CATALYST

Edition 29

In this issue:

01
Catalyst career interview with Great British Bake Off finalist, Andrew Smyth

02
Colliding black holes and gravitational waves

05
Recreating the conditions of space at our fingertips

ISSN 2047-7430

Welcome

Welcome to the 'new look' Catalyst! Packed with interesting articles, interviews and new research written by leading academics, we're confident you are going to love the relaunch of the magazine.

This edition we've got exciting articles covering biology, chemistry and physics - and all based on the latest research. We also have an exclusive interview with Andrew Smyth, Bake Off finalist and aerospace engineer.

Have you got topics you'd like to see covered? Please get in touch with your ideas and feedback - we'd love to hear from you. You can email us on catalyst@stem.org.uk.

Enjoy edition 29 of Catalyst!

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How to use guide

01

Contents

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Underlined text

This will indicate you can click here, connecting you to further information.

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Contents

01
~
Catalyst career interview - Andrew Smyth

02
~
Colliding black holes and gravitational waves
❯ **Dr Chris North**

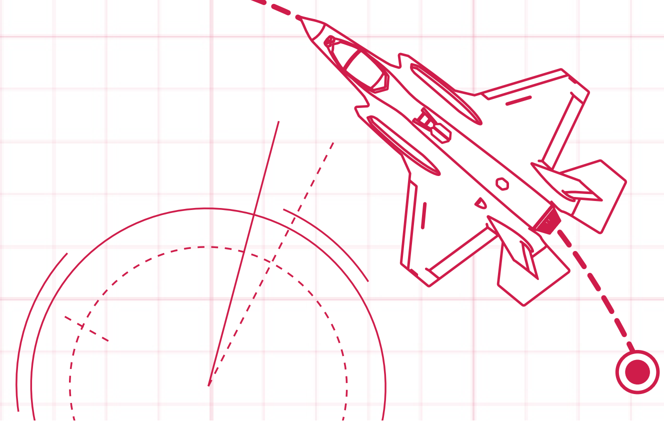
03
~
Fake news, fake science and real action
❯ **Professor Andy Miah**

04
~
For me, the idea of de-extinction is now as dead as a dodo
❯ **Robert John Young**

05
~
Recreating the conditions of space at our fingertips
❯ **Meriame Berboucha**

06
~
Bilingualism and the brain
❯ **Dr Christos Pliatsikas**

07
~
From orange peel to chewing gum
❯ **Mark Langley**



Catalyst career interview
Andrew Smyth

Q Introduce yourself – what is your name, place of work and job title?

A I'm Andrew Smyth, I work at Rolls-Royce in Derby and I am an aerospace research engineer.

Q What did you want to be when you were young?

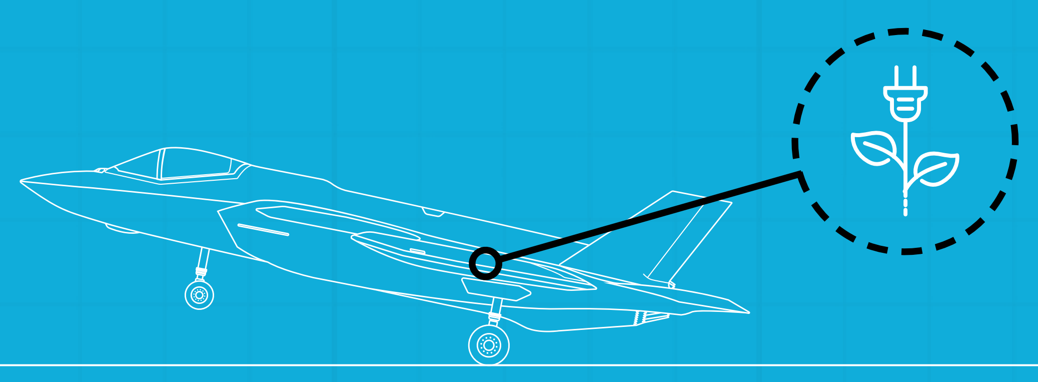
A I was always fascinated by flying and how things worked. I wanted to be a commercial pilot so I could fly around the world. I even started doing some flight training and flew solo several times.

Q What is the main focus of your work?

A When people hear Rolls-Royce, they often think cars. Rolls-Royce cars are made by BMW. In Derby we design jet engines, nuclear reactors and other power systems for the land, sea and air. My work is focused on investigating future aircraft concepts, using a computer to model them and trying to predict what future aircraft will look like.

Q How does your work affect our everyday life?

A Aircraft are essential to everyday life, be it travelling to see friends and family abroad or sending food and post via freighter flight. We try and make them as efficient as possible to reduce the impact on the environment but they still burn fossil fuels. My work is looking at how we can reduce our reliance on fossil fuels in the future to have a greener, quieter aircraft.



Q Talk us through an average work day...

A I'll arrive at work at around 9am; our office is 'agile' which means we can sit wherever we like depending on what work we're doing. I'll usually have a couple of reviews with the teams I work in and my manager, then I will run some computer simulations of aircraft concepts before lunch. After lunch I could be working on anything from electric aircraft to marine technology, often visiting universities where they carry out research for us and going to conferences to hear about the latest developments.

Q What's the best thing about your job?

A I get to work with amazing technology and amazing people. Every day I keep learning and I never lose that excitement of solving problems.

Q When and why did you decide to follow your profession?

A From a very young age, I've been fascinated by how things work. I was the kid in class who would always be asking our teacher more questions. I was obsessed with aircraft and was fairly good at maths and physics which naturally led me to engineering. My plan was to complete my degree then start pilot training but I enjoyed the engineering so much that I decided to pursue it as a career!

> "I studied a masters in engineering to join the graduate scheme at Rolls-Royce, although there are lots of different routes in from GCSE and A level."

Q What sort of personality or passions do you need to have to pursue your career?

A In my job, the main thing we have in common is being very curious about the world and we love solving problems. Beyond that there are all sorts of personalities that I work with, from those who love presenting to large groups to those who prefer to work more individually. Whatever your style, there is a job in engineering for you.

Q What qualifications did you need to gain to succeed in your career?

A I studied a masters in engineering to join the graduate scheme at Rolls-Royce, although there are lots of different routes in from GCSE and A level. The key subjects that are common are physics and maths. Things like design and technology and chemistry are useful too.

Q Are there alternative routes into your profession – such as apprenticeship schemes?

A Absolutely! Now, more than ever, there are several routes to becoming a qualified engineer. At Rolls-Royce we have several apprenticeship schemes where you can do your university course whilst working for the company and get paid to get your degree!

Q Did you do any work experience in your field? If so, did this help you decide what you wanted to do?

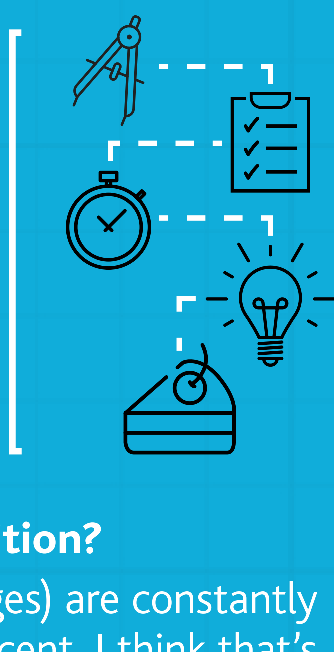
A When I was at school, I did some work experience at Belfast City Airport, which was incredibly interesting but didn't really show me what engineering was, it was much more operational. My best advice would be to try and talk to someone who actually works in the job and ask them why they enjoy it, what skills they use and what kind of work it is.

Q Do you have any career highlights?

A I've been at Rolls-Royce for around four years so it's still relatively early days for me! So far, my proudest moment has been getting to travel to our Power Systems Headquarters in Germany and presenting my work to the Head of Research over there. That was really rewarding (and nerve-wracking). I was very grateful to have the opportunity to do that so early in my career.

Q You were a finalist in 2016's The Great British Bake Off – how do you think your engineering skills helped during the competition?

A Engineering teaches you a huge variety of transferable skills. I knew I had to bring my strengths into the tent; things like precision, planning, time-keeping and creativity, which really helped me get through to the final against such tough competition.



Q What did you learn or take away from the competition?

A You never stop learning. Even the professionals (the judges) are constantly updating their understanding and not becoming complacent. I think that's true in life too, you can be confident in your skills but it's important to remain humble about what you don't know.

Q Are you still baking?

A Of course! I'm baking as much as ever, going to various food and science festivals around the country, as well as regularly appearing as a chef on the Lorraine programme on ITV. I'm trying to develop a television show combining incredible engineering with wacky bakes, so watch this space!

