Bang!

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BANG! TALKS TO GAVIN SCHMIDT

Hilary 2016

THE CLIMATE CHANGE ISSUE

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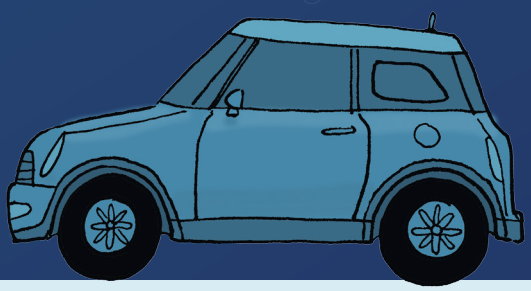

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EDITORIAL

"We are a plague on the Earth. It's coming home to roost over the next 50 years or so. It's not just climate change; it's sheer space, places to grow food for this enormous horde. Either we limit our population growth or the natural world will do it for us."

— Sir David Attenborough

It is in our nature as humans to put things off. I'll start my essay tomorrow. I'll clean the car next weekend. But what happens when we put something off for too long, and it becomes too late? The 2015 Paris Climate Summit was a major international step towards combating climate change, and ensuring that the world remains safe and habitable for life as we know it. Almost 200 countries have agreed to attempt to limit global warming to less than 1.5 ˚C above pre-industrial levels. By keeping within this range, scientists say, we should avoid the worst of the storms, floods, and droughts that come with climate disruption.

But we have already warmed our planet by 1 ˚C, and we are already beginning to see the effects of this change. Floods across the north of the U.K. this winter have been blamed on climate change, and, further from home, wide-ranging effects such as coral reef depletion and the destruction of marine life populations have begun to take hold. Is there anything we can do? Or have we waited too long before acting?

In this issue, Bang! examines this enormous and important phenomenon, looking at both the problems and potential solutions.We ponderthe possibility of a greener Sahara and its implications (page 12), and ask whether geoengineering could be the solution to all of our climate problems (page 20). Further from the effects on our landscape, we look at how changing climate and temperatures could affect one of the most fundamental properties of living organisms — biological sex (page 16). We also talk to NASA scientist Dr Gavin Schmidt about his work surrounding climate, both on the Earth and elsewhere (page 18). The Future Frontiers section from our last issue makes a return, with articles ranging from the future of cancer therapy (page 25), to modelling microscopic worms using computers (page 26).

This issue is also home to the inaugural Bang! Essay Competition, and its winning entry to the question: "How can we as a society solve climate change?" Read the entry and look over comments from our expert judges Dr Gavin Schmidt from NASA, Dr Emily Shuckburgh from the British Antarctic Survey, and Roger Harrabin, environmental analyst for the BBC (page 20).

We hope that this issue of Bang! tackles some important questions, and that it helps people to engage with the topic of climate change. This isn't something we can put off any longer: the world we live in is changing every day. You are the next generation of thinkers, engineers, scientists, activists, and politicians. You are the ones who will go out and make a difference. You are the ones who will change climate change.

Jack Cooper & Dan Murphy

Editors-in-Chief

News in Focus

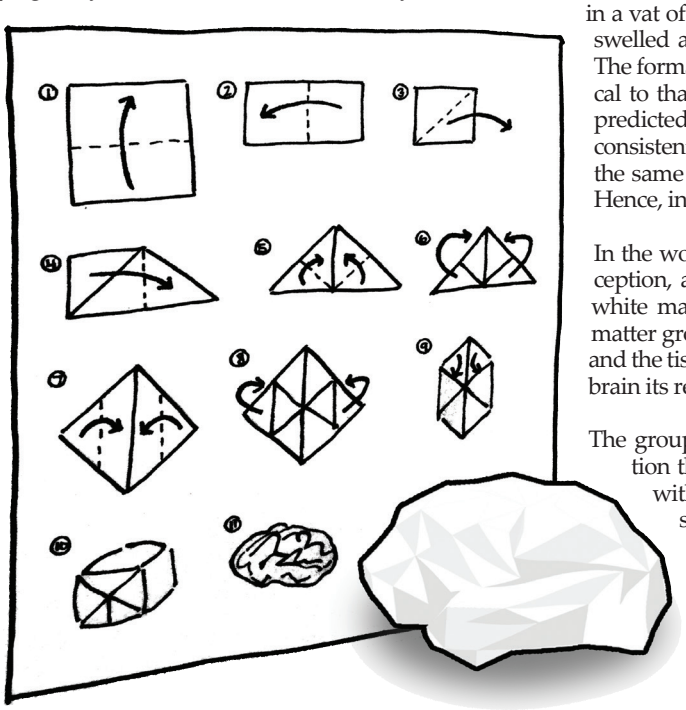
Make Up Your Mind: How Does the Brain Wrinkle?

A study conducted at Harvard University, by Professor Mahadevan and colleagues, has used 3D modelling to reveal how the brain develops its wrinkly appearance in utero. Using a gel replica, the team deduced that the folding of the brain is the result of a simple physical principle.

Ridges and crevices are found in the brains of only the most developed mammals, such as humans, apes, and dolphins, and are referred to as gyri and sulci respectively. The gyri and sulci are composed of grey matter, and are affixed to the white matter beneath. This network of nerve fibres sends and receives signals from the rest of body, with the number of neurons present proportional to the surface area of the brain. The characteristic creases increase the surface area of the cerebral cortex, meaning the cortex can possess a greater number of neurons without greatly expanding the size of the skull. This presents a clear evolutionary advantage, as it would lead to an increase in cognitive function.

Whilst the reason behind the folding of cerebral matter has long been acknowledged by the scientific community, the mechanism by which such folding occurs has been something of a mystery. Professor Mahadevan and his colleagues postulated that the brains wrinkled appearance could in simply be the result of a difference between the rate of growth of white and grey matter.

To test the hypothesis they developed a model of the foetal brain, composed of synthetic gel, and used MRI images taken during early pregnancy to ensure anatomical accuracy. The model was coated with a different gel type to represent the cortex, and then placed in a vat of organic solvent. As the solvent was absorbed the cortical layer swelled at a greater rate, resulting in an uneven and wrinkled surface. The formation pattern of larger folds was very reliable and almost identical to that found in real human brains. The smaller folds could not be predicted and varied dramatically for each experiment. These results are consistent with natural evidence, which finds that healthy humans have the same overall brain structure, but have non-uniform smaller creases. Hence, individual brains are distinguishable.



In the womb, the brain is smooth until around twenty weeks after conception, at which point the creases begin to develop. Grey matter and white matter are mechanically bound, but during expansion the grey matter grows more rapidly. The compression of neurons causes bulking, and the tissue collapses in on itself, forming the sulci and gyri that give the brain its recognisable irregular surface.

The group at Harvard were able to confirm their hypothesis to a solution that has long befuddled the world of medical research. Armed with this new understanding of the mechanism of brain folding, science has taken the latest step in unravelling the enigma that is neurology.

Reported by **Hannah Burrows**
Art by **Michael Mackley**

NEWS IN NUMBERS

FDA approved **45** **DRUGS** in 2015

IN 2016, THE GLOBAL **SURFACE TEMPERATURE** is expected to be **+.82** **DEGREES CELSIUS** greater than the 1960-1990 **AVERAGE**

2^74207281-1 **LARGEST-EVER PRIME NUMBER** was discovered in Central Missouri

PRISTIONCHUS NEMATODES can shift between **5** **DIFFERENT SHAPES**

News in Brief

Just the Right Amount of Warm

Are you one of those people that shed layers and layers of clothes in the lecture theatre. Or are your fingers always too stiff to even hold the pen?

Scientists at the University of California, funded by the US Department of Energy, are working on clothes that shuttle heat to and from the body to regulate the wearer's temperature with respect to the environment. Clothes that control warmth already exist, but are too bulky and uncomfortable to wear in everyday life so have only been used in the military, aerospace and lab experiments.

Alon Gorodetsky's team are trying to adapt squids' mechanism for reflecting visible wavelength, using a combination of proteins in their skin, to infrared wavelengths that carry heat. Such a system will establish control over the radiative heat. The scientists "are leveraging it for materials that can regulate the thermal emissions of an object", are light and suitable for everyday life, making you feel always comfy.

Clothes made of this material will be able to adjust the amount of heat leaving the body and mediate air circulation. They could significantly reduce USA's overall energy usage, 13 per cent of which is accounted by air-conditioning.

Self-Reparing Polymers

Researchers at Northwestern University have developed a new type of hybrid polymer "with nanoscale compartments that can be removed and chemically regenerated multiple times". Perfectly cylindrically shaped, it has been proposed for future use in artificial muscles, delivery of drugs and plasmids into cells, renewable energy sources and self repairing materials.

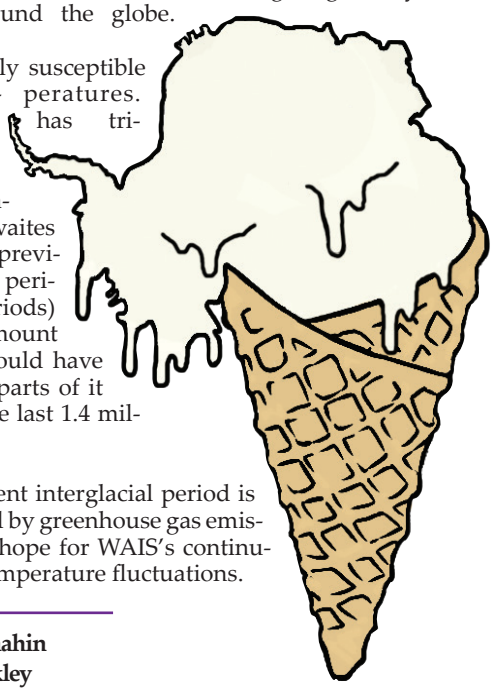
The polymer is a hybrid of two types of polymers - polymers, held together with covalent bonds, and supramolecular polymers that are formed with non-covalent bonds. The different interactions give rise to distinct nanoscale compartments, that enable the polymer to react quickly to signals from the environment and be regenerated in the location it was originally delivered to.

"We can create active or responsive materials not known previously by taking advantage of the compartments with weak non-covalent bonds, which should be highly dynamic like living things. Some forms of these polymers now under development in my laboratory behave like artificial muscles," Samul Stupp, lead author of the study, said.

The development of this hybrid polymer could lead to the creation of materials that can break down and reassemble themselves.

Melting Ice Sheets

A research team at the University of Edinburgh, led by Dr Andrew Hein, have studied the long-term stability of the West Antarctic Ice Sheet (WAIS) by investigating the slope angles and the geochemistry of the peaks of the Ellsworth Mountains. Their study concludes that further melting of the 25.4 million cubic kilometre ice sheet could cause a 3.3 meter rise in sea levels, endangering low-lying countries around the globe.



WAIS is particularly susceptible to increased temperatures. Its melting rate has tripled in the last ten years due to the fundamental instability of the Thwaites Glacier. During previous interglacial periods (warmer periods) a considerable amount of the ice sheet would have melted, but some parts of it have existed for the last 1.4 million years.

However, the current interglacial period is further exacerbated by greenhouse gas emissions, giving little hope for WAIS's continuing resistance to temperature fluctuations.

