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WEEKLY September 23 - 29, 2017

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This is Axiom, a new film premiering at New Scientist Live, aims to answer the question.

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ROBERT CARTER/CRACKED HAT ILLUSTRATION

No more games

The nuclear stalemate is crumbling. What are our options?

THE game theorist Thomas Schelling, who died last year, is one of science's great unsung heroes. It was largely his analysis of nuclear strategy that prevented the US and USSR from turning the cold war into a hot one – and immolating the human race.

That polarised conflict is now history. Rather than two superpowers, at least nine states now have nuclear weapons – the latest and most worrying being North Korea. That's not the whole story: nuclear tensions are also being ratcheted up by innocuous-looking upgrades of the US nuclear arsenal (see page 30). The arms race is back on.

So how do you solve a problem like Korea? There are no easy answers. For all the bluster, the military options are limited and economic measures handicapped by lack of consensus. We are faced not with a Schelling-style scenario of two mutually hostile states, but a Gordian knot of intertwined and incompatible national interests.

To cut the knot, the goal has to be to convince the North Korean leadership it doesn't need nukes to ward off being invaded and overthrown. The "hermit kingdom" must be drawn into the modern community of nations, where zero-sum "my nation against your nation" thinking is

increasingly obsolete and states are less and less likely to settle their differences with violence. Bringing North Korea in from the cold might achieve the same. That will be a long and delicate process, with much risk of a misstep. It also means talking to a regime whose words and deeds are repugnant, although a less bellicose stance might even lead to social reforms too.

But the world doesn't have a better option. The long stalemate is crumbling; other would-be nuclear powers are watching closely. As Winston Churchill put it: meeting jaw to jaw is better than war. ■

The live experience is back

NEW SCIENTIST LIVE is just around the corner. When we launched our festival of ideas last year, we worked hard to put on a fantastic show, and we had high hopes. But still we were thrilled when it was named Best Consumer Show by the *Exhibition News Awards*, and picked up Event of the Year at the British Media Awards.

This year will be even better: we have added an extra zone and dozens

more talks, experiences and exhibitors. It covers the breadth of science, medicine and technology – we like to think we present life, the universe and everything under one roof.

You'll find a preview in the pull-out section in this week's magazine, but here's a taster: a leader of the Cassini mission will describe how she felt as the probe vaporised. There will be a live video link to the International

Space Station. One of the world's most innovative choreographers has created a show just for us. Leading scientists will speak about everything from the origin of life to a cure for ageing. And Margaret Atwood, author of *The Handmaid's Tale*, will tell how science inspires her writing.

It runs from 28 September to 1 October, and we hope you'll come along and be inspired too.

Easy-access bioterror

EBOLA virus, the bacterium that causes plague, a pandemic strain of flu – any of these pathogens could be turned into bioweapons by terrorists. And information that might aid that weaponisation process is in danger of leaking out, says the US National Academies of Sciences, Engineering, and Medicine.

A report published last week by the National Academies says there are “multiple shortcomings” in the systems designed to stop potentially risky research from being published. Current US policies restrict research on 15 pathogens or toxins classed as “dual-use research of concern” – in other words, work that could both benefit medicine and be used to kill.

But this list should no longer be considered exhaustive, warns

the report, partly because new techniques such as CRISPR make it easier for microbes to be genetically edited or for novel life forms to be made from scratch.

Journal editors are supposed to consider security risks before publishing any research with dual-use potential. In 2011, a US biosecurity committee asked the journal *Science* not to publish research on how bird flu could be genetically altered to make it spread between people more easily.

But the National Academies report points out that such knowledge can also be disseminated in other ways, such as on “preprint” websites.

The report doesn’t offer any solutions. It concludes that there is little international consensus on policies to address the risks.



Let's not have any leaks

JOHN TLUKACK/GLOBE STAFF/GETTY

Hunger returns

GLOBAL hunger is rising for the first time in over a decade, due to local wars and climate extremes.

The number of undernourished people increased in 2016 for the first time since 2003, when 947 million people (14.9 per cent of the population) went hungry. In 2016, the figure was 815 million (11 per cent), up from 777 million (10.6 per cent) in 2015.

More than half – 489 million people – were in countries affected by conflicts. These have become more numerous,

“The State of Food Security and Nutrition in the World”.

The report blames droughts triggered by the El Niño climate cycle for aggravating conflicts and food shortages in Somalia, Syria, Sudan, the Democratic Republic of the Congo and Burundi.

It also links conflict-related food crises in Afghanistan, Iraq, Yemen and South Sudan with other climate shocks.

Together, these problems left 53.5 million people without a reliable source of food.

Prolonged droughts are proving to be potent triggers of conflict, says Cantillo. “They can lead to competition for scarce resources and increase prices, setting up a vicious cycle that spirals down into more food insecurity.”

The idea that climate change can cause or aggravate human conflicts has been controversial, but the FAO taking a side suggests that a consensus is forming.

“We think the hunger uptick is a wake-up call,” says Cantillo. He says we must make people more resilient to climate shocks – for example, by giving farmers crops resistant to droughts or floods.

Droughts can lead to competition for resources and increase prices, setting up a vicious cycle”

increasingly in tandem with droughts, floods and other climate-related shocks.

“There’s a clear interaction between climate change and conflict,” says Marco Sánchez Cantillo at the UN Food and Agriculture Organization (FAO), which has published these figures in the report

Human editing

HUMAN embryos have been genetically edited in the UK for the first time.

