I, SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE

COVER ILLUSTRATION BY TRISTAN VARELA

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

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

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I, SCIENCE

Hello and welcome to a very special edition of *I, Science*. For the first time we are venturing out of our safe haven of the Imperial College London campus, braving the scary real world, and delivering our graphically gorgeous magazine, brimming with fascinating science, to schools. Many of our new readers won't have heard of us before, so first things first – let's explain what we're about.

I, Science is a magazine and website run by Imperial College students, dedicated to providing readers with interesting stories from the world of science. The magazine comes out once a term and is full of absorbing stories, thoughtful opinion pieces and insightful interviews. Our website is regularly updated with new content including blogs, podcasts and feature articles, and its high standard of content was recognised by a nomination for a Guardian Student Media Award in 2012.

In this special edition of the magazine we hope to celebrate science in general, as well provide an insight into the kind of science journalism you can get involved in, even as a student.

Science is often the victim of stereotyping: branded with the image of test tubes, lab coats and geeky scientists. Yet it takes very little to discover that this is far from the truth. Some might see physics as the boring subject of invisible forces, complex equations and dull graphs. But on page 4 we enter a world of gas guns and controlled explosions, as Chris Clarke recounts his experiences of the shock physics lab here at Imperial College.

That might seem like an extreme job for a scientist, but remember that scientists are no stranger to danger. On page 8, Christopher Yates looks at researchers who have thrown caution to the wind and used themselves as guinea pigs in their own experiments. Where would we be without these brave (and maybe crazy) pioneers?

In biology, too, things are getting exciting. Despite a century of thinking otherwise, we're starting to realise that our genes aren't the only factor in determining hereditary traits. On page 16, Karin Valencia looks at this new field of epigenetics and what it might mean for all of us.

Of course, we can't forget what this might mean for science. As new fields emerge, and collaborations occur, the traditional labels of 'biology', 'chemistry' and 'physics' are becoming increasingly outdated. On page 18, Sarah Byrne introduces us to the field of interdisciplinary science, and how subjects that seem distinct are actually increasingly interlinked.

Science is at the heart of our modern world, and this type of new thinking is what will drive us forward. While aspects like technology and medicine are sometimes the most clearly visible in everyday life, science in general has become more integrated into society than ever before.

For those of you hoping to be part of the next generation of scientists, we hope that this magazine can provide a flavour of the things you might find yourself working on, or even trying to improve, in years to come.

With this celebration of science in mind, we give you *I, Science* – we hope you enjoy it. ■

ALEX & CONOR

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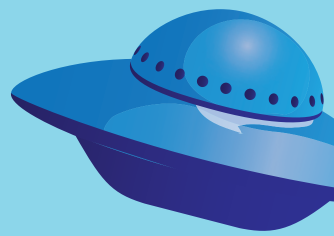


PUTTING THE SHOCK BACK INTO PHYSICS

Think of physics and you probably think of springs, formulas and mediocre diagrams. What happened to the mad scientists building rockets out of tin cans and blowing up their laboratories? ***Christopher Clarke*** *meets the new breed of friendly pyromaniacs – the shock physicists.*

Shock physics is the area of physics that deals with what happens after explosions, impacts, or anything moving at high speeds. The 'shock' isn't the reaction of nervous scientists to loud noises, but the shock waves that come from these events as lots of energy tries to move quickly from one place to another. Just as you see ripples in a pond after you throw in a stone, such effects might also be seen in a sheet of metal that's been hit by a bullet, or in the air around an explosion.

> "THE NEED FOR SCIENTISTS FROM ALL DISCIPLINES IS PRIMARILY LINKED TO THE VAST NUMBER OF APPLICATIONS OF SHOCK PHYSICS"

The job of the shock physicist is to create these events and study the resulting shock waves. This means lots of training to use enormous guns, powerful explosives and a whole range of other exciting pieces of equipment. The aim here is not just controlled anarchy, but learning to create and harness shock waves for useful purposes, as well as minimising the damage they can cause.

The popularity of shock physics has soared in recent years due to its widespread applications in both industry and the military. One of the biggest departments you'll find studying the topic is the Institute of Shock Physics (ISP) here at Imperial College London. *I, Science* visited the ISP to meet the responsible academics, the slightly less responsible students and to look down the barrel of a very big gun.

The Big Boss

Dr William Proud, or 'Bill' to friends and student journalists, is the Director of the ISP. The Institute has been around since 2008, and it's Bill's job to ensure that its various research avenues are being pursued responsibly and efficiently, as well as keeping the department in close contact with other shock physics groups around the world.

Ever since Bill became director in 2011, he's been pushing to make shock physics an area that is open to all kinds of scientists. "The ISP is a multidisciplinary centre", Bill tells *I, Science*. "I myself originally trained as a chemist."

The need for scientists from all disciplines is primarily linked to the vast number of applications of shock physics. "In the public mind there's always a very strong link to the military," Bill explains. "However, the largest users of explosives are: quarrying and mining, demolition, and petrochemical extraction. The military account for about 1% and that's even during times of conflict."

Much research, therefore, goes into improving the efficiency of using explosives in quarrying and mining. However many other research paths exist, including research into injuries sustained from shocks and even high-speed photography to watch shocks as they happen.

The Aspiring Anarchists

Every year the ISP takes on a handful of aspiring young minds to train in the art of explosive investigation.

"We smash stuff!" one of them announces cheerfully when asked whether they've been trusted with explosives yet. "But we do get to do a bit of explosives training when we go to the Czech Republic." The students explain that it is there that they undergo training with the plastic explosive Semtex.

However, according to the students, the Czech Republic isn't the only place they visit: "We work with groups in other universities everywhere, like the University of Moscow… I'm off to San Diego so we have links there too."

When probed on the subject of 'smashing stuff', it becomes apparent that the go-to device is something called a Hopkinson Bar. Two long metal rods face each other, with a sample of material in between. One of the rods is fired into the other, deforming the sample in the process, and the pulse wave of energy is measured. To give a perspective of the rate at which the samples are deformed: "A football pitch would be compressed to the size of a postage stamp in 1/300th of the blink of an eye."

The Weapon of Choice

Although the Hopkinson Bar is impressive, without a doubt the most visually exciting piece of equipment kept at the ISP is the enormous gas gun.

The gas gun is a very useful tool in shock physics, serving the sole purpose of firing small objects, called 'flyers', at very high speeds into preselected targets. This is a great way to test the reactions of various materials to high velocity impacts, including bits of aircraft and even gammon steaks (when researching shocks in bodily tissue).

> IF YOU THINK PHYSICS HAS BECOME BORING, TRY A CAREER IN SHOCK PHYSICS

The gun barrel is 6 metres long and connected to a large chamber filled with rags to collect debris. A 4 kilogram flyer can be propelled down the barrel at up to 1.2 kilometres per second by highly pressurised gas, hitting a target mounted in the chamber. The flyer is about the size of a coffee mug and imparts the same force as a transit van travelling at 90 mph.

You'd have thought this would make an incredibly loud noise, however the entire chamber is kept under vacuum, which stops sound from escaping and reduces the blast to only a dull 'thud'.

Centimetre-thick sheets of steel are torn like paper at such velocities. However everything is highly controlled — including the speed of impact — allowing careful studies to be conducted of the target after shock.

