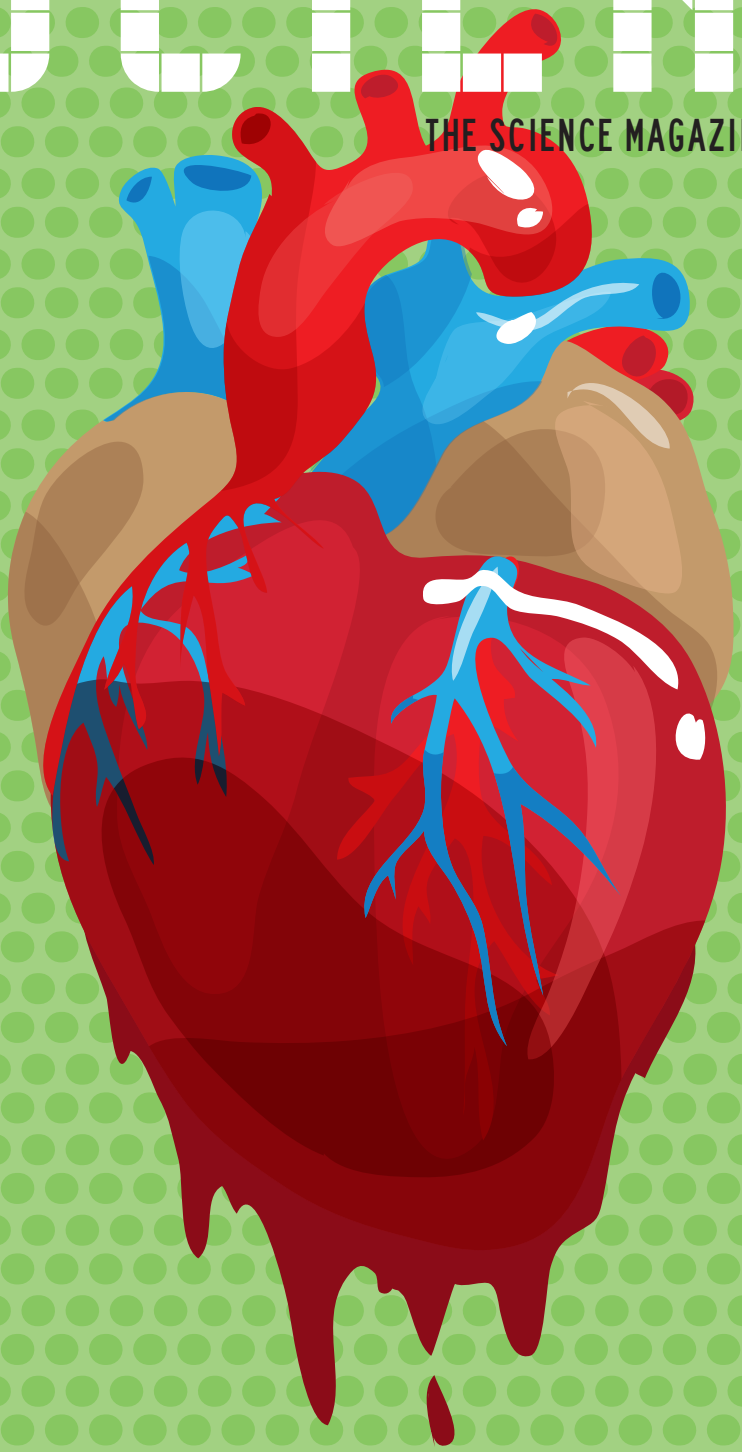
I,SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE



LIFE

I, SCIENCE
AUTUMN 2013

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I, SCIENCE

The dichotomy of life and death as a theme has delivered a rather paradoxical magazine this term. We feature the macabre side of science, dealing with extinction, disease, zombies and near-death experiences, but also a more uplifting side that considers resurrection, immortality, modern medicine and the extension of life.

In retrospect, all the topics covered could be seen as concerning both life and death; just like a Necker cube can be seen as both submerged into or projected from the page, so too can these articles be seen as just as relevant to life as they are to death, and vice versa.

In contrast to Pippa Mitchell's article on extinct specimens at the Grant Museum, we have the counter story of resurrecting extinct species by Rosamund Pearce. Alongside Charlotte Mykura's feature on how business is driving the human search for immortality, we discuss how nature got there first through various evolutionary tricks.

In the death side of the issue, Ben Stockton recounts the story of the immortal cell line of Henrietta Lacks, the woman who died from the cancerous cells that are still used globally in life saving research. On the life side, Alisa Crisp discusses how medical research over the ages, some of it enabled by Henrietta's cell line, is extending life expectancy for billions of people worldwide.

We also feature the researchers tempting fate by exploring near-death experiences with Fabian Sweeney discussing how the lines between death and life are becoming increasingly blurred - it seems the spectrum of existence cannot be as straightforwardly bisected as our magazine centrefold implies.

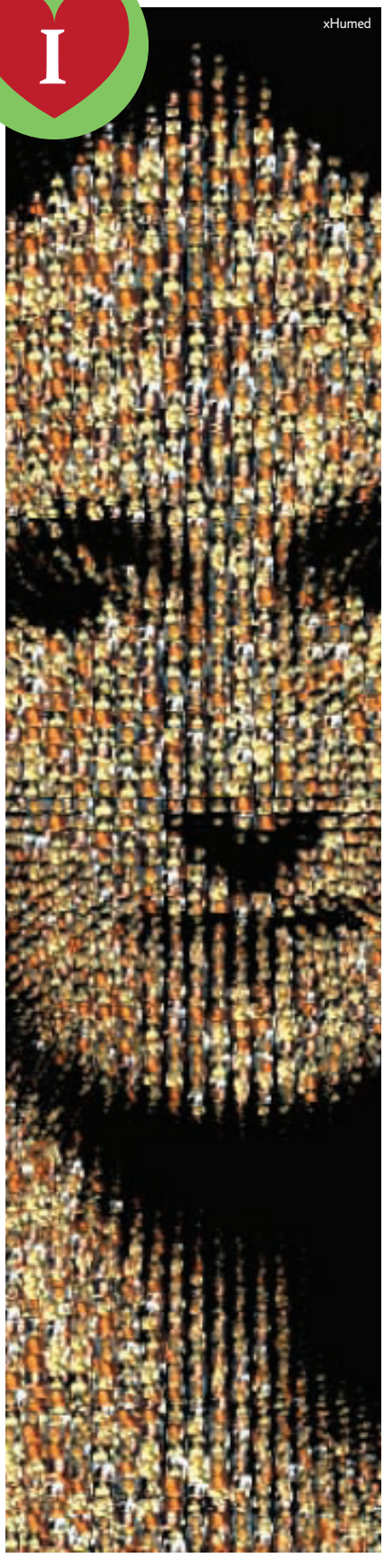
The theme this term was as broad as it was interesting, and it was a pleasure thinking about what exciting endeavours science is undertaking, or has done in the past, to understand better and push the limits of life into death, and vice versa? We hope you enjoy this issue.

PHILIPPA & TOM

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

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

CONTENTS



xHUMED

How would Frankenstein author Mary Shelley react to the artificial intelligence of today? What would science-fiction writer HG Wells say about the internet? ***Tom Bragg*** *takes a peek at how the company* xHumed *imagines digitally resurrecting great minds from the past to help us solve current problems.*

Digital resurrection is the replication of a person's neuronal network onto a hard disk so their personality and memories are preserved. Although the technology doesn't yet make this possible, *xHumed* use the idea to imagine how some of the cleverest brains of all time would react in today's world if their minds could be digitally resurrected from their DNA and media reports of their behaviour.

Jason Jones-Hall is the company's Digital Director. "We look at everything: from the technology required, to the ethics and philosophy behind it, and the cultural, sociological and psychological significance of it. Digital resurrection is the underlying theme of all *xHumed*'s work.

At a recent show in the Library of Birmingham, the largest library in Western Europe, the historical figures Mary Shelley and HG Wells were recreated alongside luminaries connected to Birmingham, including Erasmus Darwin, Matthew Boulton and Joseph Priestly. Each dead historical figure was resurrected in some creative way and then delivered a five or six minute 'speech'. Afterwards, a contemporary expert gave a TED-style ten minute talk that connected the ideas of the historical figure with the issues of today.

"Mary Shelley was a really interesting one," said Jason. "For looking at the implications of what might happen if we can essentially upload our memories or our consciousness to a cloud somewhere and then retrieve it and exhume ourselves - digitally exhume ourselves."

With the Frankenstein connection, Shelley was the obvious choice for exploring this technology issue. She was recreated through a combination of digital art and projection mapping onto a mannequin, then read a passage from Frankenstein relating to the moral and ethical implications of raising the dead. It was followed by the (living) science writer Jon Turney, author of *Frankenstein's Footsteps*, who picked up the theme and delivered a talk on the science behind digital and biological resurrection, including cryogenics and memory uploads.

The 18th century physician and inventor Erasmus Darwin described a machine for recreating the human voice, and his talk was paired with Christophe Veaux from Edinburgh University, who is working on the Voicebank project to recreate personalised voices.

The great manufacturer Matthew Boulton was paired with Nick Allen, the founder of 3D Print manufacturing company *Mak3d*. For Boulton's resurrection, a statue of him was 3D printed and then animated in a six minute video by Digital Artist Jessy Wang.

Jason's favourite resurrection is HG Wells, because of the accuracy of his predictions. "We've got HG Wells talking through his writings on the 'world brain', which is essentially describing the internet," he said. "The only words we substitute in the text are the words 'world brain' for 'the internet'. It's striking how prescient he was."

More performances are planned for 2014, including the Speakers-In-A-Box idea, where these historical icons are booked to speak at events or conferences. The new project fits into the concept of Dead Good Thinking, which Jason feels is central to all *xHumed*'s work because it recognises how brilliant minds of the past still influence and help us today. "It's about teasing out the contemporary relevance of past figures. The technology may have moved on, but many of the key principles they identified are still almost identical." ■

REVIEWS

PHYSICS THAT'S TOO BIG TO FAIL

Bankrupting Physics (English Translation)
Alexander Unzicker and Sheilla Jones
Palgrave Macmillan (2013)

It seems that modern physics is in trouble – it has become a mess of free parameters, over inflated theories and untestable nonsense. In *Bankrupting Physics* theoretical physicist Alex Unzicker and science writer Sheilla Jones argue that modern physics, just like the banking sector, has become too big to fail.