Kathy Niakan of the Francis Crick Institute in London and her colleagues studied spare embryos donated by couples who had IVF treatment. They used the CRISPR gene-editing technique to stop a gene from making a protein called OCT4. The results confirm that it is needed to help the embryo develop into a ball of about 200 cells called a blastocyst (*Nature*,

DOI: 10.1038/nature24033).

The gene has a different role in mice, showing the need to study human embryos, says Niakan.

“If we knew the key genes that embryos need to develop successfully, we could improve IVF treatments and understand some causes of pregnancy failure,” she says.

But disabling genes using CRISPR is much easier than fixing them, so Niakan’s work tells us little about how genome editing could be used to prevent disease.

Romania to kill top predators

WOLVES and bears will be hunted in Romania, less than a year after the government banned trophy hunting.

The move was announced by environment minister Gratiela Gavrilescu. Up to 140 bears and 97 wolves may be killed by the end of 2017 “under supervision”, if they are deemed “nuisance animals” that threaten livestock or frighten people.

But conservation groups fear the quotas will be used as an excuse to allow trophy hunting to resume.

“It’s unclear if hunters will be allowed to keep the bodies, or sell body parts,” says Masha Kalinina of Humane Society International (HSI).

Killing predators may not protect livestock. In a study from May 2017, Ann Eklund at the Swedish University of Agricultural Sciences found little evidence such tactics work. It may even make things worse by removing wolves that are wary of farms.

HSI favours non-lethal methods, such as bear-proofing rubbish bins.

60 SECONDS

Farewell to bats

THE Christmas Island pipistrelle, a bat found only on an Australian island, has been declared extinct.

The decision was announced in the latest update to the Red List of Threatened Species, maintained

"The world's biggest antelope, the giant eland, is now vulnerable, with at most 14,000 left"

by the International Union for Conservation of Nature (IUCN). The bat was last sighted in 2009.

The outlook is also poor for five African antelope. The world's biggest, the giant eland, is now vulnerable, with at most 14,000 left. The southern lechwe and grey rhebok are near threatened, and the mountain reedbuck and Heuglin's gazelle are endangered.

Much of their decline is due to people moving into their habitat. "A lot of people in Africa don't have access to good reliable food sources and bushmeat is an easy path to income and food," says Craig Hilton-Taylor of the IUCN.

North American ash trees are threatened by the emerald ash borer beetle. It was introduced in the 1990s, and has been wrecking forests ever since. Five of the six most widespread ash tree species are now critically endangered.

"They could well go extinct in the next 100 years if the beetle has its way," says Hilton-Taylor.



JACK PICHON/PALIN/STOCK PHOTO

Return of the hunt?



JASON HENRY/NY TIMES/REDUX/EYEVINE

Displacement heightens health risk

Hurricane legacy

ABOUT 200 people are thought to have been killed by hurricanes Harvey and Irma in the Caribbean and southern US. And as *New Scientist* went to press, Hurricane Maria was threatening more deaths. But many more will feel knock-on health effects in the coming weeks and years.

Diarrhoea and respiratory illnesses are spreading in crowded US evacuation centres. Later, people face exposure to floodwater

"People face exposure to floodwater laced with toxic chemicals and sewage bearing microbes"

laced with toxic chemicals and sewage bearing disease-causing microbes. These include the cholera-causing bacterium *Vibrio cholerae* in places where it is present, such as Haiti. The affected region also hosts mosquito-borne diseases such as dengue, and mosquito numbers will rise.

Chronic conditions can worsen in those displaced from their homes: people with diabetes, heart disease, psychiatric disorders or HIV may be separated from medications and the refrigeration they might need. After other disasters, between 30 and 40 per cent of displaced people developed depression or post-

traumatic stress disorder.

The biggest threat may be from downed electricity grids. Millions will be without power for weeks in Florida and months in Puerto Rico. The main health risks are loss of food refrigeration, emergency communications and air conditioning, especially in Florida, where elderly people caught in the heat have already died.

Farewell Cassini

CASSINI is dead; long live Cassini. On 15 September, after a few hours live-streaming atmospheric data from far above Saturn's cloud tops, the spacecraft dived into the giant planet's skies and disintegrated. It survived more than 30 seconds longer than scientists expected.

The probe entered orbit around Saturn in 2004 and its legacy will be the thousands of images it took of the planet, its rings and its many diverse moons. It revealed new ring structures, observed Saturn's weather in detail and found liquid oceans on Enceladus and Titan, making the icy moons key targets in the search for life.

Cassini was running out of fuel, and in order to prevent it from smashing into the moons and contaminating them, NASA sent it around Titan one last time, adjusting its orbit to head straight for a death plummet into Saturn.

Hear the light

Superfast light-based computers may be closer than we thought. Researchers have built a computer chip that converts light particles into sound waves (doi.org/cc7p). Light transmits data too quickly for computers to process it. Sound waves are slower than light but still faster than traditional electronics.

Dirty Trojan trick

If you installed CCleaner - free software that is meant to keep your computer free of malware - there's a good chance you now have malware. Some 2.2 million Windows users who downloaded the software between 15 August and 12 September got malware instead and leaked their sensitive data. Users are advised to reinstall any affected systems.

Super-hot year

So far, 2017 is the second warmest year on record, the National Oceanic and Atmospheric Administration announced this week. The mean global temperature to the end of August was almost 15°C - nearly a degree warmer than average, and second only to the corresponding value in 2016. It's the 41st August in a row and 392nd consecutive month with temperatures above average.