If readers are curious to know more about what goes into a jet engine, download the free Rolls-Royce UltraFan app: www.stem.org.uk/rolls-royce-ultrafan

Colliding black holes and gravitational waves

By Chris North
Ogden Science Lecturer, Cardiff University

In 1915 Albert Einstein published a theory which revolutionised our understanding of gravity. His Generalised Theory of Gravitation, often called General Relativity or 'GR' for short, gave us a whole new understanding of what gravity is. Gravity wasn't a set of invisible strings connecting every object to every other object. Instead we should imagine space as a stretchy material. This material gets pulled and stretched by massive objects, which causes objects to move differently. A good way to picture this is by imagining a marble being rolled across a trampoline, with a bowling ball in the middle.

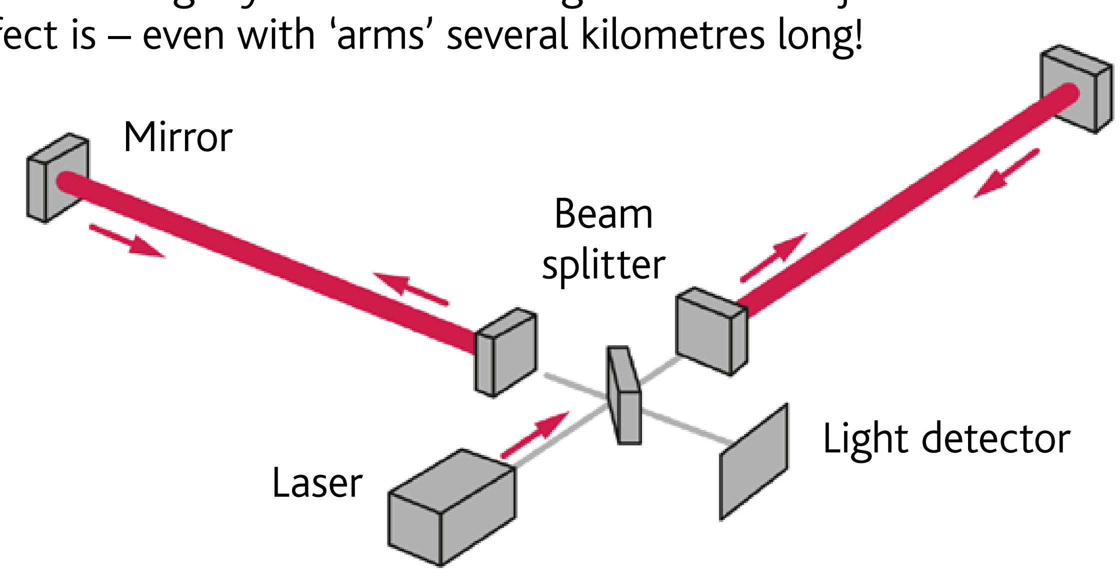
General Relativity made several predictions, some of which have been tested over the last century. So far, GR has passed every test. One prediction was the existence of objects so massive, and yet so small, that nothing – not even light – could escape from them. These objects were later dubbed 'black holes', and are some of the most enigmatic objects in the universe.

Another prediction was that as massive objects moved around, they could cause 'ripples' to spread through the fabric of space, affecting other objects in the universe. The result of these 'gravitational waves' passing through space is to stretch everything in one direction, and squeeze in the opposite. As the wave passes, the effect would switch, and the stretching and squeezing would reverse. This effect would be so small as to be almost (but not quite) undetectable. Evidence has been uncovered for the existence of these waves over the last few decades. Binary pulsars, or pairs of rotating stars, were shown to lose orbital energy by emitting gravitational waves. But direct detection of the waves themselves took longer.

In 1984, the Laser Interferometer Gravitational-Wave Observatory (or LIGO for short) was born, with the aim of directly detecting gravitational waves. Since building the twin LIGO detectors in the US, the international team has continued to grow, and they now work closely with the upcoming Virgo detector in Italy.

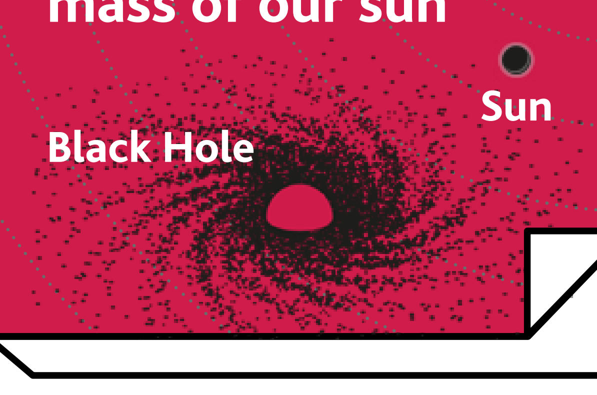
Gravitational wave detectors

Modern gravitational wave detectors all work in a similar way: a laser beam is split in two and reflects off mirrors positioned along two arms, arranged in an 'L' shape. A gravitational wave will move the two arms slightly. The real challenge comes from just how small the effect is – even with 'arms' several kilometres long!



Objects have to be incredibly massive, and moving incredibly fast, for the gravitational waves to be measureable. An extreme example would be two black holes colliding. Even then, the expected signal is very small, with the mirrors predicted to move a thousandth of the diameter of a proton. The technological achievement is staggering. The detectors use vacuum chambers, quadruple pendulums, power-recycling mirrors and ultra-stable lasers (along with many other innovative techniques) to ensure the detectors are stable enough, and accurate enough, to make the detections.

Each black hole is around 30 times the mass of our sun

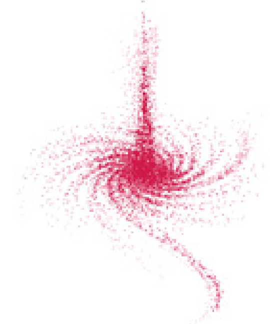


Previous generations of detectors, including the first LIGO detectors, were not expected to be sensitive enough to detect real signals. In 2015, after a huge overhaul, 'Advanced LIGO' began its first official search for gravitational waves, and was expected to detect something in the first few years. It didn't take long – two colliding black holes were detected on 14 September 2015.

It was possible to determine the properties of the black holes by comparing the observed signal with computer simulations. Each one was around 30 times the mass of our sun, and they emitted gravitational energy in the form of waves as they spiralled towards each other.

They'd probably been there for billions of years, but LIGO witnessed just the final 200 milliseconds of their lives. During this moment, they orbited each other five times and collided at over half the speed of light. The result was a black hole almost as massive as the two combined, radiating gravitational waves. Despite briefly emitting more power than all the stars in all the galaxies in the visible universe, the only measured effect was the movement of two mirrors by a few thousandths of the diameter of a proton.

Advanced LIGO has now detected three mergers of black holes, and there's much more to come. The LIGO detectors are due to be upgraded further over the coming years, and the Advanced Virgo detector is now online as well. There are also detectors being designed and built in Japan, India and even in space one day.



As these detectors become more sensitive we'll be able to see further and further into space, and see more of these events. Detectors will also be able to pinpoint the events' locations in the sky, allowing us to study them with telescopes. And it won't just be black holes. With predicted observations of colliding neutron stars and supernovae, the era of gravitational wave astronomy is just beginning.

FAKE news, FAKE science and real action

By Professor Andy Miah
Chair in Science Communication & Future Media, University of Salford

Over the last year, the media has been transfixed by discussions about 'fake news' and the impact of this on our understanding of the world has been huge.

However, a big part of that conversation has been fake. The fake news allegation is often used against genuine news, truthful news, which one party feels is somehow biased in its reporting. It is crucial that we don't forget that – but news information has also gone through a radical overhaul since the era of social media. The consequence of this has been both an erosion of journalistic integrity, and also a growing incapacity for readers to distinguish fact from fiction.

Additionally, today we have many more news creators than we have journalists producing news. We have platforms that function as news distribution networks or aggregators, but which do not have any editorial oversight or filter. We are the filters and we are the editors, and we undertake such work each time we like or share something. We also have outlets that are in the business of generating false understandings, and we have companies who deliberately blur the distinction between truth and falsehood in an attempt to satirise our world.

These are the realities of today's 'information ecosystem' and they present big challenges for all of us, not least of whom are scientists. But before we even get into the problem of how to deal with it, we need to be really honest about something: facts are often temporary.

Science develops amidst uncertainty and being a responsible scientist means first acknowledging this, and recognising the need to communicate it, while always championing that our best possible answer to any question is the one that is based on the best available evidence.

We have to accept that we make decisions under a cloud of uncertainty, but that this does not mean that all opinions are equal, or all claims about facts are sincere. Often, things are labelled as 'alternative facts' simply because some individuals willfully disregard evidence, or the views of those institutions or individuals who are best placed to assert what is our best interpretation of the world.

