilot of the Gemini 8 mission along with Neil Armstrong in 1966 before going on to be Command Module Pilot aboard Apollo 9, and finally commander of the Apollo 15 mission. As part of Apollo 15, Scott became the seventh person to walk on the Moon and the first person to drive on the Moon. Scott is currently promoting a re-release of Two Sides of the Moon – the stories and memoirs of Scott and Soviet cosmonaut Alexei Leonov during the 'Space Race'.*

I'm sorry this is a tired question – but what was it like walking on the Moon?

Yes, we are all asked that question frequently. "What is it like" covers such a broad range of "feelings" that a simple one-liner cannot tell the totality of the story. Some answers are in an article I wrote for the National Geographic in September 1973, "What Is It Like to Walk on the Moon?" Accelerating, challenging, very hard work… "Walking" (or hopping) is very much like bouncing across a trampoline; one reason being that the ankle joints on the spacesuit are easier to flex than knee and hip joints.

Is there anything you wish you'd done while you were on the Moon or in space that you didn't get a chance to do?

Yes, explore the North Complex at the Hadley Apennine site; a very geologically significant location, within easy driving range for the rover. However, complications with the drill/heat-flow experiment (due to design flaws) reduced the time available for the planned traverse; and time is the most limiting element of lunar exploration.

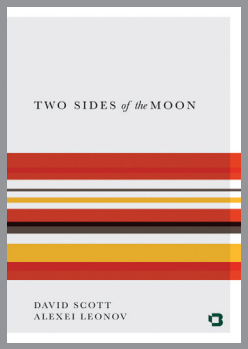
If you could go anywhere in the universe, where would it be and why?

The Moon. Because there is still some much to be learned from the Moon; and the Moon is without doubt the best site for preparation for further human expeditions into the solar system.

As explained in the book, the "space race" was very politically-driven. Do you feel that now this motive is less prominent, there is less emphasis on exploring space?

The political motive is less prominent, but the interest in exploring space is even broader today due to scientific, technical, and cultural advances of the past few decades. The Internet is an example, and correspondingly such evolving concepts as social media and the stimulation of joint space projects among many countries. Because of the 'space race' and the success of Apollo, the political emphasis in terms of funding is no longer as strong because fortunately free societies now prevail; and within our free societies, clear justification for human space exploration must be made, but the results will be even more rewarding, and far beyond the early Apollo

Left: David Scott (left), Al Worden, and Jim Irwin aboard the U.S.S. Okinawa in 1971. **Middle:** David Scott in the open hatch of the command module of Apollo 9, conducting one of the first docking maneuvers in space in 1969. **Right:** Scott being greeted by a Navy diver who has just opened the command hatch, 1971. *Images courtesy of NASA.*



The book is a reprint published by Bedford Square Books. "Much of the publishing industry is suffering at the hands of a short-lived turnover in books – from first publication to falling out of print – without much in the way of an intermediary stage to keep certain books alive," says Bedford Square Books' Harry Man. "This is one of the very first books of its kind to be produced by a London-based literary agency rather than a conventional publisher. That in itself makes the book something of an artefact."

lunar landing missions as was demonstrated on later extended scientific missions such as Apollos 15, 16, and 17.

Where do you think the future lies for human space exploration?

In the near term, the Moon. In the medium term, the Moon. In the very distant term, Mars.

Do you think manned spaceflight is necessary, or can robots now do all the tasks required from an astronaut?

Manned spaceflight is absolutely necessary, because of the natural capabilities of humans. However even the robots of today can perform many of the tasks assigned to humans during Apollo – and such robotic assistance, if properly applied, would open even more opportunities for humans to apply their unique capabilities.

Would you ever be tempted to pay for civilian spaceflight (for example, Virgin Galactic)?

No, not really. I had the best of missions and the best of the lunar exploration sites. Although civilian spaceflight would be exciting for many people, I was fortunate to have had such far-reaching experiences that something better would need to come along to grab my interest.

In the book you mention how you were the adviser on several TV shows/films documenting your NASA colleagues such as Armstrong, Cernan, Aldrin, Lovell (Apollo 13, In the Shadow of the Moon), and even yourself (From the Earth to the Moon). Did you enjoy these roles, and find the results to be accurate?