Colourful language

Not all descriptions of colour are equal. A study of 110 languages found most offered better descriptions of warm colours like reds and oranges than of cool colours like blues and greens (*PNAS*, doi.org/cc8g). It may be that warm colours are associated with more relevant objects such as animals and fruit.

Owls never go deaf

Many of us lose some hearing as we get older, but not barn owls. There was no difference in hearing sensitivity between barn owls younger than 2 years and those over 13. Even a 23-year-old bird showed little deterioration (*Proc Roy Soc B*, DOI: [10.1098/rspb.2017.1584](https://doi.org/10.1098/rspb.2017.1584)).

Quantum collapse spawns gravity?

A tweak to quantum mechanics could explain gravity's origins

Anil Ananthaswamy

HOW do you reconcile the two pillars of modern physics: quantum theory and gravity? One or both will have to give way. A new approach says gravity could emerge from random fluctuations at the quantum level, making quantum mechanics the more fundamental of the two theories.

Of our two main explanations of reality, quantum theory governs the interactions between the smallest bits of matter. And general relativity deals with gravity and the largest structures in the universe. Ever since Einstein, physicists have been trying to bridge the gap between the two, with little success.

Part of the problem is knowing which strands of each theory are fundamental to our understanding of reality.

One approach towards reconciling gravity with quantum mechanics has been to show that gravity at its most fundamental comes in indivisible parcels called quanta, much like the electromagnetic force comes in quanta called photons. But this road to a theory of quantum gravity has so far proved impassable.

Now Antoine Tilloy at the Max Planck Institute of Quantum Optics in Garching, Germany, has attempted to get at gravity by tweaking standard quantum mechanics.

In quantum theory, the state of a particle is described by its wave function. The wave function lets you calculate, for example, the probability of finding the particle in one place or another on measurement. Before the measurement, it is unclear whether the particle exists and if so, where. Reality,

it seems, is created by the act of measurement, which "collapses" the wave function.

But quantum mechanics doesn't really define what a measurement is. For instance, does it need a conscious human? The measurement problem leads to paradoxes like Schrödinger's cat, in which a cat can be simultaneously dead and alive inside a box, until someone opens the box to look.

One solution to such paradoxes is a so-called GRW model that was developed in the late 1980s. It incorporates "flashes", which are spontaneous random collapses of the wave function of quantum systems. The outcome

is exactly as if there were measurements being made, but without explicit observers.

Tilloy has modified this model to show how it can lead to a theory of gravity. In his model, when a flash collapses a wave function and causes a particle

"A spontaneous collapse in a quantum system creates a gravitational field at that instant in space-time"

to be in one place, it creates a gravitational field at that instant in space-time. A massive quantum system with a large number of particles is subject to numerous flashes, and the result

is a fluctuating gravitational field.

It turns out that the average of these fluctuations is a gravitational field that one expects from Newton's theory of gravity (arxiv.org/abs/1709.03809). This approach to unifying gravity with quantum mechanics is called semiclassical: gravity arises from quantum processes but remains a classical force. "There is no real reason to ignore this semiclassical approach, to having gravity being classical at the fundamental level," says Tilloy.

"I like this idea in principle," says Klaus Hornberger at the University of Duisburg-Essen in Germany. But he points out that other problems need to be tackled before this approach can be a serious contender for unifying all the fundamental forces underpinning the laws of physics on scales large and small. For example, Tilloy's model can be used to get gravity as described by Newton's theory, but the maths still has to be worked out to see if it is effective in describing gravity as governed by Einstein's general relativity.

Tilloy agrees. "This is very hard to generalise to relativistic settings," he says. He also cautions that no one knows which of the many tweaks to quantum mechanics is the correct one.

Nonetheless, his model makes predictions that can be tested. For example, it predicts that gravity will behave differently at the scale of atoms from how it does on larger scales. Should those tests find that Tilloy's model reflects reality and gravity does indeed originate from collapsing quantum fluctuations, it would be a big clue that the path to a theory of everything would involve semiclassical gravity. ■



Gravity comes about in a flash

EMMA JOHNSTON/SCIENCE PHOTO LIBRARY

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Store carbon forever in a deep-sea trench

TO KEEP Earth's temperature at a safe level it looks as if we might have to actively remove carbon dioxide from the air, but what to do with it?

Steve Goldthorpe, an energy analyst based in New Zealand, has a radical suggestion: dump it in deep ocean trenches, where it should sit permanently as a liquid lake.

The crucial point, he says, is that once the carbon dioxide reaches a depth of about 3000 metres, its density exceeds that of water - so it will sink to the bottom and stay there (*Energy Procedia*, doi.org/cc67).

Goldthorpe used Google Earth to explore the seabed and identify a storage site. He found the Sunda trench around 6 kilometres under the ocean, just south of the Indonesian archipelago. "It is big enough to accommodate 19 trillion tonnes of liquid CO₂, which is greater than all the CO₂ from the total global fossil fuel emissions," he says.

Carbon dioxide lakes can also form naturally. In 2006, Fumio Inagaki of the Japan Agency for Marine-Earth Science and Technology in Yokosuka described a lake of carbon dioxide deep down in the East China Sea, covered with a layer of sediment.

Ken Caldeira of the Carnegie Institution for Science in Stanford, California, once considered something similar: dissolving carbon dioxide in the deep ocean. But this would make the ocean more acidic. He says a deep-sea carbon dioxide lake would probably need a physical barrier to keep the liquid trapped. "Something like giant, plastic-encased, sausage-like tubes of liquid CO₂ lying on the sea floor could potentially store CO₂ safely and securely for many millennia."

