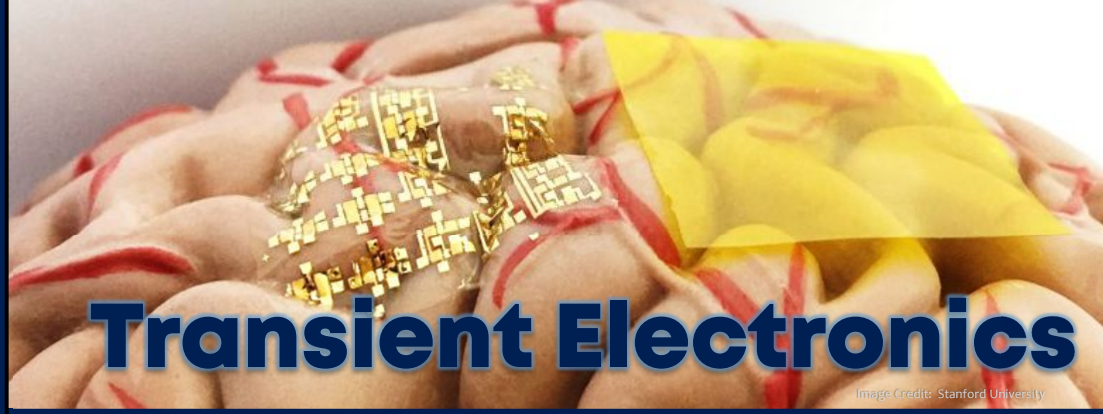


# Transient Electronics

Image Credits: Stanford University

Electronics have always been built to last. However, a new idea of dissolving ultra-thin electronics changes the emphasis. These electronics, mainly made of magnesium, silk and silicon, are built to dissolve in contact with water. The speed at which they dissolve can be changed, lasting days, weeks or years. The immediate benefits are to implants in the body, but also could be developed into more environmentally friendly technology.

***Reporting by: Laura Fraise, Joseph Holland, Joanna Powell, Jonathan Spencer & Jack Wadey***

To build a dissolvable circuit there are several components which need adapting. All the materials need to dissolve in water. The circuit board, which holds the wires and components, is made of silk. The silk is used to control the dissolving speed, by using different protein crystals size. The silk takes the longest time to dissolve, however as a protein the body can break it down naturally.

The wires connecting silicon components and forming inductors and resistors are made from magnesium. Magnesium is a metal and a good conductor. It dissolves in water quickly and safely. Silicon forms electronic transistors and diodes which control when electricity can flow. The amount of silicon used is tiny, about 1 microgram. Such small thin amounts can dissolve easily. The dissolvable silicon is as versatile as conventional silicon.

Power is provided by a coil tuned to a nearby magnetic field. This is the same technology used to power oyster cards. This avoids batteries which are difficult to make dissolvable and safe.
So far, scientists have managed to construct a variety of electronic components, such as resistors that can act as sensors of heat and light, using materials that would break down inside the body.

These components were used to construct various devices, including one capable of taking photos. Several example devices were implanted under the skin of mice, to examine the effects of the technology in living organisms. After three weeks, there was almost no trace of the implants left, and the mice showed no significant adverse reactions.

Transient electronic systems offer promising opportunities for the future of medicine. They could be used for many monitoring techniques within the body, include body temperature, pH, electrophysiology or muscle tissue activity. This could provide freedom for individuals who currently require regular appointments or invasive procedures for such monitoring.

Dissolvable electronics provide an alternative approach to treating infections beyond the traditional use of antibiotics, which bacteria are building resistance to. They could also be used for targeted or slow release drug delivery as well as thermal therapy to prevent post-surgery infection by heating the wound;. This technique has already been demonstrated in rats where it increased the localised temperature its body by 5 °C. Medical diagnosis is also a key area for development.
Outside the medical sector there are a few other potential uses. They could be extremely useful in monitoring the environment, such as tracking chemical spills and hazardous pollutants without the need to collect the equipment. Consumer electronics could incorporate dissolving circuits which would reduce electronic waste.

Future development in this technology could mean that the electronics could dissolve under different conditions such as changes in heat, pH or radiation, whereas currently only moisture determines the start of the dissolution. Further technological improvements mean that the circuit boards can be made even smaller. The main issue for pursuing this technology is manufacturing the electronics at high volume, low costs and high levels of function. Δ

# Polluting our Waistlines

**Increasing exposure to air pollution and rising levels of obesity are major challenges facing humans in the modern world. But could air pollution could be contributing to rising obesity levels**

*Reporting by: Eddie Higgins, Sophie Jenkins, Louis Pentecost, Georgina Renton, Jack Reynolds & Reece Tilley*

Image Credit: Verdict.co.uk

More than 80% of the world's urban population is exposed to air pollution which exceeds the World Health Organization's (WHO) limit. Rapid population growth and industrial development, combined with reliance on fossil fuels for power generation, have created unprecedented global pollution levels. Meanwhile, the level of obesity in developed countries is alarmingly high, with 1 in 6 children now classed as overweight or obese.

A recent study found that children exposed to high levels of air pollution had a 13.6% greater annual BMI (Body Mass Index) increase, compared to children living with low air pollution levels. There is growing evidence to suggest the two issues are intrinsically linked and that increased exposure to air pollution could be fueling the global obesity epidemic.

PM2.5 are a class of particulates with an airborne diameter of less than 2.5 micrometers. They pertain to a wide variety of chemical constituents and arise from combustion sources such as a vehicular exhaust. These small yet destructive particles could be a major driving force behind rising obesity levels. PM2.5 increase the likelihood of respiratory disease and insulin resistance. These health issues can lead to weight gain and rising levels of obesity within a population.

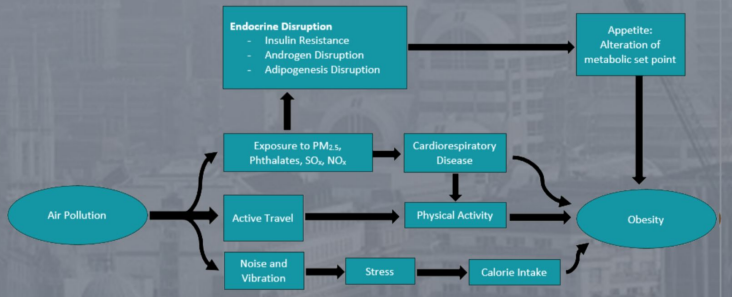
For example, sulphur dioxide and nitrous oxide are both emitted through vehicular combustion and are precursors to sulphate and nitrate particulates (components of PM2.5). Prolonged exposure can cause respiratory difficulties such as asthma. People suffering from asthma often find that exercise can provoke their symptoms, thus are less likely to participate in physical activity. Subsequent weight gain can follow and contribute to the obesity crisis.