I did indeed enjoy these roles and learned so much about film-making, and I was fortunate to be involved with so many exceptional and creative artists. All were very accurate – however, one scene in one film was an exception. One of the beauties of Apollo was its culture – everybody was encouraged to speak out and participate, especially regarding safety; never was anybody criticized or denigrated for stepping up and expressing an opinion, nor did anybody ever fear retribution or condemnation for speaking out. Unfortunately, *In the Shadow of the Moon* contains one scene that is counter to this culture and therefore does not represent reality. During Apollo, if anybody thought there were safety problems with the spacecraft or any part of the mission, they would have informed management without hesitation, with absolutely no fear of losing their jobs, absolutely none. I refer to John Young's recall of his conversation with Gus Grissom regarding the spacecraft wiring. Such an event would not have occurred during Apollo. Nevertheless, the film is otherwise excellent as are the other films you mention – the producers, directors, actors and crews went to great lengths to make these films in particular as accurate and realistic as practical, given the need for dramatic emphasis (which most of these adventures had anyway!).

Did you meet with Leonov when writing the book? Did you forge lasting friendships with the Soviet cosmonauts?

I met Alexei in June 1973 during a visit to Moscow in support of the Apollo Soyuz Test Project; we have been friends ever since. And yes, all of us have formed lasting friendships with cosmonauts. I believe that astronauts and cosmonauts share a common bond which circumvents any political ideology.

What was the defining moment of your career?

There were many, all because I was fortunate enough to be at the right place at the right time – each time a fork in the road appeared the trail to the future was clear. But probably the first defining moment in my career was when I was about 4 years old and decided that I wanted to be a fighter pilot like my Dad.

What advice would you give someone wishing to follow in your footsteps?

Set your goals. Consider very carefully the options and opportunities for each decision, perform the best you can at each and every task, compete strongly and fairly with your colleagues, and be not distracted by the easy way. ■

ANXIOUS ABOUT VIRTUAL REALITY?

*Don't be, writes **Lorna Stewart**, it could be the answer to all your worries.*

Leah Markwick has an extreme fear of heights but today she stands at the edge of a glass lift, nine stories above the ground. "Even standing on a chair I would get scared," she tells me. So how has Leah stayed calm, nine stories up? The answer lies in virtual reality.

Researchers worldwide are exploring the potential for using virtual environments therapeutically and the results look promising. Exposure therapy in virtual environments has repeatedly been shown to be just as effective as therapy in the real world. "Virtual reality is a tried-and-tested medium for exposure therapy in anxiety disorders," Leslie Muetzelfeldt, a trainee clinical psychologist, tells me when I drop by University College London to find out more. "It's been used successfully in post-traumatic stress disorder, agoraphobia, panic, obsessive compulsive disorder, public-speaking, claustrophobia, fear of flying, fear of spiders, fear of cockroaches…"

At the UCL Department of Computer Science, three projectors shine onto adjacent walls, meaning the computer-generated images completely fill your field of view. As you look up and down, left and right, the scenery changes with you. This immersive environment gives therapists a chance to teach relaxation techniques in a scenario which is safe but which replicates the most anxiety-provoking settings for patients. If you step into the virtual-reality world in Bloomsbury you could find yourself preparing to give a speech, introducing yourself to strangers at a party, or standing in a glass elevator like Leah.


Flickr: Official U.S Air Force

In the US a lobby group is trying to get virtual reality listed as a first-line treatment for anxiety disorders and now one of the main providers, Virtually Better, is opening clinics across Europe. Their previous endeavours have included building Virtual Iraq and even taking that set-up out to real Iraq to treat traumatised soldiers before they return home. Leslie points out that this work raises some important questions: "are you treating these people so that you don't have to send them home? Is that ethical?"

This all beginning to sound like a futuristic nightmare but then Leslie explains that in the right setting it makes a lot of sense. "It's quite effective when you think about the amount of therapist time that is reduced. And I think it will become more accessible and also more integrated: it's going to be more about a package of care that includes virtual reality and that is available for people who live out in the country or who don't leave the house because of their anxiety disorder."

At UCL, researchers are focused on figuring out what makes people connect with the virtual world or 'experience presence'. This is important because without that the virtual reality environment is just another therapy room, as Leah tells me. "It feels quite realistic at first but it kind of starts to wear off a bit. For the first few seconds I did feel like I was going to topple over. But then you get used to it really quickly and after a while you start to feel this is just an animation so you don't feel that scared."