We also need to stop pointing to failed predictions as evidence of no credibility. All of us make our best guess about what might happen given any situation, but it doesn't come with certainty. Life is dynamic. Circumstances change, often without our complete understanding as to what has taken place to have jeopardised the credibility of our predictions. In many cases, our comprehension of what changed is beyond our reach and we must learn to accept that, but still attach weight to the process of deriving the best prediction.

This is why consensus statements on matters such as climate change are crucial. It is only in the collective attribution of judgement that we can distinguish between competing uncertainties. That is also why science is, unavoidably, a political affair. We have to stand up and function as engaged citizens in the pursuit of our work.

So, when you think about your role as a young scientist and as a young citizen, this has to be taken into account. We all need to think about which issues we are going to stand for, in the pursuit of understanding and in the championing of evidence-based interventions. These decisions will take place with or without us.

This is why science communication must be a central part of science. It cannot just be done when science is finished, but has to be present from the outset. Science shouldn't begin until it is communicated.

There are risks associated with this. For example, a scientist engaging in controversial, experimental work may try to downplay the more radical, long-term implications of their work, so that the funding for their early exploratory research is not jeopardised.

Now, it may feel like, reading this, you have entered into the middle of a debate and that is because you have. The debate that precedes this position statement centres on a prior discussion about what our obligations are as scientists to communicate our work and my conviction is that simply communicating is not enough. We have to be prepared to advocate as well as communicate. They are part of the same process towards greater understanding.

So, how do we deal with the problem of fake news?
There is no easy solution but here are my top three routes towards being a more critically engaged consumer of information.

1 Support professional journalism

We are at a dangerous point in history, where newspapers are diminishing as media outlets. Fewer people are paying for print and the news industry is losing its contact with audiences, who are now spending far more time in social media than in newspapers. If we lose the investigative environment of journalism, we lose a crucial part of our democratic system and we need to solve this. So, identify those media outlets that you think are doing great work and support them, either in paying for them, or by sharing what they publish. Don't just read it, like it, share it, syndicate it for them within social media. But be aware also how your activity leads to a growing 'filter bubble' in what you see in your social media feeds. Remember that the algorithm that underpins your social media network draws on data from your behaviour within it. This is important to ensure you don't just see the things that support your world view point. You may be a Jeremy Corbyn fan, but the more you like his stuff on Facebook, the less you see of other stuff and you may develop a biased impression of what the public believe.

2 Become a critical 'prosumer'!

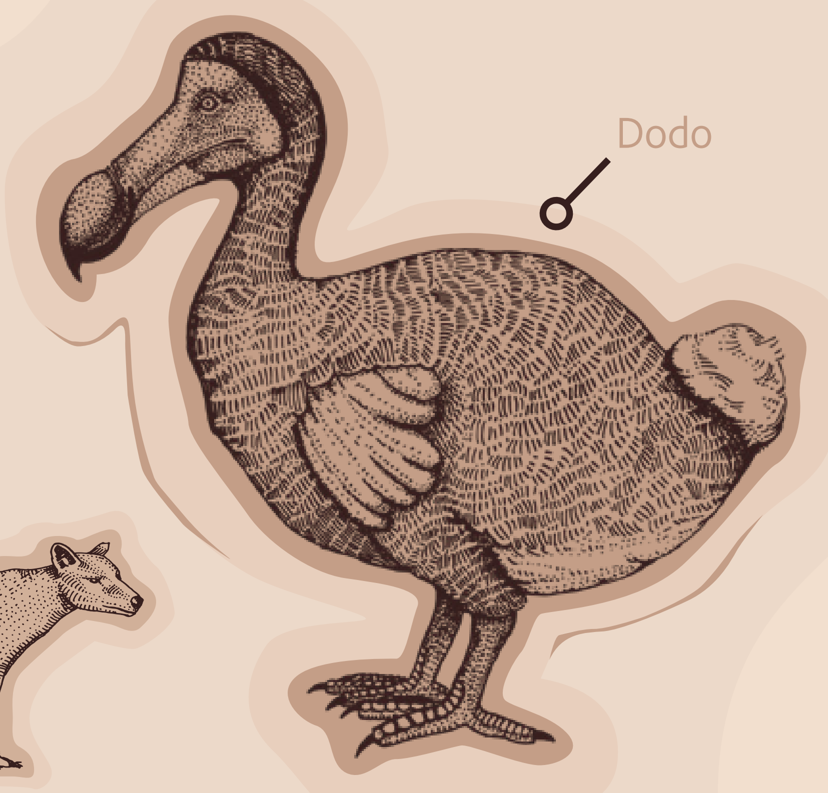
When Tim Berners-Lee developed the idea for the World Wide Web, he wrote: "this is for everyone". It is easy to forget that these times are remarkable. The digital world is remarkable. You can publish ideas, videos, essays, in ways that are now taken for granted, but which are extraordinary. This did not used to be possible. Television, print and radio, were all bound up in complicated licensing regulations and the technology was not there for us to share radical ideas. We can now and we can't forget that this is a huge opportunity to change the conversation. Being a prosumer – someone who becomes an author within this information world – rather than just a consumer is a big opportunity to correct the errors. It's also a great way for you to build confidence as a public figure. Standing up for an issue is the first step towards changing this data-driven world. Check out all the great stuff around March for Science this year as evidence of this.

3 Cross reference, then share

When you are writing your school work, always seek multiple sources for a claim, to ensure that it is accurate. Relying on just one source is a sure way to getting things wrong or failing to provide a balanced perspective. It takes time, but there is no way around it, if you want to ensure you are part of the solution, not part of the problem. If in doubt, don't share it or like it, just move on. Unfortunately, there is not yet any 'hmmm' button to click on Facebook, but we might also demand this kind of function. There should be a way to respond to a post in a way that conveys our uncertainty about its accuracy. Social media companies know this is a problem, so I think we can expect to see more help here in the future.

We live in tremendous times, where information is at our fingertips on just about anything, and where we can generate our own insights and share them with others. The problem is that all of this activity is now subject to financial interests and our data is the main currency. Each time we like something, we feed the machine and we have to think really carefully about when that's a good thing to do.

For me, the idea of de-extinction is now as dead as a dodo



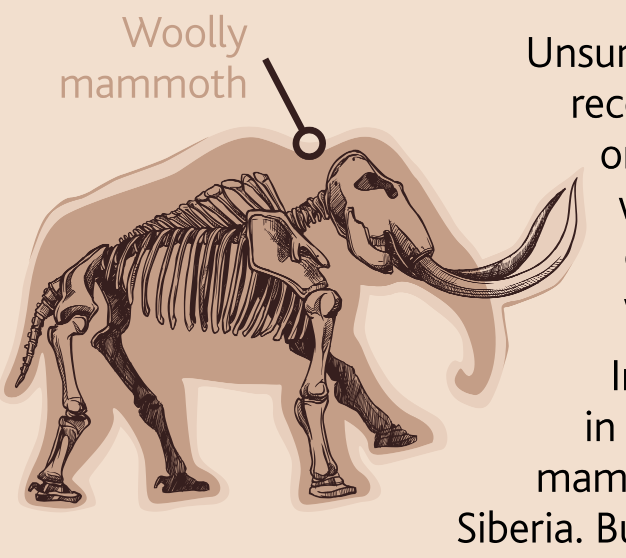
By Robert John Young
Professor of Wildlife Conservation,
University of Salford

My wildlife friends and I often talk about what species we would bring back from extinction. I am torn between the dodo and the thylacine, also known as the Tasmanian tiger. This was once a speculative, sci-fi debate but not anymore. Ever since Dolly the sheep was cloned, conservation biologists have muted the idea and the process of de-extinction – bringing back dead species – is coming closer to reality.

De-extinction by selective breeding or cloning

In the selective breeding method we try to re-create extinct species such as the aurochs (extinct large cattle from Europe and Asia) by looking for their surviving genes among existing cattle and breeding animals to favour these genes. Then you compare the genome of the resulting animals with that for aurochs until you have what is genetically an auroch.

The second method essentially involves finding the DNA of an extinct species and inserting it into a recipient egg cell and recipient animal – the cloning process. This second process is limited to species that have gone extinct more recently (hundreds of years) because you need to find intact DNA, so I am afraid there will be no Jurassic Park. We would also need to find DNA from several different individuals otherwise we would end up with problems due to inbreeding such as those seen in white tigers.



Unsurprisingly the 'instant fix' of cloning has received more interest as it would not depend on many generations of captive breeding. A wide range of species have been suggested for cloned de-extinction from the dodo to the woolly mammoth.

Initially, I liked the idea. I'd love to see a dodo in a zoo or even better to see wild woolly mammoths on an ecotourism trip to the steppes of Siberia. But such meddling raises a host of questions.