Reported by **Mery Shahin**
Art by **Michael Mackley**

Hello Darkness My Old Friend

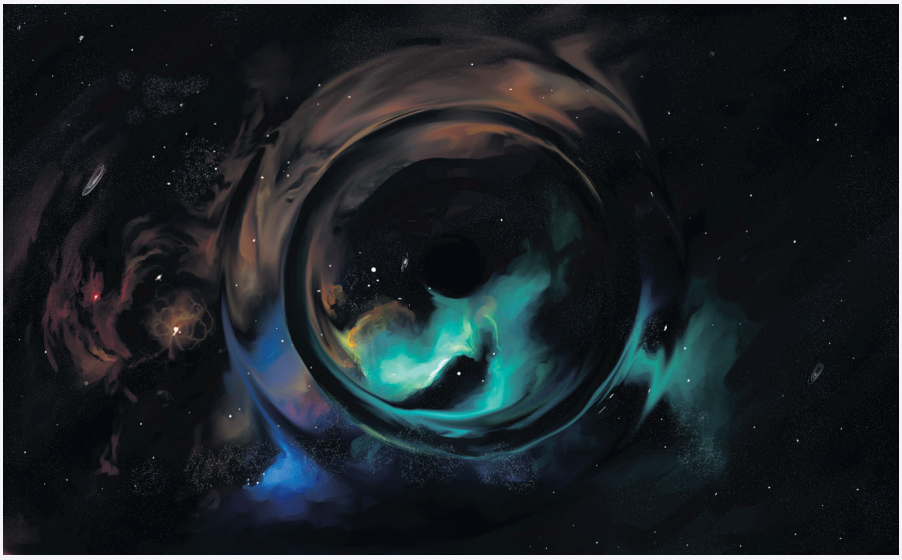
The mystery of dark matter

Despite its hundreds of billions of bright shining galaxies, our universe is dark. This 'darkness' forms dark matter halos around galactic disks and even dark stars. Right now the Earth is hurtling through a thick mire of dark matter, being riddled by billions of dark particles every second, yet we feel absolutely nothing. It turns out that dark matter, this invisible yet universal presence, is an absolute pain to observe directly.

Looking at gravitational effects on galaxies and bodies tells us that the universe is simply too light; it should be much heavier. For example, when light is gravitationally lensed by a massive object it is bent into a 'halo' of light – an Einstein ring – which surrounds the body. In certain areas of the universe, the light gets curved far more than it would if only the visible mass was present. Dark matter solves this problem by providing an explanation as to where the 'extra' mass is hiding. By analysing both gravitational effects and galactic motion, physicists have concluded that there is about 5 times as much dark matter as normal matter in the universe.

Indirect measurements provide a few properties of dark matter – its total mass in the universe, its lack of interactions, its distribution – but its composition remains a mystery. A small percentage is theorised to be regular, baryonic matter which is either too faint to be detected or emits no light; this could be in the form of black holes or brown dwarf stars that have not been found yet, sometimes known as massive compact halo objects (MACHOs). The majority, on the other hand, is thought to be non-baryonic and therefore requires more sophisticated methods of detection.

> "THE EARTH IS HURTLING THROUGH A THICK MIRE OF DARK MATTER."



The leading candidates for non-baryonic dark matter are aptly named weakly interacting massive particles (WIMPs), which only act through gravity and the weak force. The theory of supersymmetry (SUSY) readily predicts the existence of particles with these properties that would arise with energies of around 100 GeV. However, despite reaching 13 TeV the LHC has found no such particles, which casts doubt on both the SUSY particles and the lighter WIMP candidates.

According to some models, there exist much heavier WIMP candidates that would not have been found during Run 1 of the LHC. Now, after two years of maintenance and upgrades, the LHC will be able to achieve energies high enough to potentially produce these particles within the next few years; already ion collisions at energies of 1000 TeV have been achieved.

Most models predict that dark matter tends to clump together into a superfluid called a Bose-Einstein condensate (BEC) in which all the particles move in unison instead of at random. In other words, a BEC acts like one giant particle that can undergo quantum phenomena but on a larger, macroscopic scale. A team led by Chanda Prescod-Weinstein at MIT predicts that BECs made of theoretical particles called axions could have formed asteroid-sized Bose stars – tiny dark matter stars that are 20 times denser than a regular asteroid like Ceres – 47,000 years after the Big Bang. These Bose stars could eventually be detected under favourable conditions when orbiting a pulsar.

Similar interactions between stars and pulsars have been recreated experimentally on Earth: the Axion Dark Matter eXperiment (ADMX) at the University of Washington is designed to utilise the natural coupling of axions and photons to demonstrate this phenomenon. The experiment stimulates their conversion into one another, so that incoming axions from the local galactic dark matter halo are triggered into becoming photons which ADMX then hopes to detect.

In spite of the host of potential candidates for dark matter, no conclusive evidence has yet been found. However, with a multitude of new experiments and methods on the horizon, it's only a matter of time until we shed light on the dark.

Reported by **Jacques Bara**
Art by **Sumitra Ratilal**

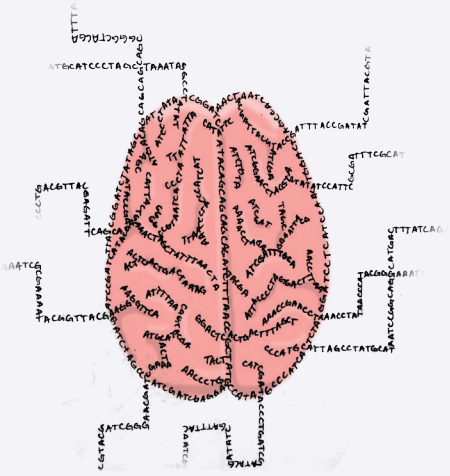
Nature vs Nurture

How do genes influence our cognition?

Several gene networks in the hippocampus have been strongly linked to variance in cognitive ability, according to research published in *Nature Neuroscience*.

The heritability of cognition,which includes memory, attention, processing and reasoning, is well-known, but no specific genes have been identified until recently. Networks of genes operating together were found to have a much greater effect on cognition than that of isolated genes, particularly two networks called M1 and M3. These were found to be involved in many general cognitive functions, such as conversion of short term memories to long term memories in the hippocampus.

The researchers, led by Michael Johnson of Imperial College London, used 122 frozen human hippocampal samples to examine interactions between genes and determine which were switched on and off. They also used genome-wide association studies to identify how the genes influenced cognition.



The M1 and M3 networks are implemented in 'fluid intelligence', which refers to adaptation to new scenarios, processing speed and delayed verbal recall. The genes in M1 also affect 'crystallized intelligence', which is utilised in adaptation to familiar scenarios. The team found that, in those with neurodevelopmental disorders such as schizophrenia and epilepsy, almost a third of the 150 genes in the M3 network had mutations. This reflects the cognitive impairment often symptomatic of those diagnosed with these disorders.

These findings could improve our understanding of how genes and the environment interact to influence human cognition. It could also shape the way we view genetic risks behind neurodevelopmental disorders and have major implications for how they are diagnosed and treated.

Reported by **Lauren Martin**
Art by **Michael Mackley**

Homo cannabilis

Discovery of a new species sheds light on our ancestors' family feuds...

Darren Curnoe, a palaeontologist at the University of New South Wales Australia, revealed that a new Late Pleistocene *Homo* species may have been discovered in Muladong cave in South-West China.

The species resembles Early Pleistocene hominins such as *Homo erectus*, yet has been dated to just 14,000 years ago. This means it is likely to be an archaic *Homo* species that managed to survive over a long period, making it the most recent known human species other than our own. The species appears to have been relatively small, and would have walked differently to modern humans, with a narrower bone shaft and larger notches where the muscle would join the bone.

Intriguingly, *Homo sapiens* remains were also found in the cave, alongside evidence that they may have cannibalised this newly discovered species. A hominin femur bone retrieved from the cave had signs of having been burnt and split to allow access to the nutrient-rich bone marrow inside. It had also been painted with a red ochre clay, a practice generally associated with human burial rituals, which distinguished the specimen from surrounding animal bones also found in the cave. Fossil evidence from a second cave nearby suggests that *Homo sapiens* also mated with the newly discovered species to form a hybrid offspring species, whose cranial remains appear to have been used by Homo sapiens for tools such as drinking vessels.

The new species may in fact be one of the elusive Denisovans, yet little can be determined until an undamaged DNA sample can be obtained. There are still many gaps in our fossil records and uncertain evidence surrounding dating of fossil remains. However, these discoveries,

alongside recent genomic evidence of interbreeding between modern and archaic humans, have challenged many existing theories of evolution and pave an exciting path for future research.

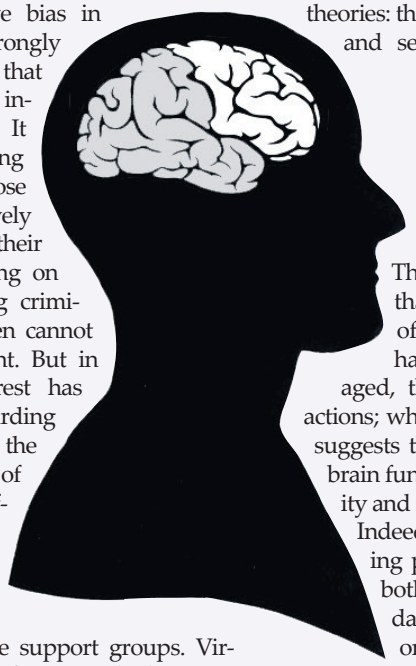
Reported by **Lauren Martin**
Art by **Dominique Vassie**

Taboo

The neurobiology of paedophilia

Combing through scientific literature regarding paedophilic disorder, one can see why researchers do not often address this subject. Arriving at a concrete conclusion about paedophilic disorder is a far too difficult task for most researchers; even the mention of the word 'paedophile' is enough to cause readers to proceed with caution.

Paedophiles are seen as evil, sexually abusive individuals. This is something that one of the few publicly self-identified paedophiles, Todd Nickerson, calls "the backfire effect": a cognitive bias in which we react strongly against something that conflicts with our internalised truths. It goes without saying that those who choose or are compulsively driven to act out their fantasies by preying on children are acting criminally, since children cannot give sexual consent. But in recent years interest has been sparked regarding the ethics behind the criminalisation of paedophiles. Self-proclaimed and non-aggressive paedophilic individuals are seeking help via online support groups. Virtuous Paedophiles, for example, has over 1200 members. The radio broadcast This American Life recently followed a young paedophile, empathising with his story of depression, acceptance, and treatment. This humanisation of non-acting paedophiles is being spurred by neurobiological research that attempts to discover the developmental and genetic abnormalities that might cause this sexual preference in adults.



Following growing concerns about child sexual abuse and growing interest in diagnosing paedophiles, the 2013 edition of the 'Diagnostic and Statistical Manual of Mental Disorders' updated its definition paedophilia. This new definition distinguishes between paedophilia as a sexual preference, with no urges or distress, and 'paedophilic disorder', which introduces personal distress and fantasies about prepubescent children. Indeed, studies have shown that 50% of child sexual abuse acts are committed by those who are not attracted to children but continue to sexually abuse due to other developmental or emotional problems. So who really are paedophiles, and what characterizes paedophilic disorder?

A recent review by Gilian Tenbergen, a doctoral student at Hannover Medical School, and her colleagues discusses three theories: the frontal lobe, temporal lobe, and sexual dimorphism theories.

> "ALL MRI STUDIES DONE ON PAEDOPHILES HAVE DISPLAYED A REDUCED RIGHT AMYGDALA VOLUME"

The frontal lobe theory posits that areas of the frontal lobe of the brain which act as behaviour regulators are damaged, thereby disinhibiting sexual actions; while the temporal lobe theory suggests that impaired temporal lobe brain function results in hypersexuality and sexually deviant behaviours. Indeed, many individuals displaying paedophilic tendencies have both frontal and temporal lobe damage. All MRI studies done on paedophiles have displayed a reduced right amygdala volume, in line with the temporal lobe theory; and many other studies on paedophiles have found varying differences in frontal lobe size and function. One study by Dr Mario Mendez, a behavioural neurologist at UCLA, and his colleagues found paedophilic tendencies exacerbated in a 60-year-old man with fronto-temporal dementia and in a 67-year-old man with hippocampal sclerosis, located in the right temporal area of the brain. These findings of neurological degeneration support the combined fronto-temporal theory. The sexual dimorphism theory alternatively attributes the brain differences in paedophiles to the masculinisation process of the brain in utero. More paedophiles are reported to have older brothers than non-paedophiles, and a higher presence of brothers may heighten testosterone level in the womb, possibly affecting the foetus. However, the sexual dimorphism theory does not account for the presence of female paedophiles; like much of paedophilia research, it is speculative at best.