BOOK REVIEW

ALONE IN THE DARK

Douglas Heaven reviews 'Blindsight' by Peter Watts

In February 2082, 70 years from now, 65,536 objects enter our atmosphere simultaneously, blanket the Earth in a precise latitudinal/longitudinal grid, emit radio signals for just over a minute, then burn up. This is first contact; this is Firefall.

A crew of post-humans – phenotypes extending into machinery both inside and outside the body – is sent to investigate a comet in the Kuiper Belt. They are led by a vampire – one of a super-intelligent species genetically engineered back into existence. Their ship, the Captain, lets them sleep for five years, waking them instead for a rendezvous with a super-Jovian beyond the Oort cloud.

So far, so Arthur C. Clarke (except for the vampires). But *Blindsight* is a novel scattershot with ideas, including 18 pages of appendices and 144 real-world citations. "References and remarks, to try and convince you all I'm not crazy," is how Watts puts it. On vampire biology, for instance: "Since intersecting right angles are virtually nonexistent in nature, natural selection did not weed out the Crucifix Glitch until *H. sapiens sapiens* developed Euclidean architecture; by then, the trait had become fixed across *H. sapiens vampiris* via genetic drift, and—suddenly denied access to its prey—the entire subspecies went extinct shortly after the dawn of recorded history." Its slow-burning narrative also builds to a resolution of the Fermi paradox that involves one of the most disturbing possibilities I have ever come across.

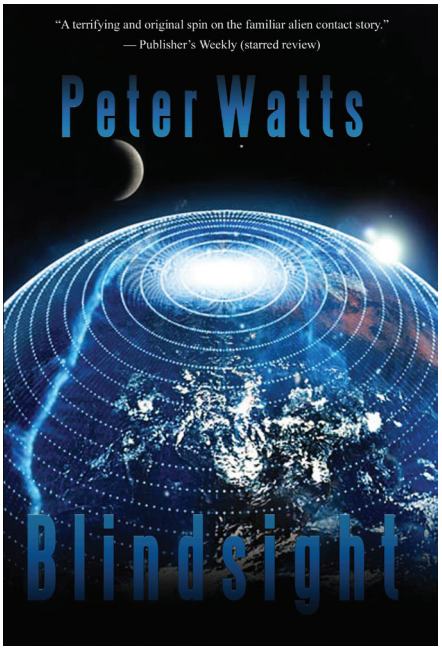
Given that the age and size of the universe ought to make intelligent life a statistical likelihood, Enrico Fermi wondered in the 1950s why there was no evidence of extra-terrestrial civilisations. The number of Earth-like exoplanets recently discovered gives Fermi's observation renewed bite. However, the devastatingly plausible premise of *Blindsight* is that intelligence need not imply sentience. Non-sentient life could exist, and evolve, and become what we would call – perhaps anthropomorphically – intelligent. The universe may even be filled with it. But it would not think. It would not reflect. It would not reach out to make contact, it would not make civilisations.

WHAT'S THE DIFFERENCE BETWEEN BEING DEAD, AND JUST NOT KNOWING YOU'RE ALIVE?"

"Everyone else is still looking for some reason for self-awareness to exist, some adaptive advantage that it confers," Watts once said. "And I really, really hope they're right, but I can't think of one." Consciousness is a distraction, it is energy-inefficient, and as New Scientist reported in 2006, conscious decisions are slower: "At some point in our evolution, we started to make decisions consciously, and we're not very good at it," Ap Dijksterhuis of the University of Amsterdam is quoted as saying. Consciousness may be an evolutionary dead end.

"We could engineer ourselves back into non-sentience, perhaps," one of the crew suggests in *Blindsight*. "But I guess that wouldn't be much of a win, would it? What's the difference between being dead, and just not knowing you're alive?"

It is often said we can feel most alone in a crowd. Looking up at the sky and imagining it teeming with unconscious life, I believe that to be true.



All Peter Watts' novels can be downloaded for free from the author's website: www.rifters.com/real/shorts.htm

REVIEWS

WHEN THE GREEN WILL OBSCURE THE GREY

***Lucía de la Riva Pérez** reviews 'From Garden City to Green City', an exhibition at the Garden Museum on the relationship between nature and urbanism.*

A visit to the Garden Museum is a perfect activity for a relaxed Saturday or Sunday morning. The former Museum of Garden History was founded in 1977 in the church of St Mary-at-Lambeth, after the discovery of the tomb of 17th century plant hunters 'the Tradescants'. A few years ago, the church underwent a dramatic transformation that turned the building into a perfect balance between history and modern design – so just having the opportunity to take a look at the architecture of the place makes it worth a visit! And, of course, visitors will have the opportunity to see the very interesting permanent collection on gardening history, the temporary exhibition, and the garden, where people can find the light-hearted 'insect hotel'. Furthermore, there are other incentives such as the kind museum staff, delicious fresh food from the quiet and lovely Café, and the many little temptations you can purchase at the shop.