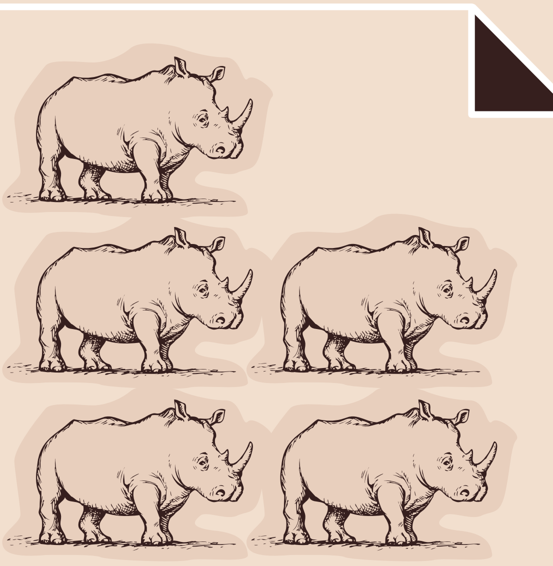
For instance, an African elephant would be the obvious recipient for woolly mammoth DNA. But as mammals learn a considerable part of their behaviour from their parents and peers, are we not just creating an elephant in mammoth's clothing? It would, therefore, seem our resurrected animals would need some kind of training to survive in the wild, which may not be unlike the survival training reintroduced zoo animals already receive.

If a species was successfully reintroduced and its population grew to previous levels it would have a major ecological impact. The animals which have occupied its ecological space may find themselves squeezed out. Governments would, rightly, be very cautious about the reintroduction of such animals.

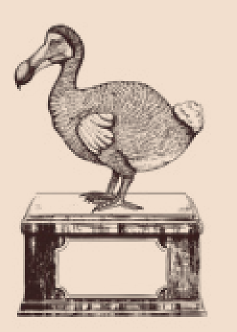
Show me the money

Given the limited money available for wildlife conservation it's not clear that the expense of bringing back the dodo makes sense. A simple utilitarianism would suggest not; the cost of resurrecting the dodo could be used to save many other living species from extinction.

For example, it now appears that a cloning approach may be the only solution to save the northern white rhinoceros from extinction – there are now only five individuals left.



However, society, thankfully, does not always run according to such utilitarian analyses. So perhaps the dodo will have its day – even if that is just living in a zoo. It may behave like a farmyard chicken but it would still be a powerful symbol for species conservation; I suspect some zoos would be shedding their giant pandas to go into dodos.



Dead as a dodo

But what kind of symbol would a living dodo be? It can no longer be the symbol of extinction; the Rubber Dodo Award for people who have contributed most to species extinction would need to be renamed. It would be testimony to how far science has come and how far science can take us.

But this sense of scientific wonder isn't always helpful. A living dodo would give out the wrong message to society and politicians – we can destroy anything we like and scientists will eventually find a way to fix it. This seems, for example, to be the hope with climate change.

As a species I think we need to accept responsibility for what we have done to this planet and not have blind faith that in the future scientists will fix all of our mistakes. We need to live with our mistakes and learn from them. It is for this reason I am not wishing for de-extinction.

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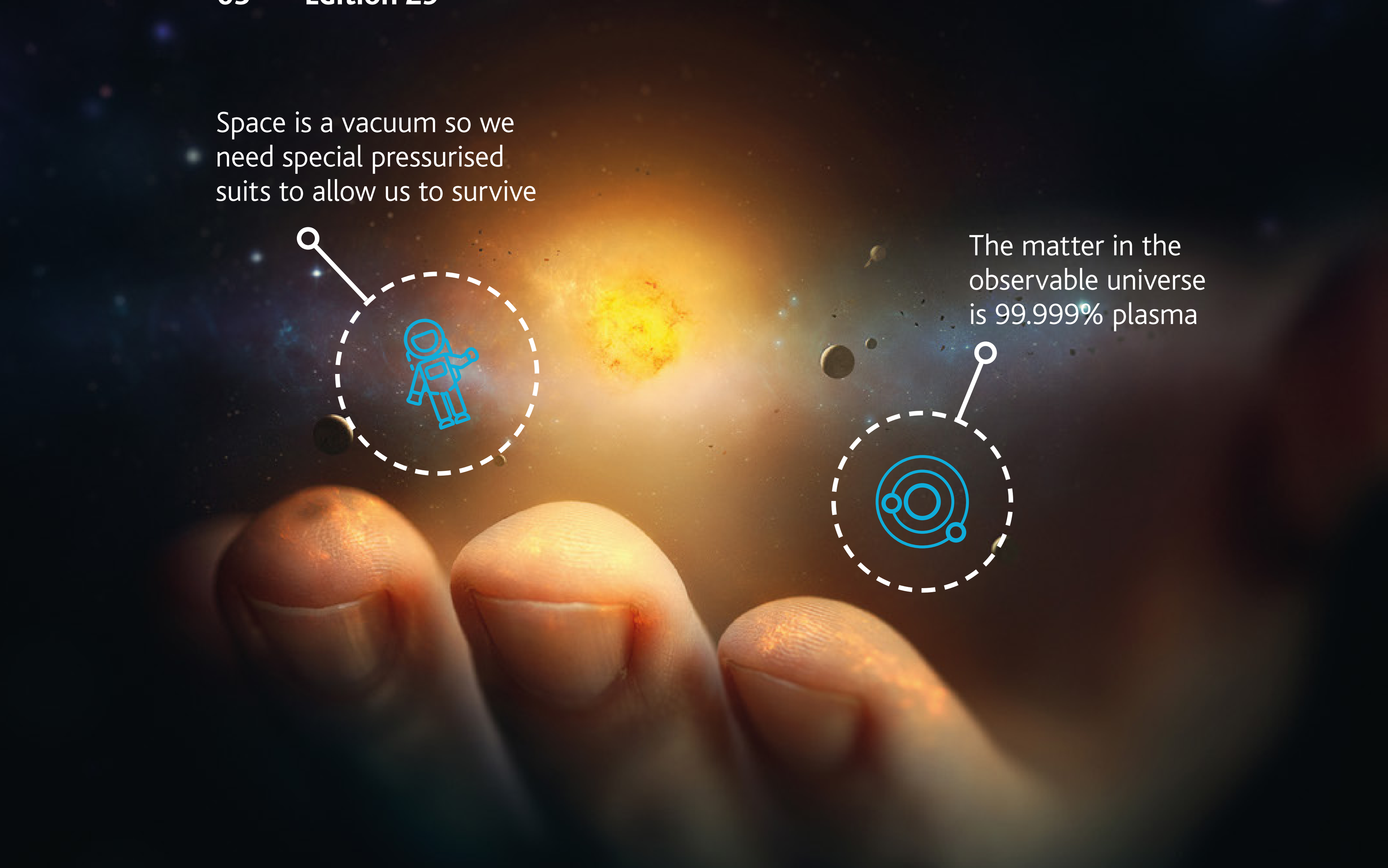