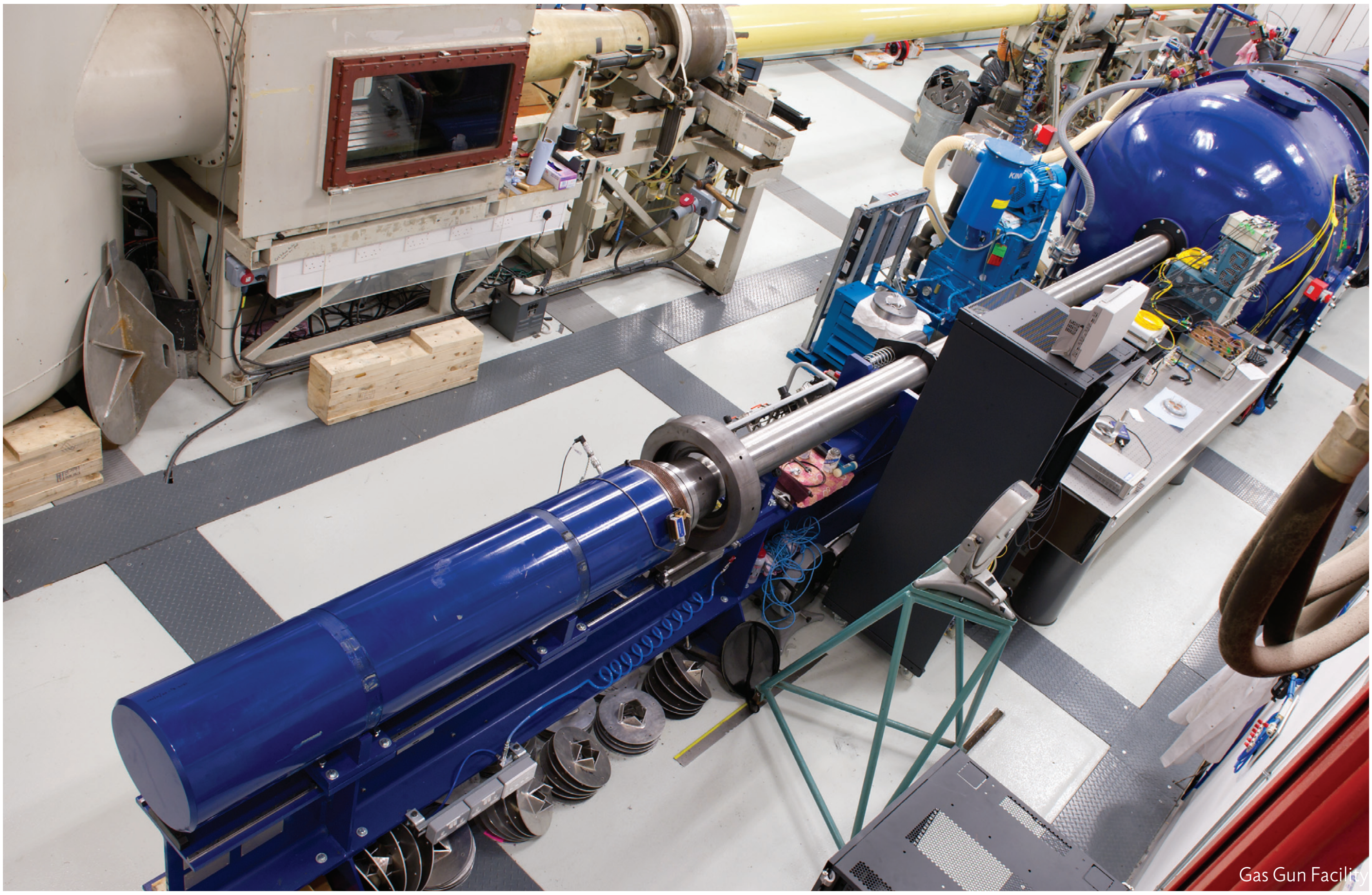
Today the ISP continues its hard work, along with similar departments all over the world, bringing us efficiency and safety through unconventional routes. So if you miss the days of the mad scientist and think physics has become boring, try a career in shock physics. ■

Discovering the world's most popular explosive

Ammonium nitrate is one of the world's most widely used explosives and is commonly found in plant fertiliser; however the full extent of its explosive capabilities was not discovered until shortly after the First World War.

In 1921, the workers in the small town of Oppau in Germany were using small charges of dynamite to try and clear solid clumps of fertiliser from a 4500 tonne silo.

Around 80% of Oppau abruptly went missing, leaving 500–600 dead, 2000 injured and 6500 homeless, in an explosion that could be heard 300 km away.



Gas Gun Facility

6 INFLUENTIAL & INSPIRING WOMEN IN SCIENCE

Women throughout the ages have helped to shape our understanding of the world through science despite often having to overcome oppression and lack of recognition. ***Arianna Sorba*** *investigates the top six female scientists.*


Wikipedia Commons

Marie Curie (1867-1934)

Gave her life to research radioactivity

Marie Curie, the Polish chemist and physicist, is perhaps the most famous female scientist of all time. Risking her life nearly every working day (although perhaps not aware of it), her groundbreaking research on radioactivity – including discovering the elements Radium and Polonium – earned Curie and her husband a Nobel Prize for Physics in 1903. She later became the first female teacher at the Sorbonne University in Paris and was awarded her second Nobel Prize, this time for Chemistry, in 1911. During the First World War, Curie led the radiology services for the Red Cross, setting up France's first military radiology centre. Beyond her personal achievements, Marie Curie – or perhaps just the genius of the Curie household – might be credited with inspiring her eldest daughter, Irene, who was awarded her own Chemistry Nobel Prize in 1935.

Rosalind Franklin (1920-1958)

Helped discover the structure of DNA

In 1953, Francis Crick and James Watson became household names after the pair announced their discovery of the double-helix structure of DNA. But few had heard of the female researcher Rosalind Franklin. First at Cambridge University, and later at King's College London, Rosalind became an expert in X-ray crystallography, and it is now thought that it was Franklin's X-ray photographs that revealed the complicated structure to Crick and Watson. She was a passionate and dedicated scientist, still conducting research and publishing papers right up until her death in 1958, four years before Crick and Watson were awarded the Nobel Prize for discovering the structure of DNA.


Jewish Chronicle Archive/Heritage-Images

Jocelyn Bell Burnell (1943-)

Made the greatest astronomical discovery of the 20th century

Bell Burnell made one of the greatest astrophysical breakthroughs of the 20th century while still only a postgraduate student at Cambridge University. After analysing miles of printouts of astronomical data, she spotted an unusual signal that she could not explain. Despite Bell Burnell's supervisors suggesting she ignore the anomaly, she persisted. The anomaly turned out to be the first ever detection of a pulsar – a fantastically dense and quickly spinning star made of neutrons. The discovery led to a Nobel Prize for her two supervisors, but not for Bell Burnell. However, refusing to be demoralised, she went on to become a Fellow of the Royal Society, a Dame, and the first female president of the Institute of Physics.

Quadrennial Physics Congress

La Gazzetta

Rita Levi-Montalcini (1909-2012)

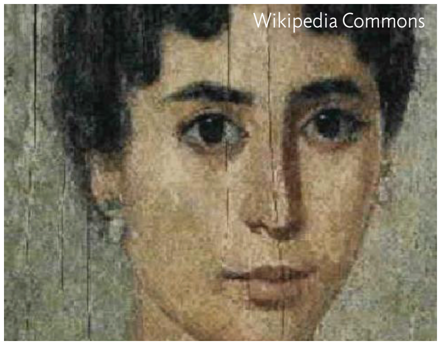
Built a secret laboratory in her bedroom

Born in Turin, Italy, to a painter and a mathematician, Rita Levi-Montalcini was determined to study medicine. However, soon after graduating from the University of Turin, the rise of Fascism in Italy forced her into hiding because of subsequent laws barring Jews from academic and professional careers. But Levi-Montalcini persevered and built a secret laboratory in her bedroom, using sewing needles and watchmaker's tweezers, to investigate cell biology using chick embryos. Her later cell research in the US earned Levi-Montalcini a Nobel Prize in Medicine in 1986. She continued to be committed to her science, working for hours every day until her death in 2012, aged 103.

Hypatia of Alexandria (c.355-415)

One of the first female scientists

Hypatia was a Greek philosopher, and one of the first female scientists in recorded history. Following in her father's footsteps, she became the world's leading mathematician and astronomer: building on her father's already detailed star charts, advancing work on geometry and fighting to preserve the Greeks' strong scientific heritage in times of passionate religious conflict. It was Hypatia's popularity as a teacher of philosophy that made her an enemy of some religious groups and eventually led to her brutal murder by a Christian mob. She has since become a powerful symbol for intellectual pursuit in the face of ignorance and prejudice.



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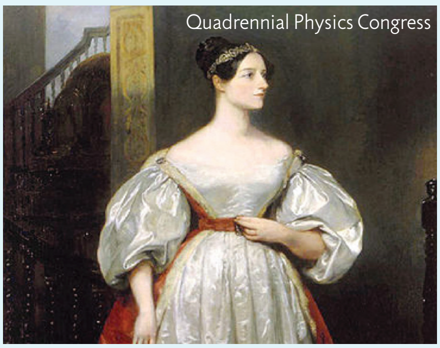


Quadrennial Physics Congress

Ada Lovelace (1815-1852)

The world's first computer programmer

Born from a brief marriage between the poet Lord Byron and Annabella Milbanke, Lovelace was taken from her 'eccentric' father at a young age and encouraged by her mother to study mathematics – an extremely unusual pursuit for women at the time. However, Lovelace's studies revealed her talent for logical subjects, and she is now known as 'the world's first computer programmer', having invented a basic algorithm that worked much like modern computer codes. Not only that, she also predicted the importance and power of such machines in the future, at a time when her peers assumed the full potential for computers was basic algebra.

SELF-EXPERIMENTING SCIENTISTS

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

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

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

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

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

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

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

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

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


JD Hancock

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

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

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

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

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

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

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

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

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

PROFESSOR PROFILE:

ARMAND LEROI

***Eliot Barford** investigates how this Imperial College Professor has been bringing his expertise to the wider world.*

Armand Leroi is not your average Professor of Evolutionary Developmental Biology. As a scientist, his expertise lies in tiny worms and why they grow to precisely the same size. But outside the lab he has written a book about human mutants, presented several TV shows about biology and done (serious) research into the evolution of pop music.

Leroi has been working at Imperial College London for over 10 years, but he is no stranger to the wider world. He was born in New Zealand, grew up in South Africa and Canada, has a doctorate from the USA, and is now a Dutch citizen. In 2003, between doing research and teaching biology students, he published a book called *Mutants: On the Form, Varieties and Errors of the Human Body.* The book looks at human variation, from the everyday to the shocking, and how it arises.