Location is the biggest issue. "Most likely, people will want to store the carbon near where the power plants are," he says. Deep ocean trenches tend to be a long way from drilling sites and power plants - so shipping the carbon dioxide to them would be costly. Michael Marshall ■



Strength is for everyone

Gender stereotypes affect kids everywhere by 10

DAMAGING gender stereotypes are ingrained from the age of 10. That is the conclusion of the first study to draw together data from high, middle and low-income countries across different cultures about how "tweenagers" perceive growing up as a boy or girl.

Researchers interviewed 450 children aged 10 to 14, plus a parent or guardian, from 15 countries, including Nigeria, China, the US and South Africa. They found that across all cultures, early adolescents were fitted with a "gender straitjacket" that has lifelong consequences linked to an increased risk of health problems. These are particularly perilous for girls.

"What we've learned is that there's more commonality than differences in 10-year-olds across the world," says Robert Blum of Johns Hopkins University in Maryland and leader of the study, which is published this week in a special issue of the *Journal of Adolescent Health*. "We were very surprised to see such universality of the myth that boys are strong, confident and leaders, while girls are weak and incompetent, who

should be quiet and follow."

One main finding showed that boys and girls are encouraged to lead separate lives in early adolescence. Parents in many cultures – particularly in low to middle-income countries – intervene at puberty to quash their child's relationships with the opposite sex.

At this age, the world shrinks for girls, while it expands for boys,

"We were surprised to see such universality of the myth that boys are strong while girls are weak"

says Blum. Girls are more likely to stay close to home, while boys are given free rein to explore and experiment unsupervised.

"This is profoundly problematic, but that's what gets played out everywhere, even in most liberal societies," says Blum.

In many places, the pressure of these stereotypes leaves girls at higher risk of leaving school and experiencing early pregnancy and sexual violence, and encourages reckless and risky behaviour in boys.

In some countries, boys faced sanctions for attempting to defy the status quo. For instance, boys in Delhi said that they expected beatings from their parents if they associated with girls. They were taught that they wouldn't be able to control their sexual urges, says Blum. Some boys reported that abuse of girls was "natural" because of these urges.

There were some positive findings. In Shanghai, for example, interviews revealed increasing support for girls to prize traits such as educational achievement and career development.

"Too often, we address gender norms late in adolescence when they are well established and have started to have negative impacts on health," says Sarah Keogh at the Guttmacher Institute in New York. "This study shows that gender socialisation happens much earlier than that."

Blum says it is possible to change stereotypes, citing altered attitudes and laws combating sexism in Europe and North America. But he says it requires the knowledge of how and when these gender myths are ingrained. Exposures to gender stereotypes start in infancy, he says, "but early adolescence may be the ideal time for interventions".

Andy Coghlan ■

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Aggression and sex link in mice brains

Jessica Hamzelou

AGGRESSION and sexual behaviour are controlled by the same brain cells in male mice – but not in females. The finding suggests that males are more likely to become aggressive when they see a potential mate than females.

The brain regions that contain these cells look similar in mice and humans, say the researchers behind the study, but they don't yet know if their finding has relevance for human behaviour.

Similar to humans, male mice are, on the whole, more aggressive than females. Because of this, most research into aggression has overlooked females, says Dayu Lin at New York University. "I would say 90 per cent of aggression studies have been done in males," she says.

But females can be aggressive too. For instance, female mice can be aggressive when protecting their newborn pups.

In 2011, Lin and her colleagues studied a region of the brain called the hypothalamus, responsible for regulating many

behaviours. They discovered a set of cells within this region in male mice that controlled both aggressive and sexual behaviours. When the cells were shut off, the mice didn't mate or show

aggression, but both behaviours could be triggered when the cells were stimulated.

Now, they have shown that the cells controlling these behaviours are separate in female mice, in both those that haven't mated and new mothers (*Nature Neuroscience*, doi.org/cc7m). The cells for aggression are close to the centre of the hypothalamus, while cells for sexual behaviour are at the edge, says Lin. "But in the

male, the cells are totally mixed up and overlap."

This might be because some aspects of mating for male mice resemble aggression, says Lin. A male mouse will have to approach a female and mount her, for instance. Female mice stay still for mating, which looks nothing like aggression.

Can the finding apply to humans? The hypothalamus looks very similar across species, says Lin. "There's no reason for me to think that humans are unique."

But Daphna Joel at Tel Aviv University in Israel doesn't think it can be easily applied to humans. "Sexual and aggressive behaviours are complex and context-dependent in mice, and of course much more so in humans," she says.

The difference seen between the male and female hypothalamus in mice doesn't mean that there are two types of brain, either, says Joel, whose own research suggests that there is no such thing as a "female brain" or "male brain".

Some research suggests that the hypothalamus can look quite different in mice and humans, says Joel. Plus other regions that are known to look different in male and female mouse brains have "considerable overlap" in the brains of women and men, she says. ■



Get out of my nest!

JL KLEIN AND M L HUBER/FLPA

Chatbot talks up corporate team building

ARE your colleagues lousy at communicating with each other? A team-building chatbot could help.

CoachBot, developed by the London-based HR company Saberr, assesses workplace dynamics, listens to staff grievances and suggests ways to make teams more productive. It is currently being trialled by 10 firms and the UK's National Health Service.