Recreating the conditions of space at our fingertips

By Meriame Berboucha
Fourth year MSci Physics student, Imperial College London

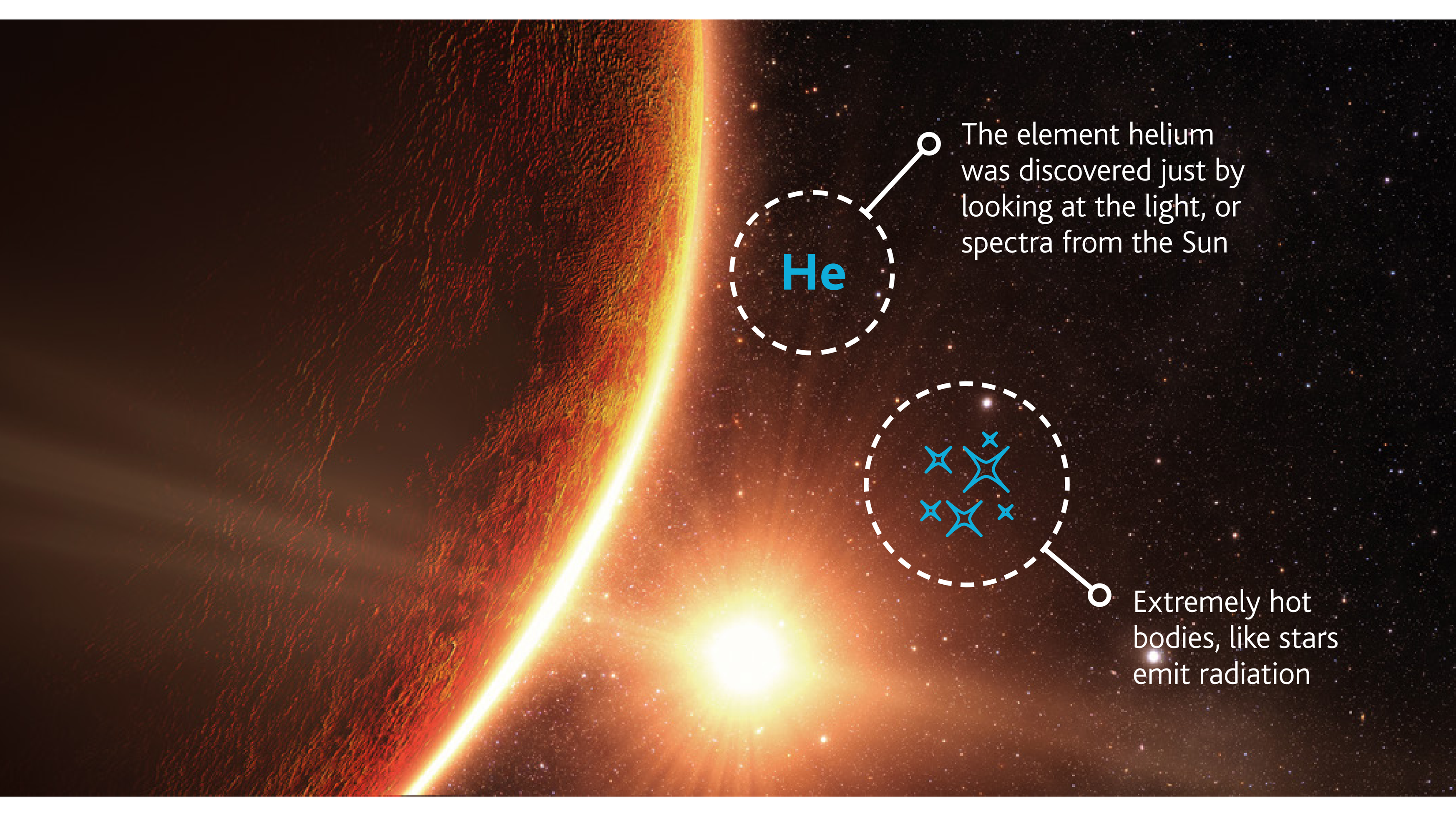
Venturing out into the depths of space is quite the challenge. It requires a large team of outstanding minds, carefully thought-out mathematics and physics, rockets and lots and lots of fuel! This makes our quest of finding out more about the universe we live in a little difficult. Firstly, space is vast and we currently don't have the technology to go out into the depths of space to collect data from exotic objects outside our solar system. Secondly, space can be a dangerous place – it's full of extremely hot bodies, like stars, that emit radiation that can be harmful to our bodies. Also, space is a vacuum so we need special pressurised suits to allow us to survive. Thirdly, many space-related events happen on timescales that are greater than the human lifespan so we can't really sit around and wait for things to evolve whilst we collect data. All in all, it's very hard to learn more about space if we go out there and take data, but what if we bring space into the laboratory? It may sound impossible but scientists from all over the world have achieved it.

Studying space from Earth

Normally, when you think of astrophysicists, you may picture a person that takes pretty pictures of the universe. Although this may be what they do, in part, they also analyse these images and extract some very useful information from them. This is because the light that originates from space carries information and if we catch this light and analyse it we can find out more about the supernova or galaxy, for instance, which the light has come from.

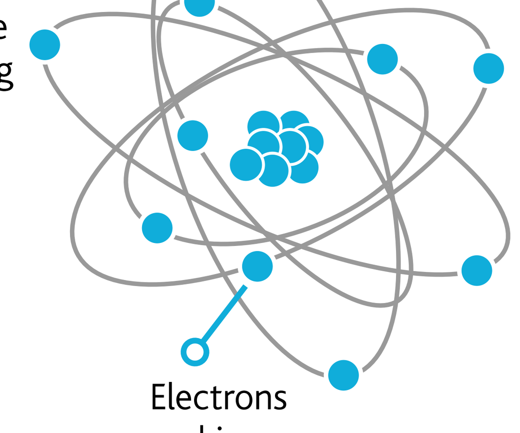
Laboratory astrophysics is recreation of the conditions of space in the laboratory.

For example, we discovered the element helium just by looking at the light, or spectra as scientists call it, from the Sun. We also learnt that the universe was expanding by looking at the shift in colour of the light coming from hot bodies, like stars. Although looking at the light from the universe is a very effective method, it doesn't always give us the information that we need. Instead, we can recreate the conditions of space in the laboratory. This field of science is called laboratory astrophysics. Of course, we cannot fit the Sun into a laboratory, but we can make a mini-sun or mini-explosion that happens very fast in our experimental chamber.



Plasmas and the universe

To recreate the conditions of space in the laboratory, we need to know what space is made of. The matter in the observable universe is 99.9999% plasma. This is the mysterious fourth state of matter that we do not regularly see in our everyday lives. Fire at the end of candles on a birthday cake, neon lighting and the Sun are just some examples of the plasma around us. Plasma can be thought of as a very hot gas, so hot in fact, that atoms can no longer exist. The electrons in atoms are stripped away from their nuclei and we are left with a soup of ions and electrons whizzing around each other. Because electrons and ions have electric charge, they are influenced by magnetic and electric fields. Electric fields can cause the ions and electrons to accelerate and magnetic fields cause them to move in circular orbits. Our first step in making a supernova, say, in the laboratory is by making a plasma.



Studying space in the laboratory

Plasmas can be made in the laboratory via high power lasers or power generators.

Huge lasers, like the National Ignition Facility (NIF) in California, can heat stuff up to very high temperatures. NIF can create these extreme conditions by focusing its 192 laser beams onto a very small area, reaching high temperatures of 30 million degrees! This is comparable to the conditions found in the centre of the Sun! NIF is a facility that is the size of three football fields and is ten stories high. It is the most powerful laser in the world and can produce a whopping 500 trillion watts of power which is equivalent to 1,000 times the amount of power that the United States uses at any given time! With the world's most powerful laser, the conditions found in supernova explosions can be recreated in the laboratory.

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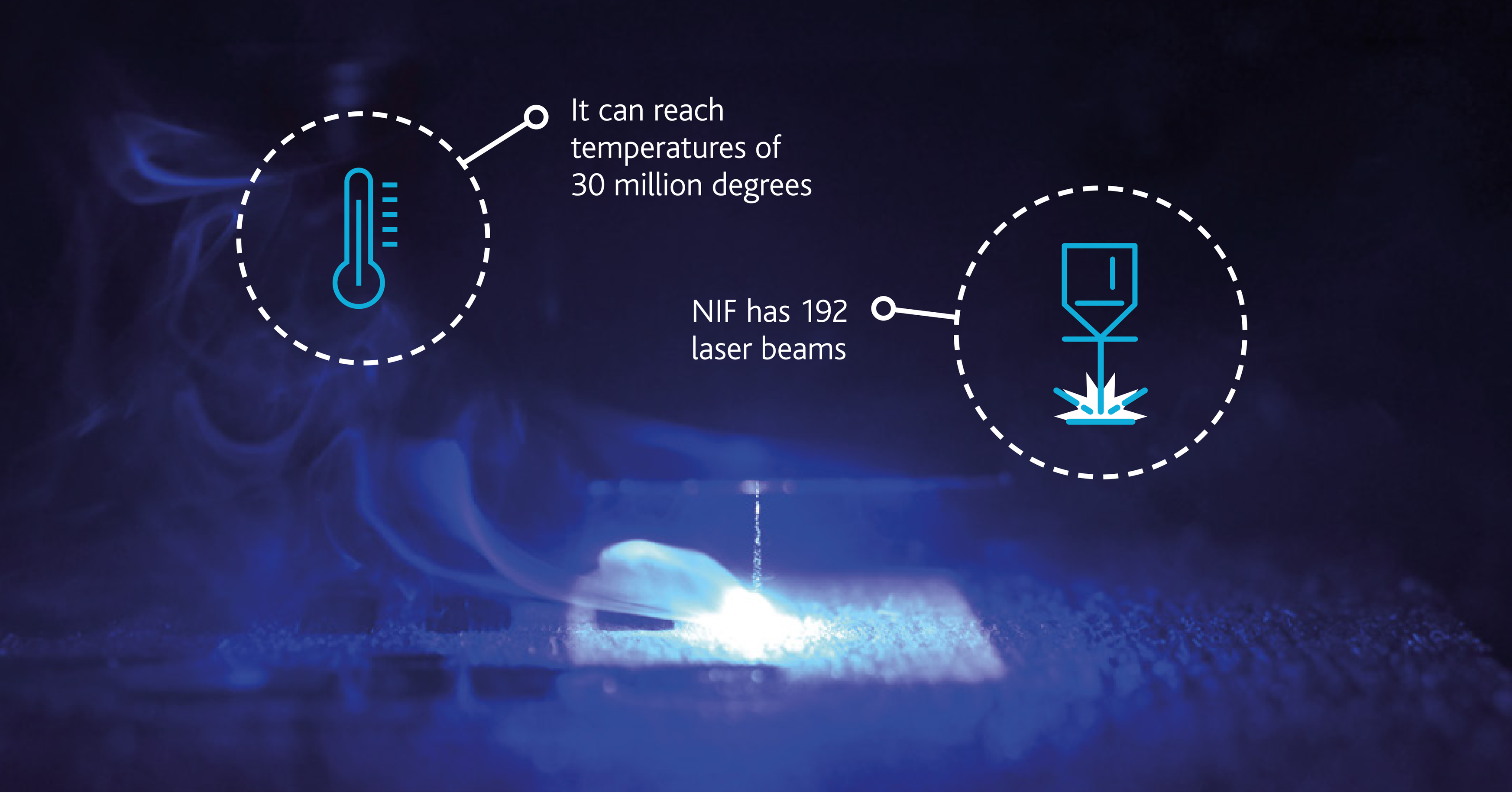


< Meriame Berboucha carrying out experiments to find out more about the environment around baby stars in the MAGPIE laboratory at Imperial College London.