Unzicker expertly guides us through the wonderful worlds of cosmology, particle physics and theoretical physics, taking an unflinching look at whether any of it actually makes sense. How, for example, have scientists managed to find a signal 'consistent' with the Higgs Boson when we still can't calculate the exact number of photons emitted when electrical charges are accelerated? Why does the standard model of particle physics need at least 36 kinds of heavy particle to explain itself?

As a physics novice I was initially daunted by the sheer quantity of cosmological and theoretical physics theories that Unzicker introduces in his book, but all the science is clearly explained; my personal favourite analogy is when he uses the idea of Madonna walking through a crowded room to explain the effect of the Higgs field.

As well as comparing physics to a big financial bubble ready to crash, Unzicker also scathingly compares the ideas in the standard model of particle physics to the overtly complicated Epicycles of the middle ages that were used to explain how the universe moved around a central static Earth.

There is a lot of wonderful physics out there but, Unzicker argues, it is becoming more and more detached from reality. *Bankrupting Physics* is a call to reason for anyone working in physics today – start observing nature again, try to falsify your theories and don't get carried away with fantastical ideas like supersymmetry, string theory and multiple dimensions unless you can test whether or not they actually exist. ■

ELLEN MEEK

A LACKLUSTRE REACTION

Reactions: The Private Life of Atoms
Peter Atkins
Oxford University Press (2013)

As a general rule, an author shouldn't apologise for how uninteresting a topic is, especially when that excuse is within the first paragraph of their popular science book. In his new book Peter Atkins does just that, setting a mixed tone for the exploration of the world of chemical reactions that follows.

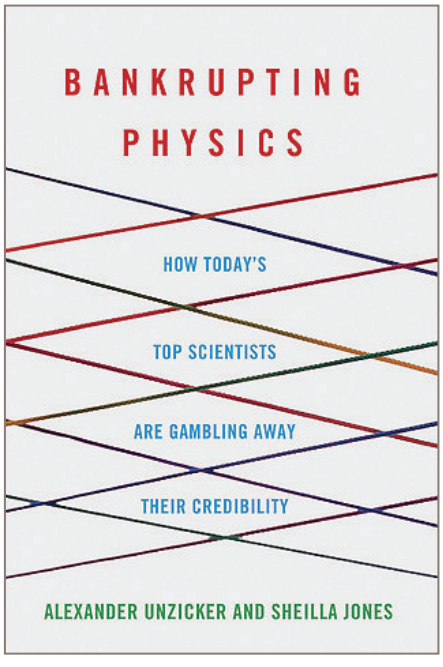
The book itself begins with simple descriptions of precipitation, oxidation and reduction reactions, at a level recognisable to A-Level students. From here it progresses to more esoteric accounts of the Wittig and Friedel-Crafts reactions. Each page is littered with 3D representations of the molecules under discussion.

While reading, I kept pondering who the book is aimed at. Its rather academic style would suggest undergraduate chemistry, or curious students of other sciences, but its rudimentary investigation of each topic doesn't lend itself well to in-depth study or analysis.

Atkins comes into his own when, after explaining a reaction, he gives some relatable examples from everyday life. For example, after discussing free radicals and combustion processes, he succinctly explains why natural gas burns with a blue flame if there is plenty of air, but with a smoky yellow flame if the air supply is restricted. These descriptions kept reminding me of that seminal work of popular science, *Six Easy Pieces*, by Richard Feynman. Unfortunately for Atkins, the similarities end there.

It succeeds in being a good accompaniment for the chemistry student or keen autodidact but fails utterly in being an engaging work of popular science. If chemistry isn't your thing, stay well away. ■

PATRICK KENNEDY

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THE BUSINESS OF IMMORTALITY

Throughout history huge quantities of money and resources have been sunk into attempts to cheat death. ***Charlotte Mykura*** *discovers that the business of immortality is as alive now as it's ever been.*

Everlasting life is a concept that we all at some stage have pondered. The creative human mind has found ways to cope with the frightening prospect of mortality since ancient times and the value of living forever is, for many, immeasurable. But what if we were to put a price on it? How much would you be willing to pay to live forever?

Achieving immortality or a 'cure' for old age is an enormous driver for business. In 2006, news coverage of the apparently revolutionary drug Resveratrol (which is derived from Japanese Knotweed) prompted enormous sales of the compound, despite the absence of evidence that it actually extends human lifespan. Today, serious attempts are being made by scientists to freeze the bodies of humans to preserve life, or even upload the human mind onto a computer.

The Philosopher's stone

High and occasionally outlandish expenditure on attempts to either scientifically or religiously extend life is by no means modern. As far back as the 3rd century, Greek writings by Zosimos of Panopolis mention the search for the Philosopher's stone (named then as Cheirokmeta). It was thought the stone could revive dead plants and create homunculi (a homunculus is a small clone of yourself, a bit like Mini-Me). Throughout the Middle Ages, Renaissance and Early Modern Period, alchemists obsessed desperately in their workshops, working harsh chemistry with metal compounds to extract or create the priceless stone and for many, the fruitless search was life-long.

Ancient Egypt's Immortals

Possibly the most magnificent symbol of the lengths to which humans are willing to go to for immortality are the great pyramids of Egypt. For the Egyptians, preservation of the body following death was the key to everlasting life. Egyptian culture was heavily based around the river Nile; it was believed that death was in fact a journey across the Nile, from life on the east to everlasting afterlife on the western bank.

Upon coming into power, a new Pharaoh would immediately secure the mines needed to generate the millions of tons of stone that would be used for his pyramidal tomb. Pyramid Khufu for example, was built of 2.3 million stone blocks averaging 3.5 tons each. These colossal structures demonstrate the Egyptian king's enormous dedication to generating wealth and coordinating a workforce in order to secure his immortal afterlife.

The process of Egyptian mummification was a skilful art. Following the death of Pharaoh Ramses the Great, a 70-day process began in which the corpse was carefully prepared for the afterlife by the high priest Anubis. It was cleansed, purified and dried. The brain was removed by inserting a hook up the nose, and the internal organs were extracted via a slit in the side of the torso. The body was stuffed with herbs, spices and salts then left to dry. The process was highly ritualistic, steeped in prayers and special perfumes were anointed upon the mummy.

Today, most of the pyramids lie in ruin. The mummies themselves are cared for by the Egyptian government. Ramses the Great, for example, is preserved in a glass box in Cairo Museum surrounded by inert gases that will protect his body from further decay.

So what actually happens when we age?

Essentially, over time the body accumulates damage, which causes our body to physiologically malfunction. Not only this, but a ticking 'molecular clock' in the body actually causes a cell to signal to itself to die when the body ages. The damage we accumulate, coupled with our altered cellular program leads to a multitude of age-related diseases, such as pulmonary fibrosis, cirrhosis and type two diabetes. As our cells age, they secrete pro-inflammatory and pro-tumorigenic factorsthat increase the likelihood of impaired immune function and certain cancers.

The telomere clock is ticking

Our DNA is linear, and every time the cell divides some DNA is lost from the end of the chromosome because of the way DNA polymerase - the enzyme used to replicate DNA - functions. Without special protection, the telomeres shorten, fray and break. This is known as 'telomere attrition' and occurs when the telomeres lose the structure that protects the ends of chromosomes, which causes the chromosome ends to become sticky and fuse to one another leading to genomic instability and gene misregulation.

In some cells the telomeres are regenerated every cell cycle by the enzyme telomerase but the vast majority of human somatic cells do not have this enzyme. This is central to ageing: with every cell division, our chromosomes become a bit shorter and a bit more vulnerable, if the division isn't accompanied by telomerase activity.

Telomerase, therefore, must be the secret of long live and a way for some plucky scientist to make their fortune, but the enzyme can also be problematic. Over 80% of cancers rely on reactivated telomerase in order to immortalise themselves and divide indefinitely so the lack of telomerase in the majority probably protects against cancer.

Despite the cancer risk, laboratories are looking for ways to supply our telomeres with exactly what they need to prevent damage and shortening, without making them malignantly immortalised. Studying long-lived animals such as the naked mole rat could solve the telomerase conundrum and unlock a multi-billion pound industry in lengthening life.

"STUDYING LONG-LIVED ANIMALS SUCH AS THE NAKED MOLE RAT COULD SOLVE THE TELOMERASE CONUNDRUM AND UNLOCK A MULTI-BILLION POUND INDUSTRY IN LENGTHENING LIFE"

Cryonics: freeze your body and save it for later

The concept of cryonics is simple: preserve the human body at temperatures of -192°C so that it exists in frozen suspended animation. The tissues can be warmed at a later date in the hope that future technology will allow us to bring the cryogenically frozen human back to like.

You pay for membership with the Cryonics organisation then, when your heart stops beating, a team bounces into action, supplying your brain with oxygen, packing your body with ice and filling your circulatory system with heparin to prevent blood clotting. The body cannot be simply frozen, since the ice crystals that form would make mincemeat of body's cells. Instead, the cryonics team fills the tissues with cryoprotectant: an elusive human antifreeze which apparently protects cells from the freezing process. The result is then placed in dry ice to cool and, finally, into liquid nitrogen at -192°C.

The cryonics institute is making a lot of money using this technique. Their website describes how cryonics is incredibly affordable, but at a minimal cost of $150, 000, many would beg to differ. In a fun twist, you can pay a meagre $50,000 to have only your head preserved in this way.

So does cryonics actually work? The addition of cryoprotectant to cells has an untested effect, but could permanently poison them. Furthermore, there is currently absolutely no technology that can bring a dead, frozen organism back to life.