Overall, the popular opinion is that paedophilic tendencies result from an interaction between neurodevelopmental factors and a genetic predisposition. Genetics research on paedophilia is still in its initial stages, but studies have already shown that sexual paraphilias are both heritable and more complicated than expected.

Even before attempting to begin epigenetic research, the field of paedophilia studies must address its current flaws - primarily in the exclusive use of convicted paedophiles in all studies. Without non-offending paedophilic participants, all research will be compromised by confounds associated with other psychiatric disorders and the effects of criminalization. Two studies have shown that out of paedophiles in treatment: two-thirds suffer from anxiety or another mood disorder, 60% from substance abuse, and another 60% fit the criteria for a diagnosis within the realm of personality disorders. To combat these flaws, research must make use of younger, non-acting paedophiles. This is why people like Todd Nickerson, online forums like Virtuous Paedophiles, and stories like the one on This American Life are important. Novel neurobiological approaches in the field are benefited by the growing community of paedophiles who want to aid research and thus be aided themselves.

With technological advances and the cooperation of people with paedophilic disorder, this neurological and social issue is within reach of those who wish to understand it. Paedophilic disorder is no longer fodder for psycho-erotic novels such as Nabokov's Lolita. This complicated sexual preference is beginning to be understood.

Reported by **Eliza Burr**
Art by **Michael Mackley**

Cerebral Organoids

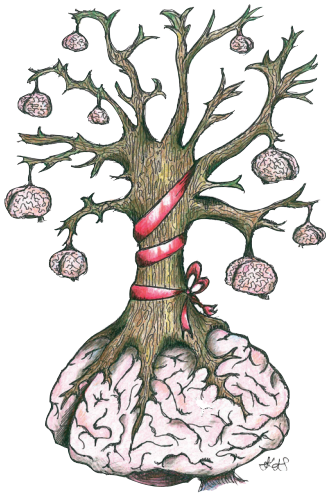
Why use any old brain when you can grow a new one?

It is often said that the human brain contains more connections than there are stars in the universe. Although this is patently wrong, the fact that such a hyperbole seems believable indicates just how impressive the brain is.

While this complexity makes for compelling popular science it also makes for difficult research, a pressing issue given aging populations worldwide and the increasing prevalence of neurodegenerative disease. In the UK alone, it is predicted that there will be 1.5 million dementia sufferers in 2030 – and this is just one of many diseases.

Studying the human brain with animal models is naturally limited, studies in human patients are rare, and whole-brain computer models are decades away. So why not grow a human brain? Or at least something resembling one: a cerebral organoid.

Cerebral organoids are artificially grown organs just millimetres in diameter. They share anatomical and functional similarities



with the cortical and choroid plexus layers of the mammalian brain, or specifically the human brain if grown from human cells. To form one, stem cells are cultured in a 3D rotational bioreactor, enabling the generation of multiple cell types and a 3D tissue.

First created by Madeline Lancaster, the organoids provide an in vitro model for studying neurodevelopment, disease progression, as well as investigating treatments and screening drugs. This is an important step in understanding neurodegenerative diseases, and conditions such as schizophrenia that are suspected to have underlying developmental causes.

But while the organoids may be a big step towards greater understanding of the human brain, nothing compares to the original.

Reported by **Jack Cooper**
Art by **Kai Lin Sun**

The Climate Change Section

A Shifting Landscape

Will climate change turn the Sahara green?

Climate change in the near future is potentially full of a number of surprises. Our planet is an extremely complex entity, with an environment that has its characteristics tightly regulated by an array of different interconnected natural systems. It should come as no surprise that global warming – due to increased atmospheric carbon dioxide concentrations – both has been inflicting and will continue to inflict a variety of significant changes on the climates of different areas of the Earth's surface. One of the more interesting areas where this could be observed is North Africa's Sahel.

The Sahel is essentially the climatic mid-point between the extremely arid Sahara desert to the north and the tropical Sudanian Savanna to the south. It covers an area in excess of 3,000,000 km², and contains the majority of Mauritania, Mali, Niger, Chad, and Sudan. Possessing a semi-arid climate, the Sahel doesn't receive large amounts of precipitation. This means droughts and even megadroughts are a common local occurrence; they have historically had devastating effects on local people, especially given that local economic development is amongst the most limited in its extent in the entire world.

However, an interesting debate has recently emerged in climate science: have the Sahel's rates of precipitation been increasing since the 1980s? Satellite images taken of the region between 1982 and 2002 indicate increasing apparent greenness when the area is looked at from space, with a lot of the increase taking place since 1994. Some areas, especially particular locations in northern Nigeria, southern Chad and South Sudan, even saw visible greenness increases of over 200% between 1982 and 1999. Naturally, the obvious initial conclusion is that local rates of vegetation cover are increasing.

A sceptic might argue that the increasing apparent satellite-observed greenness might not necessarily be completely attributable to increasing vegetation cover on the Earth's surface. After all, another cause for the observation could exist. However, according to Physical Geography professor Lennart Olsson at Sweden's Lund University, in 2008, "Meticulous quality assessment of other parameters related to the data strongly supports the conclusion that the observed trend is a real change on the land surface".

> "THE OBSERVED TREND IS A REAL CHANGE ON THE LAND SURFACE"

As anyone who has studied elementary biology, ecology, or physical geography would know, a maintained and consistent increase in the Sahel's vegetation cover would almost definitely indicate a significant increase in local rates of precipitation. Interestingly, analyses of time series rainfall data collected from 40 stations across the Sahel region, conducted by Olsson and his colleagues in 2005, have confirmed that local rates of precipitation have indeed broadly increased over the period of increasing Sahel greenness. However, why is this the case?

According to Martin Claussen of Hamburg's Max Planck Institute for Meteorology, "the water-holding capacity of the air is the main driving force". This is because water vapour can be carried by air at a higher maximum pressure at warmer temperatures, allowing more water molecules to be carried in a given volume of air. Consequently, it should come as no surprise that average rainfall rates in the Sahel's wet season, between July and September, were predicted to rise by as much as 2mm per day by 2080 according to a 2005 study published in Geophysical Research Letters. This study, conducted by a group of researchers including Reindert Haarsma of the Royal Netherlands Meteorological Institute, suggests that the recent increase in regional rates of precipitation looks set to continue as a temporal trend into the near climatic future.

However, it should also be considered that a number of similar climate models for the Sahel region, such as one published by the US National Oceanic and Atmospheric Administration's (NOAA) Isaac Held in 2005, actually predict a decrease in rates of precipitation in the coming years of this century. Does this mean that the trend towards increasing vegetation cover we have seen in the Sahel over the last few decades is

set to lapse? In essence, the answer is that climate researchers as a scientific community are unsure. According to Martin Claussen, "Half the models follow a wetter trend, and half a drier trend".

North Africa is possibly the region in the world where the greatest disagreement exists amongst climate modellers regarding local climatic characteristics in the near future. This is due to a wide variety of reasons, including the complex wind cycles in the region, which naturally play a very significant role in determining local distributions of precipitation. Given the complexity of the various interconnected environmental systems of our planet, it should come as no surprise that accurate climate models are often challenging to create. The development of such models requires the quantification of the importance of an extremely wide range of factors to changes in climatic characteristics over time. When considering future increases in regional air temperatures, for example, values such as the amount of carbon dioxide that will be released into the atmosphere due to human activities in the coming decades must be predicted.

Obviously, it is very hard to make such predictions and quantifications; therefore, it seems completely understandable that there is significant variation between the underlying assumptions used to construct different climate models of the Sahel region. In fact, this is one of the most important dilemmas facing climate science as a whole today, in both the academic world and the public sphere. If different models of future climate activity in specific global regions like the Sahel come up with different projections, how are local legislators and policymakers able to decide what action to take in order to best mitigate the impacts of global climate change on their local nations and communities? Should governments in countries like Burkina Faso, Mali, and Senegal anticipate increasing rates of precipitation locally over the next 50 years, or should they expect the opposite to occur? It is crucial that climate models continue to become more refined and increasingly accurate if these questions (amongst many others!) are to be answered.

The Sahel has been greening. Rates of precipitation and vegetation cover in the area have been noticeably increasing for a number of decades now. However, it is unclear if this trend will continue or not; this is causing controversy amongst climate researchers, with different models predicting different climatic futures for the Sahel within this century.

Reported by **Alexander Curtis**
Art by **Christina Rode**

Bang! Essay Comp

How can we as a society solve climate change?

In our society, science is often seen as existing in a vacuum. We look for strictly scientific solutions to what we see as strictly scientific problems. In setting the qestion for our inaugural essay competition this issue, we wanted to encourage people to think outside the scientific box. The impacts of political, social, and economic variables on looking for a solution to the problems af climate change cannot be overstated, and these factors must work in conjuction with science to help save our world.

In this essay, Rebecca Shutt tackles these issues on an individual scale. She asks what we as human creatures are doing to fix the problem that, collectively, we have ourselves caused. In the face of grand governmental and super-governmental initiatives, what can ordinary people do to change climate change?

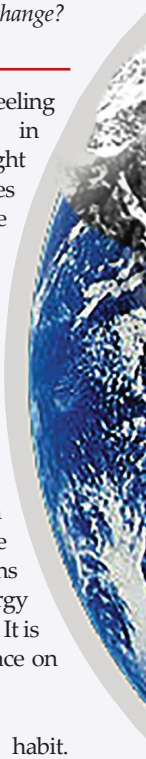
Climate change is gaining momentum as a major issue in the eyes of the leaders of our world. In the wake of the 2015 Paris Climate summit, countries are beginning to cooperatively attempt to tackle the issue at a policy level.

Science promises much in the innovation of methods to combat the issue of anthropogenic climate change, like carbon dioxide utilisation and energy storage technologies. Research in these areas is also receiving increased backing from new funding initiatives from both leaders of countries (Mission Innovation), and the financial giants (Breakthrough Energy Coalition), which could do much in the way of bridging the gap between the laboratory and the global market.

All in all it is a more promising outlook in terms of pro-action, but even if nations manage to meet their targets, it is estimated the climate deal signed in Paris will miss its primary objective to keep global surface temperature to a maximum 1.5 C increase. The powers that be have great influence as to shaping change for the future, but there also lies power in the masses. Are we, the general population, doing all we can to curb this foreboding threat? Yes we may turn off the lights, recycle waste, and save water… but we must ask ourselves - are we really trying?

In human nature we have a tendency to lack the motivation to really work hard at something unless the alternative peril is imminent. In my experience of the student population, one can never seem to get one's heads down and just write that essay till the eve before the deadline. The adrenaline fuelled essay crisis that follows somehow manages to see us through till the last full stop is dotted with a satisfied (or zombie-like) flourish as the daybreak chorus sings forth and the lazy sun begins to peep over the spires. But this behaviour is not a profitable practice that we should propagate. If we want to invoke further change in our lives for the good of the environment, that change should be enforced now.