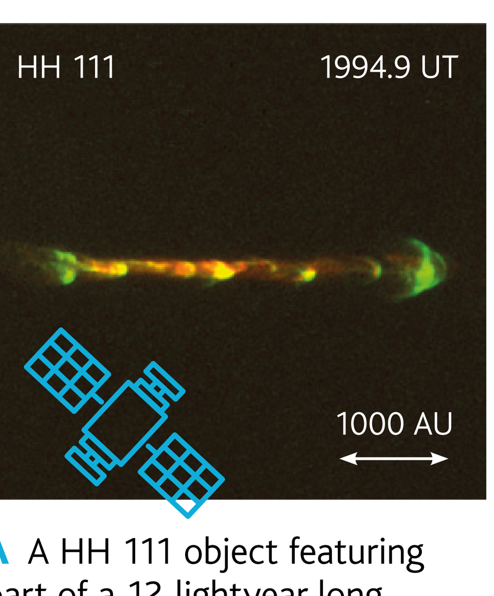
MAGPIE generates one terawatt of power - more than the average power output of the UK National Grid.

Making plasmas with a pulsed-power generator

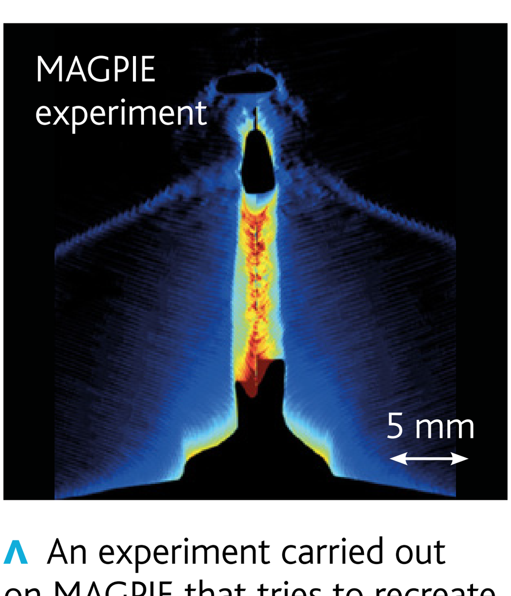
Another way we can create plasmas in the laboratory is via pulsed-power machines. These are essentially large electrical generators that provide a lot of power in a short period of time (a pulse). If we concentrate all this power through very thin metal wires (as thin as a strand of hair), for instance, the wires will heat up so much that they start to vaporise! This vapour is the plasma, and is metal that is so hot that the atoms can no longer hold themselves together. From this we get a 'soup' of metal ions and electrons. This process happens in a vacuum chamber, so that we can mimic the environment of space.

MAGPIE (Mega Ampere Generator for Plasma Implosion Experiments) at Imperial College London is one of the places in the UK where you can create plasmas in this way. Here, scientists can recreate the astrophysical events, such as astrophysical jets and supernova explosions.

MAGPIE works by discharging four large capacitor banks simultaneously and letting the huge surge of current pass through the very thin metal wires in the central vacuum chamber to make a plasma. More than one million amperes of current are released from these capacitor banks in less than 240 billionths of a second! MAGPIE generates one terawatt (1 followed by 12 zeros) of power – more than the average power output of the UK National Grid. All of this happens in the basement of a university! With this large amount of power, we can recreate the extreme conditions of space in the laboratory and mimic astrophysical events so that we can widen our understanding of the incredible universe we live in.



∧ A HH 111 object featuring part of a 12-lightyear long astrophysical jet. Credit: Hubble Space Telescope.



∧ An experiment carried out on MAGPIE that tries to recreate an astrophysical jet. Red areas show regions where there is more plasma and blue areas are regions with less plasma. Credit: F. Suzuki-Vidal (2012)

Bilingualism and the brain

By Dr Christos Pliatsikas
Lecturer in Psycholinguistics in Bi-Multilinguals, University of Reading

Learning a new skill might change the shape of the parts of the brain that are responsible for that particular skill.

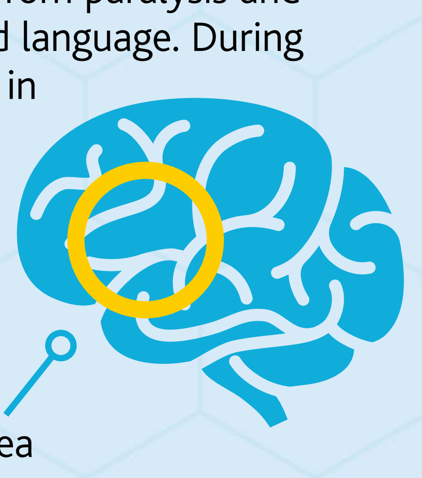
Your plastic brain

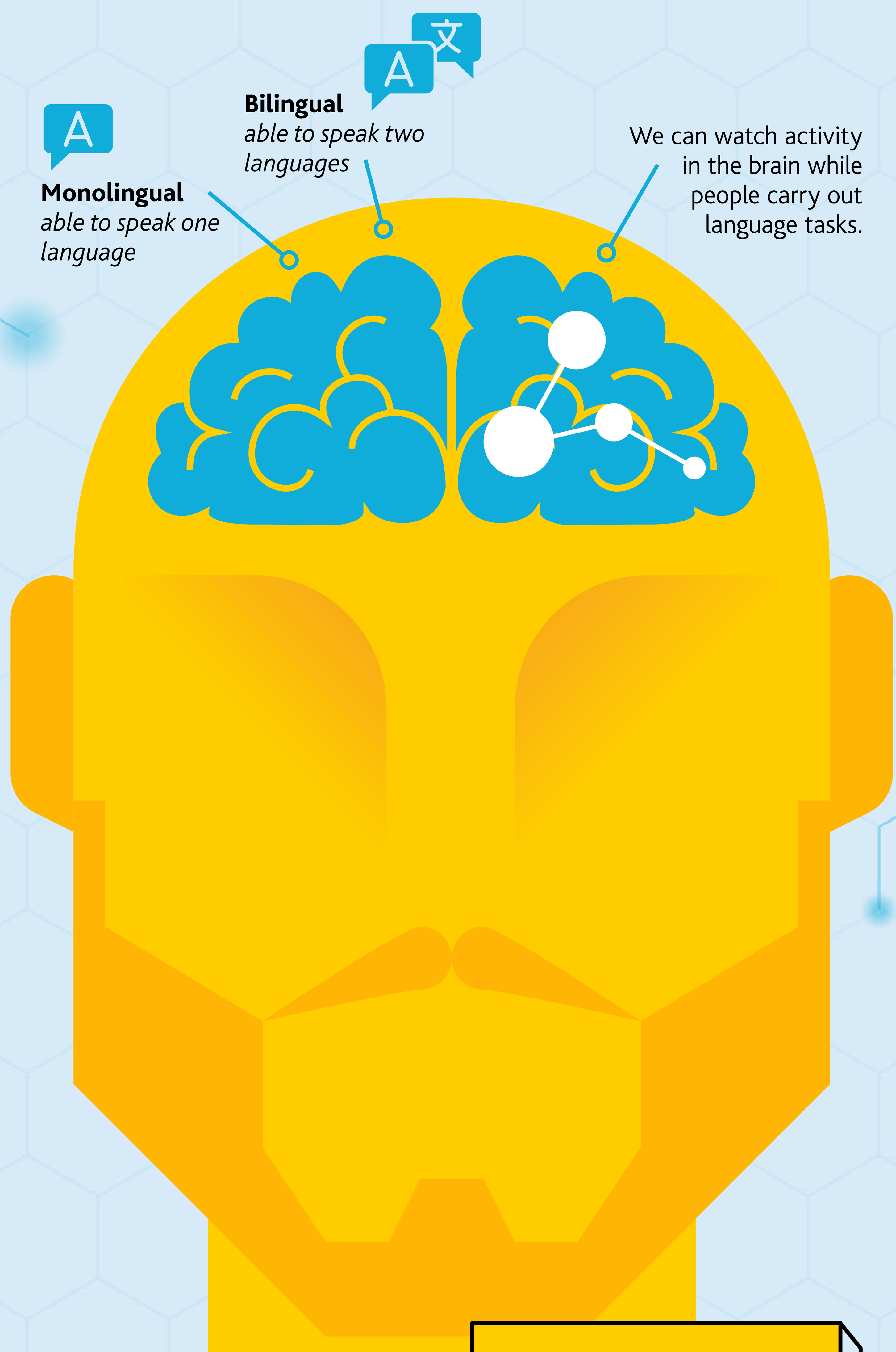
Any new knowledge, memory or skill that we learn needs to be stored somewhere in the brain, so you can access and use it in the future. Studies have shown that learning a new skill might change the shape of the parts of the brain that are responsible for that particular skill.