The future for immortality

It seems that, for now, despite nearly three millennia of trying to crack the immortality code, we are still no closer to delivering the promise of extended life beyond counselling on the health benefits of a good diet and regular exercise. That's not to say the pursuit of immortality has been a worthless endeavour; the Cairo skyline certainly would be very different if the ancient Egyptians had lost faith in their effort to bring eternal life to their pharaohs. And the dream of perdurability continues to motivate economic activity - cryogenics comes at a cost, but does it hold hope too? Will telomerase research lay the foundation for the ultimate biotech start up a few years down the line? If science continues to progress with its understanding and manipulation of the aging process, living forever may one day be an option worth saving the pennies for. ■

IMMORTALITY IN NATURE

The Pando Tree
The forest of Quaking Aspen in Utah is actually only one genetic individual - every tree is connected by a giant root system. The entire plant weighs 6,000,000 kg and is an estimated 80,000 years old.

The Glass Sponge
These rigid sponges are found in oceans across the globe, and are thought to live up to 15,000 years. Their skeletons form massive deepwater reefs that other, live Glass Sponges can inhabit.

Planarian Flatworms
With apparently limitless telomere regenerative capacity, these flatworms appear to be able to live forever.

Tardigrades
These microscopic 'water bears' are polyextremophiles: they can withstand temperatures from near absolute zero to above 100°C, they can endure enormous pressures, and they have evewn been found on shuttles returning from outer space. Their trick is the ability to suspend their metabolism for up to ten years, which enables them to survive in very adverse conditions.

Lobsters
These crustaceans grow throughout life and build new muscle during every moult cycle. Most of their cells contain particularly active telomerase, which empowers them to live as long as 50 years due to the age resisting properties of the telomerase enzyme.)

The Naked Mole Rat
These rodents are resistant to cancer and have healthy circulatory systems into old age. They can live to over 30 years, which is ancient by rodent standards, and their longevity is thought to be due to the ability to slow their metabolism, thus preventing oxidative damage in cells.

Immortal Jellyfish
When a mature Turritopsis dohrnii jellyfish becomes threatened, injured or starved, it reverses its lifecycle. The adult form undergoes deterioration and transforms back to a polyp, which can go on to spurn new, genetically identical polyps that wmature into new jellyfishes.

PHILIPPA SKETT AND
CHARLOTTE MYKURA

IV ORGANS FOR GROWTH

One way to push back the aging process is to replace failing organs with healthy new ones. ***Ben Stockton*** *assesses the growing field of body part substitution.*

In the UK alone, one thousand individuals in need of an organ transplant die every year due to the shortage of availability. This crisis not only costs lives, but has also led to a substantial increase in the demand for alternative treatments. Advances in molecular diagnostics could enable detection of lethal diseases before clinical manifestations occur, which would facilitate pre-emptive transplants, but this is likely to only increase the demand for organs.

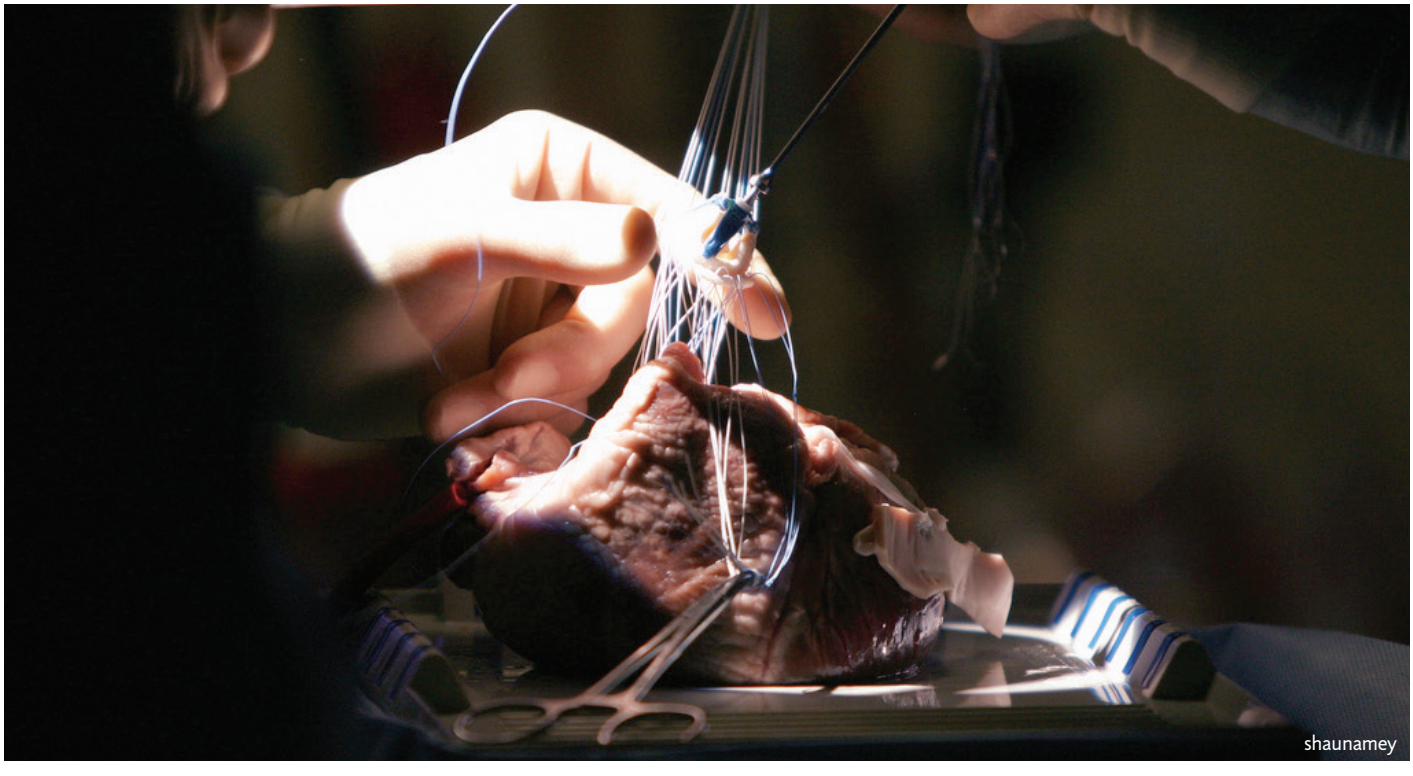
To address this issue, researchers are working on novel techniques that are moving the field of organ transplantation into uncharted territory.

The ability to grow human body parts was thought an insurmountable task, but scientists across the world are starting to get positive results. Although it's clear that we're still a long way from transplanting lab-grown lungs or livers into patients, there is reason to believe that this could be a plausible future for organ transplantation.

Two years on from the implant of a synthetic blood vessel into four-year-old Angela Irizarry, all is well. Scientists coated a biodegradable tube with stem cells harvested from the child's bone marrow and the subsequent graft successfully treated her heart defect. The technique used 3D printers, and created scaffolding structures that fully supported the patient's stem cells.

With traditional methods, one of the greatest problems facing scientists is the chance that the body may reject the donated organ. This occurs when the body's immune system, specifically the T-cells, recognise the cells from the transplanted organ as 'non-self' and so attack and ultimately destroy the alien organ. To prevent this, post-transplant patients have to take immunosuppressant drugs that leave them highly susceptible to infection - to the point where transmission even of the common cold can be extremely dangerous.

The beauty of growing new parts in the body is that, as in the case of Angela Irizarry, the stem cells are taken from the patients themselves; meaning that transplantation



shaunamey

doesn't hold the same fear of rejection and that patients don't need to continuously take debilitating immunosuppressants.

Dr Paulo Macchiarini, a Professor of Regenerative Surgery in Sweden who pioneered this procedure, has now carried out six life-saving operations through windpipe transplantation. In each, scaffolds were bioengineered and stem cells from the patients were grown over the top of them. It was initially believed that stem cells had the ability to differentiate into the appropriate cells once transplanted into the region. Surprisingly, it appears that this is incorrect. Studies in mice showed that the original seeding cells die relatively quickly, and it is the incoming cells from other vessels that are the cause of the transplant functioning normally.

Although this works well for single blood vessels and windpipes, it's much harder to achieve for more complex organs. In response, some labs are trying to overcome organ rejection by washing the cells off organs before transplantation leaving only the natural scaffolding structure, which they cover with a patient's own cells. Using this technique, it is theoretically possible that a pig organ matrix painted with human cells could be successfully transplanted. The transfer of an organ from one species to another is called Xenotransplantation and dates back to the 1980s. Pigs are a common focus as they have organs that are anatomically similar to our own. Until recently, tests have been incredibly unsuccessful with extremely high fatality rates, but this new protocol opens exciting doors for the field.

An alternative to transplantation is dialysis, where the function of an organ is replaced by a machine that is external to the body. Currently, this is normally only used when a patient is waiting for a donor, but recent developments show that a scaled down dialysis machine could function as a completely artificial organ. Work in this area gained a widespread following after How to Build a Bionic Man aired on Channel 4 in February. The documentary showcased the cutting edge of prosthetic limb and artificial organ research. Arizona based company SynCardia Systems Inc. now offers an entirely artificial heart that replaces both failing ventricles and all four heart valves. To date, the longest a patient has been supported by the artificial heart is just under four years, suggesting that this is a very conceivable future for organ transplantation.

> "THE BEAUTY OF GROWING NEW PARTS IN THE BODY IS THAT, AS IN THE CASE OF ANGELA IRIZARRY, THE STEM CELLS ARE TAKEN FROM THE PATIENTS THEMSELVES"

Other work in the field looks at techniques that ensure donor organs are up to standard. The problem originally faced by surgeons was that tissue degrades so quickly once removed from the body that immediate transplantation is crucial. Furthermore, particularly fragile organs like lungs can be damaged when a patient dies with the result that only about 15% of donated lungs actually being usable.