"Team members start by saying

"hello to CoachBot, and are then asked about who they are and what they do," says Tom Marsden, Saberr's CEO. After a 10-minute session identifying any problems, "CoachBot creates a plan to try to improve the team's overall performance", he says.

One early adopter is Hertfordshire Partnership University NHS Foundation Trust, which specialises in mental health. The trust is now using the chatbot for 30 employees over a 12-month period to see if it helps improve outcomes for patients and employees' perception of the effectiveness of their teams.

"It means we don't have to take

days out of service for long courses," says staff member Jess Lievesley.

CoachBot asks questions like, "Is your team productive?" and "Do you trust each other?" If team morale is low, it suggests activities to try to improve things. These come straight out of "management science", and include revamped meetings and playing board games together.

But don't expect too much beyond that. "One of the key skills of any

human coach is to pick up on the emotional aspects of a group – something which a bot is probably not so good at doing," says André Spicer at Cass Business School in London.

Even if the technology develops, it might not benefit staff at all, says Carl Cederström at Stockholm University in Sweden. "I think it could be successful in a rather cruel and sinister way because it will force people to record every little move they make," he says. "If it turns out that when this data is processed that a person is not performing as efficiently as they should, they could be left out of a team." Timothy Revell ■

"If team morale is low, the bot suggests revamped meetings or playing board games together"

Proxima may be an interloper from far away

THE outlier in the stellar system closest to our own, the star Proxima Centauri, may not have formed with its two siblings. If so, nor would its planet, Proxima b, which is good news for the chances of life on it.

Proxima Centauri's orbit is currently bound to Alpha Centauri A and B, but it is unclear if it will remain stable, say Fabo Feng and Hugh Jones at the University of Hertfordshire in the UK. They modelled 100 Proxima clones in orbits around their binary partners.

Over a simulated 10 billion years, Proxima Centauri became unbound from the pair due to an unstable orbit 26 per cent of the time. If it had been born in the system, it is unlikely the orbit would be unstable aeons later (arxiv.org/abs/1709.03560). So, Proxima may have been captured by the stellar pair.

Previous studies have found that Proxima contains much less metal than its binary companions, another hint that it might have come from afar. Feng says a more recent appearance might be good for the habitability of Proxima b. At certain points in its orbit, Proxima Centauri could get so close to the other stars, they could destabilise its planet's orbit and push it out of the zone with temperatures right for life.

But if Proxima Centauri has only been there a short while, there would have been fewer chances for its planet to be knocked out of this zone.

Proxima b would have had longer in a stable orbit around a single star before feeling the influence of Alpha Centauri A and B. "Life needs time to develop and emerge. This scenario gives it more time," says Feng.

But a capture would actually make Proxima b's orbit less stable than if it had formed as part of the larger system, says Scott Kenyon at the Harvard-Smithsonian Center for Astrophysics in Massachusetts. "If the three stars have been orbiting each other for a few billion years, one would think they'd be a nice happy family," he says. Leah Crane ■



What's really in the wheat?

Scanner instantly divines how nutritious food is

FARMERS can now zap their crops with a handheld scanner to instantly determine nutritional content, which could prove crucial in mitigating the effects of climate change on food quality. It also brings similar consumer gadgets a step closer – so we can find out what is in our food for ourselves.

The device, called GrainSense, analyses wheat, oats, rye and barley by scanning a sample with various frequencies of near-infrared light. The amount of each type of light that is absorbed allows it to precisely determine the levels of protein, moisture, oil and carbohydrate in the grain.

This technique has been used for decades in the lab, but this is the first time it has been available instantly on a handheld device.

"Today you have to send at least half a kilo of grain to the lab," says Edvard Krogius, the co-founder of GrainSense, the Finnish company developing the system. "It can take days or weeks to get results."

By contrast, GrainSense

requires a sample of just 50 to 100 kernels and can reveal their composition in about 5 seconds. This information, along with the GPS coordinates of where the measurements were taken, is linked to a mobile app.

Farmers can use the app to assess the impact of changing

"Real-time results mean farmers can add fertilisers or tweak moisture levels as crops grow"

conditions, such as extreme weather and soil quality, on the quality of their crops from year to year.

Traditionally, farming has been guided by instinct and inherited best practice, but information is becoming increasingly important as the environment becomes more unpredictable. In August, for example, Harvard University researchers showed for the first time that rising carbon dioxide levels are significantly reducing the amount of protein in staple

crops. That puts 150 million more people at risk of developing protein deficiency by 2050.

While tractor and soil sensors can reveal conditions in fields, and drones can show areas in need of irrigation or pest treatment, farmers only find out how their grain actually fared after harvest. "An accurate, real-time estimate of crop components is of significant importance," says Salah Elsayed from the University of Sadat City in Egypt. It could allow farmers to mitigate the negative effects of climate change early by adding fertilisers or tweaking moisture levels as crops grow.

GrainSense will be launched at the Agritechnica fair in Hanover, Germany, in November. And Krogius and his team are already thinking about adding corn and rice to its repertoire. But the technology could be adapted to assess the protein content of any organic material, including meat.

Other companies are developing similar gadgets for consumers, and sensors that can be fitted onto a smartphone. Whether we all start making healthier food choices is another matter. Sandrine Ceurstemont. ■

Tool-using monkeys suck shellfish dry

Aylin Woodward

HUMANS aren't the only primate to have pushed their prey towards extinction. Monkeys have also over-exploited animals for food.

Long-tailed macaques forage for shellfish on islands off Thailand, then crack them open with stone tools. They target the largest rock oysters, bludgeoning them with stone hammers, and pry open the meatiest snail and crab shells with the flattened edges of their tools.