PM2.5 also influences body mass in other ways. In a controlled study, young mice exposed to PM2.5 gained significantly higher levels of fat tissue compared to those exposed to filtered air. It is suggested that in early childhood development, certain metabolic pathways can be disrupted by PM2.5, which cause insulin resistance. This is known to exacerbate weight gain by raising blood sugar levels, therefore increasing appetite. Given the observed impact of fine particulate matter on mice, it is highly plausible that a similar mechanism exists in humans. This could be a significant factor contributing to the elevated levels of obesity in heavily polluted areas.

Air pollution is also linked to obesity through the interaction of phthalates. Phthalates found in construction materials such as pipes and wire coating can easily leach into the environment and become an air pollutant. Inhalation of phthalates can reduce the activity of a hormone responsible for growth and development (androgen) which can lead to obesity. There is also evidence that phthalates may inhibit the differentiation of fat cells. However, some uncertainty surrounds this inhibitory processes, as studies did find a disparity in results between sexes.

To fill these gaps in our understanding, more research is needed to investigate the role of phthalates in rising levels of obesity. Studies conducted on prenatal exposure to air pollution and its link to childhood obesity focus on polycyclic aromatic hydrocarbons (PAHs) which are major environmental air pollutants. Findings show that children of women with greater prenatal exposure to PAHs exhibit a greater relative risk of obesity at ages 5 and 7 compared to children of mothers with lower exposure levels. Cell culture experiments showed that exposure to certain PAH's cause inhibition of lipolysis (breakdown of fats). This causes fats to accumulate in the body, potentially leading to obesity.

Weight gain can be directly triggered through metabolic and chronic disease pathways, but can also be as a result of intrinsic social and psychological factors. For example, high levels of smog reduce active travel and discourage people from going outside to exercise, leading to potential weight gain. Increased noise and vibration resulting from high volumes of traffic and associated pollution can increase stress raising calorie intake and again leading to weight gain. Both examples emphasise that the pathway from air pollution to weight gain is complex and can be influenced by behavior and psychological patterns.




Making connections: A flowchart illustrating the different pathways from air pollution to obesity

The extent to which air pollution is responsible for weight gain in populations globally is uncertain. While some studies have found strong associations between air pollution and obesity, others remain more skeptical. Factors such as diet and socio-economic background compound the association. We need to further explore the applicability of underlying biomedical mechanisms (studied in rodent models) to humans. Findings suggest a significant link between air pollution and obesity which merits further research. According to the WHO in Europe obesity is responsible for 2-8% of health costs and 10-13% of deaths. Air pollution and the consequential enhanced greenhouse effect is already recognized as a driver of climate change, terrestrial and marine destruction. The growing link between air pollution and obesity puts further pressure behind the movement to combat current levels of air pollution - for the sake of our planet, our health and our waistlines. Δ

# Creating the Perfect World

The human race has always strived for perfection, whether that be in the diseases we can cure, the food we eat, or the way we look. Our ability to change the aspects of life that we 'don't like' has improved exponentially, thanks to breakthroughs in gene-editing and manipulation. So that 'perfect world' we long to live in may become a reality, even in your lifetime.

*Reporting by: Anisha Chana, Martin Cull, Hayley Gilbert, Julian Owen & Nathan Richardson*

Image Credit: Antimicrobial Resistance Learning Site

For hundreds of years, genetic modification has been part of society. Early attempts came in the form of selective breeding, whether it be to change the colour of carrots or to produce digestible maize plants. Since then, the focus of GM has shifted to altering organisms at the microscopic level, with the development of several single-gene editing techniques. One of these, CRISPR-Cas9 is taking the scientific community by storm thanks to its high precision, low costs and potentially world-changing implications. But what is it, and what does it mean for the future of both our species and of those around us?

Genetic information of all living things is encoded in genomes, which can be thought of as the libraries of life, each containing knowledge about a particular organism. Within these libraries, chromosomes are books consisting of DNA pages made up of genes which are the words strung together on each page. Scientists use the CRISPR-Cas9 system to carefully edit these genetic words, allowing us to rewrite life itself.

CRISPR is a family of DNA sequences found in the DNA of prokaryotic organisms following an attack from an invading virus. The sequences are fragments from the DNA of the virus that have integrated into the hosts DNA. CRISPR associated (Cas) enzymes copy these DNA segments to help to identify and destroy DNA from similar viruses in the future, acting like a pair of molecular scissors and cutting them out of the genome with precision.

In the CRISPR-Cas9 gene editing system, Cas9 enzyme is used with a strand of guide RNA (gRNA) to form a Cas9 complex, which is introduced into a cell. Once inside the cell the gRNA acts as a navigation system for the complex, guiding it through the vast genetic library to the specific target DNA strand. The complex latches on at the target site and the gRNA unwinds the part of the DNA helix it matches. The Cas9 enzyme then slices both strands, allowing the desired genes to be cut out. The cell's own repair mechanism mends the DNA by inserting a replacement segment into the now vacant space.

This system allows us to effortlessly cut unwanted words out of a cell's DNA pages, and even replace them with our own. Scientists believe this will provide the means to combat genetic disorders like Huntington's disease and muscular dystrophy by replacing existing segments of DNA, or editing even just a single defective letter within it.

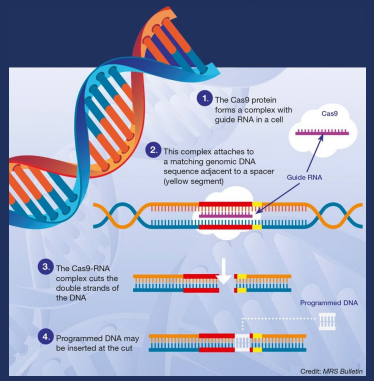
But CRISPR-Cas9 isn't limited to *our* genes... In the modern world one of the greatest threats to human life comes from infectious diseases, such as malaria. In 2017 there were 435,000 malaria deaths reported by the World Health Organisation. Those worst affected are in sub-Saharan African countries where poverty, overpopulation and insufficient infrastructure mean existing strategies for fighting the disease are difficult to implement effectively. However, this may soon change thanks to a promising concept known as the CRISPR-Cas9 gene drive.