A machine developed by Dr Shaf Keshavjee in 2008 not only permitted lungs to remain viable ex vivo for an extended period of time but also made it possible for doctors to 'enhance' the organ, leaving it healthier than its pre-transplant state. Whilst in the machine, doctors can study the anatomy of the lung using fibre optic cameras and also deliver therapies to targeted areas. It is believed that this technique will not only help organs remain viable for transplantation for two to three days, but will also massively increase the number of organs that are suitable for donation.

With an ageing population, illnesses like heart failure and liver disease will compound the problem of high demand for organs but with the new methods on the horizons, it would be rational to believe that we've a chance of coping with the problem. The collaborative works of medics and bioengineers forecast a future where lab derived or manipulated body parts are commonplace. The field has extremely exciting prospects and will, no doubt, be instrumental for the health of the global population in the coming decades. ■

HOW MEDICINE HAS EXTENDED LIFE

Ten thousand years ago the average life expectancy for homo sapiens *was around 30 years.* ***Alisa Crisp*** *charts at how subsequent medical developments have more than doubled that figure in many parts of the world*

Medicine has been a part of human culture for thousands of years. Modern medicine now allows us to cheat death more often and for longer than ever before. So what have been the most important advances to date.

Life expectancy

The most common way to measure the extension of life in a population is life expectancy. For most of human history, the average life expectancy for a population didn't deviate much from 25–35 years, although individual life spans were often much longer than this. Even by 1850, when the advance of modern medicine had truly started,—life expectancy was still below 40 years of age. Since then, average life spans have almost doubled in many countries, including the UK. While much of this improvement can be attributed to public health changes such as improved sanitation, medical advances have had a big impact on how long we live.

Infections

Meningitis. Tuberculosis. Malaria. Pneumonia. Thanks to advances in infection control, all of these diseases that were once so deadly can now be controlled, if not cured completely. Preventing death from infections is an important way medicine cheats death every day. Three crucial paradigm changes in medicine have allowed this to happen: vaccinations, antimicrobials, and the use of antiseptic conditions.

Vaccinations

Although some form of vaccination has been used for over a thousand years in the form of small pox inoculations in India and China, the wide range of vaccinations now available is a recent phenomenon. From Edward Jenner and the use of cowpox to vaccinate against smallpox in 1796, through to Louis Pasteur and the discovery of bacteria, and onto the first genetically engineered vaccine for Hepatitis B in 1986, vaccination has only increased as a method to prevent disease and so extend life. Perhaps the best example: a total of 80 percent of infected children died from smallpox at the beginning of the last century, as well as 30 percent of adults. Finally eradicating this disease in 1979 was a large step forward and provides hope that it might be possible for other infectious human diseases.

Antimicrobials

Penicillin, discovered in 1928 by Alexander Fleming, was developed as an antibiotic in 1940. Penicillin and its derivatives have been instrumental in preventing death from bacterial diseases and kick-started the antimicrobial revolution in medicine. Though plant-based antimicrobials had already been in use since the 15th century, the search for antibiotics didn't begin in earnest until World War II.

flickr // Pranjal Mahna

Antiseptics

Developed by Pasteur in 1864, germ theory is the idea that microscopic cells are all around us and can be deadly. As a result, germ theory is a main cause of the widespread adoption of antiseptic techniques. In 1847, Ignaz Semmelweis, a physician from Hungary, had shown that hand-washing could save the lives of women giving birth. At the time, up to a third of women would die from childbed fever, spread by the doctors delivering babies without washing their hands.

Following this in 1867, Joseph Lister's sterilisation of air and instruments in surgical theatres with carbolic acid was also an important move towards the antiseptic conditions that save lives today. But we still have much further to go; infection rates in hospitals are still high, and often allow the spread of increasingly antibiotic-resistant infections like MRSA.

Anaesthetics

The use of anaesthetics has allowed surgery to become far more sophisticated in the last 150 years. Ether, laughing gas, and chloroform were all discovered in the 1840s, and more effective anaesthetics have since been developed, as well as better monitoring techniques. The use of an anaesthetic also prevents post-operative shock, a major cause of death among early surgical patients.

Biology

From the chemical reactions of life to the discovery of cells, many medical advances would not have been possible without our increasing knowledge of the biology of the human body. The huge range of drug treatments at the moment owes a lot to our understanding of the cellular basis of diseases, including cancer. While many types of cancer are still almost untreatable (melanoma and lung cancer as two examples), we are now coming close to being able to cure people of other types, including some breast and testicular cancers. Our understanding of immunology has led to increased use of transplant operations, saving multiple lives from just one donor. One of the next big questions is how to slow the ageing process itself. With new advances year after year, we can look forward to continuing to extend many more lives.

> "DEVELOPED BY PASTEUR IN 1864, GERM THEORY IS THE IDEA THAT MICROSCOPIC CELLS ARE ALL AROUND US AND CAN BE DEADLY"

Giving life

It doesn't end at extending life. In vitro fertilization (IVF) treatment has allowed around 5 million babies to be born worldwide since the birth of the first test tube baby in 1978. TTo put that figure in perspective, that's roughly twice the urban population of Birmingham. Fertility treatments are bringing new life to more and more families around the world.

The flipside

The flipside to this coin is the massive healthcare disparity throughout the world. While life expectancy in Western countries is high, it remains just above Victorian levels in many places (such as the 46 year average in Sierra Leone). Every five seconds a child somewhere in the world dies of a preventable cause—usually pneumonia, diarrhoea, or malaria. These deaths could still be prevented.

While medicine is continuing to advance, our own lifestyles are starting to get in the way, and might cause life expectancy to start to decrease for the first time in 150 years. Our propensity for unhealthy diets, a sedentary life, and a fondness for cigarettes and alcohol are all levelling the playing field. By doing nothing about these common health issues, we're starting to let death back in too. ■

VI

DE-EXTINCTION

Would we want to bring back recently extinct species, perhaps even a Neanderthal? ***Rosamund Pearce*** *digs up the latest in de-extinction.*

The loss of a species was once thought to be as final as the demise of its last survivor but now, thanks to advances in biotechnology, reviving extinct species may be more than pure fiction. Instead of asking "can it be done?" the conversation is changing to "should it be done?"

The possibility of bringing species back from the grave – a process known as de-extinction - was widely popularised by Michael Crichton's 1990 book, and Spielberg's 1993 film, *Jurassic Park*. Inspired by the advent of genetic engineering, Crichton's notorious tale gained cult-status, but just as Aldous Huxley's vision of artificial reproduction was brought closer with the advance of IVF technology, so the process of de-extinction has moved from sci-fi concept to real life science.

In 2003, a team of French and Spanish scientists achieved the impossible task of bringing a species back from the dead, although only temporarily. The Pyrenean Ibex was a large, mountain-dwelling member of the goat genus *Capra* that went extinct due to grazing pressure from domestic and wild ungulates in 2000. When the last Pyrenean Ibex died, its cells were preserved and, later, a nucleus from these cells was injected into a denucleated domestic goat egg, which was then implanted into a surrogate mother. In 2003, a clone was born. For the first time ever an animal had been brought back from extinction.

Sadly, the baby ibex died shortly after birth due to lung defects. Rather than rejuvenating the Pyrenean Ibex, it served only to provide an unfortunate demonstration of the obstacles that remain in reproductive cloning technology. Not only that, but of the 439 eggs used, only 57 developed into embryos, only four made it to full term, and only one survived to birth – a pretty poor survival percentage.

Despite these problems, this breakthrough gave hope to the emerging de-extinction movement and, propelled by a combination of curiosity and conservation, many more de-extinction attempts are on the horizon. The Tasmanian tiger and the passenger pigeon are just two of the candidates being vetted for resurrection. Furthermore, in March 2013, a team from the University of New South Wales announced that they were attempting to bring back the gastric brooding frog – a bizarre creature that used its stomach as a womb.

The birth of the ibex has also fuelled more ambitious and controversial ideas. For instance, could such technology be applied to ancient, long-dead species? Unfortunately, it doesn't seem like dinosaurs will be brought back any time soon as DNA decays with time, and cloning technologies require pristine DNA for success. Within hours of death, cells start the process of apoptosis, which releases enzymes that shatter DNA into an indecipherable mess. As it ages, DNA also undergoes chemical changes that alter the nucleotides – the base guanine changes into adenine, and cytosine changes to thymine.

> "IF A GOOD SOFT-TISSUE SAMPLE IS FOUND, THE RESEARCHERS SAY A WOOLLY MAMMOTH COULD BE BORN IN A MATTER OF YEARS"

So much time has passed that it's inconceivable the full genome of dinosaurs such as *Tyrannosaurus Rex*, which died out around 65 million years ago, would have survived to the present day.

Could a woolly mammoth be a more realistic goal? Disappearing between 6,000-10,000 years ago, well-preserved mammoths are routinely dug out of the Siberian tundra and scientists have been able to collect enough DNA fragments to piece the genome back together. Sadly, cloning requires much more than a reconstructed genome.

Artificially assembling DNA can be done easily with current technology, but the free-floating DNA that results is of little use to a cell. The real challenge is packaging the DNA into chromosomes and inserting this into a nucleus. The shape of the DNA affects how it interacts with chemicals in the cell, and these interactions control gene expression, a factor every bit as important as the DNA itself.

Finding a living mammoth cell would sidestep such difficulties, and a Japanese-Russian collaboration is currently leading the hunt for such a cell. The team plan to use a technique pioneered for cloning mammals from frozen tissue, which was successfully implemented on a mouse that had been frozen for 16 years. The idea is for an elephant to then be used as an egg donor and surrogate to grow the properly packaged

DNA. If a good soft-tissue sample is found, the researchers say a woolly mammoth could be born in a matter of years.

Even so, there is a great difference between bringing back an individual and bringing back a viable population. De-extinction would at best produce a handful of individuals that may or may not reproduce. And how can we engineer the mammoth's social structure and behavioural adaptations?

Despite these challenges, ambitious plans have already been made for a Pleistocene Park in North-Eastern Siberia. In a similar spirit to the *Jurassic Park* of literary fiction, the dream is to restore the tundra to the mammoth steppe, a vast grassland habitat. Bison and reindeer have already been reintroduced, but the arrival of the mammoth may take a little longer.