Elite athletes, such as basketball players, have been shown to have enlarged brain regions related to the control of movement. Taxi drivers in London have an enlarged hippocampus compared to the general population. The hippocampus is responsible for forming new memories and is very important for navigating around the world. These examples show that our brain is plastic. This means that its structure does not remain the same throughout our life and can change in response to new experiences.

Language and the brain

We have known that particular areas of the brain are involved in speech since the 19th century. Back then, most of the information about the brain was gleaned using post-mortems carried out on people with language problems, like Louis Victor Leborgne, a French man who suffered from paralysis and had lost the ability to speak – but could still understand language. During an autopsy a lesion, or wound, was found in his brain – in the frontal lobe of his left hemisphere. This area is now known as 'Broca's area', after Pierre Paul Broca who discovered what this area did. Carl Wernicke also studied patients with brain injuries that affected language and he discovered a region which was involved in the comprehension of language.





The brains of bilinguals show significant restructuring of those regions that serve language learning and language control.

Learning a language

Since the 19th century, our knowledge of the brain in relation to language has shown that many parts of the brain are involved. The ability to scan the living brain has been an enormous benefit to research, as we can watch activity in the brain while people carry out language tasks.

We no longer have to wait for people to die to examine their brains and, importantly, we can see the changes in the brain as language skills develop. This has been particularly useful in studying people as they learn and use additional languages, in other words becoming 'bilingual' (able to speak two languages), rather than 'monolingual' (able to speak one language). It might not seem obvious, but learning additional languages is a demanding task.

First, you have to learn new names for items and actions that you already know, ie the lexicon of the new language. You then have to learn a whole new set of rules about the structure of the new language, or its grammar, which sometimes are very different to the ones you are used to.

Last, but not least, you have to learn the sounds of the new language, which can be very different to the sounds you already know, and also extremely difficult to learn (this is why many non-native speakers of English have a foreign accent).

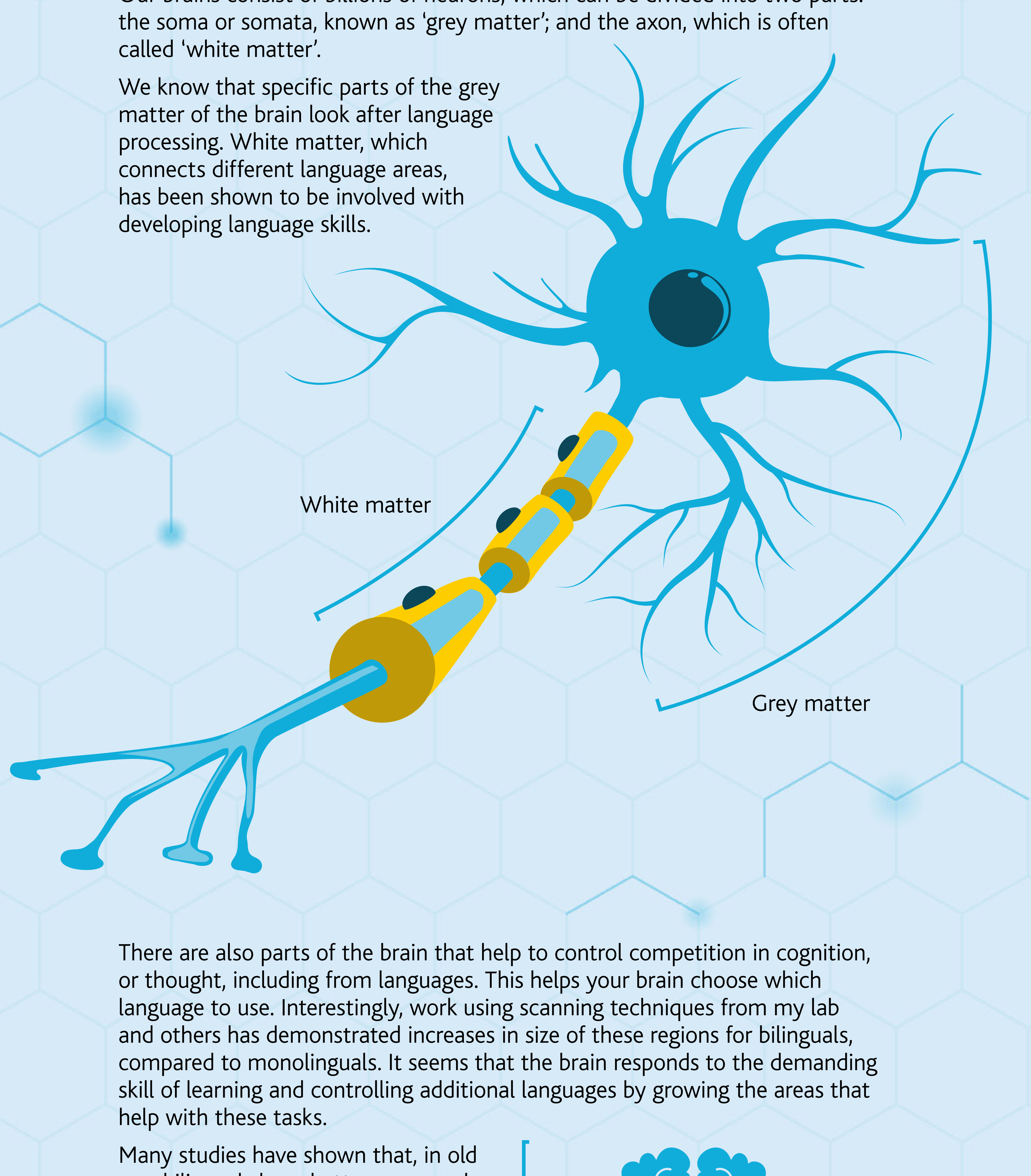
However, the biggest challenge is to control which of the languages you want to use at a particular time. Studies have shown that both languages are active and compete against each other each and every moment we try to speak. This means that the bilingual brain faces an ongoing challenge, which does not apply to the monolingual brain: constant controlling of competing languages. The brain tackles this task successfully almost all of the time, however, sometimes this control fails, and that's when bilinguals might produce words in the 'wrong' language.

Bilinguals do get better with practise and experience, as they gradually acquire a better command of their additional language, as well as better control of which language is active each time. This improvement shows in the structure of their brain; like the brains of well-trained elite athletes, which get restructured to accommodate fine movement and balance, the brains of bilinguals show significant restructuring of those regions that serve language learning and language control.

Restructuring the brain

But which areas of the brain do this, and how does the brain change shape? Our brains consist of billions of neurons, which can be divided into two parts: the soma or somata, known as 'grey matter'; and the axon, which is often called 'white matter'.

We know that specific parts of the grey matter of the brain look after language processing. White matter, which connects different language areas, has been shown to be involved with developing language skills.