As an individual, there is also the feeling of smallness and insignificance in affecting global change. The thought process "What difference does it make if I use the lift this once instead of the stairs?" can perhaps be understandably adopted in an overwhelmingly large population of wanton energy consumers. Will in fact that one choice to burn a little more energy and make life a little easier today be the deciding factor as to whether Bangladesh is lost to the rising ocean in the future? It is easy to see why the answer can be argued no. But a world where every individual is making decisions to not actively reduce the global energy demand is a dangerous place to live. It is time to increase the gravitas we place on the lifestyle we choose to adopt.

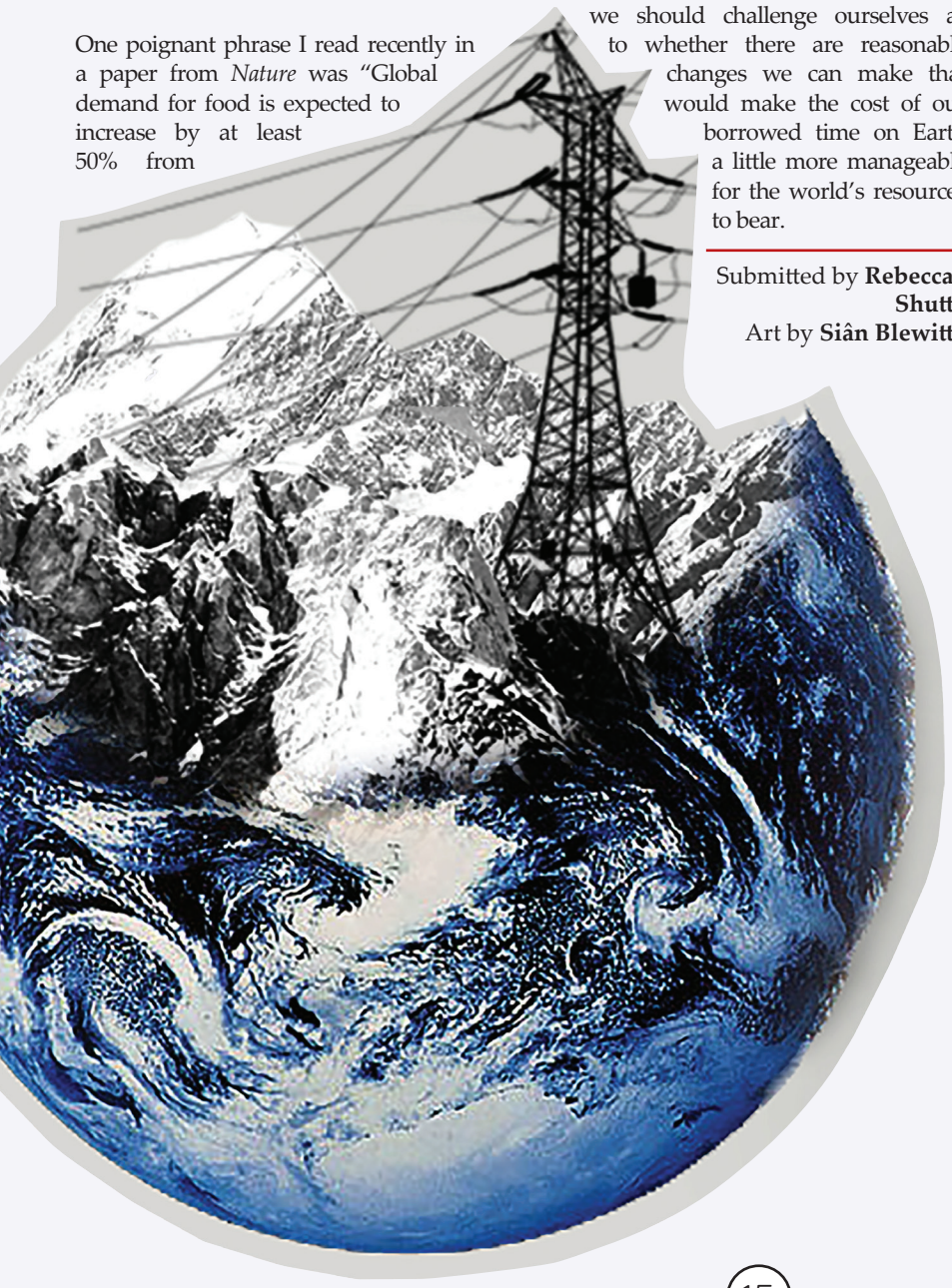


Additionally, we are creatures of habit. Some neuroscientists estimate that as much as 98 % or more of all brain activity is unconscious. The mind slots very easily into repetition, and once nicely nestled

into its routine it can be very difficult to persuade that a little change can be more than manageable. When I first considered changing my diet to omit meat and fish for environmental reasons, my brain panicked at this proposed uprooting of my entire world (it was a little dramatic). I worried about not getting enough essential nutrients and what impacts the change might have on my social life – no more Byron burger!! But a couple of weeks after enforcing the change my perspective on what is normal and easy for me shifted. A way of life can be a passively accepted as an indoctrinated norm because "It's what we've always done.", but our lifestyles can and should be an active and conscious choice.

One poignant phrase I read recently in a paper from *Nature* was "Global demand for food is expected to increase by at least 50% from 2010 to 2050 mainly as a result of population growth and a shift towards a more 'westernized' diet in developing regions", and this reasoning is a recurring theme in papers and articles concerning an increasing demand on natural resources. The western lifestyle is superfluous to the needs of leading a fulfilling and productive life, and we should readdress how we balance what we want, what we need, and what is sustainable.

I think what is urgently needed to mitigate climate change is for we as individuals to hold a greater personal responsibility over our daily lifestyle choices. If climate change is an issue we would like to combat, we should challenge ourselves as to whether there are reasonable changes we can make that would make the cost of our borrowed time on Earth a little more manageable for the world's resources to bear.



Submitted by **Rebecca Shutt**
Art by **Siân Blewitt**

Judges' Comments

"I thought this covered an interesting, diverse range of different science dimensions to the topic, including mention of technological innovation, psychological responses and resource scarcity. I would additionally draw attention to studies looking at the climate impact of dietary choices."
– Dr Emily Shuckburgh, British Antarctic Survey

"[This essay] was an obvious winner for its clarity and its well-argued connection between international and personal action."
– Roger Harrabin, BBC Environment Analyst

"[This entry] stresses an important component (individual lifestyle choices). My own take on the suggested title is that our individual actions can go beyond our consumer choices - to include influencing our wider networks (towns, churches, communities, schools, states, countries etc.) but that this kind of engagement can only work with an informed populace with a strong commitment to really sustaining it.And that means taking real steps to make sure that actions can be sustained beyond the 24 hour news cycle, the election cycle and even longer. It's not going to be easy, it's not going to be smooth, but like many things, the benefits will outweigh the costs."
– Dr Gavin Schmidt , NASA Goddard Institute for Space Studies

Sex-Changing Climate

Climate change does much more than melt ice caps...

When we think of climate change, the classic image of a polar bear clinging to a melting ice cap springs to mind. However, meteorological changes impact some animals in the most unlikely of ways – by changing their sex.

Sex determination in animals is extremely varied, ranging from complete genetic control in humans to being determined by the environment in the slipper snail. A multitude of factors are involved in environmental sex determination, such as the presence of a predator, or by the temperature of incubation, as seen in fish, turtles, and alligators.

Therefore, climate change could create problems for the reproduction of many species. Rising nest temperatures pose a significant threat towards genetic diversity in turtles, as eggs incubated at higher temperatures produce females.

Such change is already being observed in the wild; for on the beaches of Playa Grande, Costa Rica, the nests are 70-90% biased towards female hatchlings. In fact, on some beaches it has often become too hot for the eggs to hatch at all, forcing scientists to move the nests in order to allow the turtle eggs to hatch.

In the short term, an increase in the female population of turtles is unlikely to cause a huge problem for the species - it may even be beneficial! After all, the more females that are produced, the more eggs that can be laid; making a population increase highly likely. However, in the long term there will be a serious problem –as there will be insufficient males left to fertilise their eggs. Consequently, rising global temperatures could potentially lead to the extinction of a multitude of turtle species in the long term.

It was thought that the emergence of a skewed sex ratio was a potential extinction driver exclusively in species with temperature dependent sex determination, yet a recent study published in the journal 'Nature', led by Dr Clare Holleley from the University of Canberra, shows this is not the case. Dr Holleley and her colleagues show that a rise in temperature can also perturb an apparently stable genetic sex determination system, making the species population in question increasingly feminised, an so increasing the risk of extinction.

Dr Hollely and her group used a population of wild Australian bearded dragons as their research subjects. In this population, the researchers made a major discovery – the first ever report of sex reversal in the wild. Bearded dragons have a genetic mechanism of sex determination where the females have the genotype ZW and the males ZZ (a comparable mechanism to humans but in reverse - males are XY and females XX).

However, the high temperature was able to override this system and feminise males to produce sex reversed females. Not only were the sex reversed females viable and fertile, but they also laid around two times more eggs per year than the genetically female lizards of the same age. This suggests an immediate fitness advantage to sex reversal. The team also found that the sex of the offspring of sex reversed mothers was more frequently reversed, and at lower temperatures. Additionally, over the duration of the study there was a rise in the rate of sex reversal observed in the wild.

The findings of the aforementioned study should extensively increase concerns about the adaptation of animals to rapid climate change. Rising global temperatures can have huge widespread and long term effects on the gender makeup and viability of various populations. Crucially, such changes don't just affect the well-being of the single species in question – they can have cascading effects across the ecosystem.

So, next time you see a climate change campaign; remember to think beyond the polar bears!

Reported by **Victoria Pike**
Art by **Dominique Vassie**

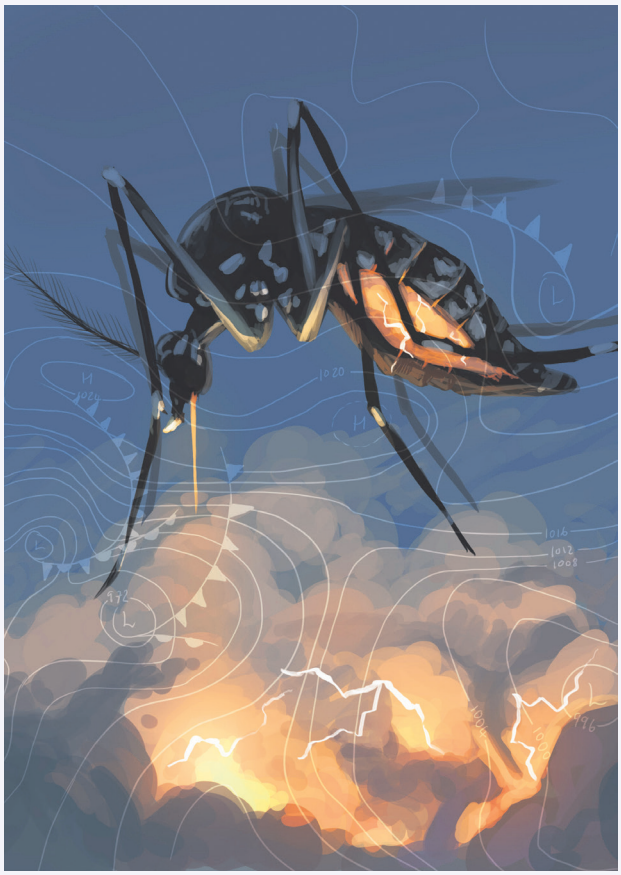
Unexpected Consequences

The dangerous link between climate change and infectious diseases...

When you hear the phrase "climate change", what springs to mind? Weakening polar bears pining after their melting ice caps? The arid ground of the Sahel cracking under the heat of the beating sun? Although we are perfectly justified in imagining such scenes, many of us are unaware that climate change is impacting life on Earth in ways that are harder to perceive. Climate change has altered the dynamics and transmission of infectious diseases, which many populations in developing countries are experiencing the brunt of.