Unsurprisingly, de-extinction is highly controversial. The implications of such initiatives are hard to predict, and there are questions regarding the well-being of the clones. Recent sequencing of Neanderthal DNA has made cloning the homo species theoretically possible, bringing us into unfamiliar ethical territory.

Even efforts to resurrect recently extinct animals are divisive. While advocates say that we have a moral responsibility to bring back the creatures we drove to extinction, critics argue that such strategies hinder efforts to save the habitats and species that remain.

Perhaps resources would be better used by boosting the populations of currently endangered species. In anticipation of this, San Diego Zoo has created the 'Frozen Zoo' project, a biobank storing tissue from over 1,000 extant species. In a similar vein to the Millennium Seed Bank Project, it is hoped that Frozen Zoo can help the survival of critically endangered species as well as providing a kind of insurance policy against extinction.

Like it or not, de-extinction technology does have a future. When science is this exciting we just can't help being curious. After all, who wouldn't jump at the chance to see a real life woolly mammoth? Whether or not it leads to the all action sci-fi style ending remains to be seen. ■

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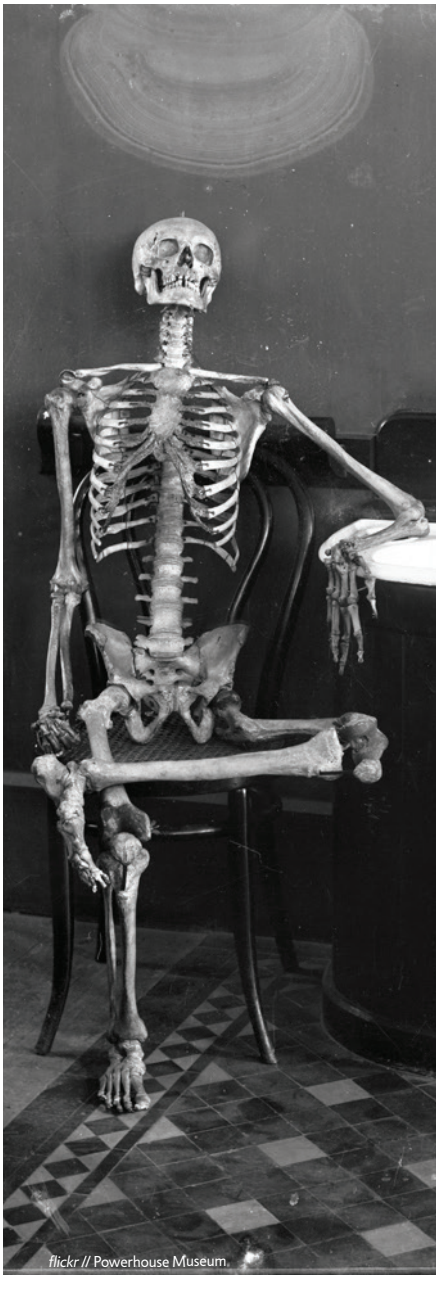
THE MATHS OF LIFE AND DEATH

There are more people alive today than have ever lived in the history of the species. ***Fatema Kassimali*** *does the maths on the remarkable rise and asks if it can be sustained.*



flickr // Powerhouse Museum

Approximately 30,000 years ago, our *Homo erectus* ancestors died out leaving us *Homo sapiens* as the only 'humans' remaining on the planet. Some believe that we all evolved in Africa and spread from there to China, Asia, and Europe, whilst others think that we developed simultaneously all over the globe. Either way humans, as we exist today, have inhabited the planet for the last 30,000 years.

Population has not remained stagnant over this time; we reached five million in 8000 BC, but by 1 AD we were around 100 million strong. Growth continued steadily until the year 1800, by which time the global population had reached one billion.

After the Industrial Revolution, the population boomed and each successive billion was reached faster than the last—three billion within 30 years, four billion within 15 years, and five billion after another 13 years. We reached seven billion in 2012 and are predicted to reach eight billion by 2024.

There are clear reasons behind these trends in population growth. In our early years, we lived a hunter-gatherer or nomadic lifestyle: food was often in short supply and infanticide was a common way to combat this. The Black Death, although it appeared in Britain in the 14th century, first emerged in 542 AD in Western Asia. It is thought to have killed half of the Byzantine Empire—nearly 100 million people—and such pandemics are a key reason behind the stagnation of population levels.

The population boom of the Industrial Revolution was due to faster food production and better living conditions. Although infant mortality remained high because of poor sanitation in cities, healthcare began to improve and when infant mortality rates started to fall as a consequence, the population surged further. Improving healthcare has also had an effect on longevity, and males born today are expected to live to 79 years of age, while female life expectancy is 83. By contrast, in 1901 the life expectancy was 45 and 49, respectively. In 2032, it is predicted to be even higher: 83 and 87 respectively.

> "AFTER THE INDUSTRIAL REVOLUTION, THE POPULATION BOOMED AND EACH SUCCESSIVE BILLION WAS REACHED FASTER THAN THE LAST"

The latest prediction shows we're not able to sustain the rate of increase and life expectancy is expected to plateau—at least for the near future. With such a great population boom coupled with no signs of slowing down energy or material consumption, our finite resources are becoming increasingly strained.

It could be that the almost exponential rate of the population increase may indeed become an issue in terms of resource management and possible effects on the climate. The future of the global population is simply a numbers game, but ours may be about to run out. ■

DEAD MOLES AND DINOSAUR BONES

There is a museum in London filled with interesting zoological specimens. ***Pippa Mitchell*** *went there, and spoke to some moles in a jar.*

Deep behind enemy lines, somewhere amongst the buildings of University College London, there lies... dead things.

The Grant Museum of Zoology is the last university repository for gruesome zoological artefacts in London. Imperial, Queen Mary and King's all gave up their fossil and pickle collections in the dim and distant 80s, but UCL kept going, and now the museum is home to over 67,000 dead things, parts of dead things, and dead things turned into stone by minerals leaching into them.

The most famous inhabitants of the Grant Museum are probably 18 moles, pickled together in a single jar. They are on twitter @GlassJarOfMoles, and have six times as many followers as I have. Their cramped living conditions are allegedly down to the cost of preservation fluid and shelf space, but there was probably a scientist's sick sense of humour involved somewhere too. See how long you can spend trying to work out which claws belong to which mole.

But the moles aren't the only celebrities to be found within the walls of the Grant Museum. There is a cast of a Compsognathus, the chicken sized dinosaur made famous by *Jurassic Park* for being very small and very evil. There is also a cast of *Archaeopteryx*, the creationist busting 'first bird'. The skeleton of a very small dinosaur is just visible, its neck bent all the way to its spine, and around its arms are the ghosts of feathers. Only ten more specimens have been found since its discovery in 1861, but none of those are "mounted in a fetching blue, wooden, glass-topped box" (quote from the Grant Museum catalogue).

For those who prefer their extinct reptiles a little less mainstream, the museum also houses a Dimetrodon skull. Iconic for the enormous sail on its back, Dimetrodon was a reptile that became extinct approximately 40 million years before the dinosaurs appeared. It is often misidentified as a dinosaur, but it walked like a modern lizard, with bent legs sprawled out to either side. Despite this, it is more closely related to mammals than it is to either lizards or dinosaurs.

Some people want to get that really guilty feeling from a museum visit, and the Grant Museum caters to them as well, with a selection of specimens of species driven to extinction by humans. There is an incomplete dodo skeleton, remarkable for how normal it looks compared to the stuffed examples in other museums.

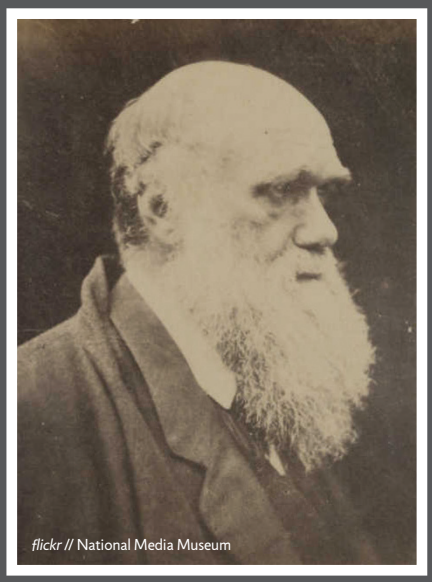
It also houses a complete set of quagga bones, one of only seven in existence. The quagga was (debatably) a subspecies of plains zebra that lived in South Africa until the late 19th century. It had zebra markings only on the front half of its body, with horse colouring on the back half. This unusual combination led to its popularity amongst the wealthy, who used it as a carriage horse, and also amongst hunters, who killed it for its skin. This is presumably the reason why the museum has to make do with just the skeleton.

If you like your dead, pickled and informative with a sprinkle of sparkling wit, the Grant Museum is probably the place for you. ■

The Grant Museum is open to the public (for free) every Monday to Saturday, 1-5pm. Access to the museum and all its collections is step-free. ucl.ac.uk/museums/zoology

Grant Museum

DARWIN AWARDS



flickr // National Media Museum

Selecting yourself out of the gene pool might be seen by some as an honourable admittance of failure. We doubt the following unfortunates had the brain power to make such an existential choice. ***Pippa Mitchell*** *and* ***Letizia Diamante*** *pick their top six Darwin Award winners.*

Wendy Northcutt, the founder of the awards, was just a biology student at Stanford University when she thought to create the website to "commemorate individuals who protect our gene pool by making the ultimate sacrifice of their own lives," in an extraordinarily idiotic manner.

It features stories including that of the chap who was killed by a vending machine whilst trying to tip it forward for a free drink, the escaping prisoner whose rope of bed sheets was 86 feet short of the ground, and the man who tried to rob a gun shop, but was instead shot by customers and the clerks. Surprisingly, these aren't even the cream of the crop of stories available, so here we have compiled our top six.