Mutants won the Guardian First Book Award in 2004. It has a remarkable cast of characters, from Petrus Gonsalvus, the hairy-faced fixture of 16th century royal courts, to the Ovitzes, a family of dwarfs who survived Auschwitz thanks to being the subject of pointless experiments. In his book, Leroi wanders through the centuries and across the globe, providing biological explanations of hair colour, sex, ageing and plenty more. It turns out that we are all mutants to some degree; we just differ in the way we express it.

Though accessible, *Mutants* was grounded in Leroi's scientific expertise in evolutionary developmental biology, or 'evo-devo' for short. The field tries to explain how our developmental processes work. For example, how do our arms, eyes, kidneys, brains and other organs form from just a few cells? And why do they look like they do? It's when these processes go wrong that we tend to get the most unusual mutations, so studying mutation can tell us a lot about our developmental processes.

But why *evolutionary* developmental biology? Well, studying evolution shows us why we are different from all the other living things on Earth. Development is a big part of that difference. You might expect us to develop completely differently from, say, a microscopic worm, but you'd be wrong. In fact, over millions of years evolution has never really reinvented development. Instead, small mutations mean that similar genes, used in a slightly different way, can give rise to the millions of different forms that exist today. So in evo-devo, biologists compare how different organisms develop to find out how they (and we) evolved.

In 2004, Leroi adapted his book into a television series called *Human Mutants* for Channel 4. This became the first in a string of biology documentaries he has presented, covering subjects like evolution, its discoverer Charles Darwin, and the ancient Greek philosopher/naturalist Aristotle.

Leroi's most recent media escapade looked at the "evolution" of music. Last year, in *Darwin's Tunes* for BBC Radio 4, Leroi suggested that music, along with the rest of our culture, evolves in a way similar to biological evolution. He and his colleagues proved this by applying the process of natural selection to computer-generated random sounds to eventually create music without human musicians or producers.

Today, Professor Leroi is working on several new books and regularly publishes new research. If you want to find out more about him his work, visit his website at www.armandmarieleroi.com.

THE WHAT PARTICLE?

*For something so hard to find, the Higgs boson has been absolutely everywhere for the last few years. But despite trending on Twitter, and even having its own iPhone app, most people still ask, "What exactly is it?" **Conor McKeever** is here to clarify and describe its significance in explaining the forces that govern the universe.*

The Higgs boson is, at its simplest, an elementary particle: a particle that cannot be broken down into anything smaller. Such particles are the building blocks of the universe, and a number of them are already known: 12 fundamental fermions (such as electrons), which make up matter, and 4 fundamental bosons (such as photons), which give rise to forces.

But we can also think of these particles in a different way. Imagine a weather map where wind speed has been mapped out: each arrow on the map is a point in space with a known 'amount' of wind speed, and where that value is not zero, we say there is wind. We can do the same thing for particles: every point in space can be assigned an amount of 'electron-ness', and electrons are present when this is more than zero. This all-present potential for 'electron-ness' is called an electron field, and in a similar way, the Higgs boson is an excitation in the universal Higgs field.

Despite all the hype about the Higgs boson, it's the Higgs field that's so important for physicists because it's how particles get their mass. Particles that interact strongly with the Higgs field gain a lot of energy from it; energy that we interpret as mass, thanks to Albert Einstein's $E=mc^2$ equation. Without this process, the equations describing particle behaviour cannot explain why most elementary particles have mass.

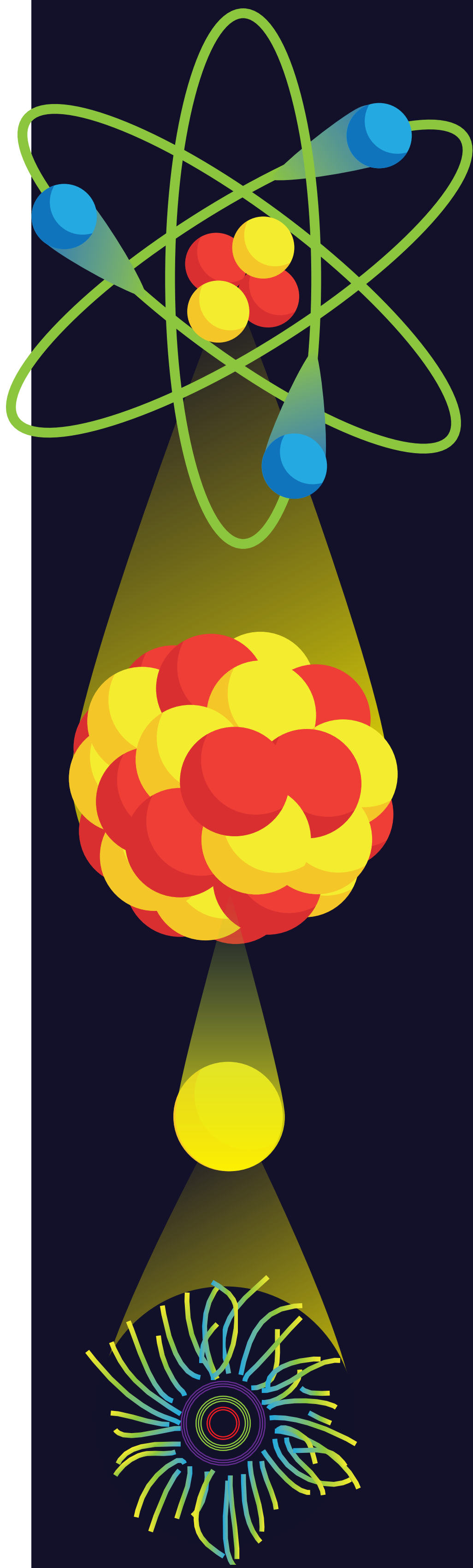
So why are we chasing the Higgs boson? Because we can't measure the Higgs field directly: we need to find the Higgs boson to prove the field exists. This search happens at the Large Hadron Collider at CERN, where 'bunches' of protons are accelerated to 99.9999991% of the speed of light, before colliding up to 600 million times per second. The elementary particles (such as gluons) that make up the protons then have enough energy to interact with each other, and can produce a Higgs boson.

Unfortunately, the Higgs boson is so massive that it immediately turns into other, lighter particles, meaning we can't just look for it in the results of the collision. But we can predict what it should decay into – and if we see that same ratio of particles in the detector, then we may have made a Higgs boson. In fact, lots of other pathways could go to make those particles, and by chance it could be the same ratio, but if we run enough experiments, and the same results keep coming up, then we can be more confident that there's a Higgs boson involved.

And that's what happened: in 2012, after 4 years of running trillions of collisions, CERN announced that they had "probably" found a Higgs boson, with only a 1-in-3.5 million chance that the results were just down to chance.

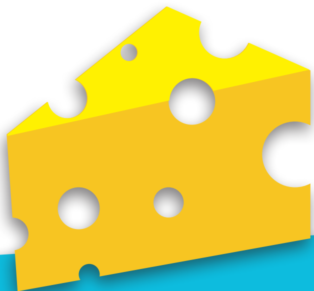
But this is just the beginning – our standard model of physics doesn't tell us where gravity comes from, so if the Higgs boson fits the model exactly, we haven't got any new information to point us in the right direction. If it does something unexpected, it could help us find the holy grail of physics: a theory that describes all the forces in the universe.

Perhaps the Higgs deserves the title 'God Particle' after all. ■



TOP 6 'CREATIVE' DIY INVENTIONS

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

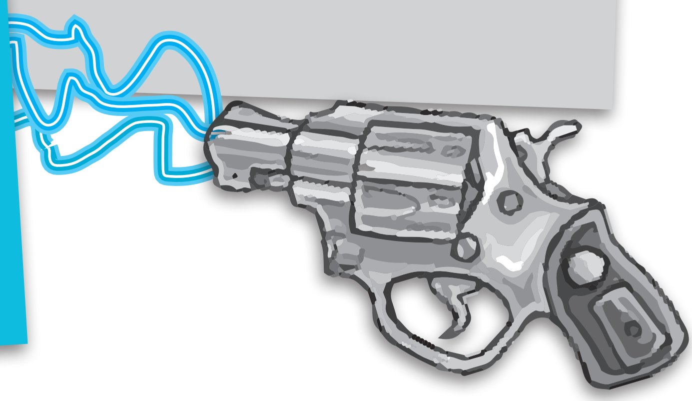


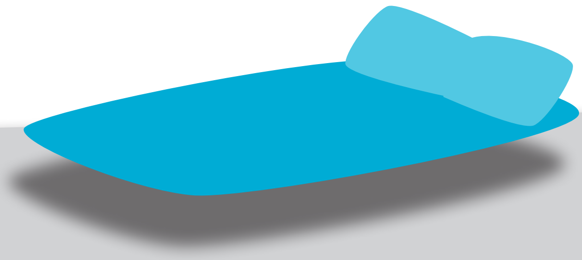
THE CHEESE-CONTROLLED CAR

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

TESLA GUN

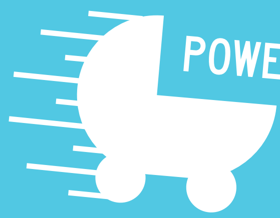
By using mainly scavenged parts, Robert Flickenger managed to construct his own fully-functional 20,000-volt Tesla coil gun for only £500. He created the body of the gun by melting down aluminium scrap metal and pouring it into a mould of a plastic Nerf toy gun. The current, provided by a lithium ion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





LEVITATING BED

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



POWER PRAM

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

MACHETE-SHOOTING SLINGSHOT

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

SET PHASER TO 'STUN'

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

SCIENCE BEHIND THE PHOTO

Framed against the Dubai skyline, it's the physical processes of refraction, reflection and constructive interference that create the explosion of colour in this giant bubble.