Gene drive is a method of making a gene more favourable during sexual reproduction, causing it to become more propagatable through a large population. In the CRISPR-Cas9 gene drive, the Cas9 complex is accompanied by a sequence containing the desired gene, which is copied into the organism's DNA during the post-cut repair. This edited gene has an increased chance of being passed onto offspring, and this increase grows larger in each generation spreading the desired alteration through the population quickly. Ethan Bier and Valentino Gantz, have been working on such a drive using fruit flies and have been surprised at how effective the method is. Bier says: "I figured this was beautiful on paper, but the odds of it really happening were pretty long". But as it turns out, said Gantz, "it worked first time".

There are two ways this could be implemented to reduce the spread of malaria. The first is to make mosquitoes immune to the malaria parasite so they would be unable to pass it on to the people they bite. Unfortunately, mosquitoes would gradually become resistant to it, which would limit its long-term benefit. The second way is more drastic. It involves either making the reproductive cycle of mosquitoes favour male offspring (who don't bite so cannot transmit malaria), or introducing genes that make females infertile. Both options would limit transmission of malaria, potentially saving thousands of lives. However, either approach comes with ethical concerns as no one can be sure of the ecological implications of culling a species in such great numbers. Although mosquitos have no natural predators, eradicating them could destabilise ecosystems which could lead to a cascade of wider impacts through the system.

We're on the brink of a golden age in genetic modification, where breakthrough technologies like CRISPR-Cas9 pave the way for an era of major development. In the not-so-distant future, genetic defects may be erasable with a simple treatment, and diseases like cancer and AIDS could just be words in history books. But sadly the story may not be so sweet. Once we set off on the journey of genetically modifying our species, there may be no turning back. In the future, will it become unethical to not cure a person of an affliction if we have the means to? And if we can edit our genes to cure diseases, why not edit them to also improve our vision, fitness, metabolism? We run the risk of creating a society in which we will be defined by the quality of our genome, ostracising those who aren't 'perfect'.

Moreover, the ability to manipulate the genes presents an issue of who should be responsible for such a powerful technology. Who gets the power the rewrite the life, or cause the death, with a snap of the fingers? Our craving to change the things that hinder us is what underpins our evolution as a species, but without care in the future it may also be our undoing. Δ




## How CRISPR works

1. Cas9 enzyme forms a complex with guide RNA in the cell
2. Navigates to target DNA
3. Unravels DNA and binds to matching section creating guide
4. Enzyme cuts DNA based on guide
5. DNA repairs cut section or replacement DNA inserted into cut section

Image Credit: MRS Bulletin

# "I'm never drinking again..."

Image Credit: Metro

Drinking plenty of water and eating a greasy fry-up are commonly executed recovery tactics following a big night, but could looking at the biochemistry of alcohol in the body could be key to discovering better tactics.

***Reporting by Phoebe Ellis, Emma Guest, Lucy Hubbard, Zara Mohammed & Anna Robson***

Our bodies are unable to store alcohol, so after absorption into the bloodstream it is transported to the liver for metabolization. Here, it undergoes a two-stage oxidation, firstly into acetaldehyde and then acetate which can be expelled. It is thought that acetaldehyde, the partial oxidation product, is the main cause of a hangover due to its high toxicity – around 10-30 times higher than alcohol itself. It is usually quickly cleared when the secondary oxidation stage oxidises it into nontoxic acetate, catalysed by aldehyde dehydrogenase and glutathione.

However, with high concentrations of alcohol consumption, glutathione cannot be produced as quickly as it is used, and the process slows, causing a build-up of acetaldehyde. This causes the headache, vomiting, stomach pains and fatigue characteristic of a hangover. Furthermore, chemicals called congeners are produced when alcohol is fermented and are broken down into toxic formaldehyde when ingested, also contributing to vomiting and nausea.

Other symptoms of a hangover can be attributed to the rebound of glutamine, the brain's natural stimulant. This occurs as an after effect of alcohol's presence in the body. Alcohols depressive nature causes suppression of glutamine release, which then causes a compensatory increase when consumption ceases. The stimulant overload prevents the deepest sleep stages occurring when you finally get home, causing fatigue. Raised blood pressure, anxiety and restlessness often reported after drinking can also be attributed to the increase in the stimulant the next day.

Many people are quick to blame dehydration for the symptoms of a hangover. Alcohol is a diuretic which increases the production of urine by inhibiting secretion of vasopressin, an antidiuretic hormone, and causing the kidneys to release water rather than reabsorbing it. This leads to dehydration as well as electrolytic imbalances, instigating fatigue, nausea and headaches which closely coincide with hangover symptoms.

However, closer research on the correlation between level of dehydration and the severity of a hangover suggests that hangovers and dehydration are independent but co-occurring processes. Instead, research is now looking towards changes in immune system parameters including increased concentrations of pro-inflammatory cytokine [IL-12] and interferon-gamma [IFNγ]. These act upon the hippocampus (memory consolidation centre) and other cognitive brain areas to induce sickness and memory loss, as being a more likely cause than dehydration.

The rate of acetaldehyde breakdown varies by person, so genetics could explain why your friend looks and feels great the next day while you feel like you've been hit by a bus. A genetic mutation has been found in the gene encoding alcohol dehydrogenase which makes it more efficient, thus facilitating faster conversion of alcohol to acetaldehyde. This usually co-occurs with a second mutation in the gene encoding aldehyde dehydrogenase, which conversely decreases the rate of its reactions for acetaldehyde clearance. Therefore, a heightened build-up of acetaldehyde causes heightened hangover symptoms. These genetic mutations are often found in people of East Asian origin, although can also be found in other populations.

Waking up with a dry mouth, a pounding headache, and a faded memory of the night before, swearing never to end up here again. Sound familiar? But whether it's spirits, wine or beer that's landed you here, why is it so hard to stick to that resolve? Once your head has cleared and your strength has returned, inevitably your willpower starts to waver and you find yourself accepting an after work invitation to the pub, reaching for a glass on a Saturday night, or planning the next big club night. So why don't we learn?!