THE MANLIEST OF MEN

In 1995, Krystof, a Polish farmer, was drinking with friends when someone suggested they take off all their clothes in a display of their 'manliness'. At first, they fought each other with frozen turnips, but to up the ante, one of the men whacked out a chainsaw and cut off the end of his foot. Not to be outdone, Krystof swung at his own head, and decapitated himself, landing himself firmly on the Darwin awards shortlist.

flickr // OSU commons

ELECTRO-NIPPLES

Have you ever wondered what would happen if you connected your nipple piercings to an electronic control tester using crocodile clips? A 23 year old man in Pennsylvania, USA, did. It turns out that you get electrocuted. His coworkers attempted to resuscitate him, but were unsuccessful. He died at the scene, but his untimely exit was immortalised on Wendy's gruesome list for all to read.

flickr // The Library of Congress

TOP 6

FOR THE LOVE OF A MOPED

Rosanne, a 50 year old woman from North Carolina, took her moped out for a spin and a beer during some serious flooding in 2009. She told her mother that she would be fine, but on the drive back, she skidded off the flooded road, and into a creek. She was rescued by Highway Patrol, but then jumped back into the creek in an attempt to rescue the moped. She subsequently drowned, although it is unsure if the scooter made it back to the bank in a workable condition.

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YEAR OF THE TIGER

It was on New Year's Day, 1996 when friends Prakesh and Suresh had the reckless idea that would result in their downfall. They decided to put a flower garland on a tiger in Calcutta Zoo, as a New Year's greeting. Suresh threw the garland but the distgruntled tiger responded by attacking him. Prakesh, in an attempt to save his friend, kicked the tiger in the face, after which the tiger mauled him to death.

flickr // National Library of Ireland

THIS BAG IS A NOT A TOY

In 2002, a farmer in Sao Paulo took it upon himself to remove a bees' nest from his orange tree. Putting a plastic bag on his head to protect himself from stinging, he grabbed a torch, and began to burn the hive. Unfortunately, he forgot to put air holes in the bag. His wife found him, asphyxiated, a few hours later.

flickr // The National Archives UK

LORRY SURFER

As a lorry trundled along the Main Street of Shepparton, Australia, the Spring Nationals country festival 2000 was in full swing, and everyone was a little drunk. A man in a sombrero attached a rope to the lorry and surfed along the road on a piece of cardboard. The rope then became caught amongst the wheels, and the man was pulled in. Unfortunately he could not be saved, and next to the body bag lay his sombrero.

flickr // The Library of Congress

THE SCIENCE OF THE OTHER SIDE

Scans reveal a kick of brain activity just before death but no clear cause has been determined. ***Fabian Sweeney*** *explores the phenomenon of near-death experiences.*

Does a rat's life flash before its eyes before it dies? This is precisely the question Professor Jimo Borigjen and her team attempted to address in their recently published research into the phenomena of near-death experiences. Roughly 20% of heart attack victims who have experienced clinical death can recount a near-death experience that they described as including highly lucid visions of their soul leaving their body, and feelings of extreme bliss and happiness. Some even report meeting dead relatives and even religious figures.

When we talk about scientifically investigating this, you would be forgiven for thinking of the 1990 film Flatliners, where Kiefer Sutherland leads a team of rogue young medical students that includes Julia Roberts and Kevin Bacon, into a series of somewhat improbable, dark experiments involving induced death followed by resuscitation in order to experience 'the other side'. But beyond Hollywood movies, the fact that these experiences occur so regularly and have been reported across cultures has convinced some scientists to take near-death experiences seriously as a subject for scientific investigation.

Several ideas about the biological processes that underlie near-death experiences have been put forward. Some have proposed that damage to retinae due to hypoxia results in a tunnel vision similar to that reported by pilots exposed to high-G manoeuvres. Others suggest that the near-death experience is a result of changes in blood chemistry or alterations in levels of brain chemicals such as glutamate or dopamine. Epilepsy-like activity in the temporal lobe - a brain region associated with vivid hallucination - as well as psychological explanations regarding our expectations of the afterlife, have also been offered.

The big question, however, is whether or not the brain is capable of generating the kind of lucid hallucination associated with a near-death experience when the blood supply to the brain has been cut off. Even if it can, what's the method by which it happens? Can we explain this strange phenomenon in terms of brain function? Professor Borigjin and colleagues hypothesised that if the brain is producing a near-death experience, then scientists should be able to detect brainwaves that indicate consciousness after a heart attack.

Borigjen and colleagues set up an experiment where they artificially induced heart attacks in rats and simultaneously measured the animal's brainwaves. What they observed was a brief spike in brain wave activity; specifically brain waves known as gamma oscillations. These are the waves believed by some scientists to underpin consciousness, because they appear to arise when we attempt to recall

flickr // Miami University Libraries

memories or are being consciously aware of our surroundings. The way these brain waves were organised in the rat brains after cardiac arrest might suggest a heightened level of consciousness. Importantly these findings were also seen when animals were killed by carbon dioxide asphyxiation, suggesting the results were not caused by pain or other specific aspects of cardiac arrest.

The research does however come with numerous caveats, the most obvious of which is that we can never really know what's going on in a rat's mind. We don't know if they experience consciousness in the same way that humans do. Furthermore, we aren't certain that gamma brain waves are only associated with consciousness. We therefore can't conclusively say that the rats in the study were experiencing a near-death experience, but that is not to say that the study is meaningless.

What is important about this study and generating the controversy is that it appears to have located in the human brain the processes that could possibly underlie the near-death experiences.
Many have argued the lucidity of the near-death experiences reported by those who have recovered from heart attacks as being so intense that they could not possibly be the product of the human mind. Some, such as Howard Storm, author of the controversial best seller My Descent into Death, have gone so far as to say that near-death experiences offer a proof of heaven, hell and life after death. The lastest results appear to provide a start, at least, into a rational understanding of this phenomena. ■

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TALES OF THE UNDEAD: HAITIAN ZOMBIES

The legend of the zombie has it's roots in the mysterious and ancient religion of voodoo. Could there some be scientific evidence of real zombies? ***Mark Atwill*** *investigates some compelling evidence that has emerged from the tiny island heart of Voodoo, Haiti*

In 1980 a dead man came back to life. In a rural Haitian village, Clairvius Narcisse stood pointing out a tombstone to Canadian ethno-botanist and anthropologist Wade Davis. The inscription was faded and barely legible, but closer examination showed it was his grave.

Eighteen years earlier, Narcisse had been brought to the Albert Schweitzer Hospital in Deschappelles, Haiti, spitting blood and running a high fever. He was declared clinically dead three days later. Almost two decades later, he approached his sister in a crowded market. She admitted that their elder brother had put out a voodoo contract on Clairvius following a land-dispute. A bokor had then turned him into a zombie. In voodoo, this is to create one of the lowest social order, it is an act of enslavement and humiliation.

Narcisse recounted that the fate of many zombies is to be put to work as a plantation slave, as a mark of being of the lowest social order. His fate was no different. However, he was involved in a mass zombie breakout after only two years of enslavement. He was forced to wander Haiti for fear of his brother's wroth, and could only return home after hearing of his death.

With inside knowledge of the zombification contract, Narcisse's family was never in any doubt that this man was who he claimed to be, even after so many years of being dead. The BBC vigorously tested this account in a documentary into the ritual of the zombie. Without digging up the grave to check for remains, they were forced to conclude that this was no fraud. The evidence was very strong. With an intimate and detailed knowledge of his childhood, and accounts of his travels corroberated by witnesses around Haiti, it seemed that Clairvius Narcisse really had come back from the grave.

However improbable Narcisse, the man who 'died' eighteen years before, must have been induced to a near death-like state, intered in his grave, and then exumed before he suffocated. These factors could potentially be explainable by the bokor zombie powders, which are used in ritual acts of supposed sorcery. In many pharmacological investigations, several ingredients are common. An irritant is used to induce breakages in the skin, human remains are used to capture the spirit, and a special toxin is introduced into the bloodstream. Isolated from puffer fish, this toxin – tetrodotoxin – has been shown to capable of inducing the death-like state associated with the zombification ritual. Even in tiny doses, the toxin lowers the metabolism to the point at which the victim appears dead; while they remain fully conscious until the final moment, they are completely paralysed.

flickr// Tyne & Wear Archives & Museums

On recovery, the exhumed individual is supposedly convinced of their passage between life and death. In voodoo, the belief in the separation of the soul and the physical body permeates much of their belief about the nature of death, so to convince the victim of this ocurrence is more acceptable. To induce the state of childlike apathy, Davis suggested that the bokor may use datura, or 'zombie cucumbers'. Containing powerful psychotropic agents, these plants induce visions of hell, delirium and can cause schizophrenia. Under this level of psychological stress, zombie-like compliance could be more easily achieved.

Narcisse himself believed he was drugged by a voodoo bokor. He recounted how even as he was being treated, and finally declared dead, he was aware of all that was happening. He remembered the sheets being pulled over his eyes, and even has vague recollections of his funeral, and of being lowered into the ground. He was buried under a large concrete slab, which shows no signs of ever having moved once placed. Narcisse however claims that he was dug up by a bokor, and a ceremony lasting several days was inflicted on him to convince him that he was passing between the realms of the living and the dead.

Many believe that most stories about the zombification of relatives can be put down to mistaken identity. In 1997, British anthropologist Roland Littlewood and Haitian doctor Chavannes Douyon investigated the cases of three individuals who had returned home following their supposed deaths some years before. Zombies are identified by a fixed, mournful expression and odd quirks of repetitive behaviour and speech that are thought to be by-products of the zombification

process. Others, however, have linked these behavourial oddities to psychological problems; it is not uncommon for the mentally ill to wander the island of Haiti. It would be easy for a bereaved and grieving relative to find one such person and impose the identity of the dead onto them.

This was indeed found to be the case in the 1997 study published in the *Lancet*. Three individuals who we shall call FI, WD and MM had all died at least ten years before, and subsequently returned to their relatives by happenstance. Following medical and psychological examination, it was found that all three exhibited characteristics of learning disabilities, brain damage or catatonic schizophrenia. DNA testing revealed that none of them were who they or their 'relatives' claimed they were.