Scientists once believed that we emit light beams from our eyes, allowing us to see. However, in the 11th Century, the Arabian scholar Abu Ali al-Hassan Ibn Al-Haytham used experiments to disprove this emission theory and show that light rays actually enter our eyes. His many experiments on light often involved refraction and reflection.

Similar to how we see the colours in rainbows, we perceive colour on the surface of bubbles through the reflection and refraction of light waves. White light is made up of a spectrum of colours that each have a different wavelength. Just like ocean waves, light waves have peaks and valleys (crests and troughs). Red light has the longest wavelength and so the largest distance between each consecutive trough. A bubble consists of an inner bubble wall and an outer bubble wall that are a few micrometers apart. When a light ray hits the outer surface some light is reflected, while the rest is transmitted to the bottom layer where it is then also reflected.

The light rays that are transmitted through the bubble are refracted slightly. Although light rays travel in straight lines, when they enter a denser medium, in this case the soapy bubble film, their speed slows down and so they change direction. This, in combination with constructive interference produces the intensified colours we see in the photograph.

It was in the early 19th century that the English polymath Thomas Young first established the role of interference. Light reflected from the inner surface of the bubble will have travelled a few micrometers further than light reflected at the outer surface, and thus the two separate reflections will be out of step. These two reflections will interfere with each other. If the light waves meet crest-to-trough the colours will cancel each other out and we will see no colour – known as 'destructive interference'. However, if the troughs of each reflected wave coincide they combine to cause an intensified colour effect – known as 'constructive interference'.

The bubble's structural formation creates the perfect medium for the processes of constructive interference, reflection and refraction to interact and produce such vivid colours. Ibn al-Haytham's early work on the theories of refraction and reflection and Thomas Young's explanation of interference were both paramount to our understanding of how colours form in bubbles.

PHOTO AND TEXT BY TASCH MEHRABI

THE EXCITING WORLD OF EPIGENETICS

The field of epigenetics is eroding scientists' belief that genes are the only inherited information. By turning certain genes on and off, ***Karin Valencia*** *wonders if, one day, we might be able to create super-humans.*

Are the fantasies of superheroes so far-fetched, or might it be possible to change our bodies to acquire superhuman abilities? Epigenetics, one of the most recent and important discoveries in the science of heredity since the gene, might hold the answer.

Biology students have traditionally been taught: "1. The genome contains all the instructions necessary to make up an organism; and 2. Genes are passed on unchanged from parent to child, and to subsequent generations: any genetic changes brought about by lifestyle cannot be inherited." These ideas now appear to be outdated (although it might be worth remembering them for your biology exams).

It turns out that there is another set of instructions, known as the 'epigenome'. These instructions are additional to the genome: interacting with and modulating our DNA. By switching certain genes on or off, the epigenome determines which genes get expressed into traits. But this is not the end of the story. Epigenetics happen as a response to a signal from our environment, meaning that changes brought about by nurture can indeed be inherited. In other words, once made, epigenetic changes can be very long-lived, lasting greater than one or two life-times.

> ALTHOUGH TWINS SHARE THE SAME GENOME AT BIRTH, THEIR SOCIAL INTERACTIONS, DIETS AND EXPOSURE TO TOXINS LEAD TO DIFFERENT EPIGENOMES

ethermoon; flickr

So the word 'epigenetics' means both 'the development of an organism through the regulation of how genes are expressed' and also, 'forms of inheritance of these modifications of DNA sequences'.

But, what exactly is the power of epigenetics? One of the most clear-cut examples of the influence of the epigenome can be seen in identical twins. Since they come from a single embryo, they share the same genome, and, being twins, they shared a very similar environment in the womb. But as the twins get older, their social interactions, diets, differences in physical activities, and exposure to toxins such as cigarettes, differ. These environmental factors create different needs and signals in their bodies; the epigenome responds by activating and silencing different genes in order to cope with the varying demands. Since the environment of the twins is different, their epigenome responds differently. The genomes of the twins are unaffected, but their epigenomes change, leading to different patterns of genes.

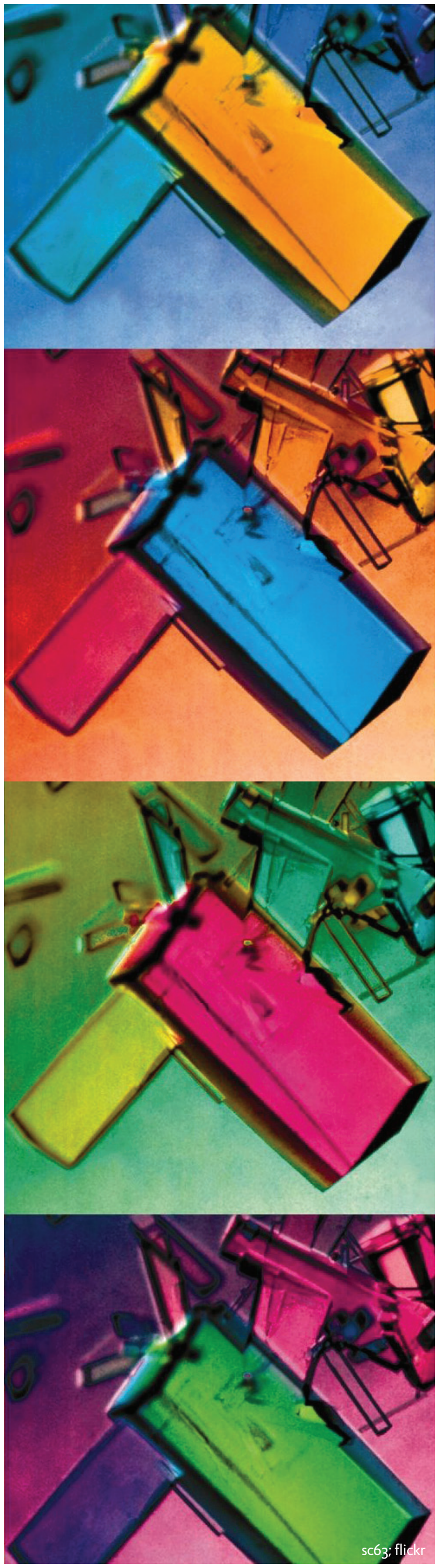
The exciting discovery of epigenetics has led some to question whether we can use this newfound knowledge to enhance our physical condition. And like Peter Parker after being bitten by a genetically modified spider to become Spiderman, we won't have to go through the trouble of replacing our whole genome; we just need to modify it. So now we know that the correct question isn't: "what gene can I delete or acquire in order to become stronger?" Instead, we should ask: "can I epigenetically regulate the genes I already have to make my muscles grow larger and stronger?"

If it's endurance you want to improve, the genes responsible for generating red blood cells could be tweaked so that abnormally high levels are created and your muscles are supplied with oxygen faster than normal. You'd be able to do physical activities for hours, while experiencing less fatigue. If you want to acquire Sherlock Holmes' abilities of deduction, it might be a little trickier to tackle, but increasing the neuron development in our brains would help.

Exactly how to upscale or downscale the expression of genes is currently not well understood, and is under intensive investigation, so superhero-like abilities may not be possible for some time. However, epigenetics will clearly have many important applications in the future of medicine. ■

EXPLORERS OF A MOLECULAR LANDSCAPE

*Want the thrill from climbing Everest or reaching the South Pole? Professor Stephen Curry explains to **Katherine Powell** how he feels structural biology is just another form of exploration.*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Did you always think you wanted to be a scientist?

No I didn't. I first wanted to be an astronaut, then I thought that was probably unrealistic and I wanted to be a pilot – then I realised a pilot is really a glorified bus driver so it's probably a bit boring after a while... It wasn't until after I got to university that I started to think about being a scientist.

So was it a fascination with space and aviation that made you want to be a physicist?

Well, looking back, I can't really remember. I had considered aeronautical engineering so obviously there was a trace of fascination with aviation. But, I thought that engineering is a bit vocational and physics kind of left lots of doors open.

What got you interested in biophysics?