Since the 19th century, our understanding of infectious diseases has progressed by leaps and bounds. Thanks to decades of research, we now know that infectious agents vary significantly in size, type, and mode of transmission. We know, in detail, how diseases can be transmitted by viruses, bacteria, protozoa, and multicellular parasites. We know that they can be water-, air-, and vector-borne. We know that simple precautions, such as using mosquito nets, can reduce the risk of malaria. Yet, even with this vast collective understanding, scientists have not always been able to counter the increasing rates of infectious diseases worldwide. This surge has been attributed to altering demographic, social, technological and environmental patterns, the latter of which have arguably stemmed from the looming threat of climate change.

Climate change is often perceived on a large scale, focusing on broad patterns of temperature and rainfall across continents or regions. However, it is important to remember that climate change equally occurs on a local scale. As a result, growing climate instability has been associated with spikes in cases of infection on both scales. While increasing temperatures expand the potential ranges of infectious diseases, making them harder to contain, intense rainfall can influence the transport and circulation of water-borne infectious agents, increasing human exposure.



Extreme and unpredictable weather events can have major consequences for disease transmission dynamics. For instance, in 2000 Mozambique experienced a 5-fold increase in cases of malaria in regions affected by flooding. This flooding was the outcome of three cyclones and unremitting heavy rainfall during the months of January to March. Events such as this have been documented elsewhere in the developing world and have had crippling effects on vulnerable populations. Early in the last century, the river-irrigated Punjab region experienced periodic malaria epidemics due to an unexpectedly harsh monsoon and high humidity. These extreme weather events were once attributed to the El Niño/Southern Oscillation (ENSO) phenomenon, a periodic change in climate of the tropics and subtropics caused by fluctuations in surface temperatures over the eastern Pacific Ocean. However, it has recently become apparent that extreme weather events are on the rise, independent of ENSO, making them more challenging to predict and harder for those at risk of infectious diseases to take precautions.

> "CLIMATE CHANGE IS OFTEN PERCEIVED ON A LARGE SCALE, FOCUSING ON BROAD PATTERNS OF TEMPERATURE AND RAINFALL INCREASES OR DECREASES"

The potential for climate change to increase the prevalence of infectious disease is not solely confined to the developing world. In Sweden, changes in the transmission dynamics of tick-borne encephalitis (TBE) – a viral infection whose symptoms include fever, headaches, tiredness and muscle pain – have been attributed to increasing temperatures. Researchers have observed that TBE-bearing tick populations are moving further northward with each warmer winter, increasing the number of people who are at risk.

Changes in the transmission and abundance of infectious diseases are a major, if relatively unknown, consequence of climate change. Global health is threatened by the growing climatic instability and extreme weather events associated with global warming. Scientists have worked hard to understand the complex causal relationships between climate and disease, and by applying this knowledge to the prediction of forthcoming trends, we might be able to avoid future epidemics.

Reported by **Jessica Mundy**
Art by **Dominique Vassie**

Bang! talks to...

Dr Gavin Schmidt

Bang! talks to Director of the NASA Goddard Institute for Space Studies

* * *

What work does the Goddard Institute for Space Studies (GISS) do relating to climate change?

We were set up in the 1960s to be a theoretical division for NASA. They felt that they wanted to have a connection to academia and generic scientific research, and that's basically how we've kept it. The topic that we looked at was initially mostly astrophysics: we worked on some of the early Venus and Mercury missions, and we had an instrument on one of the early Galileo probes to Jupiter. But as we moved into the 1970s we started focusing much more on satellites that are observing the Earth, using the same techniques that we'd been using on other planets. At the time we knew more about the ice caps on Mars than we knew about the ice caps on Earth. And so our focus became the things that are driving climate change on Earth.

We started working on simulations. We're one of around 25 groups around the world that build simulations of the climate system. We also spend a lot of time looking at climate impacts, how these things actually change agriculture, or change sea-level rise and urban environments. And we still work on instruments: we're trying to get an instrument on one of the next satellite launches to measure aerosol particles in the air. And then we have a new project which is kind of going back to our roots, which is using what we've learnt about the Earth system climate and applying it to exo-planets, and what kind of climates you would see on exo-planets that we're starting to observe now with the Kepler satellite. So yeah, we do a lot of stuff.

What current climate research are you most excited about?

My personal interests are in trying to understand what happened in the past, and seeing if we can explain those things — paleoclimate: climate changes before the historical record. You're looking at proxies for climate change, things which are connected to climate but aren't measures of temperature or rainfall — they're measurements of isotopes, or of lake sediments, or shells or something like that — and you're trying to quantify those and then try to interpret them in a way that gives insight into what happened in the past. Looking at my own research, the earliest stuff that I worked on was the Cretaceous period, about 100 million

years ago. I still maintain a lot of interest in that, but now we mostly focus on the last 100,000 years. Also looking at what's happened during the holocene, the relatively mild period that we've been living in, that all civilisation has been living in, for the last 10,000 years — there's interesting things there. You're looking backwards and you can't see things very distinctly the further back you go, so you look for things that have a similar signal/noise ratio. The ice age's is very large, and we don't know exactly why but we have a similar signal/noise ratio for the ice age as we do for the last 100 years. Which is odd, you'd think we'd do better.

How optimistic are you about the impact of the recent Paris Climate Summit?

The Paris Climate Summit does not exist in a vacuum — if it was just that, you would not be particularly excited. But it is symptomatic of a better level of conversation and better level of appreciation of the problem globally, with the small exception of a particular colony of people in Washington DC. I think it's obviously better that there was an agreement than there wasn't, and governments around the world are talking in ways that are commensurate with the size of the problem, which has to be a precursor for taking actions that are commensurate with the size of the problem. My sense is that once people really start to get going on this, like in many other environmental problems, people will find things that work, and very smart people will apply themselves to finding things that work and making them much cheaper and more efficient, and there will be a cascade of best practices that go out from that. That's my hope, that there will be a cascade of actions that will lead us to a situation where by the end of the century — or hopefully before that — people will be thinking much more sensibly about how we deal with carbon. But it's a long process, and if people think that one signature on a piece of paper is going to change anything then that's not appropriate.

> "AT THE TIME W
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This is a problem that is unique in its scope, unique in its timescales, unique in its global nature, and we can't fix it. All we can do it moderate

it, but we need to moderate it in a way that hopefully does not lead to disasters. And that's very hard, that's an enormous challenge, and again it's a unique thing that we have to do here. With unique things, we'll be able to look back and say that we tried a bunch of things, and these are the ones that worked, but I don't think it's going to be clear what those are going to be. So I would say I'm cautiously optimistic, but that's tempered with a realization that this is a really big problem, and it's not going to be solved just by a bunch of people going to Paris.

One of the articles in this issue discusses geoengineering as a potential climate change solution. What is your opinion on such large-scale scientific projects?

So that's the thing, that isn't a scientific project. The science that goes into it is not that difficult, it's not that surprising. There are side-effects to the geoengineering plans that people have come up with for the ozone layer, for rainfall in the tropics, but quite frankly if that was the only issue people would probably just go ahead and do it. The bigger issue is how geoengineering fits into world geopolitics, and the ethical, legal and governmental issues associated with it. For projects like this, either something good happens or something bad happens. If something good happens they go away and gain credit, if something bad happens, they run away and say "Well you can't prove that we did that!", and, well, you can't. And so even after more than 50 years of weather modification research, there's still no one significant result that demonstrates that it makes any difference at all.

"WE KNEW MORE ICE CAPS ON WE KNEW ABOUT S ON EARTH"

Nobody has any idea if these things work, and yet people still pay money. There was one attempt to control a hurricane, [Project Cirrus]: they were tracking it, so when it was going out to the Atlantic and they decided to seed it, they decided to throw lots of [dry ice] into it. But then the day after they did their thing, the hurricane pivoted and started heading directly for [Georgia], where it made landfall, caused enormous amounts of damage, many people died, lots of flooding — at which point they said "Oh well, you can't prove it was us." Of course, the whole thing was shut down immediately. Probably they had nothing to do with it, but that's what happens: at some point something bad will happen — because it's the weather — and they will be blamed.

The reason geoengineering won't work is… nothing to do with the science, and I think a lot of times people look at issues that have science components and they think that resolution of those issues will be about the science, and they're totally wrong. The reason why these things are issues is because of clashes of values: it's who wins, who loses, who pays, who benefits. Science never says anything, science informs, but all of these things are value judgments that are very human and very political in a very broad sense, and when people try and squeeze the politics out of things that are clearly political issues, you end up with a situation where it's scientists that get blamed for the bad choices that politicians make.

"PEOPLE HAVE NO IDEA WHAT A MODEL IS. NONE. THE WORD IS MEANINGLESS."

Which climate change myth would you most like to dispel?

People have no idea what a model is. None. The word is meaningless. People say "Oh, it's just a model," and what I'd love is if people had a better idea of how science works, how we take something complicated and we make something slightly simpler. And it doesn't matter if it's quantum mechanics, or a climate model, or a statistical model. All of these models are wrong, none of these models are right, there's no truth in modeling but there is skill. And you can demonstrate that you learn things from using models of the real world that allow you to make decisions in the real world that actually work out more often than they don't. And people have no clue. That would be the one thing that I spend the most time telling people about, and every time I say something along those lines, it's like I'm saying it for the first time.

You are a passionate communicator of science, being a founding member of the RealClimate blog and an active user of Twitter. Do you think all scientists should take a more active role in public communication?

All scientists? No [laughs]. I run an institute, and we have about 150 people work for us. They're all different levels of people and all have very interesting things to say about stuff, but I look across them and maybe 10 would benefit from media training. And then I look at other people, and they should never be let in front of a camera. Communication is a craft and you can get better at it, but like many crafts there are some people that are completely talentless. To communicate, you have to put yourself in the position of the other person — what is it that they could hear that would make a difference? You can't just say what you want to say, because that's a disaster in terms of communication, you have to listen first then talk. So the idea that all scientists should be out there communicating — no.

But should there be a deeper bench, so that we don't have just Brian Cox and Bill Nye. It's not good when science is three people, science is a much deeper thing. These people are usually all guys, and they're often from the hard sciences. Yeah they're smart, but they're not representative of what science does, or is, or thinks about. And this is not to criticise Brian or Bill, but they're all of one type. Emily Shuckburgh [Bang! Essay Competition Judge] — she doesn't have the reach of Brian, she doesn't have her own TV show. And Neil Degrasse Tyson — he's breaking down some barriers in terms of the kinds of people that are doing these things, but they're a very homogeneous group of people in terms of worldview, in terms of experience, and science is a far more diverse place than that.

Interview by **Jack Cooper**
Photography by **Bruce Gilbert**

Air Conditioning

Can we engineer the Earth?

With the 2015 Paris Climate summit still fresh in our minds, there is greater public focus on slowing the effects of climate change by reducing the amount of greenhouse gases released into the atmosphere. Unfortunately, climate change talks are often negative and may seem unproductive, as discussion centres mostly on damage limitation. However, there are a group of scientists (including Oxford Professor Steve Rayner) who are trying to not only stop the effects of climate change, but to reverse them. Exploring the possibilities requires delving into the unusual world of geoengineering.

Geoengineering is defined by the Oxford English Dictionary as "the deliberate large-scale intervention in the Earth's climate system in order to moderate global warming." Previously only featuring in the realms of science fiction, the field of geoengineering is starting to be taken seriously, thanks in part to a landmark report by the Royal Society in 2009.