The crossover between biochemistry and psychology provides the answer to this question. Alcohol categorizes as a drug of abuse due to its actions on the brain's reward circuit – the mesolimbic pathway – giving potential to elicit addictive behaviour. It interacts with the GABAA receptor complex and potentially also dopamine and opioid peptides in this pathway, leading to pleasurable effects. The biochemical reward facilitates psychological learning mechanisms to take place which explain our tendency to drink again.

The simplest form of learning – Pavlovian conditioning – would predict that a repeated negative consequence would result in the action not being repeated. However, drinking seems to be exempt from this classical learning curve. Instead, learning follows an operant curve, whereby the mesolimbic activation acts as immediate reinforcement to drinking, and because there is a delay before the punishment (hangover) occurs the negative outcome is less likely to become associated neuronally with the behaviour. This resistance to developing an aversion was demonstrated in a study which surveyed 500 students on their drinking habits over the previous year. 14 common positive outcomes and 35 common negative outcomes were identified, however, students rated the positives as more likely to happen in the future, showing closer association of reinforcement to the behaviour than the punishment. This operant framework is also affected by other factors, including social pressures, impulsivity, boredom, normalization and many more, which all affect how reinforcing the outcome is, and how tightly it is associated with the behaviour of drinking in comparison to the punishment.

So, there isn't a magic cure for preventing or curing the killer hangover, and due to our psychological learning mechanisms mean we're likely to continue to experience its affects. But, by taking into account alcohol's biochemical interactions, we can understand the pathways it disrupts and can design methods to lessen the severity. Making use of good behaviours to prepare for a night out and lessen the impacts of alcohol on our system by reducing the build-up of toxic acetaldehyde and formaldehyde, reducing dehydration, preventing stomach irritation, and recovering from glutamine rebound will ensure the morning after feels not quite so life-threatening after all! Δ

## Kill or Cure

### Do

**Eat up! -** Lining your stomach with fats reduces the rate of alcohol absorption and reduces the build-up of toxic acetaldehyde

**Rehydration Station!** - As a diuretic dehydration will co-occur with symptoms directly caused by alcohol to make you feel worse. Drink plenty of water and isotonic drinks to combat dehydration.

**Recovery Food—**Amino acid rich foods, such as eggs, help break down formaldehyde, and potassium rich foods, including bananas, can help to restore electrolyte levels

**Light = alright—**Darker drinks have higher levels of congeners which breakdown into formaldehyde making your hangover worse.

**Catch some Zzzzzz—**Glutamine rebound prevents deep stage sleep which causes fatigue, extra sleep will allow the body to recover

### Don't

**Hair of the Dog**— drinking again purely postpones your hangover

**Caffeine**—Because caffeine causes narrowing of blood vessels it can worsen headaches and as a diuretic it will worsen dehydration.

**Fizzy drinks**—Fizzy drinks contain high levels of carbon dioxide which speeds up alcohol absorption which increases the build-up of acetaldehyde so avoid fizzy drinks or fizzy mixers.

**Getting drunken shots—**Shots will spike your blood alcohol and lead to more acetaldehyde build-up.

# The Problem with Plastic

## How what we see is just the tip of the iceberg

Image Credit: KinYu-Z.Net

*Reporting by Samuel Aird, Bonni Jee, Stephen Marr, John Rutt, Andreas Singarajah & Hannah Wilding*

Plastics in the ocean are killing wildlife and increasing the risk of extinction for at risk species such as sea turtles, whales and seabirds. Greenpeace reported in 2006 that more than 250 species have suffered from entanglement or ingestion of marine debris and recent research out of the University of Plymouth finds this is just this tip of the iceberg discovering nearly 700 species encounter and are threatened by marine debris on a daily basis.

Plastic is not biodegradable, but it is photodegradable, meaning it can be broken down by UV rays. Research has found that in warm ocean water plastic can degrade within a year and the by-products of this degradation; tiny pieces of plastic called microplastics and toxic chemicals, such as such as bisphenol A (BPA) and PS oligomer, can then infiltrate the food chain.

These materials impact hormonal function in animals which in turn has a negative effect on reproduction and have also been found to affect the health of organisms by influencing feeding behaviour. There can also be direct toxicity from the absorption of lead, cadmium, and mercury (from other pollution sources) into the plastic debris, which could cause cancer, birth defects and immune system dysfunction.

The dangers of plastics in the ocean are not restricted to direct impact on species that encounter it but also present a risk to those who rely on those species including humans. Toxins ingested directly by smaller organisms accumulate as they move through the food chain. And it's not just fish. In 2015, the presence of microplastics in sea salt was proven. Think of that the next time you're putting salt on your chips...

Each year, around 8 million tonnes of plastic waste enters the oceans. To clear this up is an enormous task. Most of the plastic remains near the coastline and is very dispersed making it difficult to collect. However, some is taken by ocean currents and collects in great masses across the world.

The largest of these plastic eddies is the Great Pacific Garbage Patch. Between California and Hawaii, around 4,500 to 129,000 tonnes of plastic swirls around an area roughly seven times the size of the UK. Due to the high density of waste in a relatively concentrated area, it is possible to attempt a manual removal of the plastic by scooping.

This year, a device known as System 001, invented by Boyan Slat, is being trialled. It is 600 metres long and is pulled along by boat to gather up this garbage. Its net will collect 92% of the plastic with the remaining 8% being microplastics - too small to collect. However, this method will only work for large amalgamations of trash; most plastic waste in oceans is too spread out. In addition to this there is the challenge of what can be done to dispose of the plastic once it is collected?

One avenue that has been explored is the use of microbes. Plastics are made up mainly of carbon. Microbes break down the plastics to release this carbon, along with energy, which they can then use to survive. Polyethylene has already been found to be degraded by bacteria from the *Staphylococcus*, *Pseudomonas*, and *Bacillus* species. PET and polystyrene have also been broken down. This presents a possible solution to the pollution problem. However, as it stands, the rate at which plastic enters the seas greatly exceeds the rate at which it can be removed. Until we reduce the garbage influx, anything that we take out will be just a drop in the ocean.

Plastics are cheap, easy to manufacture, and durable. While actively reducing the volume of plastics thrown out each year is vital, another thing to take into consideration is the nature of the plastics themselves. You can modify a plastic's properties by changing the conditions of the manufacturing process or the plastic's chemical building blocks or monomers. One example of this is bioplastics.