In the final year [of my physics degree] I did two courses orientated towards biophysics (the application of physics in biology), so things like structural biology, but also electrophysiology (measuring electric currents in nerve cells) and the physical basis of colour vision. And having decided that, yes, I would like to do a PhD, those were the areas that interested me most because there was a link to human beings and health. While there are many interesting areas of physics, many are abstract. I always felt that I would like to do something that would be easy enough to explain to someone at a party, so, in the end I did one on the mechanisms of general anaesthesia.

> "THERE'S A GREAT THRILL WHEN YOU DISCOVER OR SEE SOMETHING FOR THE FIRST TIME"

And your research at the moment, what are you looking into?

I'm a structural biologist. I figure out what molecules look like using a technique called X-ray crystallography. We look at, proteins and nucleic acids like DNA and RNA, which are too small to see even with microscopes. Crystallography gives us a tool for revealing the 3D structure of these molecules. The particular types of molecule that I'm interested in are ones that have a prominent role in virus infections. I'm interested in a very particular class of viruses: small, single stranded RNA viruses. There are two groups that we work on primarily. One is the foot-and-mouth disease virus, an important pathogen of agricultural livestock. The other is a norovirus, the winter vomiting bug.

What is it about your work, at the moment, which most excites you?

Well, one thing that has struck me as quite a privilege is that you can get remunerated for exploring the natural world and that there are so many things as yet uncovered. That was one of the appeals of the life sciences rather than physics: they are much younger sciences and it seemed there was more scope for finding out something important compared to physics which is older – a lot of the good bits have already been done. There's a great thrill on those occasions (they don't necessarily happen too often) when you discover or see something for the first time. Our particular type of work is generally about discovery. Every now and then we are in the position that we have solved a new structure and we can gather round the computer screen and see it. It's a bit like conquering Everest or getting to the South Pole – I wouldn't necessarily put it on a par with those achievements but it is a similar type of experience. We are explorers of a molecular landscape and every now and then we come across something that no human has seen before, and that's quite a thing. ■

KEEPING YOUR OPTIONS OPEN:

HOW THE TRADITIONAL SUBJECT BOUNDARIES IN SCIENCE ARE DISAPPEARING

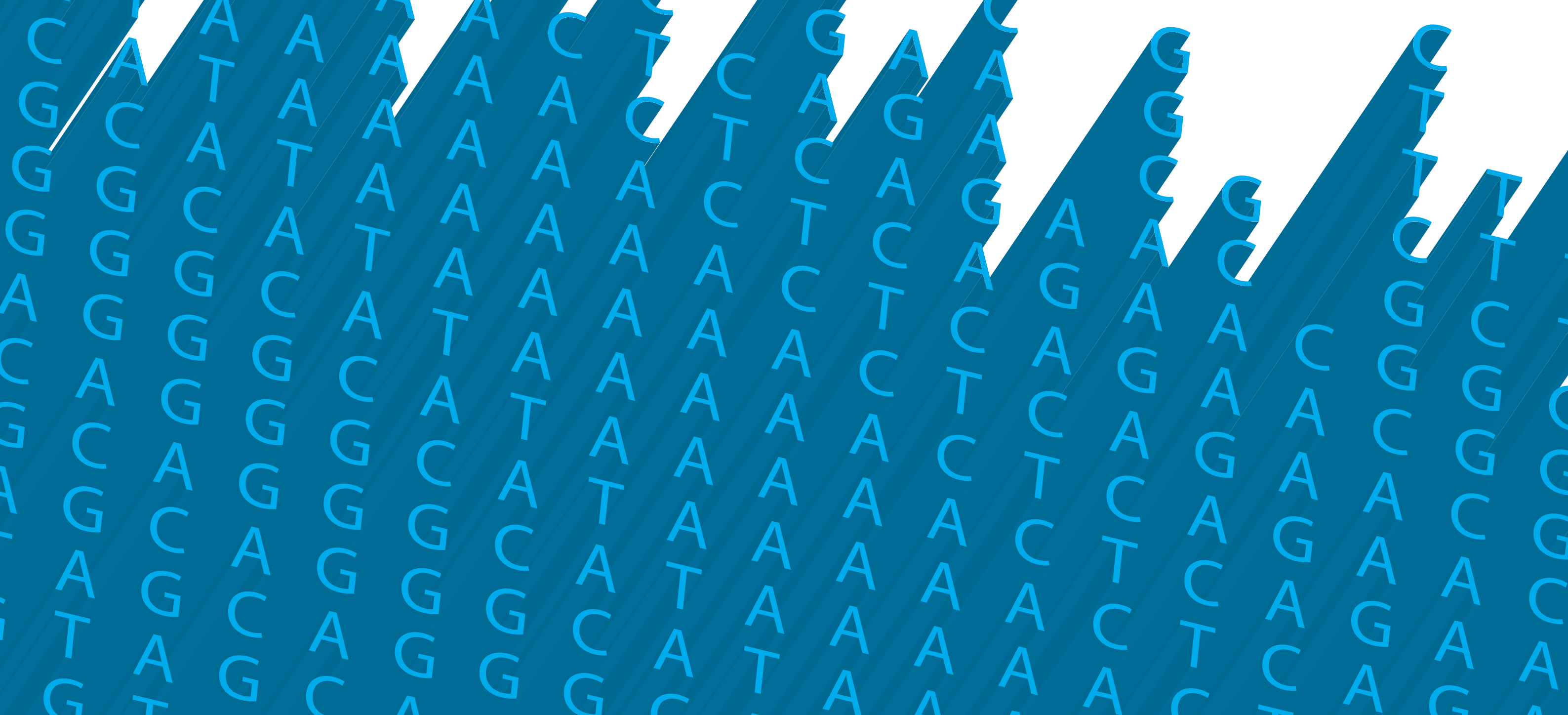
***Sarah Byrne** reflects on the growing interdisciplinarity between scientific disciplines and the opportunities it brings, both in scientific research and academic study.*

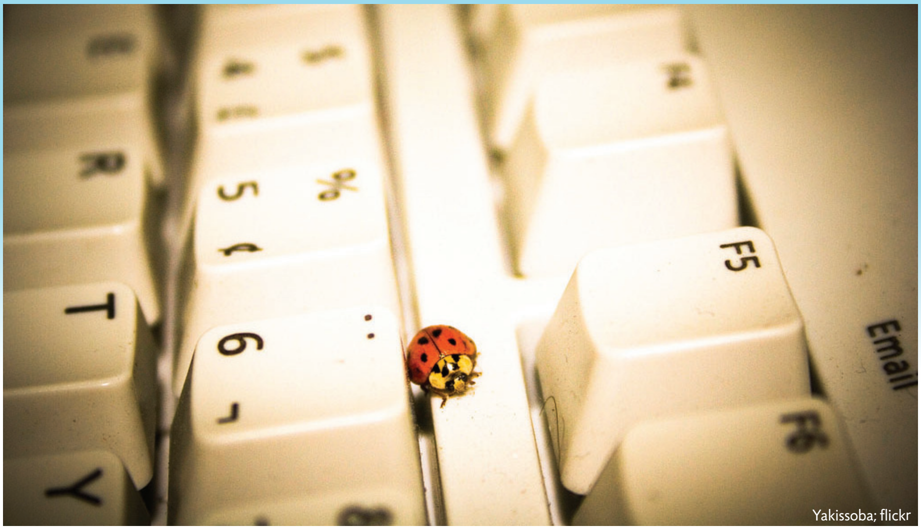
At school, science usually comes neatly packaged into individual subjects. Maths, chemistry, biology, physics – all taught by different teachers and without much thought for how they fit together. You might be forgiven for thinking they don't have much to do with each other.

However, at the cutting edge of scientific research, the boundaries between these subjects are becoming increasingly blurred. This approach, called interdisciplinarity, brings together scientists from different backgrounds to work on a project or solve a problem. This is not an entirely new concept, but it is one that has gained popularity in recent years, mostly due to the increasing complexity of modern biology.

Around 2000, an obscure field called systems biology started to gain recognition. It suggested that studying individual components of, say, a cell could only get us so far, since things were increasingly found to be connected together in complex networks or systems. An example is gene regulation networks: most genes do not act in isolation, but instead in systems of hundreds which can switch each other on and off, and regulate each other's activity. Understanding what happens when you modify a gene, then, is not straightforward. The only practical way is to model the network mathematically, using a system of differential equations.

There were many more biological questions that could not be answered with traditional methods. The protein folding problem – how and why an amino acid chain folds into the complex three-dimensional protein structure – is still not solved, but great progress has been made using computer algorithms, and immense processing power, to simulate the folding process. These algorithms are 'fed' with atomic-level data from physical chemistry and even quantum physics, in order to simulate the complex and random motions of atoms.





Yakissoba; flickr

> AT THE CUTTING EDGE OF SCIENTIFIC RESEARCH, THE BOUNDARIES BETWEEN SUBJECTS ARE BECOMING INCREASINGLY BLURRED

Then there is the question of data: the Human Genome Project churned out vast quantities of results, and an estimated 10 terabytes a day are generated by gene sequencing projects at one institute alone. Clearly processing this amount of data requires expertise in database management, data mining and information science.