These macaques are one of three primates that use stone tools, alongside chimpanzees in Africa and bearded capuchins in South America. "Stone tools open up an opportunity for foods they otherwise wouldn't even be able to harvest," says Lydia Luncz at the University of Oxford.

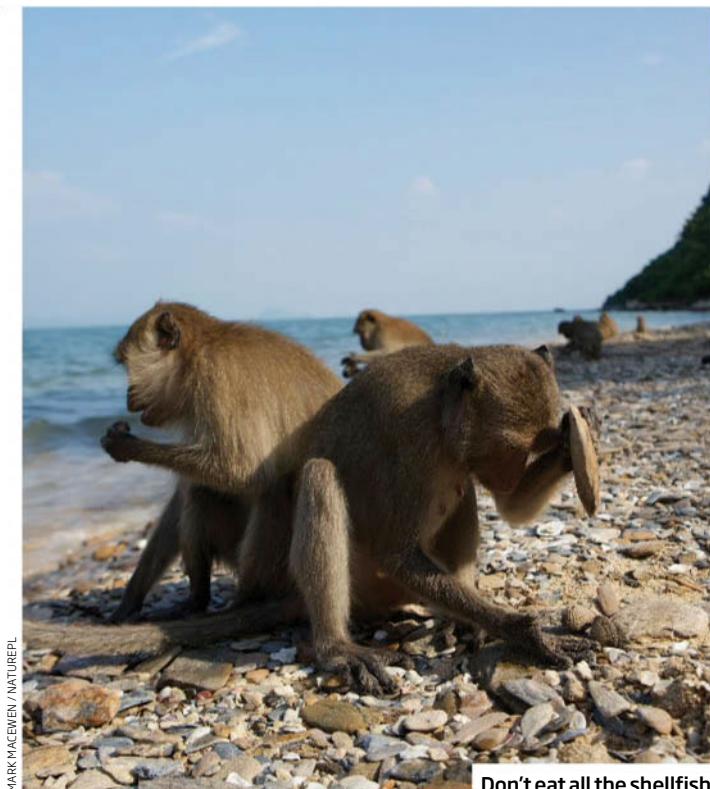
Luncz wanted to investigate the impact of the monkeys' shellfish snacking on the prey themselves. Her team followed 18 macaques on their daily foraging routes along the shores of Koram and NomSao, two neighbouring islands off eastern Thailand, recording their tool selection

and use. On Koram – the more densely populated island, home to 80 macaques compared with NomSao's nine – Luncz's group saw not only smaller oysters and snails, but also fewer of each species. Multiple prey species were less abundant on Koram than NomSao, with four times as many tropical periwinkles on NomSao as on Koram (*eLife*, doi.org/cc7d).

"It's been shown that systematic predation causes prey of smaller size," says Nathaniel Dominy at Dartmouth College in Hanover, New Hampshire. The oysters on Koram were about 70 per cent smaller than their counterparts on NomSao, and the periwinkles were less than half the size. A single tool-using monkey on Koram can eat over 40 shellfish a day, so Luncz's group thinks this predation pressure is driving these shellfish changes.

Luncz says the macaques might deplete the prey on the islands. Afterwards, they will stop using stone tools and even forget how.

"Tool use, a socially learned behaviour, has always been viewed as this positive thing that opens up resources," she says.



Don't eat all the shellfish

"But by over-harvesting they're putting their technology knowledge at risk."

What's more, Dominy thinks the study might help us better understand modern humans' exit from Africa over 70,000 years ago. One idea is that our ancestors didn't travel overland, but instead followed the Asian coastline, relying on shellfish for food.

"Over time, we see a reduction in shell size in the archaeological record, which suggests a systematic use of shellfish," Dominy says. But nobody was sure whether size reduction was due to changing ocean conditions, or large-scale human predation. "This paper is the first to offer compelling evidence in support of the former," he says. ■

Blind people use visual brain for language

PEOPLE who are blind use parts of their brain that usually handle vision to process language - highlighting the brain's extraordinary ability to requisition unused real estate for new functions.

In blind people, neurons in the part of the brain normally responsible for vision synchronise their activity to the sounds of speech, says Olivier Collignon at the Catholic University

of Louvain (UCL) in Belgium. "It's a strong argument that the organisation of the language system... is not constrained by our genetic blueprint alone," he says.

Collignon and his colleagues used magnetoencephalography to scan electrical activity in the brains of volunteers who were sighted or blind. While this happened, the volunteers were played three clips from an audio book. One recording was clear and easy to understand; another was distorted but still intelligible; and the third was modified so as to be completely incomprehensible.

Both groups showed activity in the

brain's auditory cortex, a region that processes sounds, while listening to the clips. But the volunteers who were blind showed activity in the visual cortex, too.