Many methods of geoengineering have been proposed, but they all fall into two basic categories:

1) Solar Radiation Management (SRM) – methods that block and reflect some of the Sun's light and heat back into space, cooling the planet.

2) Carbon Dioxide Removal (CDR) – methods that directly remove the greenhouse gas carbon dioxide (CO_2) from the atmosphere.

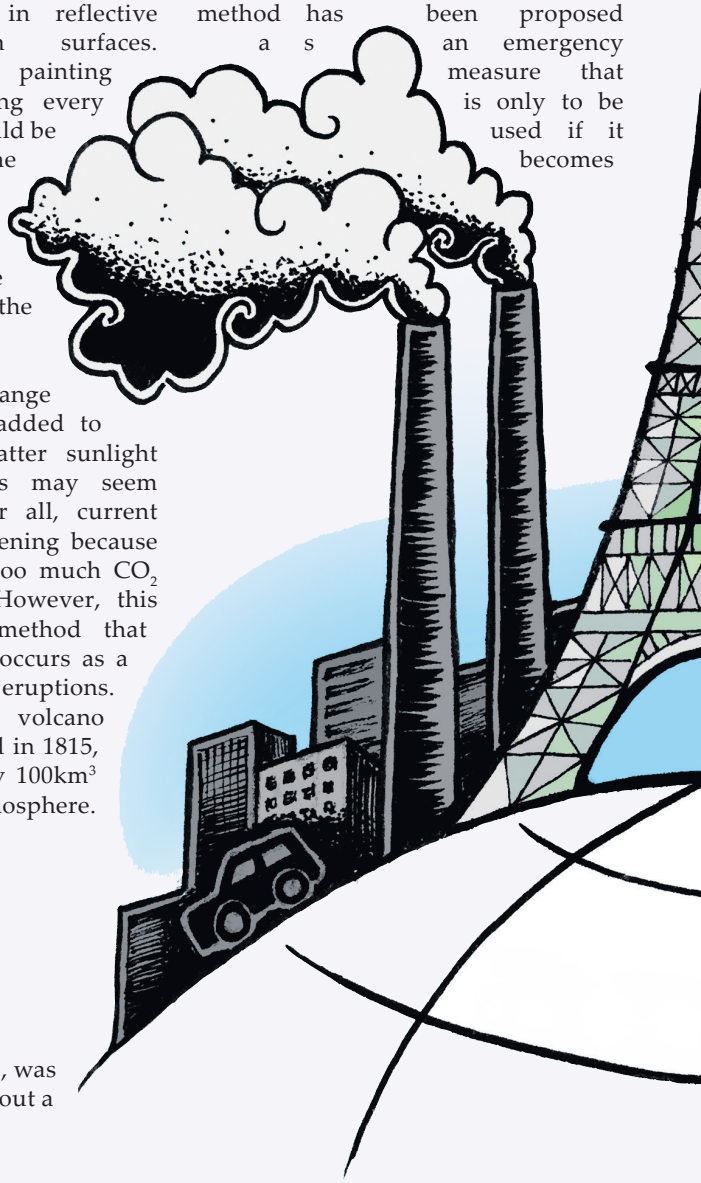
> "PREVIOUSLY ONLY FEATURING IN THE REALMS OF SCIENCE FICTION, THE FIELD OF GEOENGINEERING IS STARTING TO BE TAKEN SERIOUSLY."

SRM aims to increase the amount of light and heat from the Sun that is reflected away by the Earth. Reducing the amount of sunlight reaching the Earth's surface induces a cooling effect which balances the warming effect of greenhouse gases. The reflectiveness of a planet is called the 'albedo' and one type of SRM is designed to increase the albedo of Earth by brightening the planet's surface. This can be achieved by simply painting all rooftops in settlements white or by covering deserts in reflective polyethylene-aluminium surfaces. However, the cost of painting each house or covering every desert on the planet would be extremely high, and the resulting cooling effect would be relatively small since urban areas and deserts constitute only a small area of the Earth's surface.

> "THE COST OF PAINTING EACH HOUSE OR COVERING EVERY DESERT ON THE PLANET WOULD BE EXTREMELY HIGH."

Alternatively, a wide range of particles could be added to the atmosphere to scatter sunlight back into space. This may seem counterintuitive – after all, current climate change is happening because humans are pumping too much CO_2 into the atmosphere. However, this is a geoengineering method that is known to work – it occurs as a consequence of volcanic eruptions. When the Indonesian volcano Mount Tambora erupted in 1815, it ejected approximately 100km^3 of material into the atmosphere. The following year, 1816, was known as the 'Year Without a Summer' as the average global temperature dropped by approximately 0.7°C.

It is entirely feasible for a group of nations to pump an aerosol, such as sulphur dioxide, into the atmosphere today and induce a similar effect. However, this is an extremely risky strategy that could lead to too little sunlight and worldwide crop failure. As such, this method has been proposed as an emergency measure that is only to be used if it becomes



necessary to rapidly reduce the Earth's temperature.

The main issue with SRM is that it does not actually stop the greenhouse effect. Instead, it merely offsets it by altering an entirely different part of the Earth's system, i.e. the amount of sunlight reaching the surface. On the other hand, CDR actually removes CO_2 from the atmosphere, thus reducing the amount of heat that is trapped by the gas. After CO_2 has been removed from the atmosphere there are several places it can bestored such as the biosphere, the oceans, or inside the Earth itself.

Most of our energy comes from burning fossil fuels, which must be mined from underneath the Earth's surface. However, once all of the coal or oil is extracted, all that remains is an empty mine. The space left by the fossil fuels could be used as storage for liquid CO_2 that has been removed from the atmosphere. Although this is a satisfying solution, the logistical nightmare of cooling and pumping enough CO_2 underground, as well as the risk of future CO_2 leaks, makes it difficult to implement.

> "A SIMPLER OPTION WOULD BE TO MAKE USE OF THE BIOSPHERE: THE COLLECTION OF ALL LIVING THINGS"

A simpler option would be to make use of the biosphere: the collection of all living things on the planet. Plants in particular require CO_2 to photosynthesise - the greater the number of forests, the more CO_2 is taken in from the atmosphere. Planting more trees is a straightforward and safe method of geoengineering, but with the population set to grow to over nine billion by 2050, land will always be in demand to grow more crops or build more houses, leading to deforestation. There is also the option of growing genetically modified crops (GM) to take in more CO_2, but this is very much a work in progress.

> "THIS IS AN EXTREMELY RISKY STRATEGY THAT COULD LEAD TO TOO LITTLE SUNLIGHT"

By far the largest amount of CO_2 on Earth is stored in the oceans – about sixty times more than in the atmosphere. As a result, any method that could draw more CO_2 into the oceans would be extremely effective in tackling climate change. A potential option is iron fertilisation; iron is a vital nutrient for life in the oceans, and increasing its concentration could increase the growth rate of species, such as algae and plankton. By dumping iron into the ocean, the extra life will photosynthesise more, hence drawing more CO_2 out of the atmosphere. Again, this method is proven to work - small-scale experiments on ships in the Southern

Ocean have found a marked increase in oceanic life when iron is added to the surrounding water. However, disrupting ocean ecology in this way could impact heavily on some marine species. For example, massive algal blooms have been known to draw lots of oxygen from the water when they respire, suffocating fish and other sea life in the process.

A final possibility to consider is the acceleration of weathering. When rocks weather and break apart, they react with CO_2 to form carbonates, hence removing carbon from the atmosphere. This is an incredibly slow process, but if it were possible to speed it up, this would be the ultimate geoengineering method - removing CO_2 and tackling global warming with no harmful side effects.

Many of these ideas may seem far-fetched, but with time and research they could become a reality. Perhaps in fifty years from now we will live on a planet cooled by artificial clouds and superfast weathering, while GM crops turn our deserts green. It is thanks to the curiosity and inventiveness of humanity that we are experiencing global warming, but it may be those same traits that allow us to turn the tables and solve the problems we have created.

Reported by **Daniel de Wijze**
Art by **Michael Mackley**

Not In My Back Yard

Five Oxford start-ups combating climate change

Global energy consumption is expected to increase by more than 50% by 2040, but how can we mitigate the effects of this demand? Five companies, founded in Oxford with the support of Isis Innovation, are developing innovative ways to reduce the environmental impact of energy consumption.

1 First Light Fusion hopes the reaction that powers the sun could one day power your kettle. The company is working to make the dream of harnessing nuclear fusion, which could provide limitless clean energy, into a reality.

Their patented process uses hydrogen isotopes found in water. First Light Fusion deliberately introduces imperfections – bubbles and cavities – into the fuel. Whilst other attempts at fusion have aimed to avoid such instability, First Light Fusion is working to harness energy released when these cavities collapse, in order to initiate fusion.

Founded in 2011 by Professor Yiannis Ventikos and Dr Nicholas Walker, First Light Fusion raised £22.7 million in August 2015 to develop this relatively low-cost process.

2 Integrating jet-engine technology into the humble saucepan, Flare produces cooking pots that use 40% less heat than conventional pans, in the hope of cutting domestic energy consumption.

Normally, when using a gas hob, much heat is lost to the surrounding air. Professor Thomas Povey, an expert in heat transfer, designed a pan incorporating fins, which are also found in jet-engine cooling systems. The fins act as a heat exchanger, extracting more heat from the flame by driving it up the sides of the pan, which results in more efficient cooking. Povey received the 2014 Hawley Award from The Worshipful Company of Engineers for "the most outstanding Engineering Innovation that delivers demonstrable benefit to the environment."

> "INTEGRATING JET-ENGINE TECHNOLOGY INTO THE HUMBLE SAUCEPAN, FLARE PRODUCES COOKING POTS THAT USE 40% LESS HEAT THAN CONVENTIONAL PANS"

3 UK businesses waste £129 million per year just on energy, according to The Carbon Trust. Oxford start-up Pilio has helped hundreds of clients, including Whitbread, the YMCA, and the Royal Albert Hall, to understand and manage their energy consumption.

Developed at Oxford University's Environmental Change Institute, Pilio's software enables clients to visualise and identify patterns in their energy use. Importantly, Pilio pairs energy data with weather information.

CEO Catherine Bottrill explains: "Weather drives energy use, but it's often overlooked by managers because the data is difficult to access and analyse. Pilio has information from weather stations worldwide, so we can compare buildings in colder and warmer environments, fairly."

Pilio was named one of the "most exciting energy management companies to watch in 2015" by Verdantix.

4 Technology developed by Oxford PV may one day turn skyscrapers into vertical solar farms. The company is working on the production of thin, low-cost solar cells, which can be printed onto architectural glass.

Whilst conventional solar panels use rare earth metals and toxic materials, Oxford PV uses perovskite – an abundant and inexpensive mineral – to absorb solar energy and convert it into electricity.

The semi-transparent cells can also be printed onto other types of solar cell, including silicon panels, boosting their performance by up to 20%.

Co-founder Professor Henry Snaith was named as one of "ten people who mattered in 2013" by Nature magazine. Oxford PV has raised over £15 million to continue research and development of perovskite solar cells.

5 Exploiting the technology used to make re-writable DVDs, Bodle Technologies has developed a smart material that creates vivid displays using little power.

This new, cost-effective material could be used in smartphone screens. Since powering the display accounts for 90% of a smartphone's battery use, phones using the Bodle material would be much more energy-efficient than current models.

Developed by Dr Peiman Hosseini and Professor Harish Bhaskaran, the material can also be used in windows to block infrared rays, which could keep a building cool without air conditioning. Buildings with this 'smart glazing' could reduce their energy consumption by 20-40%. Similarly, the technology could be used in electric vehicles, to reduce battery drain caused by air conditioning.