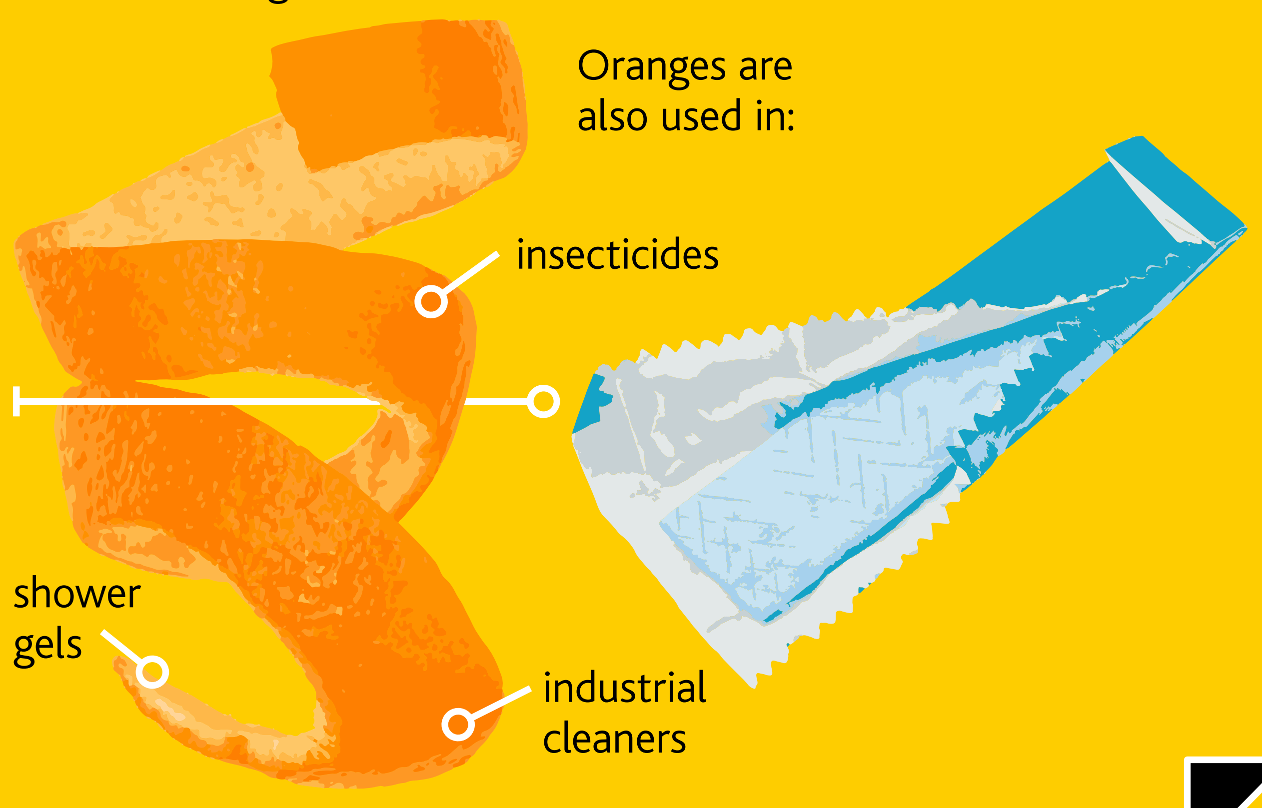
There are also parts of the brain that help to control competition in cognition, or thought, including from languages. This helps your brain choose which language to use. Interestingly, work using scanning techniques from my lab and others has demonstrated increases in size of these regions for bilinguals, compared to monolinguals. It seems that the brain responds to the demanding skill of learning and controlling additional languages by growing the areas that help with these tasks.

Many studies have shown that, in old age, bilinguals have better preserved brains than monolinguals. Some researchers have even suggested that the first symptoms of dementia might appear later in life in bilinguals versus in monolinguals. In other words, learning another language makes the brain more resilient to ageing, and keeps it healthy for longer!

The lesson is: we should all be learning languages, and using them.

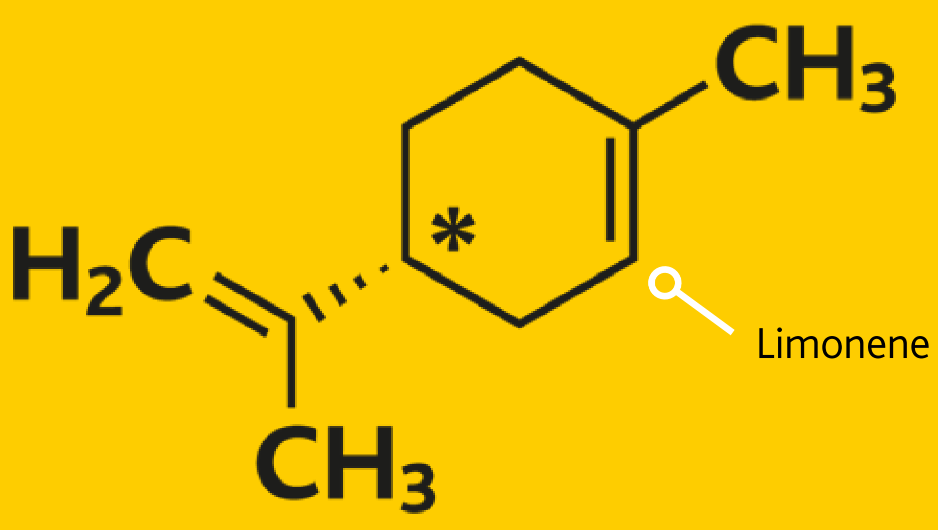
From orange peel to chewing gum

By Mark Langley
STEM Learning

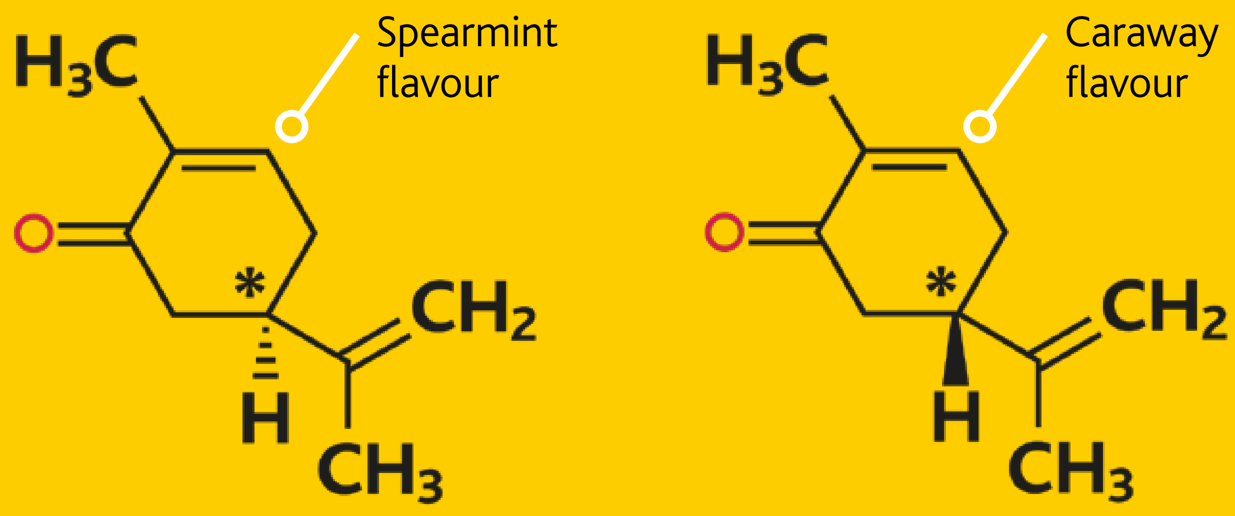


Oranges are a rich source of limonene – this terpene is found in high concentrations in the peel and has a raft of commercial uses, from being used in shower gels, through to industrial cleaners and insecticides. Easily extracted from the orange skins left by the orange juice industry by steam distillation, or using a centrifuge, it is a cheap, biodegradable, natural product. But it has another, surprising, use – in chewing gum.

If you look closely at the molecule, there is a chiral centre, so that limonene comes in two versions (d-limonene and l-limonene). Chiral molecules are identical in atomic structure to each other, but are mirror images. Biologically, only one version is made, while synthetic routes often make a mixture which can be hard to separate. So, in oranges, the d-limonene (the (R)-enantiomer) is made, giving a pure product which can be used as a starting point for many synthesis routes.



One of these is the oxidation to produce carvone, which also can be found in two chiral forms. The (S)-enantiomer has the taste and smell associated with caraway seeds, while the (R) form is spearmint. The fact we can tell identical, but mirror-image molecules apart just by smell also points to how our body reacts to chiral compounds.



While the (R)-enantiomer of carvone can be extracted from spearmint, it is a delicate process and needs a lot of mint! So, given how much orange peel is left over from juicing oranges, it makes sense to convert the extracted limonene into (R)-carvone, to use as a mint flavour in all manner of products, from air fresheners to food. So, quite possibly the minty taste in your chewing gum or toothpaste might have started its life in an orange!

Limonene and carvone are both trivial names, as the systematic names are more complex: limonene is *1-Methyl-4-(1-methylethenyl)-cyclohexene* and *2-Methyl-5-(prop-1-en-2-yl) cyclohex-2-en-1-one* is carvone!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