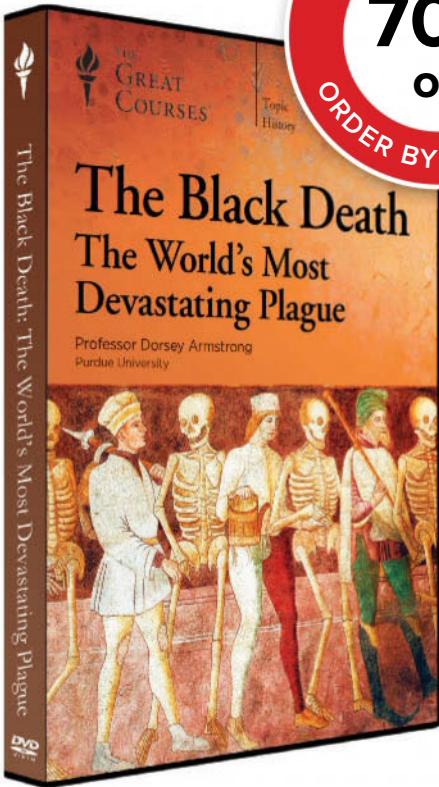
The blind volunteers also appeared to have neurons in their visual cortex that fired in sync with speech in the recording - but only when the clip was intelligible. This suggests that these cells are vital for understanding language (*bioRxiv*, doi.org/cc7c).

"The organisation of the brain's language system is not constrained by our genetic blueprint alone"

"The new finding is perhaps not surprising, but it is groundbreaking," says Daniel-Robert Chebat at the Israeli Ariel University in the West Bank. "It shows that these parts of the brain are not only recruited [to receive new kinds of input], but can adapt and modulate their response."

Collignon hopes the work will aid treatments to restore vision. Several groups are currently working on bionic eyes, for instance. By understanding how the brain adapts to new inputs, it may be possible to predict whether such treatments can rewire the brain to allow a patient to see.

Jessica Hamzelou ■



How Did the Black Death Change History?

In the late 1340s, a cataclysmic plague—known to us as the Black Death—left up to 75 million dead across Europe.

While the story of the Black Death is one of destruction and loss, it is also one of the most compelling and deeply intriguing episodes in human history. Understanding its aftermath provides a highly revealing window on the forces that brought about the Renaissance, the Protestant Reformation, and modernity itself. Speaking to the full magnitude of this world-changing historical moment, *The Black Death: The World's Most Devastating Plague*, taught by celebrated medievalist Dorsey Armstrong of Purdue University, takes you on an unforgettable excursion into the time period of the plague, its full human repercussions, and its transformative effects on European civilization.

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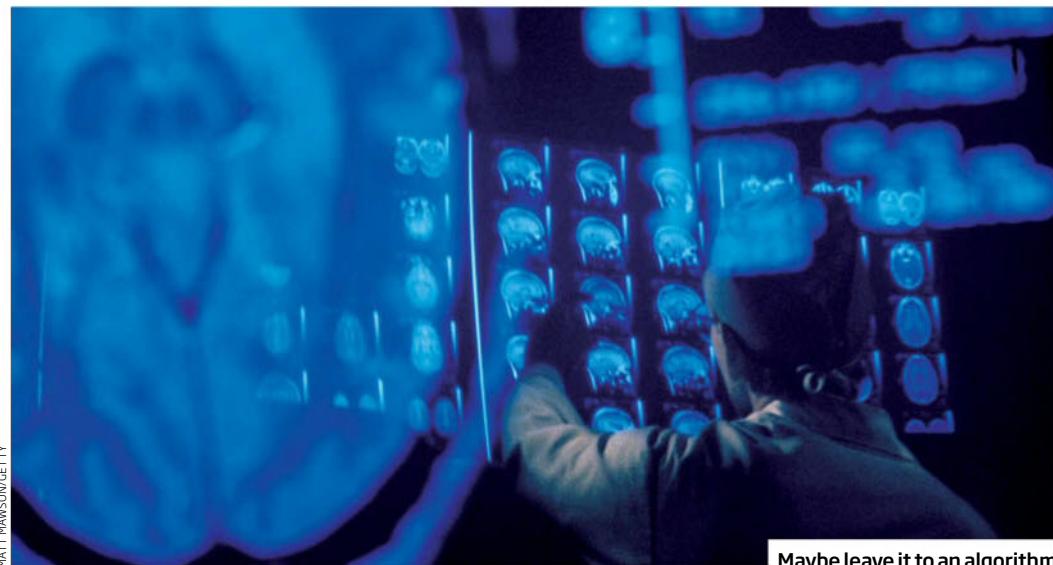
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Alzheimer's AI can spot early changes

Anil Ananthaswamy

ARTIFICIAL intelligence can identify changes in the brains of people likely to get Alzheimer's almost a decade before doctors can diagnose the disease from symptoms alone.

The race is on to spot Alzheimer's as early as possible. Although there is no cure, drugs in development are likely to work better the earlier they are given.

To enable earlier diagnosis, Marianna La Rocca at the University of Bari in Italy and her colleagues developed a machine learning algorithm to discern structural changes in the brain caused by Alzheimer's disease.

First, they trained the algorithm using 67 MRI scans, 38 of which were from people who had Alzheimer's and 29 from those who didn't.

The idea was to teach the algorithm to correctly discriminate between brains with and without the disease. The researchers divided each brain scan into small regions

and analysed the neuronal connectivity between them, without making any assumptions about the ideal size of these regions for diagnosis.

They found that the algorithm was most accurate at identifying Alzheimer's when the brain regions being compared were about 2250 to 3200 cubic millimetres. This was intriguing since this is similar to the size of the anatomical structures connected with the disease,

"A method that predicts the disease a decade before symptoms appear would be incredibly valuable"

such as the amygdala and hippocampus, says La Rocca.

The team then tested the algorithm on a second set of scans from 148 subjects. Of these, 52 were healthy, 48 had Alzheimer's disease and 48 had mild cognitive impairment (MCI), but were known to have developed Alzheimer's disease 2.5 to nine years later.