If Clairvius Narcisse really was the man he claimed to be, a zombie returned to life, then his only mistake was to return to his home, only to shunned by all who ever knew him. While he himself fully recovered from his alleged ordeal, he was from then on a social pariah. According to Wade Davis, zombification to Hatians is a form of "social and spiritual death, and so someone who's been made a zombie is marked for all time. No one wants them." In our culture, we have a vague fear of being attacked by a zombie. In Haiti, they fear becoming one.

With a plausible scientific explanation in place, and confirmed legal cases of zombification, the mystery of this legend has extremely deep roots. Perhaps, the true nature of the zombie will never be fully disclosed, although the speculation undoubtedly makes for fascinating bed-time reading. Sleep well. ■

UNDEAD CELLS – THE HELA CELL LINE

In 1951, Henrietta Lacks, an African American woman from Baltimore, USA, died from an aggressive form of cervical cancer that had spread to multiple tissues in her body. The cell line derived from her cancer was found to be remarkably durable, and went on to be the precursor for the oldest and most commonly used cell line across the world.

George Otto Gey was the scientist that first propagated the HeLa cell line. He lived in Baltimore and worked at the Tissue Culture Laboratory at John Hopkins University, when he first received the cervix sample of Henrietta Lacks, who died in the oncology wing of the hospital from uremic poisoning. Her cells successfully grew and multiplied outside the body, a challenge that hadn't been previously achieved, and became the first human cell line.

HeLa cells can be found in labs around the globe and enable scientists to run tests on human cells. It is estimated that together global HeLa cells weigh more than one hundred Empire State Buildings.

HeLa cells have been instrumental in our understanding of the human cell. Work involving HeLa cells not only saved millions of lives in 1950s by helping scientists to develop a Polio vaccine but have also been part of Nobel Prize winning research on several occasions.

HeLa cells contain the enzyme telomerase, which extends DNA at the end of chromosomes and allows HeLa cells to grow and divide indefinitely, hence the cells are referred to as 'immortal'.

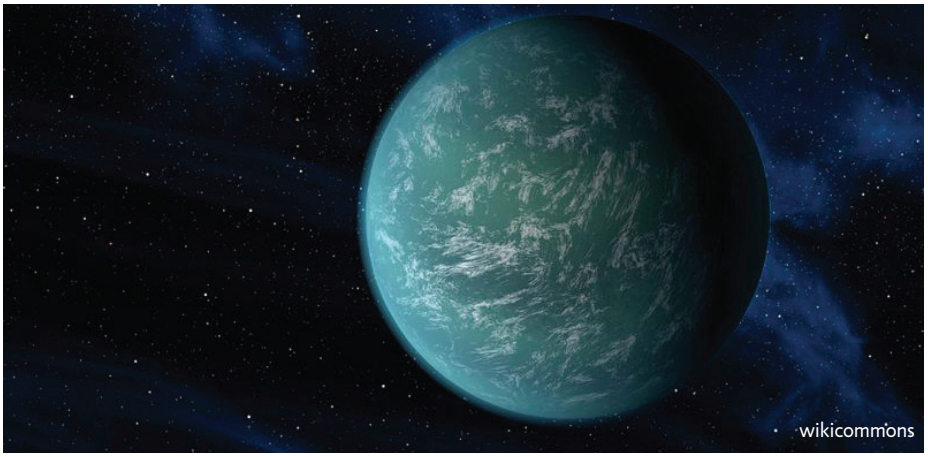
However, it was only recently that this story was made known to the general public. Henrietta's doctor at the time, Howard Jones, had biopsied the tumour without her permission and removed both a healthy and cancerous portion of her cervix. These eventually became the HeLa cell line, but the controversy surrounding taking tissue without consent meant that few people were willing to openly admit where the cell line was sourced from.

The family only discovered that scientists were using her cells almost twenty years later, when they began to request familial genetic information. It was only in 1996, over forty years after the first biopsies were taken, that Henrietta Lacks was officially recognised for her posthumous contributions to the many advances in modern medicine her cells have enabled. ■

PHILIPPA SKETT AND BEN STOCKTON

WORLD NEWS

PICK OF THE BEST



MOST EARTH-LIKE EXOPLANET

For the first time, scientists have identified an exoplanet bearing similarities to Earth. Astronomers from NASA's Kepler observatory succeeded in measuring the mass and orbit of Kepler-78b, a planet slightly larger than ours, orbiting its star 400 light years away.

Identifying the presence of an exoplanet is one thing, but determining its density – which holds clues to its composition and similarity to Earth – is much more challenging.

A team led by astronomer Dr Francesco Pepe of the University of Geneva, calculated the 'wobble' motion exerted by the planet on its host star in order to estimate its mass. This wobble is characterised by Doppler shifts, which is the change of frequencies in the waveform of the star's light. The group found that Kepler-78b has a mass that is just 1.86 times that of the Earth.

But two sets of calculations are better than one. Independently to Pepe's work, astronomer Dr Andrew Howard from the University of Hawaii and his research group estimated the mass of the exoplanet at 1.69 times that of Earth. Together, the results make the discovery 'rock solid'.

Kepler-78b is unique because its density is so close to that of Earth, which suggests that it has a similar composition of rock and iron but, by itself, this similarity does not make the planet suitable for life. It orbits its star much closer than the Earth orbits the Sun, and 40 times closer than even Mercury. This is so close that its surface is thought to reach blistering temperatures between 2,300 and 3,100 Kelvin.

Additionally, Kepler-78b belongs to a group of exoplanets with short orbital periods: one year on the planet lasts a mere 8.5 hours on Earth.

Despite these differences, astronomers are still excited by the discovery: its size, mass and composition make Kepler-78b the most Earth-like exoplanet discovered to date. It may be a faraway sister with a very hot temper, but it's still the best we know about outside our solar system. ■

MARION FERRAT

TAU TANGLING IN ALZHEIMER'S

A new imaging method has recently been developed that enables the visualisation of potentially damaging proteins in the brains of living patients. This technique could provide new insights into Alzheimer's Disease or other neurodegenerative diseases, and possibly lead to innovative treatments or cures.

Tau proteins are important for the stabilisation of components of the cellular scaffolding known as microtubules, especially in the brain. In those suffering from Alzheimer's disease, they are deposited incorrectly in neurons, forming neurofibrillary tangles. Finding a way of tracking the distribution of tau proteins is thus an important goal in Alzheimer's research.

Based on what we know about the chemical structure of the proteins, researchers synthesised a variety of fluorescent tau markers called PBBs. By comparing their binding distribution with that of PIB—a previously confirmed biomarker of amyloid-ß, the other hallmark Alzheimer protein—they selected the three PBBs most suitable for live tau imaging. The researchers established that PBB retention differed sufficiently between transgenic mice with a human tau protein mutation and normal controls.

Moving on from mouse models, the team conducted a small exploratory clinical trial with Alzheimer's patients. The two biomarkers for tau and amyloid-ß were radioactively labelled so that the patients' brains could be scanned using positron emission tomography (PET). Interestingly, the spatial distribution of PBB3 (tau) overlapped far better than PIB (amyloid-ß) with the brain regions implicated in cognitive decline in Alzheimer's.

Previously, neuropathological knowledge of Alzheimer's came from post-mortem histological assays, which are difficult to link to the behavioural characteristics of Alzheimer's patients. This new live imaging method will hopefully begin to bridge the neuroscientific gap between biology and psychology in Alzheimer's disease and other tauopathies. ■

SARAH WELLS

SPHERICAL ELECTRONS

Recent findings concerning the elusive shape of the electron gave rise to what could be considered a major breakthrough in the debate surrounding the Standard Model of particle physics, yet skepticism has already surfaced as it becomes clear that this debate may be far from over.

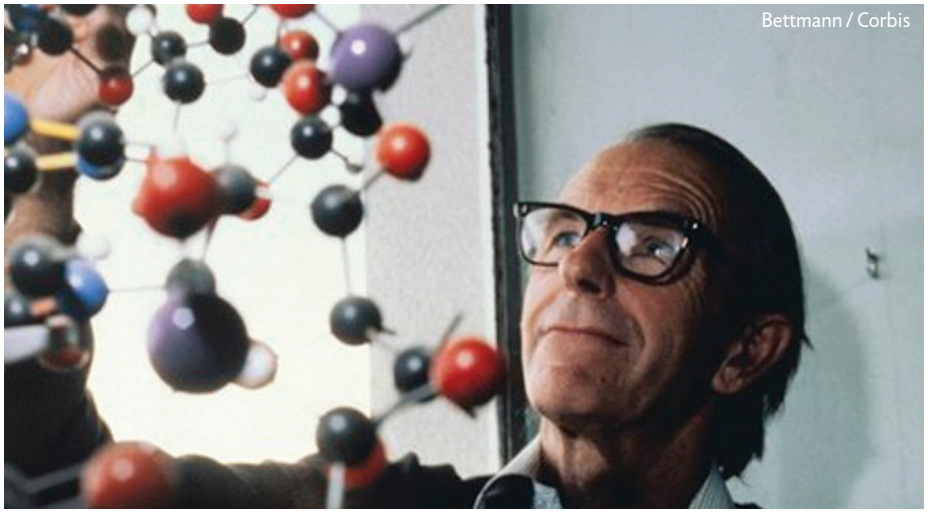
According to the new results, the electron has the shape of an almost perfect sphere. The ACME research team, led by Professor David DeMille of Yale University and Professors John Doyle and Gerald Gabrielse of Harvard University, performed highly sensitive measurements with microwave spectroscopy on spinning electrons in order to detect their electric dipole moment. This serves as the primary means of determining potential (anti-) symmetry in particles; a very small dipole moment is indicative of nearly perfect symmetry.

The team considered electrons in heavy thorium monoxide molecules in order to facilitate the detection of possible 'wobbling behavior', which would be expected from a non-spherical, asymmetric particle. The observed dipole moment of nearly zero would be in accordance with the implications of the Standard Model.

Some extensions of the Standard Model, supersymmetry in particular, predict the existence of so-called supersymmetric twin particles which have so far evaded discovery. Yet given that their occurrence should be detectable, the elegant theory of supersymmetry is now being challenged.