Bioplastics are plastics either made from a renewable resource or those which are biodegradable. One such bioplastic is polylactic acid (PLA), which is derived from natural products such as corn starch and sugarcane. PLA retains the versatility of its petrochemical cousins such as polypropylene (PP) and polyethylene (PE) and can even be manufactured in the same production plants as conventional plastics, keeping down costs.

However, there are still many problems associated with the use of these bioplastics. Bioplastics cannot be recycled as easily as conventional plastics. PLA looks similar to PE so when mixed in a recycle bin, they become difficult to separate and recycle, undermining our existing efforts to recycle plastics. Furthermore, when a material is described as being 'biodegradable' is means it can be eventually broken down but this can still take many decades. And in marine environments, water tends to impede the degradation, meaning retention times for many bioplastics in the world's oceans would be much longer. Also there is an ethical question about using land to grow crops for bioplastics at a time of food insecurity in the developing world. Bioplastics also feed into the 'disposable' mentality which forms part of the current problem

The true solution is for us to reduce our impact in the first place. It's almost impossible to live a plastic free life currently, so what we use we must recycle. This conserves raw materials, saves energy and allows the materials to have a second life. But plastic is one of the more difficult materials to run schemes to recycle, with 7 different types and only 3 of them 'widely recycled', there is confusion among the public about what can and can't be recycled. Contamination of recycling by food and inclusion of non-recyclable materials leads to rejection and landfill of recycling which means even those trying to do the right thing are unknowingly contributing to the problem.

Additionally we now face the problem of what to do with the plastic collected for recycling as China who took 7.3 million tonnes of plastic waste have now introduced a ban on all plastic imports leaving the UK scratching its head about how to deal with collected waste. It is still early days but ideas are starting to emerge with one company finding a way to use plastic as a bitumen alternative in for building roads.

The Government also has a role to play by continuing to push through policies which aim to curb the problem. The carrier bag charge has been highly successful since its introduction in 2014, a policy to ban microbeads was approved last year and there are further policies in the pipeline taking aim at disposable coffee cups, plastic straws, cotton buds and coffee stirrers. These are all steps in the right direction, but is it enough?

Many of our European counterparts make use of bottle-deposit schemes on plastic bottles which have resulted in high recycling rates are high and very little public litter. There has also been very slow uptake across the retail and food sector for reducing the amount of packaging on products and zero-waste stores. These are areas the Government could intervene in to force change. At the end of the day it is up to the people to make the right choices, shun disposables and choose products with less or no packaging but the Government need to ensure they have the infrastructure to do this. Δ

# AI can read your mind

Around the world, scientific institutes are racing to be the first to develop artificially intelligent algorithms that can access our thoughts. This idea is not new; mind reading has been a prevalent theme in sci-fi since the 1960s. Now, with the explosion in artificial intelligence (AI) technology in the last 10 years, reality is finally catching up with fiction.

***Reporting by Jonathan Austin, Megan Groom, Bethany Husband, Zachary Peggs & Elysia Pughe***

This year alone, AI experts in China, Japan and the US have published research, showing that computers now have the ability to reconstruct images and thoughts with the use of functional magnetic resonance imaging (fMRI) machines. fMRI produces images of blood flow to the brain to detect areas of activity. More oxygen is consumed by parts of the brain which are active, and so the fMRI can detect deep neural functions through oxygenation changes in the blood.

So far, most research has been aimed at teaching AI to decipherer images that a subject is looking at, based on shapes or letters the AI has been taught to recognise when viewed through a subject's mind. This year, however, research from Japan's ATR Computational Neuroscience Laboratories and Kyoto University has taken this further, showing that the AI is able to decode and represent images it had not been previously trained to recognise. The practical applications of this research has the potential to greatly benefit humanity.

Brain scanning technology can be used to detect consciousness in patients considered to be in a vegetative and disconnected state. Currently, clinical assessments rely on testing eye movement and reaction to stimuli such as sounds, pain and touch. These tests rely on physical, rather than neural, feedback so cannot confirm whether a patient is truly brain dead. An estimated 24,000 patients in England are in a permanent vegetative state or are minimally conscious. Using AI to interpret fMRI images, new methods are being developed to transform the way we interact with these patients .

Neuroscientist Adrian Owen began research in this field when a past lover fell into a vegetative state following a brain haemorrhage. Working with patients who made occasional involuntary movements, but did not respond to external stimuli. He began by showing them family photos and found their brains lit up, indicating that people in a vegetative state could have cognitive function. But this test alone cannot confirm consciousness as facial recognition is an automatic neural response.

In the next stage patient were asked to imagine playing tennis, an activity that would activate the brain's premotor cortex. Using fMRI, it was possible to see activity in this part of the brain and when asked to stop imagining, this activity stopped. This was the first time anyone had demonstrated consciousness in someone in a vegetative state, and it could have dramatic consequences for the future treatment of patients.

Brain scan technology has applications for people with other brain abnormalities too. For example, for prosopagnosia, a neurological disorder that inhibits facial recognition, AI has been able to reconstruct faces that sufferers had previously seen by deciphering their brain scans. It seems that the information is inside the brain, even if the person themselves can't consciously access it. This new information means that technology can be developed which will completely change the lives of people with these disorders.

Most people don't remember their dreams, despite the fact that we dream every time we sleep. But new research may bring an end to the age of dreamland amnesia; Japan's Advanced Telecommunications Research Institute has shown it may be possible to read someone's mind while they are asleep. Although still in its early stages, it is possible to train an AI to describe basic details of a dream. This opens up the possibility for you to watch movie-style highlights of your forgotten dreams.

More serious applications include accessing memories for court cases. Eyewitness testimonies could be replaced by 'brain witness testimonies'. With artificial intelligence able to accurately interpret our thoughts, witnesses could be made indefensible to interrogation. However, given the consequences of court cases compared to a controlled research project; a serious analysis of the weight and reliability of brain imaging would be required. For example, psychopaths are pathological liars and so lying does not affect their brain in the same way, making 'lie detection' potentially inaccurate.

Large technology companies have turned their efficacious funds to neurological research. Facebook has embarked on a project which aims for users to someday type solely using their thoughts. Head of the project, Regina Dugan, explains the concept, "This isn't about decoding random thoughts. This is about decoding the words you've already decided to share".