To address the demand for interdisciplinary scientists, several universities have set up doctoral training centres (DTCs), funded by the UK research councils, with the specific mission of training postgraduate students to work at the interface between disciplines.

These include Warwick University's Systems Biology DTC; the CoMPLEX programme at UCL, which trains mathematicians and engineers to work on complex interdisciplinary problems; and Imperial College's own Institute of Chemical Biology (ICB). The focus of the ICB is using techniques from chemistry to study molecular interactions in cells. This has wide-ranging applications from biomedical (drug discovery for cancer and other diseases, developing medical imaging techniques) to agricultural (improving the efficiency of photosynthesis, strategies to overcome pesticide resistance). Students on the Masters and doctoral programs work together with supervisors from both biology and physical sciences departments, gaining unique experience and real expertise in both disciplines.

Interdisciplinary subjects are appearing at undergraduate level as well, with many universities offering degrees in subjects such as biophysics, bioengineering and bioinformatics.

But this isn't really such a novel approach. In fact, interdisciplinarity was the original way of doing science. The ancient study of natural philosophy encompassed what we would now call physics, astronomy, mathematics and life sciences. Science was simply knowledge, a quest to understand and explain the world around us. We still see the vestiges of this in the ancient universities such as Cambridge, UCL and Durham, with their broad Natural Sciences degrees. Trends and fashions change in academia, as in every other walk of life, and sometimes things come full-circle.

You may have noticed a pattern in the examples mentioned so far: more people go from the physical sciences and mathematics/engineering/computing into biology, rather than the other way round.

Partly this comes from the way these collaborations first developed. It was the biologists who had the problems that needed solving, and it would have been easier to hire people who already had the skills and tools required, rather than having to gain that expertise themselves. The mathematicians and chemists might have had to pick up some biology in order to help, but they weren't required to become experts.

Some might suggest it's because some subjects are harder than others. That it's easier for a 'harder' scientist to learn a 'softer' subject than the other way round. And this attitude is found on both sides of the divide; it isn't just physicists and mathematicians disparaging their biology colleagues.

As an interdisciplinary scientist, this is a familiar scenario: you stand up to present your research at a conference of biologists, and see the look of panic on people's faces when they realise you're going to talk about maths. That there are going to be equations.

"So…you're the mathematician?" one asked me tentatively at a recent symposium, looking at my poster as though the equations might jump out and bite him. It's scary stuff, apparently.

In fact, one well-respected Durham professor confidently informed me that it would be 'impossible' for a biologist to learn the math skills I use in my research. I didn't like to tell him that actually, my first degree was in — guess what — biology. Of course it's not impossible. Very few things are.

So yes, make sensible and strategic decisions about what you study, with an eye on the potential career paths you might take. But never feel that your subject choices now have closed off opportunities in the future to work on the scientific problems that interest you. Increasingly, there is more than one way to get there.

And above all, it's old advice and a bit of a platitude, but true all the same: study something that interests you, something that inspires and motivates you. That way, you're likely to do your best work, and make a success of it — whatever the subject. ■


Ashfield Swim School

GOGGLE VISION

*Our inability to see underwater has hidden a world just below the waves. **Julie Gould** explains how this world came into focus with the invention of the humble swimming goggles.*

Humans might be the dominant species on land, but we've fared less well underwater, partly due to our inability to see clearly. This meant a world of adventure was inaccessible to us until the invention of the humble swimming goggles. When this happened is unclear, but 16th century paintings show Venetian coral divers using rudimentary goggles made with wood and polished glass. We've come a long way since then: now goggles are designed by computers and made out of the most advanced materials. But why do we need them in the first place?

> THE CORNEA ACCOUNTS FOR TWO-THIRDS OF THE OPTICAL POWER OF THE EYE: THE LENS ONLY ACCOUNTS FOR THE REMAINING THIRD

When light travels from one medium (e.g. air) to another (e.g. water) its path is bent, a phenomenon known as refraction. This bending is because light travels at different speeds in different materials. The refractive index of a material is a measure of how quickly the light moves through it, compared with the speed of light in a vacuum. As the density of the material increases, so too does its refractive index.

The refractive index of air, for example, is roughly 1, as there is very little that will slow it down. However, when light moves through water, which is much denser than air, it is slowed down to about 75% of its speed in a vacuum, and so water's refractive index is about 1.33. The bigger the difference in refractive index between two substances, the more the light will bend as it moves from one to the other. This is why a straw in a glass of water looks like it has bent at the surface. It would appear to bend even more if you put it into a diamond (refractive index: 2.4).

To exploit this, our eyes have bulging, rounded corneas and a layer of liquid in front of the pupil. These bend and pre-focus the light, enhancing the eye's optical power – its ability to focus – before the light reaches the lens. In humans, the cornea accounts for two-thirds of the refracting (optical) power: the lens only accounts for the remaining third.

Our eyes are poorly adapted to seeing in water because the refractive indices of water and our cornea are so similar. This means the light is hardly bent at all before it reaches the lens. The lens is then the wrong shape to focus the light properly onto our retina – it is too flat. Instead, the image is focussed somewhere behind our retina. The effect is similar to a projector being too close to the screen.

> GOGGLES PLACE A BUBBLE OF AIR IN FRONT OF OUR CORNEA, ALLOWING US TO SEE CLEARLY

We use goggles to correct for our lenses being too flat to see underwater. Goggles place a bubble of air in front of our cornea, allowing our eyes to bend and focus the light the right amount so that we can see clearly.

Humans have the ingenuity and innovative drive to create objects to help us overcome a debilitating problem underwater. Even if we cannot become the dominant species in the seas, we can still explore and observe to our heart's content. ■

SCHOOLBOY'S ASTRONOMICAL LEAP

Margaux Calon explains how a schoolboy, at only 15-years-old, made a discovery that could shake the very foundations of astrophysics.

Early 2013 played host to a story that proves it's never too early to get involved in serious scientific research. Following an above-average work experience, Neil Ibata, a 15-year-old French schoolboy, co-authored an astrophysical paper that might debunk the ideas of Einstein and challenge most of the established theories about how galaxies are created. Not only that, the study ended up being published on the front page of *Nature*, making the 15-year-old the youngest ever contributor to the prestigious scientific journal.

Neil had been undertaking a work experience at the Observatoire Astronomique de Strasbourg, where his father, Rodrigo Ibata, is a senior researcher. Rodrigo had asked his son to learn the programming language Python, so that he might help him study the evolution of galaxies around Andromeda, the closest major galaxy to our own Milky Way. But in analysing the latest observations of the galaxy – provided by the Pan-Andromeda Archaeological Survey and collected, from 2008 to 2011, using the Canada-France-Hawaii Telescope – Neil turned up some surprising results.

> AN ASTROPHYSICAL PAPER THAT MIGHT DEBUNK THE IDEAS OF EINSTEIN

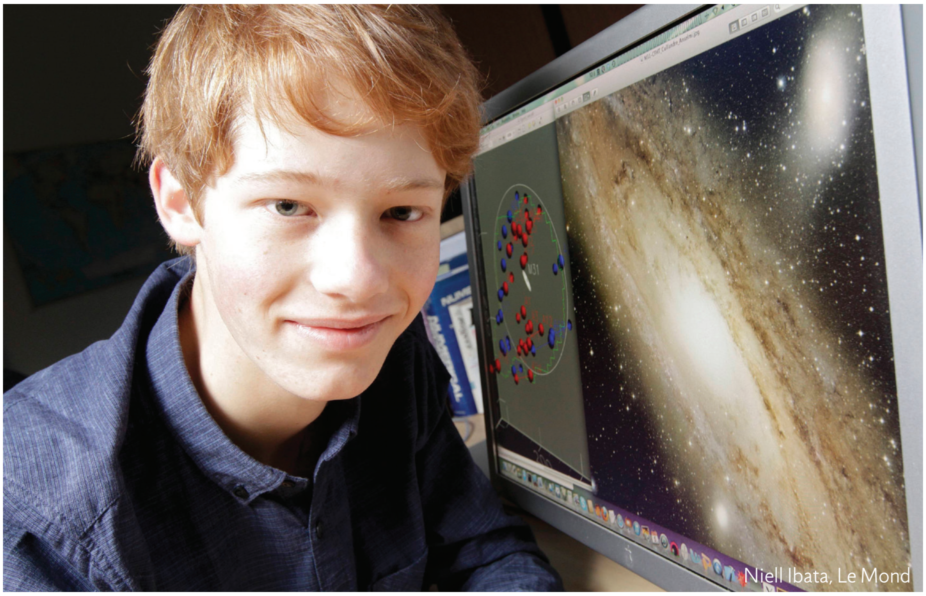
"I asked my son to program a model of … [the] dwarf galaxies' movements, and, within the weekend, he discovered that the dwarf galaxies formed a rotating disk!" explained the proud father. Astronomers have long been aware of the presence of dwarf galaxies around bigger galaxies like Andromeda or the Milky Way, but Neil's contribution revealed that most of the galaxies around Andromeda are organised in a huge rotating flat structure as opposed to moving randomly, as previously thought.