Some theoretical physicists continue to argue that more specialized versions of supersymmetry models might still be able to accommodate the small observed dipole moment. However, it would appear that more sensitive experiments will be necessary in order to make the implications of the above finding less a matter of perspective and more a matter of undisputable evidence. ■

MADELEINE KOTZAGIANNIDIS



Bettmann / Corbis

DR SANGER DIES

In more saddening news, Dr Frederick Sanger, known by some as the 'father of genomics,' passed away on November 19th. The British biochemist who had been awarded not one, but two Nobel Prizes for his work in the field, died at the age of 95, leaving three children.

Dr Sanger was born in Rendcomb, Gloucestershire in 1918 and studied biochemistry at St. John's College, Cambridge. He worked on his doctorate during the Second World War and, after receiving it in 1943, stayed on in Cambridge to investigate the protein composition of bovine insulin.

His first success was in the complete amino acid sequencing of the two polypeptide chains of insulin. From this he deduced that proteins have a determined chemical composition and in 1958, he received his first Nobel Prize in Chemistry for the breakthrough.

Following from this, he became the head of the Protein Chemistry division at Cambridge, and began looking into sequencing RNA and DNA. Although he was beaten by researchers in the United States to sequencing the first ever tRNA molecule, he did develop the Sanger Method for sequencing long stretches of DNA rapidly and accurately and in 1980, he received his second Nobel Prize in Chemistry for his development, this time shared with Dr Walter Gilbert and Paul Berg. Gilbert and Sanger were awarded the Prize "for their contributions concerning the determination of base sequences in nucleic acids." The Sanger Method was first used to sequence human mitochondrial DNA in its entirety, and in subsequent years it was employed for the sequencing of the human genome.

It was in 1992 that the Wellcome Trust and the Medical Research Council founded the Sanger Centre, now known as the Sanger Institute; a research centre dedicated to the study of genomics and genetics. Located on the Wellcome Trust Genome Campus just outside Cambridge, the institute is only a few miles from where Sanger had settled into retirement a few years previously. This centre went on to make the largest single contribution to the final genome sequence produced by the Human Genome Project in 2003 and is still internationally recognised as a centre for genetic research.

He spent the last years of his life gardening in his home in Cambridgeshire. Described by the journal *Science* as "the most self-effacing person you could hope to meet," he was a very modest man who felt himself to be "just a chap who messed about in a lab." He declined a knighthood, but did accept the award of the Order of Merit, in 1986. ■

PHILIPPA SKETT

NEWS FROM
IMPERIAL COLLEGE

IMPERIAL PROFESSOR STANDS UP FOR SCIENCE

This term saw Imperial College's own Professor Nutt win the John Maddox Prize for Standing Up for Science, following his controversial paper in *Nature* concerning drug legislation earlier this year.

The prize, a joint collaboration from the journal *Nature*, the Kohn Foundation and charity Sense about Science, is named after a previous editor of *Nature*, Sir John Maddox, FRS. Maddox edited the journal for 22 years, and was a founding trustee of Sense about Science, a UK charitable trust that aids understanding of how science evidence can be used in public discourse.

The prize is awarded to those who promote scientific evidence in public discussions and Nutt, a Proffesor of Neuropsychopharmacology, was given the prize for his "continued courage and commitment to rational debate, despite opposition and public criticism."

Nutt was previously a government advisor for the Department of Health, the Ministry of Defence, and the Home Office, before taking up the position of chairman of the Advisory Council on the Misuse of Drugs in January 2008.

He has often claimed that drug classification systems in various countries need to be revised, and that substances should be prohibited based on their scientifically quantified harm, rather than their social or economic damage. He has also stated that alcohol and tobacco are more harmful than LSD, ecstasy and cannabis with regard to the physical harm that dependency on the two legal drugs can exert on the body. These views led to his dismissal from the Advisory Council on the Misuse of Drugs, and the then Home Secretary, Alan Johnson, stating that: "He was asked to go because he cannot be both a government adviser and a campaigner against government policy."

It is this hostility he has faced that merited the John Maddox prize. Despite setbacks, Nutt continued his research into substance abuse, and has published various papers since then concerning drug harm, psychoactive compounds and pharmacotherapy. His published book, *Without the Hot Air: Minimising the Harms of Legal and Illegal Drugs* was released in 2012, to critical acclaim.

Professor Colin Blakemore, a neuroscientist at the University of Oxford and one of the judges, said that working "in circumstances that would have humiliated and silenced most people, [Prof Nutt] continued to affirm the importance of evidence in understanding the harms of drugs and in developing drug policy."■

PHILIPPA SKETT

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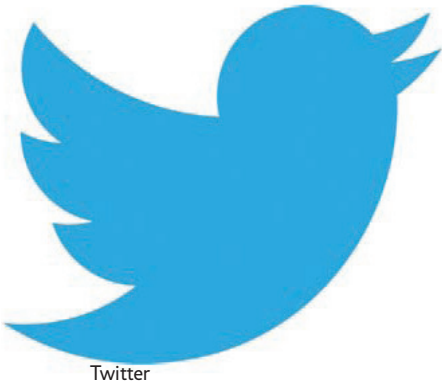

Twitter

T-INDEX

Researchers at Imperial College London have come up with a way of statistically measuring the impact of a single tweet. The value, referred to as the 'T-index,' can be used to find the most effective tweeters on a specific topic.

It's worked out by calculating the number of tweets by a Twitter account on a specific topic along with the number of retweets their posts received. For instance, a T-index value of 20 would mean that the tweeter has written at least 20 tweets on the topic that have each been retweeted 20 times. The formula is similar to that used for the 'H-index', which measures the impact of published work by academics.

According to Dr Dominic King, a clinical lecturer at Imperial College, there are many companies that measure influence on twitter, but they do not make it clear to the public how their figures are calculated and concentrate solely on individuals rather than topics.

The new T-index will enable users to search any topic and connect to the tweeters with the 10 highest T-index values, and thus 'twitter impact,' on the searched topic. The users can then follow these super-tweeters to receive the latest and most popular information on their chosen topic. ■

DALMEET SINGH CHAWLA

SYNTHAHOL

In early November, David Nutt, Professor of Neuropharmacology at Imperial College and former government drugs advisor, revealed he has developed a drug with effects that are 'indistinguishable' from those of alcohol.

Nutt spoke about the substitute on Radio 4's *Today* programme, appealing for investment. He felt the drinks business would want to buy into the idea and was surprised the drug hadn't been the topic of conversation earlier as "it's such an obvious target for health improvement."

Alcohol mimics the neurotransmitter GABA, which acts upon GABA receptors within the brain. This gives the feeling of inebriation but GABA also binds to other receptors in the brain less specifically. The synthetic alcohol substitute binds to GABA receptors more selectively so it stimulates the desirable effects of alcohol consumption, but avoids the undesirable effects such as hangovers, and memory and co-ordination loss. In addition, the effect of the drug can be reversed by an antidote enabling almost instant sobriety.

In 2009, Nutt famously ranked alcohol above LSD, ecstasy and cannabis in terms of the harm it causes, which led to his sacking from his government advisory post. Since then, evidence has continued to mount supporting his claim, with alcohol accounting for 2.5 million deaths a year.

Alcohol's toxicity to body tissues and likeliness to cause dependency could mean that, if discovered today, it would not be allowed to be sold under current food regulations. Apparently, Nutt's alcohol substitute is not toxic to the brain or liver and does not heighten aggression in the consumer. The health and social benefits of the drug are undeniable, with Nutt believing that it will cause a 'health revolution'. It is estimated the NHS could save £3.7 billion if the synthetic alcohol substitute was reasonably priced.

The health benefits may soon put synthetic alcohol on the radar of the NHS. Nutt would "like the government to make a recommendation that we try to improve the health of our people by allowing these kinds of substitute alcohols to be legal." Although it is hoped that the drug will not face licensing problems, the arguments are dragging on and so it could be years before we see alcohol substitutes on the market. ■

BEN STOCKTON

PUTTING WASTE TO GOOD USE

A team of students from Imperial College has created genetically engineered bacteria to turn landfill waste into plastic, and their project won a gold medal at the International Genetically Engineered Machine (iGEM) competition in November, coming third in the competition overall.

The seven students from the biology, biomedical engineering, and biochemistry departments genetically engineered *E. coli* cells to produce a bio-plastic by inserting genes from naturally plastic-producing bacteria. The bacteria live on non-recyclable mixed waste—such as wood, plastics, and paper—that cannot currently be recycled. This waste is converted to glucose and can then be turned into the bio-plastics suitable for reuse.

The plastic granules can be processed in a similar way to petrochemical plastics and then extruded or 3D-printed to a final result.

Team member Jemma Pilcher, a third year biochemistry student, is optimistic about the future applications of the technology. "Our system could provide a sustainable way to make an environmentally friendly alternative to petroleum-based plastics, which would reduce our dependency on oil," she said.

Other bio-plastics are made from plant-based materials and so need agricultural land for production. By using waste that would otherwise be incinerated, the team hopes that this can be a more sustainable solution to the world's waste management problems. According to Pilcher, "This system would divert rubbish away from landfill sites and incinerators—which have very negative effects on the environment by releasing toxins—and instead use it as a resource."

The initial plastic product does not biodegrade and cannot be melted and reformed in the same way as petrochemical plastics, so the team have engineered a second bacterial system that breaks down the material and reforms it. This ensures that there is a sustainable end-of-life solution for the plastic produced.

Currently, only 17 percent of waste is recycled around the world. The team hopes that synthetic bacteria could reduce the amount of waste ending up in landfills and also provide us with a valuable resource to reduce our dependency on oil.

Looking to the future, team member Margarita Kopniczky hopes that "technologies such as ours could one day be used to deal with the global challenge of how to dispose of ever increasing levels of waste. Perhaps in the future we will have household appliances that contain engineered bacteria that turn domestic waste into new 3D printed bio-plastic objects." ■

ALISA CRISP

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I, SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE

DEATH