Perhaps the most developed brain-computer interface is MIT's AlterEgo. This works similarly to Facebook's project, but detects thoughts from tiny neuromuscular signals in the jaw, which are then translated by an AI. The AI then replies through bone conduction audio, meaning the user can listen to the computerized voice whilst still interacting with their surroundings. This has the potential to replace awkwardly talking aloud to Alexa, or removing your focus from a conversation to check a definition or fact on your phone.

The world has recently witnessed the risks posed by poorly regulated technology companies and this type of technology would expose not just the information that we choose to share but what is happening in our minds. While this technology has the potential to revolutionise human activity it is important to consider risks. In syzygy to heightened knowledge and understanding of our minds, laws are needed to protect private identity and set limits on the weight given to 'brain evidence'. Our future with AI is both exciting and daunting and there is still much to consider before we truly enter a world which was once thought to be fantasy. Δ

Image Credit: Getty Images

Image Credit: Science News Journal

# Drinking to Forget

We've all been there, the morning after a big night out, with the shame of the previous night's actions weighing down on us . Our favourite scapegoat is, of course, an excess of alcohol. But why do we find it so difficult to remember what we have done after a few too many drinks? And does this have consequences ranging beyond social embarrassment and short term memory loss?

*Reporting by Emilia Biondi, Kate Firth, Sean Forshaw, Jack Kearney, Conor McCann & Oliver Pitts*

When you have been drinking, ethanol the small molecule in alcohol that causes its potency, distributes itself throughout your brain, disrupting the membranes of neurones and affecting the function of your brain. The main way that ethanol does this is by interfering with the action of neurotransmitters, the chemicals that neurones use to communicate which play an important role in controlling behaviour, emotion and physical activity. The effects of this interference are that drinking alcohol depresses activity in some parts of your brain, which leads to an increase of activity in other parts of your brain. Parts which are usually held in check by your normally-functioning sober brain.

Ethanol increases the effects of endorphins, neurotransmitters that interact with opiate receptors in the brain, this produce similar effects to drugs like morphine and codeine by reducing pain and producing feelings of euphoria. Alcohol also interferes with excitatory neurotransmitters such as glutamate which plays an important role in learning and memory. The interaction of ethanol with glutamate receptors in specific parts of the brain such as the hippocampus, amygdala and striatum supresses the release of glutamate and impacts impulse control and judgement. This leads to a lowering of our inhibitions and increases the likelihood that we will make irresponsible choices.

Most importantly inhibitory neurotransmitters in your brain such as GABA are also impacted. Inhibitory neurotransmitters act by making target neurones less likely to respond to signals. Ethanol mimics the effect of GABA by binding to receptors causing inhibition of central nervous system activity. This leads to a number of effects such as slowed reaction time, slurred speech and impaired memory as well as a feeling of relaxation. But rather like the 'beer jacket' myth the feeling of relaxation is also a red herring and common effects of alcohol include anxiety and stress. It is the effects that alcohol has on the inhibitory pathways of the brain which lead to it being considered a depressant.





When you drink too much alcohol in a short space of time, your memory is affected. Memory systems can be split into either declarative (memories that could be shared by telling) or procedural (memories that can be demonstrated by doing). Declarative memories include memories about events that have occurred and within this, episodic memories are tied specifically to events that have happened to us and fixed to time and place. It is these declarative memories which are impacted most severely by drinking through the impact of alcohol on the hippocampus, one area of the brain where new memories are formed. Drinking alcohol suppresses neuronal activity in the layer of cells in the hippocampus called the CA1 and CA3 pyramidal cells, these cells affect episodic memory causing holes in our memory or blackouts. A 2012 survey of more than 700 undergraduate students conducted by White et all found that 51% of students who consumed alcohol had experienced some sort of memory loss related to a night in which they been drinking demonstrating that this is a common experience for drinkers.

While the effects of alcohol on short term memory are well understood there is less understanding of alcohol's impact on long-term memory. Chronic alcohol use leads to a variety of long-term memory deficits due to the cumulative effect of affected 'memory making' as well as retrospective memory loss where you lose access to memories previously formed because of corruption in the process to retrieve memories. If you consider your brain to be a library full of billions of books to be able to access the book you need you keep a database of locations of the books, if some of those database entries get deleted or corrupted then the book can no longer be recalled. In severe cases of alcohol dependency you begin to see a range of conditions which are grouped together as alcohol-related brain damage (ARBD).

ARBD are long-term conditions affecting memory and thinking which are found in around 0.5% of the population. There are several mechanisms by which alcohol abuse leads to the development of these conditions including: damage to the biochemistry and tissues of the brain; thiamine deficiency (vitamin B1); head injuries; and damage to blood vessels which can lead to conditions which cause brain damage. ARBD are broadly split into two main conditions Korsakoff's Syndrome and Alcoholic Dementia.

Korsakoff's syndrome is the most well-known form and often develops as part of Wernicke–Korsakoff syndrome (wet brain) a combined manifestation of two named disorders where an initial acute phase of Wernicke's encephalopathy (WE) or disrupted brain function is followed by a chronic phase of Korsakoff's Syndrome (KS) characterised by amnesia and sensory deficits. This is a severe disorder that results in permanent brain damage in 75% of cases and the need for residential care in 25% of cases. This condition is heavily linked to deficiency in Thiamine (Vitamin B1). Thiamine helps the body to make use of carbohydrates when required to meet energy requirements and this is particularly important to the function of brain tissue which has high energy requirements. Deficiency of thiamine leads to energy starvation of the brain's tissues. It is possible for an individual to develop WE without it progressing to KS providing that treatment with high doses of thiamine are received but left untreated KS usually develops. There are also some cases of KS developing without an initial period of encephalopathy but these are not well understood.

Alcoholic dementia has a more varied range of symptoms that KS and is not as tied to episodic memory and shows more impairment to executive functions (thinking, planning and judgement). There is generally global deterioration of intellectual function resulting from damage to the frontal lobes, causing disinhibition, difficulty controlling impulses and emotions and assessing social acceptability of behaviours, along with executive function shortcomings such as making decisions, planning and organising, and reasoning. In addition people with alcoholic dementia often experience a wide range of psychiatric problems including depression, anxiety and personality changes.