The exhibition 'From Garden City to Green City' is on display until the 1st of April. It explores the relationship between nature and urbanism from the pre-industrialisation era to now, looking further into the future too. Visitors might be confused by the way they are expected to follow the story, and may find looking at some exhibits and reading the accompanying labels a bit inconvenient. But its relevance, and the feeling of optimism about the possibility to turn the big smoke into a sustainable system thanks to 'green urbanism', is a precious reward.

From horizontal to vertical: the transition from garden towns with parks and private gardens to green cities building up into the sky is told mainly with photographs, paintings, maps, posters, and videos. There is also a big 3D structure by Found Associates, which represents the conciliation between urban environments and nature. I personally found the lithographs by the German artist Wieland Payer, which portray the romantic idea of nature taking over architecture, particularly moving.

After visiting the exhibition, I had a look at the book *The Principles of Green Urbanism* by Steffen Lehmann. It contains some shocking figures: 1) cities occupy just 2% of the world land surface but they consume 75% of its resources, 2) if world population continues to grow at the current pace, it will reach 9 billion by 2050, and 3) in order to accommodate this increase, the equivalent of a new city of 1 million people will have to be built every week. The environment is suffering the consequences of over-population, but the good news is that there are many ways of tackling them.

We actually can make cities greener and more sustainable – and the exhibition shows how. For example, by building 'vertical farms', which tackle the lack of space for gardening and farming by building upwards and reduce food miles by growing locally. A shop in London called FARM:shop is now implementing this idea. Another alternative is the construction of 'vertical forests', like Bosco Verticale in Milan, which is currently being built and will be the first vertical forest in the world. I look forward to a future where whenever I fancy enjoying nature I won't need to go far – I can just look up into the sky.

MVRDV
MG arquitectos

"PEOPLE SHOULD GO HOME WITH A SLIGHT URGE TO TAKE THEIR MICROWAVE APART"

*I, Science talks to Malte Oppermann, organiser of '**Jiggling Atoms**', an exhibition event aiming to combine science and art to communicate fundamental physics.*

WHAT IS YOUR 'DAY JOB' – WHAT DO YOU DO AT IMPERIAL?

I am a 3rd year PhD student in the Quantum Optics & Laser Science group at Imperial. I work in a laboratory, where we try to capture and control the motion of atoms and electrons inside molecules via extremely short laser pulses. Understanding these fundamental dynamics is a first step towards controlling more complicated molecular processes – like photosynthesis, for example.

WHAT IS YOUR ROLE IN THE 'JIGGLING ATOMS' EXHIBITION PROJECT?

We would like to give everyone in the project a basic understanding of physics to start with. Together with Jennifer Crouch, I am preparing a series of lectures to introduce a few basic concepts and principles. Getting from Newton to Feynman is quite a challenge in such a short time, but our main aim is to get everyone excited about some great ideas in physics, which have radically changed our way of thinking about the world. Apart from the lectures we will also work on an installation for the exhibition, where we'll try to further explore the visualisation of such ideas.

CAN YOU TELL US A BIT ABOUT WHAT YOUR LECTURES WILL BE BASED ON?

I have taught tutorials to physics undergrads before, but this is different as we have to start from scratch. We want to present physics as a way to describe the world via abstract models and concepts, as this is the starting point for the whole project. For this we will begin with some basic math to show how it is used as a language in physical theories. Eventually, all fundamental forces in physics should be covered and we'll throw in lots of experiments, anecdotes and pictures to keep it as lively as possible.

WHAT IS YOUR AIM AS A SCIENTIST IN GETTING INVOLVED WITH SUCH A PROJECT?

I often have the feeling that, as scientists, we need to make a bigger effort to tell people what we are actually doing. Current areas of research – from particle- to biophysics – have become so abstract that we need to help people catch up, because sooner or later these ideas might appear again as the latest technology in their kitchen.

WHAT DO YOU HOPE PEOPLE WILL GAIN FROM THE PROJECT?