> IF WE FOLLOW THOSE PRINCIPLES, THE OBSERVED LINEAR ORGANIZATION OF THE GALAXIES SEEMS IMPOSSIBLE

One reason this discovery is so impressive is that it questions the very foundation of astrophysics. According to the standard theory on the formation of galaxies, based on Einstein's Theory of General Relativity, dark matter is formed by disorganized cosmic filaments. If we follow those principles, the observed linear organization of galaxies seems impossible. So, is it time to reject Einstein's foundation of relativity? Professor Françoise Combes, an astrophysicist at the Observatoire de Paris, warned that might be premature: "Many more identical observations are necessary to prove that the standard theory can't produce this kind of linear behaviour."

Thanks to his observations, Neil (now known as the 'Milky Way Kid') was able to co-author the study in *Nature* along with his father and 14 other scientists from Europe, Australia, Canada and the United States. Although Neil is one of the youngest contributors to *Nature,* the youngest person ever to have research published in a peer reviewed medical journal was an American called Emily Rosa. She was only 11-years-old when her study into therapeutic touch, which she both conceived and performed, was published in the *Journal of the American Medical Association* in 1998.

As well as incredibly impressive, these stories, more than anything, demonstrate that with a keen interest in science, you're never too young to get involved in genuine scientific research.



Niell Ibata, Le Mond

DIY SCIENCE FOR THE DEVELOPING WORLD

*Leaving behind the expensive equipment and industrial laboratories, **Alice Hazelton** reports on how it's Do-It-Yourself Science that might most help developing nations.*

Modern science is usually associated with prestigious academic institutions or industrial laboratories. And with these advanced forms of scientific research comes the requirement for prohibitively expensive and highly specialised equipment, a problem furthered by the increasing complexity of today's specialised research. Perhaps as a result of such restrictive complications, there has been a growing trend in DIY (Do-It-Yourself) science: a form of science which utilises easy-to-find resources and low-expense ingenuity to create home-built technologies. DIY scientists are undertaking all sorts of projects, such as spotting supernovas from their back gardens or setting up molecular biology labs in their garages. But being cheap and easy means that DIY science is also the perfect way for developing countries to benefit from new innovations. One idea that could vastly improve the quality of life of thousands of people is a special type of toilet.

"DIY SCIENTISTS ARE SPOTTING SUPERNOVAS FROM THEIR BACK GARDENS, OR SETTING UP MOLECULAR BIOLOGY LABS IN THEIR GARAGES"

According to the World Health Organization (WHO), nearly two billion people still live without appropriate sanitation facilities. This means that bacteria and viruses from human waste can end up in the water supply, leading to diseases such as dysentery, typhoid and cholera. The WHO reports that two million people, most of whom are children, die from such diseases every year.

In the western world, we've managed to eradicate these deadly diseases due to modern sanitation technologies such as the flushing toilet. Although now part of our everyday lives, devices like this remain unviable for many developing countries due to the large amount of water and complex sewage systems required. This is where DIY science can help: to develop less costly and easier-to-make alternatives that are suitable for the developing world.

Marc Deschusses and David Schaad, environmental engineers from Duke University in the US, have designed a composting toilet that can be made from readily available and inexpensive materials. The concept involves a bioreactor system that will convert waste to biogas – a gas produced by the breakdown of organic material – which can then be burned to sterilise the faeces. A sealed PVC chamber receives the solid waste and, in this oxygen-free environment, anaerobic bacteria break down the waste, producing methane gas. Instead of releasing the gas into the environment, the system burns it, killing the bacteria and viruses within the waste. By harnessing the methane generated by the anaerobic bacteria, rather than releasing it into the atmosphere, the system is not only efficient but is also better for the environment, because methane is a greenhouse gas 25 times more potent than carbon dioxide.

Bill and Melinda Gates Foundation

"We believe the proposed system could represent a major advance in environmental and health protection for developing countries," said Deschusses. The Bill and Melinda Gates Foundation – an organisation which supports initiatives in education, world health and alleviating poverty – has already granted the project $100,000. Deschusses says the money will be used to test the system in the laboratory before producing a prototype to test in the field.

This is just one example of how DIY science could dramatically improve the quality of life for people in developing countries. Other innovative technologies that have evolved from DIY science include refrigerators made from clay, solar cookers and bicycle-charged mobile phone chargers.

These DIY science solutions represent an alternative solution to the standard approach of affluent nations simply donating money. Instead, these countries should share their knowledge and expertise with the developing world so that local, inexpensive resources can be used to engineer life-changing technologies.

JURASSIC PARK OR NOAH'S ARK?

__Alex Gwyther__ discusses how conservation has started to turn to more drastic measures in order to preserve endangered species.

Despite conservation efforts, approximately 30% of all marine, fresh-water and land animals will become extinct in the next 50 years. In desperation, conservationists are turning towards the 'Plan B' approach of conserving animals outside of their natural habitat. But some of these methods are a bit more ambitious than a simple zoo: namely, the cryopreservation and cloning of endangered species.

Using cryopreservation, tissue samples from animals can be stored in liquid nitrogen (at −196 °C) for potentially hundreds of years, later to be thawed out and re-grown. Normal body cells can be stored safely and one day used to reproduce the animal via cloning. Several projects have already been established to start collecting samples of living animals before they become extinct. For example, the University of Nottingham, the Zoological Society of London and the Natural History Museum have been running their Frozen Ark Project since 1996.

Animal cloning uses a method called 'somatic cell nuclear transfer'. A nucleus is extracted from a normal body cell (a 'somatic' cell) and transferred to an empty egg cell that has had its own nucleus removed. An electric current is then applied to make the nucleus and egg cell fuse together. If it is successful, and the egg begins to divide normally, the resulting embryo is then implanted into the uterus of a surrogate mother to continue developing.

As cloning only requires a body cell from the animal to be cloned, it is particularly useful when the egg or sperm cells of the animal are difficult to acquire. Just look at the movie *Jurassic Park*: scientists used blood cells to resurrect dinosaurs. So, by using cryopreservation and cloning, could we preserve cells from currently endangered animals and one day resurrect them even after they've gone extinct?

It has, in fact, already been done. In January 2009, a Pyrenean ibex was cloned from the preserved DNA of a skin sample taken before the last animal died in 2000. However this individual, the first animal to ever become 'un-extinct', only survived for seven minutes before dying of lung defects.

A major problem with the cloning approach is its dismally low success rate of only 6%. There can be many complications, such as early stage incompatibility of the nucleus and egg cell, complications in pregnancy or a long list of abnormalities in the clone due to incorrect gene expression.

But cloning technology is fast improving.

In November of 2012, Brazilian scientists announced they were preparing to clone eight endangered species, including black lion tamarin monkeys, collared anteaters and jaguars. And in December 2011 a research team declared they were hoping to clone a woolly mammoth within five years, using a well-preserved sample of bone marrow and an African elephant as a surrogate mother.

However, many conservationists dislike the idea of relying on cloning to save endangered species, and insist that all efforts must primarily be focused on habitat conservation: after all, what use is being able to clone an animal if its natural habitat is gone? These cloned animals will not be adapted to live in the new environment. In addition, a population of clones originating from only a few individuals would be genetically weak, and with no parents to teach them their natural behaviour they might not survive at all. So while it may be possible, cloned animals would only really hold aesthetic value. Surviving in zoos as nothing more than exhibits, rather than repopulate the planet, they would simply remind us of the awful job we had done at sustaining the biodiversity of our planet. ■

epsos.de

ILLUMINATING MATERIALS SCIENCE

Deciding on what to study at university can be hard, especially when some subjects have names that you might not have heard at school, such as biomedical engineering or geophysics. To help shed light on one such subject, ***Zoltan Hiezl****, an Imperial College PhD student, describes his experiences in materials science.*

As a member of the Department of Materials, my research is based in the Centre for Nuclear Engineering, where I am preparing and characterising UO_2-based materials, to simulate those materials found in spent nuclear fuel.

By studying in the Department of Materials, you are given the opportunity to attend conferences, travel and work abroad, and meet people from industry in order to build up good relationships and hopefully help you with your future career. Indeed, researchers at the Department of Materials work closely with industrial partners to make production more effective and to create better products. The majority of our research applies to sectors such as transport, energy conversion, environmental protection, healthcare and electronics.

There are hundreds of projects within these groups, allowing anyone who is interested in materials science to find a theme that suits their interests. Our six core research themes are: advanced alloys; functional materials; biomaterials and tissue engineering; nanotechnology and nanoscale characterisation; ceramics and glasses; as well as theory and simulation of materials.

It is also an interdisciplinary research group, bringing together researchers from many different fields. Within the research group there are material scientists, engineers and physicists. Personally, I am a chemist with an extensive background in radiochemistry. Furthermore, some of us are experimentalists, while others are doing calculations and modelling systems on computer.

If this kind of work sounds interesting and you want to join the Department of Materials, you really need to be studying at least one of maths, physics or chemistry at school. Although additional biology knowledge is also welcome for certain research projects.