When alcohol is regularly consumed, it starts to have more far reaching effects on the balance of neurotransmitters in the brain. This includes serotonin and dopamine which are responsible for creating a pleasure response which encourages the drinking of more alcohol. Once the brain becomes adapted to the suppressive presence of alcohol and finds it difficult to manage without it. Abstinence from drinking leads to compensatory activation of their central nervous system and physical withdrawal symptoms which can include: anxiety, shaky hands, headaches, nausea, vomiting, insomnia and sweating. This cycle of pleasure caused from drinking and punishment created by abstinence reinforces the addictive properties of alcohol and create a cycle which can be hard to escape from. Exacerbating this is a condition known as kindling, where the withdrawal symptoms worsen each time an individual attempts to quit and some of the more severe kindling symptoms include seizures and delirium tremens.

While we all enjoy a drink every now and again it is important to remember that alcohol can have profoundly negative effects on our bodies and minds and is capable of tricking us into wanting more and trapping us into a harmful cycle. As a result alcohol should always be enjoyed in moderation. Δ

# Is GM a solution to food allergies?

*Reporting by Amy Guest, Daniel Harris, Hannah Rogerson, Dharini Roula & Zachary Stentiford*

Image Credit: CNN.com

Milk from cows contains the protein Beta-Lactoglobulin (BLG). This protein is found in some other mammalian milk too but is not present in human breast milk. BLG's function is currently unknown although it is associated with the transport of small water repelling molecules. BLG is thought to be a major contributor to milk allergies and approximately 2-3% of children in developed countries are allergic to BLG. In order to reduce the number of allergic responses, scientists in New Zealand have genetically modified a cow so it produces milk without traces of BLG.

An allergy is essentially caused by an over-reactive immune system (the body's built-in defence system against foreign bodies). Substances that will be regarded as harmless by a regular immune system are seen as a threat to a sufferer's, resulting in an allergic reaction. The origin of an allergy could derive from a number of factors; genetics, age, pollution and quantity of allergen present are just a few examples. Allergies can be treated with medications like antihistamines which suppress the allergic response.

The main technique used messenger ribonucleic acid (mRNA) which is the genetic information that makes proteins. Micro-RNA (miRNA, a snippet of RNA) blocks the production of the BLG protein by sticking to the corresponding mRNA. This process is known as gene knockdown. The scientists in New Zealand tested many different types of miRNA to see which one was most effective in blocking the production of BLG. They tested these different miRNA's on the mRNA of sheep and cows, and found it most effective on cows. They then modified the miRNAs to replicate themselves back to back three times in the same strand, this was found to be more effective.

The first test was on single cells, where miRNA was injected into cells that produce BLG. Less BLG was produced so, as a precursor to the cow's milk modification, mice were used as a model to test if the idea of miRNA interference (the blocking action) was an effective way of blocking BLG production. After more success, the technique could then be tried on cows.

To produce the genetically modified cow, an egg was collected, and the nucleus (the part of the cell which contains the genetic information needed to develop) was removed. The nucleus of the genetically modified cow was put into the empty egg. This was then left to grow to form an embryo which was then implanted into a mother cow.

Unfortunately, the inefficiency of the process is apparent – 57 embryos were produced, resulting in 6 pregnancies, and only one of these lead to a calf being born. Her name is Daisy. Because cows take a couple of years to produce milk naturally, a drug was given to Daisy to accelerate lactation.

This pioneering research was highly successful in removing all traces of the milk protein BLG. The technique that was developed could potentially be applied in other situations such as improving disease resistance. However, it did have its flaws. Daisy was born tailless which has animal rights implications, but it must also be noted that a cow being born without a tail is a very rare, yet natural, genetic mutation so may not necessarily be caused by the experiment. The scientists are currently investigating the genuine reason as to why this occurred.

The milk produced, although achieving the main aim of the research, is far from being marketed and the scientists have yet to see the results from milk produced by a cow that was not given a development accelerant. The milk is currently undergoing extensive tests to discover if consuming BLG-free milk has any adverse effects, especially on developing children. Δ



Biggest stories of 2018

# The Future or Regenerative Medicine

*Reporting by Carl Alexander, Alex Morgan, Victoria Phillips, Emma Spector & Joshua Williams*

Image Credit: Shutterstock

Stem cells are unspecialised cells found in all organisms with two main features. The first is the ability to self-renew; stem cells continually divide to replace damaged cells and tissue. The second feature is their potency; the ability to differentiate into specialised cells. This ability has potential to be extremely beneficial in the world of medicine.

There are two types of stem cell; embryonic and adult. Embryonic stem cells are removed from fertilised egg cells about 5 days into development and have the ability to differentiate into any tissue in the human body. Adult stem cells are found in pre-formed tissues such as the brain, blood and skin and can become activated by disease or tissue injury. Scientists have been researching ways to replicate this process artificially in the lab with the aim of inducing specialisation into tissues needed in medical treatment. However, most scientists think adult stem cells are limited in their ability to differentiate based on the tissue of origin.

In this line, it is the ability of stem cells to grow into specific organs or tissues for donation and transplantation, which makes them so valuable in the medical field. For example cultivation of heart cells, brain cells and skin cells can therefore be used to treat medical conditions such as cardiovascular disease, Parkinson's disease and burns. Their uses range from treating diabetes to spinal cord injury to HIV to memory loss. The pharmaceutical industry can also benefit by testing drugs on stem cells which can generate more accurate results than testing on animals.

The harvesting of stem cells requires the destruction of the embryos. If the embryo is considered human then the destruction is murder and therefore morally unacceptable. The debate is complex as its foundation, the point at which life begins, is itself controversial. Opponents of the research argue a human is living directly after fertilisation whereas advocates suggest the start of life is at greater cell differentiation or even when it has achieved a higher mental capacity.

Aside from the ethical issues, stem cell treatments face several scientific challenges before their use in medical practice becomes common place. One major fear is that of uncontrolled or misdirected growth after implantation in the body. Scientists do not fully understand the process by which stem cells differentiate and multiply and therefore there are fears that uncontrolled stem cell development could form tumours in the body. Similarly misdirected growth could lead to the wrong type of tissue developing. Another real risk is rejection whereby the patient's immune system treats the stem cells as foreign objects and thus seeks to destroy them. The use of adult stem cells and immunosuppressant drugs to prevent rejection also have complications associated with them including the risk of advantageous infections.