By illustrating concepts in physics from different perspectives, I hope that we can make people curious about how science constantly changes our way of thinking about the world. In the form of technology, these ideas are everywhere and often enough we are not even aware of them. So ideally people should go home with a slight urge to take their microwave apart. ■

Jiggling Atoms is co-ordinated by illustrators Natalie Kay-Thatcher, Rosie Eveleigh and Jennifer Crouch, with help from Dr Ben Still and Malte Oppermann.

THE EVENT

A description from the organisers:

"Jiggling Atoms is an upcoming exhibition event about illustrating and explaining particle physics, named after the first programme in a BBC series entitled 'Fun to Imagine,' where Richard Feynman explained the invisible forces behind everyday occurrences. A wonderful teacher of physics to non-scientists, Feynman was able to communicate by relating to people, using charm, metaphor, humour and anecdotes. It is this attitude and passion that has inspired this event – as visual communicators and lovers of science, we want to explain physics to people.

"Collaboration is an important aspect of this project, so as well as receiving assistance from the Institute of Physics we have built up a small team of experts to help bridge the gap between art and science. Dr Ben Still and Natalie Kay-Thatcher will assign illustrators content to work from, and will attend a series of elementary physics lectures delivered by Malte Oppermann at Imperial College.

"On the opening night the work will be exhibited and we will host a series of workshops and talks, with involvement from Super/Collider, Robin Ince, Mark Pilkington, and Dr. Ben Still. Alongside the exhibition we're also producing a publication featuring all the work, in association with Camberwell Press."

Jiggling Atoms is being held in the summer of 2012. Exact dates to be confirmed. Check the website for updates: www.jigglingatoms.org

The joy of chemistry can't always be contained in a lab; ***Kazimierz Janowski*** *recalls his experiences at home, in the playground, and psychedelic music gigs in the late 60s*

EXPLOSIVE AND PSYCHEDELIC: MY LIFE WITH CHEMICALS

My infatuation with chemicals started with a Kay Chemistry Set, which I bought in the early 60s, in a sports shop of all places! I was spellbound by the names of the so-called 'common substances': antimony sulphide, cobalt chloride, potassium permanganate – for me, these names read like poetry. My home chemistry set soon grew into a home laboratory. As the years went by I started to accumulate an collection of flasks, retorts, tubes and burners.

When I had exhausted the benign experiments the Kay set offered I moved on to richer and stranger things. Inspired by a fine book I found in my local library called "The Young Chemist" by F. Sherwood Taylor my experiments became ever more hazardous. My favourite chapter was "Fireworks and Flames". At that time it was still possible to purchase some extraordinary substances from your local chemist or ironmonger.

My friends and I developed a range of 'procurement techniques' for the more dangerous reagents: "A pound and a half of saltpetre, please."

"What's that for, sonny?"

"Oh, it's for my mum – she needs it to preserve some meat" or "A few ounces of magnesium powder, please."

"And what's that for?"

"We're doing some flash photography."

And so it went on. Eventually, of course, one grew older. I passed on what was, by now, a substantial collection of apparatus and chemicals to my girlfriend's little brother, along with my notes. Things didn't go so well for him. He detonated a large heap of nitrogen iodide in his school playground and clearly hadn't read Sherwood Taylor's warning, "DON'T SHUT IT UP IN A BOTTLE, FOR IF IT EXPLODED THE BROKEN GLASS MIGHT BE DANGEROUS". Silly boy. He got the cane for that.

By the late 60s I turned my love of chemicals to the creation of artistic effects at psychedelic music venues. My old friends, hydrogen peroxide, tincture of iodine, acetone and ether, mixed with Fairy liquid and coloured inks and sandwiched between glass slides, produced the most delightful array of colours when projected onto screens behind our favourite bands. We were called Gromit Lights and our local competitors were a bunch of girls who called themselves Pale Green Limousine.

I remember they used Pifco hair-dryers to heat up their liquids to boiling point. We only used volatile liquids such as the ones I've just mentioned. At one time it was suggested that we join forces with the girls, then we could call ourselves Pale Green Vomit – but it was not to be. The public taste for psychedelia died down and it was becoming ever more difficult to get the inks and chemicals we so much needed. Solvent abuse and international terrorism finally did it for home chemistry.

These days I have to be content with watching my sloe gin mature from pale pink to deep burgundy in one of my surviving reagent bottles. Fortunately the psychedelic effects are still there if you drink enough of it. It's what sees me through the long winter nights. ■