So if the idea of inventively applying science to solve the challenging problems of real industry and engineering appeals to you, why not consider studying in the Department of Materials? We bring science to every day life.


jacquelinetinney; flickr

THE INSPIRE PGCE PROGRAMME

*Thinking about becoming a teacher after university? **Dr Annalisa Alexander**, Mentoring and Tutoring Programmes Manager at the Imperial Outreach Office, tells us how the Imperial programme is helping to inspire a future generation of physicists and chemists.*

The Postgraduate Certificate in Education (PGCE) is a short-term course that helps train postgraduate students to become teachers. Imperial College London, in conjunction with Canterbury Christ Church University (CCCU), has been running a bespoke PGCE training scheme since 2007 and since then over 40 postgraduate students have gone on to become physics or chemistry teachers at schools across the Greater London area.

What makes INSPIRE (the Innovative Scheme for Postgraduates In Research and Education) stand out from other courses is that the PGCE students are either at PhD or Masters-level in physics or chemistry, and that they can bring a range of extra-curricular 'Inspire Activities' to the schools enrolled on the scheme. Many of the schools have been a part of INSPIRE since the beginning, having seen first-hand how their pupils become engaged and excited by these notoriously difficult science subjects.

The PGCE students grow in confidence over their nine-and-a-half-month programme and quickly pick up the teaching reins after just a few weeks, much sooner than on a traditional PGCE programme. Under careful observation from their school mentors and CCCU tutors, their progress is monitored and the students devote their non-teaching time to working on essays and reflective journals. Incorporated into the programme are educational trips to Kew Gardens, the Royal Institution and Centre of the Cell. These visits are an engaging and informative way for the students to develop their lesson plans, and are also a good opportunity to get new ideas to enrich the curriculum.

The annual INSPIRE cohort is small – no more than 14 students at any one time – but this means that they bond quickly and are extremely supportive of each other. Andrew Guerriero, one of the students from 2012's cohort, explained his views on the course: "The INSPIRE programme is a unique teacher training course, characterised by its small cohort of students, holding doctorates or masters from leading universities. The tutors from CCCU offer an exceptional level of assistance, guidance, and a tailored, personalised support package."

"The training component is exceptionally rigorous. The contribution from Imperial College is via overall project management and the delivery of fun science lessons, so-called 'Inspire Activities', to all partnership schools on the programme. My experience has been challenging, but very rewarding. I wholeheartedly recommend this programme, because of its uniqueness, over other more conventional PGCE programmes. I know that the INSPIRE programme will continue to translate a very high calibre of research scientist, into dynamic and charismatic teachers."

The scheme would not be able to run without the support and teaching expertise of Canterbury Christ Church University or the input and management of Imperial College London. INSPIRE also receives funding from the Foyle Foundation to provide the PGCE students with attractive bursaries, while the Ogden Trust supports INSPIRE in bringing Physics alive in state secondary schools in particular. INSPIRE continues to grow in strength and we hope to continue training and producing exceptional physics and chemistry teachers to inspire the next generation of budding young scientists. ■

"STUDENTS GROW IN CONFIDENCE OVER THEIR NINE-AND-A-HALF-MONTH PROGRAMME AND QUICKLY PICK UP THE TEACHING REINS AFTER JUST A FEW WEEKS"

WHY COMMUNICATE RESEARCH?

Tom Bragg details how public engagement has become a key feature of 21st century science.

A major part of any career in science, no matter what the discipline, is carrying out scientific research in a chosen speciality. Budding young scientists may conduct their first serious scientific study at university, for example, as part of their dissertation. After that, they might continue professional research at an institution or move to the private sector. Whatever course a research career takes, it is now seen as essential to properly communicate discoveries to the outside world. This is known as Public Engagement with Science and Technology (PEST) and it affects nearly every scientific enterprise today.

However, it was not always so. Roughly 50 years ago it had become clear to some that society was splitting into two different camps. In his contribution to the Rede Lectures in 1959, Charles Percy Snow, a chemist and novelist, gave a lecture at Cambridge University entitled 'The Two Cultures', in which he described a gap forming between the arts and the sciences because of a breakdown of communication between these 'two cultures'.

> "THE BODMER REPORT PORTRAYED THE PUBLIC AS AN EMPTY VESSEL WAITING TO BE FILLED BY THE TEACHINGS OF SUPERIOR SCIENCE"

Coverage of science in the media had dwindled and many innovations went unreported. While disheartening for science hoping for publicity, it also meant that much of the general public lost a connection with many important scientific advances of the time. However, it wasn't until the early 1980s that this lack of communication and the growing public distrust of science were seriously addressed.

In 1985, the Royal Society delivered a report on The Public Understanding of Science (PUS), also known as The Bodmer Report, to assess the relationship between the general public and modern science. In the report, there was a call for the public to receive a better education in science and that scientists should consider science communication as integral to their work. However, the report later received much criticism, with many finding fault in its condescending tone and view of the ignorant public as an empty vessel waiting to be filled by the teachings of the 'superior' science.

During the 1990s, various incidents and developments suggested that new understandings of the relationship between science and society were required, and so the House of Lords delivered a new report in 2000, which recommended that "Research Councils and universities should strongly encourage communication training for scientists and, in particular, training in dealing with the media." In summary, this report suggested that the public should be involved in dialogue with scientists such that they might be better informed about potential research, as well as allowing them the potential to have some input into the future direction of scientific studies. This seems entirely fair as not only is it the taxpayers' money that usually funds scientific research, but often members of the public will be affected by its outcome.

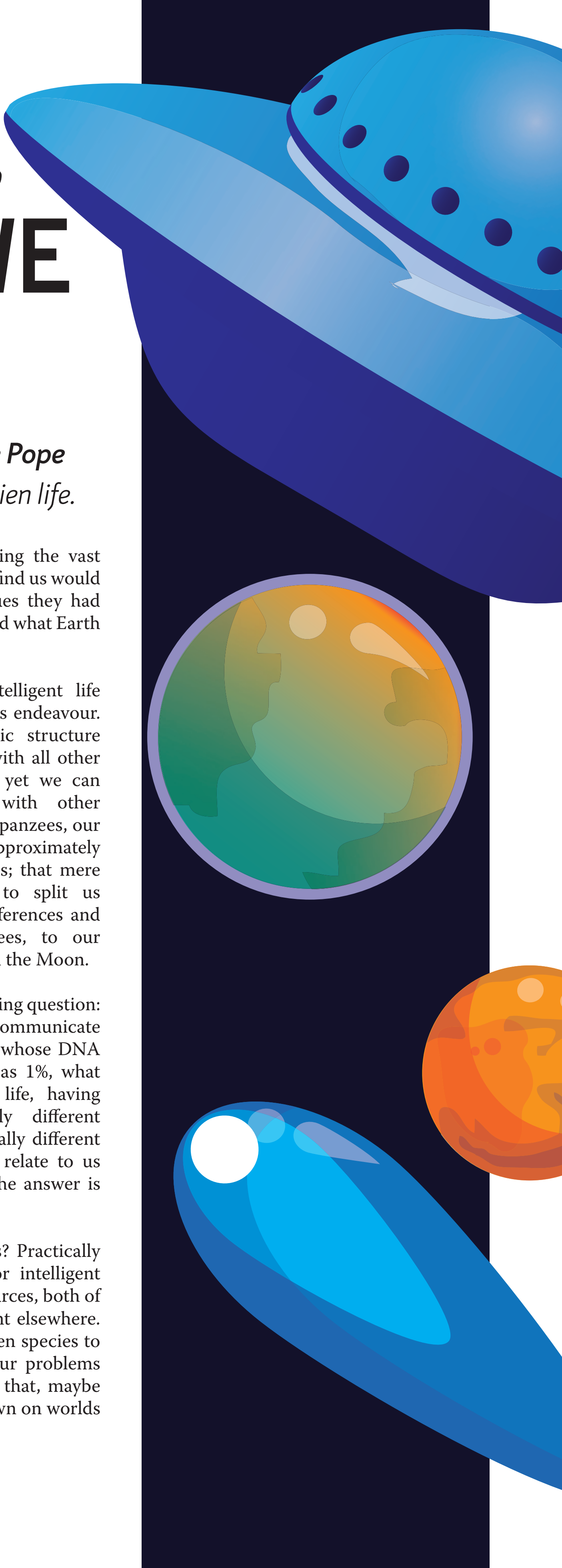
RDECOM; flickr

The question of the public's knowledge of science had moved to a question of trust, and the House of Lords report resulted in the establishment of the Public Engagement of Science and Technology. As well as involving the PUS ideals of displaying research at fairs and talking to journalists about new discoveries, PEST developed the concept of an improved two-way process of communication, with science participating in public dialogue through means of citizen juries, focus groups or deliberative polling.

These dialogues involve a group of people that represent the public having a discussion with scientists, politicians and people in affected industries, about the use of some proposed research. The discussions explore the implications and potential benefits of the research for wider society. The intention is that these discussions will result in not just scientists, but also the affected public, having a direct effect on how the proposed research proceeds.

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

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



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

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

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

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

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

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

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