Yamanaka and Gurdon have recently received the 2012 Noble Prize in Physiology and Medicine for their work on stem cells. Gurdon's work, in 1962, showed that the specialisation of cells is reversible and as recently as 2006, Yamanaka created the first induced adult stem cells able to specialise into any body tissue thereby reducing the need for the ethically controversial extraction of stem cells from embryos.

Fundamentally, throughout the past 40 years, stem cell research has advanced dramatically and is still very much at the forefront of regenerative medicine. Δ

# 2024 Mission to Mars

## Is it feasible

Image Credit: SpaceX

In the past decade, Tesla founder Elon Musk has made his mark in the technology industry as a leading entrepreneur and idea-maker. Musk claims that within the next few years SpaceX, a company he founded in 2002, will make history by putting the first humans on Mars. He has shown that he can dream big and win but is his latest aspiration an achievable goal or is he being too ambitious this time?

*Reporting by David Johnson, Alec Matthews, Charles Peters, Thomas Smith, William Smith & Elizabeth Taylor*

On the 21st of July 1969, Neil Armstrong stepped onto the moon and became the first human to place his feet onto an extra-terrestrial body. In total there were 6 successful missions to the moon taking 12 people to the surface and back. It was to be the birth of a new age in space travel and colonisation, like the introduction of commercial flight and the discovery of the new world.

Instead, space exploration declined, as public interest, and funding, waned. The last moon landing occurred in December 1972, and humans haven't left low earth orbit since. It seemed we were satisfied with simply knowing we could get there. Although plans for a lunar base and manned missions, not only to mars but throughout the solar system, were drawn up, a lack of funding meant they never got off the launch pad.

Enter Elon Musk. In 2002, he was in Russia attempting to buy a rocket capable of travelling to Mars. But he returned home empty handed finding them too expensive and inefficient and decided to develop his own. More than 15 years later, SpaceX is a serious competitor in rocketry. Their main success has been in slashing the cost of launches - Falcon 9 was developed on a budget of $400 million, NASA estimates developing a similar rocket would cost 10 times that.

The main factor in the reduction of cost is the reusable launch system development programme. They aim to recover and reuse rocket boosters used to take payloads into orbit, with the ultimate goal of returning both first and second stage to the Launchpad. Getting to this point required developing technologies to overcome challenges posed by decelerating a rocket from hypersonic speeds and landing it in a reusable condition.





The increased mass to facilitate recovery due to propellant for the return flight, heat shielding and extra mechanical systems like landing legs create further challenges. Using innovative materials to minimise mass; such as carbon fibre coated aluminium honeycomb landing legs and high pressure helium has helped the Falcon 9 to overcome some of these challenges but they have not yet managed to create a recoverable second stage. However, the newest rocket, the Big Falcon Rocket (BFR), is planned to be fully reusable.

Getting into low earth orbit is one thing but getting to Mars is very different and SpaceX has yet to even put an astronaut into space, never mind another planet. The Apollo missions lasted between 8-12 days and missions on the International Space Station can last months, but they are only a few hours away from Earth. It takes about 300 days to get to Mars, and launch windows only open every 2 years. This increased distance is a big factor as if something did go wrong, help is very far away.

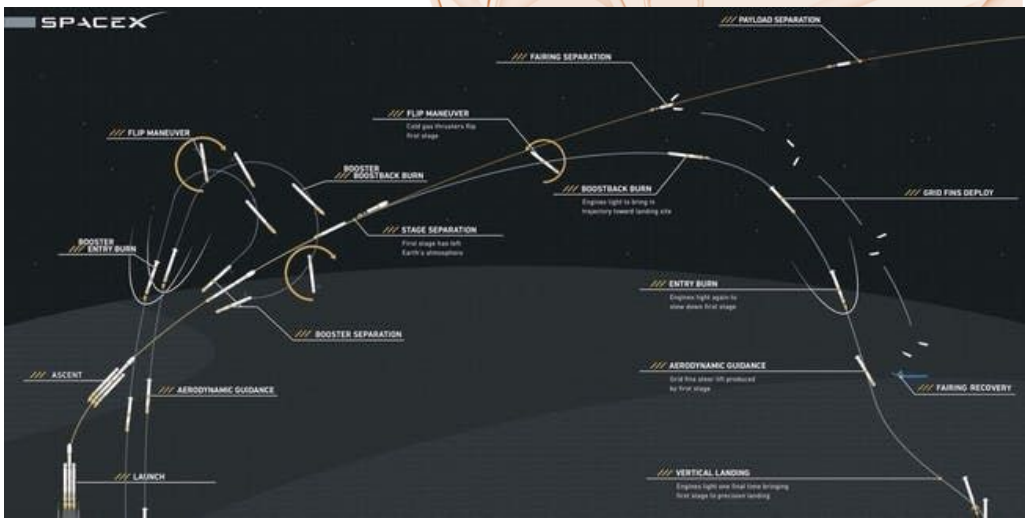
The distance means a Mars mission would need to be better equipped; with supplies for several years, a larger capsule along with a semi-permanent base and some way of generating power, food and a breathable atmosphere. Astronauts would need to be able to operate for years at a time without help from Earth, and the effects of such a long period in space aren't well understood.

There are early ideas for how to meet some of these challenges such as using Martian gases to create breathable air, suggestions for how to grow food and even create rocket fuel, but these are theoretical and haven't been put into practice so it is possible that they will be difficult to implement.

While BFR will start suborbital test flights next year there are still many challenges which are yet to be overcome beyond the technology to build a cost effective rocket. And Musk has a history or setting overly optimistic timelines. But that doesn't mean he won't get there. Musk has shown considerable determination and progress in getting to Mars and there is competition in to spur him on with NASA working towards a manned mission to Mars by the mid-2030s and the Chinese also showing interest.

Funding remains the biggest hurdle to many of these organisations with NASA in particular being hamstrung long term political will. In fact, since the retiring of the space shuttle, NASA can't even get its astronauts off the ground, instead relying on Russian Soyuz rockets. This is where SpaceX have an advantage being funded privately by Musk means freedom from these restrictions.

So while it is not very likely that SpaceX's manned mission to Mars will happen by 2024, if Musk continues on his current trajectory SpaceX will be very likely to carry the first man to the infamous red planet. Δ




Trajectory of the first stage on its return to Earth and the trajectory of the payload

Image Credit: SpaceX