Reported by **Katie Sissons**
Artwork by **Michael Mackley**

Brand New Hands

State of the art prosthetic limbs

Prosthetic limbs have been used for over 3,000 years, having progressed from wooden toes to being capable of responding to nerve impulses. But it is only in the last decade that technology has been sophisticated enough to allow prosthetic limbs to progress beyond being anything more than immobile stand-ins for their responsive natural counterparts.

Once, prosthetic hands were simply hooks attached to the arm by an unwieldy harness, but now, artificial hands have articulated fingers which are controlled by several tiny motors. These hands are even capable of complex manoeuvres beyond the realms of possibility for normal hands - think 360 degree wrist rotation with a wrench-like grip. However it is one thing to engineer a machine that can perform these movements, and another to actually control the movements.

For an artificial limb to be controlled by nerve impulses it must receive them from the ends of the muscles where the limb ends, and translate them into a specific movement. Researchers have programmed them to do this by instructing patients to visualise performing specified movements, and then mapping the impulses received. These impulses are then turned into a code that instructs the artificial limb. So far this has only been done for individual patients, and so isn't available to all prosthetic limb users. Hopefully if this is repeated on enough people, a common impulse pattern could be identified, but due to the differences in where people have lost limbs this could be very difficult.

Touch Bionics has even developed an app which can communicate with the company's artificial hands, allowing users to select movements for the artificial hand to perform. The field of bionic tech is increasingly exciting, with the future holding possibilities such as artificial limbs that provide sensory feedback, and even ones which could be directly and permanently attached to nerves.

> "THINK 360 DEGREE WRIST ROTATION WITH A WRENCH-LIKE GRIP."

Reported by **Liv Grant**
Art by **Michael Mackley and Daniel Murphy**

A Painless Future

Uncovering the secrets behind human pain...

Whether it's stubbing a toe on the foot of your bed or burning your finger on a boiling pan, we can all relate to a feeling of pain. Everybody would agree that pain is an unpleasant sensation, but beyond that it is subjective. Pain is unique, complex and cannot be measured. These factors mean that pain is not very well understood and is difficult to treat.

There are two different types of pain. Acute or short term pain (such as a pinprick) is not a major issue as once the stimulus causing the sensation is removed the pain also usually ceases. However, the second type, known as chronic or longstanding pain, is a considerable problem.

Chronic pain by definition is not transient and lasts for at least three months. For the duration of this time the pain can have large and detrimental consequences on many aspects of the sufferer's life, such as a decrease in their independence and problems sleeping.

In 2011 there were over 100 million sufferers of chronic pain in America alone, costing around $600 billion in medical treatments. Additionally, a recent survey has shown 1 in 5 people in Europe suffer from chronic pain. With the population growing and ageing this is likely to get even worse.

This inspired a team of scientists at UCL, led by Professor John Wood, to tackle the problem of pain head on. The first step was to try to uncover how humans actually feel pain. They began by considering the role of channels - proteins found in cell membranes that are often involved in signalling.

In 2006 it was shown that the sodium channel Nav1.7 is important for signalling in pain pathways. This is highlighted by the fact that people who are born without a functioning Nav1.7 do not feel pain.

The research team used transgenic mice (meaning they had been modified in order to carry the genetic information of other organisms) with the same mutation that prevents humans from feeling pain.

> "PEOPLE WHO ARE BORN WITHOUT A FUNCTIONING VERSION OF THIS PROTEIN DO NOT FEEL PAIN, "

A key breakthrough made by physiological experimentation on the mice was that the level of opioids (naturally occurring substances in the body which act on the nervous system) in the transgenic mice were around 12 times higher than in the unmodified mice from the same litter.

The next stage was to determine if the opioids were important in the desired recipe for painlessness.

The team gave naloxone, an opioid blocker, to the genetically modified mice and with the blocker they were able to feel pain.

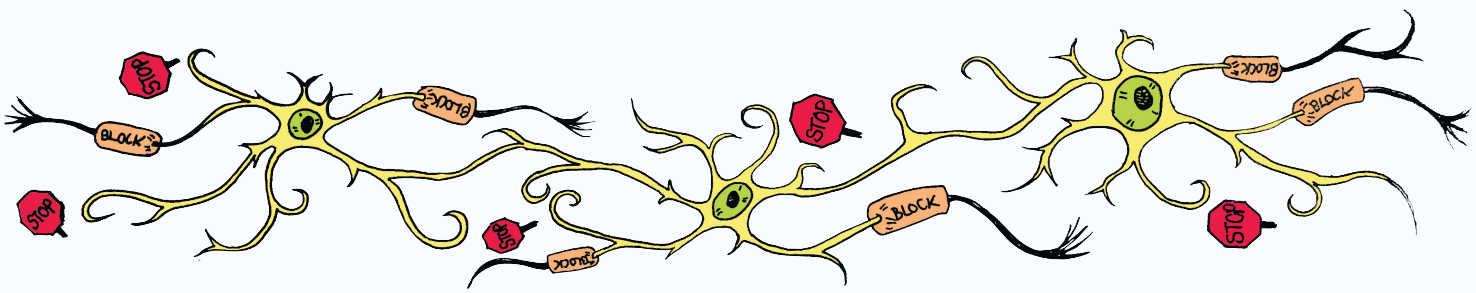
Remarkably, these results have been replicated in a human. A 39-year-old woman with a rare mutation meaning she could not feel pain was found to also have higher level of opioids. What's more, when given naloxone she reported feeling pain for the first time in her life.

Until now there has been little progress in the development of therapeutic agents despite the major problem of chronic pain. Usually the drugs used to prevent pain are anaesthetics which are broad-spectrum sodium channel blockers (meaning they don't differentiate between sodium channels, they just block them all). These drugs are not long term solutions to tackling pain as they cause complete numbness and can have major side effects. Furthermore, opioid painkillers such as morphine are very effective when used alone, but over long periods the body can become dependent on them and develop a tolerance.

The UCL scientists have overcome these obstacles and made significant advances in the development of a potential treatment. The drug is not only targeted to a specific channel (Nav1.7) rather than affecting all channels but also the level of opioid required in combination with specific Nav1.7 blockers is very low so eliminates the issue of tolerance.

The approach is hoped to be trialled in humans by 2017. If it is a success it will have a revolutionary impact upon the sufferers with chronic pain.

Reported by **Victoria Pike**
Art by **Evelyn Finnie**



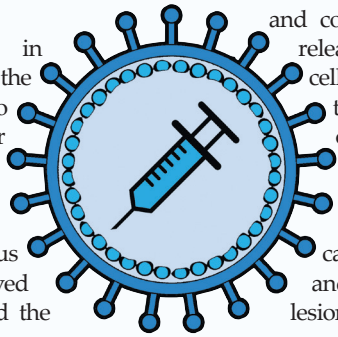
Fighting Sickness With Infection

Is virotherapy the future of cancer treatment?

Each year, more than 13,000 people are diagnosed with malignant melanoma in the UK. Melanoma is the most dangerous form of skin cancer, and its incidence has increased dramatically in recent years. If detected early, the chance of survival is very good; however, the prognosis of advanced melanoma is a 16% chance of survival over 5 years, lower than breast, ovarian, and prostate cancer.

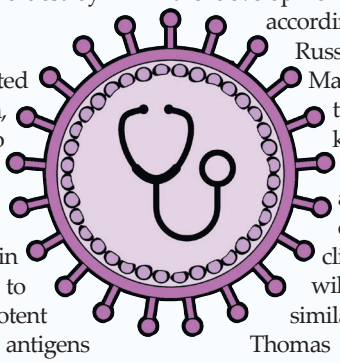
Treatment of advanced melanoma is complex, and commonly involves multiple therapies over the course of the disease, often with little overall benefit.

However, recent advances in immunotherapy - activating the patient's immune system to more effectively target cancer cells - have shown potential for improved treatment of all cancer types. Once such novel therapy is Imlygic, a cancer-fighting virus that has been newly approved for clinical use by the FDA and the European Commission.



Imlygic, or T-VEC, is the first approved oncolytic virus therapy, and uses a genetically modified strain of the Herpes Simplex virus (HSV-1) to target cancer cells in inoperable melanoma that has not spread to the brain, bone, lungs or gut. The wild-type HSV-1 is one of the most common pathogens to infect humans, and manifests clinically as cold sores. Despite its natural pathogenic tendencies, scientists have been able to harness the virus' ability to infect and kill human cells to use as anticancer treatments.

A number of viral genes are deleted or altered to reduce the virus' ability to evade the immune system, as well as to provide tumour-selective replication and enhance viral growth in cancer cells. A transgene coding for the protein GM-CSF is inserted into the genome; a combination of this protein and the presence of viral particles and tumour cell antigens enhances the immune response to recognise and destroy other cancer cells.



The viral treatment is injected directly into a melanoma lesion, where it selectively binds to molecules on the surface of tumour cells and enters the cell. It exploits the cell's energy stores and uses them to replicate within the cell. Ultimately this leads to cell lysis and death, and a potent mix of tumour-associated antigens and copies of the virus are released from the cancer cell. The viral progeny can then infect and destroy other cancer cells in subsequent waves, generating a long-term immune response that can target both primary and metastatic tumour lesions.

Imlygic can enter healthy cells, but once inside, the virus is not able to replicate and cause cell lysis. This targeted therapy has the advantage of having much less severe side effects compared to conventional therapy, such as chemotherapy, with the most common being flu-like symptoms of mild or moderate severity.

However, when tested clinically in a global Phase III trial, Imlygic produced mixed results. Nearly half of the 2116 tumours directly injected with Imlygic disappeared, together with 212 tumours that were not injected. In contrast to this positive outcome, the difference in overall survival rate between Imlygic treatment and the control was not statistically significant (a difference of 4.4 months).

Despite the modest improvement in survival rate, the approval of Imlygic for clinical use represents a 'huge milestone' in the development of cancer treatment, according to Dr Stephen Russell, researcher at the Mayo Clinic. It is the first time a therapy of this kind has shown success in a Phase III trial, and the introduction of Imlygic into a clinical environment will set the stage for similar future therapies. Thomas Zindrick, CEO of biotech company Genelux, predicted that 'Imlygic's availability as a solo therapy will give physicians time to get comfortable with engineered viruses – and that alone could boost the entire field of oncolytic virus development'.

A promising development in the story of Imlygic is its use with other immunotherapeutic agents. These combination therapies have already shown encouraging preliminary results, with greater overall response rates than each therapy used alone.

> "THE APPROVAL OF IMLYGIC FOR CLINICAL USE REPRESENTS A 'HUGE MILESTONE' IN THE DEVELOPMENT OF CANCER TREATMENT, "

Continued research and development is essential for this emerging field of immuno-oncology, but it is hoped that virotherapies will provide an alternative treatment option that will bring significant advances to patient survival. Hailed by Forbes as one of the 'milestones of 2015 in the war on cancer', the future of virotherapies looks bright.

Reported by **Laura Stokes**
Art by **Michael Mackley**

Crowdsourcing Consciousness

How the OpenWorm project is simulating the brain

"What can a microscopic, transparent worm teach us about neuroscience?" – a question that undoubtedly keeps many of us awake at night. The answer? Quite a lot, actually. For the past few years, an astonishing open science project has been underway aiming to produce a computational model of *Caenorhabditis elegans*, recruiting the expertise of biologists, engineers, computer scientists and mathematicians alike. With the long-term goal of entirely simulating *C. elegans* at a cellular level, this open access project brings neural circuitry into beautiful harmony with behaviour, and has exciting implications for the future of neuroscience.

These little worms contain far fewer neurons than higher organisms such as ourselves, making them ideal candidates for looking at complex neural processes on a much smaller scale; in addition to this, they all conveniently have exactly 302 neurons. These neurons have stereotyped connections and functions, with their cell bodies clustering in several ganglia, which has been incredibly useful in allowing the connectome of these organisms to be mapped out so well.

In terms of functioning, *C. elegans* are fairly simple – they move in what you might call a 'typical' worm way, wiggling in a wavelike manner, display food seeking behaviour, and have been shown to have the capability for learning. From just 302 measly neurons however, the diversity of behaviour that these creatures exhibit is remarkable – and the idea that we could possibly understand the neurological basis of such behaviours thoroughly is an ever so exciting prospect.

The OpenWorm project was born several years ago in the minds of a group of ambitious researchers who set about completely simulating this worm computationally, particularly its motor behaviour - from sensory detection through to motor response. In order to achieve this, they modelled neural activity with the help of the Hodgkin-Huxley equations, formulated after a series of beautifully elegant experiments all too familiar for the neuroscientists amongst you.

Back in the late 1930s and early 1940s, Hogkin and Huxley investigated action potentials in the giant axon of the squid. The large axon diameter made for easy measurements of membrane potential during neural activity, allowing formulation of equations that were based on the movement of sodium and potassium ions across the membrane, long before we had any understanding of ion channels. With these equations providing a reliable method of modelling the neural activity, the actual mechanical activity of these organisms was modelled using a smoothed-particle hydrodynamics algorithm that is able to simulate fluid flow.

> "FROM JUST 302 MEASLY NEURONS, THE DIVERSITY OF BEHAVIOUR THAT THESE CREATURES EXHIBIT IS REMARKABLE, "

This open science approach to such a task has allowed this project to be independent of academic and industrial politics and move into the public realm, recruiting minds from across the world in a very open and interactive manner. This fantastic initiative uses an online platform to bring together the contributions of many into an easily accessible space, allowing for scrutiny and improvement.

The ultimate aim of the project is to simulate every aspect of *C. elegans* behaviour. And in doing this, it is hoped that exciting new ways of simulating our own neural activity and behaviour will be developed. This has huge implications for areas of computational neuroscience such as artificial intelligence, where a more thorough understanding of how we can model neural activity to correlate with behaviour and learning can be applied to our own computational systems.

The best part? You too can get involved and learn plenty about this near-invisible worm both on your computer and mobile. The OpenWorm team have created an app and a website that allows you to play around with the virtual simulation and find out much more. Similarly, all the code they have developed is freely accessible to anybody with an Internet connection – they sure know how to please a science geek!

For more information, head over to browser.openworm.org and have a fiddle with their simulation.

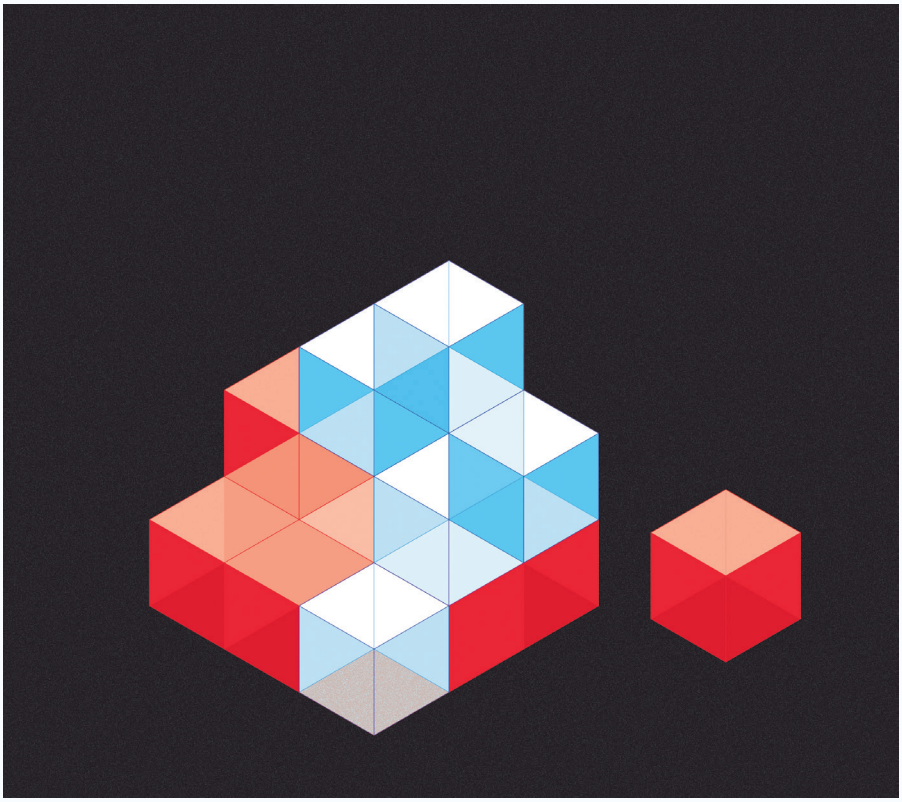
Reported by **Josh Newman**
Art by **Christina Rode**

Reaching the Stars

Is antimatter the rocket fuel of the future?

Planet Earth has a limited period of hospitability: the longevity of humanity is challenged in both the near and distant future. On a cosmic timescale the earth will be engulfed by our sun, but on the scale of millennia natural catastrophes like climate change are a very real threat to our species, making it all the more pressing to consider a future as a multi-planetary species. At this stage it seems little more than science fiction for humans to be considering interstellar exploration: our nearest star system is over four light years away so rockets – even with our most powerful chemical propulsion – would take tens of thousands of years to reach it.

Chemically propelled rockets have been used as the workhorses of space programmes so far, but their low energy output per unit mass makes them an inefficient choice of fuel for travelling further than the reaches of our sun. A generation of interstellar rockets should be propelled by a far more efficient source that harnesses, for instance, nuclear processes.



A more abstract proposition is that of 'solar sails' which involves sheets of solar panels and a complex of ultra-high power lasers to fire at the 'sail' and generate the electrical power for the rocket engine. Another idea is that of 'Nuclear Pulsed' rockets propelled by the shockwaves caused by ejecting a series of mini hydrogen bombs from the back of the rocket. In the 1950s it was calculated that such a ship could have a top cruising velocity of just less than ten percent of the speed of light. However, even at this speed it would take nearly a lifetime to reach our nearest star. The project was banned in 1963 when the Limited Test Ban treaty was signed and was also deemed too dangerous.

> "WHEN ANTIMATTER INTERACTS WITH REGULAR MATTER IT 'ANNIHILATES.'"

Using antimatter (predicted in the 1920s by British physicist Paul Dirac) as a fuel is a more attractive idea. For every particle of matter there is a twin antiparticle of antimatter of equal mass but opposing charge which can be formed in pairs with matter when there is an unstable amount of energy in a system. In this sense, antimatter is very much like normal matter, except that when antimatter interacts with regular matter it 'annihilates', releasing this monumental amount of energy.

An atomic bomb is only about one percent efficient, whereas an antimatter bomb would convert 100% of its mass into energy over a billion times greater than the energy released by the same mass of chemical rocket fuel. This makes antimatter a far more efficient store of energy and consequently a precious weight saver. It has been theorized that as little as four milligrams of anti-electrons would create enough energy to propel a rocket to Mars in a period of just a few weeks, significantly faster than the timescales predicted on current space programs.

However, it appears that antimatter will remain an unrealistic choice of rocket fuel in the near future as physicists have yet to master the technical difficulties of both producing and containing antimatter in our world constructed almost entirely of matter. Accelerators at CERN and Fermi Lab combined have only ever managed to manufacture a few hundred anti-atoms which would barely have the power to sustain a light bulb for a matter of minutes. Also, as antimatter annihilates upon contact with any containers made of matter, an antimatter rocket engine would have to keep ionised clouds of antimatter magnetically confined to prevent any contact with matter. But if we could develop a more efficient way of creating antimatter or even find pockets of antimatter in space that can be harvested, antimatter engines may still one day be our most powerful design for an intergalactic starship and could be our best hope for traversing the stars.

Reported by **Charlie Arrowsmith**
Art by **Eleanor Taylor**

Dr. Amy Farrah Fowler's PhD

The real scientist of *The Big Bang Theory*

Sorry to disappoint fans of *The Big Bang Theory* (*TBBT*), but rumours hint that Season 10 will be the E4 comedy's last season. Currently on its ninth season, *TBBT* has recently had its fair share of shockers, but what is probably most surprising is that one of the actors, Mayim Bialik, who plays neurobiologist Dr Amy Farrah Fowler, has a neuroscience doctorate herself.

Dr Mayim Bialik, to give her full academic title, rejected her offers from Harvard and Yale when applying for undergraduate studies, in favour of UCLA. With sun, Hollywood, and Beverly Hills, who can blame her? She then went on to research Prader-Willi syndrome for her doctoral degree, which she actually put in the miscellaneous section of her CV when she applied for her role in *TBBT*!

Submitted and approved in 2007, Bialik's PhD thesis was on 'Hypothalamic regulation in relation to maladaptive, obsessive-compulsive, affiliative, and satiety behaviors in Prader-Willi syndrome.' Prader-Willi syndrome (PWS) is an interesting condition as it sheds some light on how appetite is regulated by the brain and can have an epigenetic origin.

Like most syndromes, PWS refers to a constellation of symptoms. PWS is characterised by constantly feeling hungry, leading to compulsive and excessive eating. Usually, they start life growing slowly and they have delays in motor development, but then between the ages of one and six, they develop an enormous appetite, which grows to become extremely disruptive. Parents often have to find ways to hide their food by locking cupboards and refrigerators, otherwise the children become morbidly obese. Learning difficulties are also often associated with PWS along with temper tantrums and stubbornness – signs of compulsivity.

Bialik then became interested in looking at how the hypothalamus is part of the PWS story. On assessing the symptoms, she surmised that this may be a disorder affecting how the hypothalamus controls the stress response by promoting the release of the stress hormone cortisol. Long-term heightened cortisol is itself associated with increased impulsivity and appetite. Bialik looked at 21 PWS patients and compared their levels of oxytocin, vasopressin, and cortisol against 30 healthy controls. Alongside this, she gave all 51 participants quantitative assessments of compulsivity, problem behaviours, personality type and overeating.

She found that patients with PWS had significantly higher levels of oxytocin and vasopressin in comparison to healthy controls, with male patients having more oxytocin than female patients. In men with PWS, higher vasopressin levels were associated with lower maladaptive behaviours and lower incidences of overeating. In women with PWS, higher levels of cortisol were linked to problematic behaviours. Furthermore, the more oxytocin the female patients had, the more likely they were to show obsessive-compulsive behaviours and nurturing behaviours.

So what does this all mean? What Bialik concluded is that the data supports the idea that PWS involves a dysfunction in hypothalamic activity and that more research is needed. Nobel Prize for you there, Mayim… Bazinga!

Teasing apart and interpreting the relative contributions of each hormone to the behaviours we see in PWS is a lot more difficult, especially when we take into account that PWS is a syndrome; PWS patients will have different genetic lesions, others will even have epigenetic mutations. What complicates the story even more is that oxytocin and vasopressin have a myriad of other functions - including regulating social behaviours and urine production - that could be creating artefacts in her data.

How the various genes in the PWS locus regulate behaviour via gene regulation mechanisms is still yet to be understood, but Bialik's thesis begins to understand how hormones could regulate the behaviour we see in PWS – an exciting field indeed as molecular biology learns more about how genetic and epigenetic lesions in turn can affect hormonal release. I certainly look forward to the field's progress, despite Bialik's absence in the scientific community, and I also certainly look forward to Season 10 of *The Big Bang Theory*!

Reported by **Marco Narajos**
Art by **Evelyn Finnie**

Pascal found order in a game of dice.

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