Maybe leave it to an algorithm

The AI distinguished between a healthy brain and one with Alzheimer's with an accuracy of 86 per cent. Crucially, it could also tell the difference between healthy brains and those with MCI with an accuracy of 84 per cent (arxiv.org/abs/1709.02369v1).

This shows that the algorithm could identify changes in the brain that lead to Alzheimer's almost a decade before clinical symptoms appear. The researchers were limited by the scans available, so they were unable to test whether the algorithm could predict the onset of disease even earlier.

Alzheimer's disease has been linked to the formation of sticky beta-amyloid plaques and tau tangles in the brain. Blood tests that look for biomarkers of these features could be even cheaper and simpler than the new technique, but none are on the market yet.

Patrick Hof at the Icahn School of Medicine at Mount Sinai in New York says a method that might predict the disease a decade before symptoms appear would be "incredibly valuable" should preventative therapeutics emerge.

La Rocca hopes to extend the technique to help with the early diagnosis of other conditions, such as Parkinson's disease. ■

Ultrafast lasers catch electrons kicking back

NO ONE can match these electrons when it comes to relaxing. Within a few hundred attoseconds - billionths of a billionth of a second - of being hit by an X-ray pulse, they are already back where they were, sitting calmly in a low-energy state.

Experiments that have clocked them doing so have solved a decades-old puzzle about the way electrons behave inside solids. We know that when an electron inside an atom is excited by energy from a photon of light, it leaves a positively charged hole in its former, non-excited place. Together the hole and excited electron create a particle-like effect called an exciton.

But physicists can't agree whether excitons form in all such situations. In particular, if an atom inside a solid such as a silica wafer is hit by an X-ray photon and a hole forms, it's not clear that the excited electron hangs around to form an exciton. It might instead escape the atom and move freely through the silicon. It doesn't help that surrounding electrons are attracted to the hole and destroy it very quickly. This means that even if an exciton forms, it would be too short-lived for anyone to observe it - until now, that is.

Eleftherios Goulielmakis at the Max Planck Institute for Quantum Optics in Garching, Germany, and his team have used laser pulses short enough to photograph any excitons before they "relax", or dissipate (*Science*, doi.org/cc59). He and his colleagues zapped a 125-nanometre-thick wafer of silica with a 200-attosecond pulse of low-energy X-rays. Then they used similarly short pulses of visible light to take "snapshots" of the system, getting visual evidence that excitons really do form inside such solids - although some of them disappear again in just 750 attoseconds.

"This is the fastest relaxation process we have ever seen in a natural solid system," says Goulielmakis. Colin Barras ■

Pop Quiz

Q: Are you at least 3 years past your doctoral degree?

Q: Have 10 or more peer-reviewed publications?

Q: Have at least 5 peer-reviewed publications as first author?

Q: Have you shown prominence through awards, invitations to speak at major scientific meetings, or other recognition?

Q: Do you have expertise in one of these fields?

- Earth sciences
- Heliophysics
- Planetary science
- Astrophysics
- Space bioscience
- Aeronautics
- Engineering
- Human exploration and space operations
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MATT HAWSON/GETTY

Storms ahead

Cargo ships trigger lightning storms

Lakshmi Supriya

SHIPS spewing soot into the pristine ocean air are causing extra lightning strikes along busy maritime routes. It is a bizarre example of how human activities can change the weather.

When Joel Thornton at the University of Washington in Seattle and his colleagues looked at records of lightning strikes between 2005 and 2016 from the World Wide Lightning Location

Network, they noticed there were significantly more strikes in certain regions of the east Indian Ocean and the South China Sea, compared with the surrounding areas. Unusually, they occurred along two straight lines in the open ocean, which coincided with two of the busiest shipping lanes in the world. Along these paths there were twice as many lightning strikes as in nearby areas.

"We were quite sure the ships had to be involved," says

Thornton. But they still had to eliminate other factors that influence storm intensity, such as wind speeds and temperatures.

Once these had been ruled out, the team concluded that aerosols from the ships' engine exhausts were the culprit. Aerosol particles act as seeds, around which water vapour condenses into cloud droplets. In clean air there aren't many seeds, so the cloud drops quickly grow and fall as rain.

But when there are a lot of seeds, like over busy shipping routes, a greater number of small cloud drops form. Since these are light, they rise up high into the atmosphere and freeze, creating clouds rich in ice.

It is this that leads to more

intense thunderstorms: lightning only occurs if clouds are electrically charged, and this only happens if there are lots of ice crystals.

A key giveaway that aerosols were behind the effect was that the lightning was most pronounced at times of the year when powerful atmospheric convection currents form that can carry the aerosol particles high into the sky (*Geophysical Research Letters*, doi.org/cc7b).

Although lightning activity is higher over the shipping lanes, the amount of rainfall is no different to nearby regions.

While the study provides clear evidence that aerosol particles affect the development and intensity of storms, Thornton says it cannot be directly generalised to the air above land because there are other factors that need to be taken into account.

"Understanding this anthropogenic effect can help us predict future climate," says Orit Altaratz Stollar of the Weizmann Institute of Science in Israel.

The study shows how the changes we make to the atmosphere affect clouds and even the development of stormy weather. Thornton also suggests that the pollution we have released over the last few hundred years may have affected storms and lightning in many places, creating lightning where there was none. ■

A virtual aide could help you plan for death

COULD chatbots lend a non-judgemental ear to people who need to make hard decisions about the end of their life? A virtual assistant is set to be trialled in Boston with people who are terminally ill.

The earlier people start considering where they want to die and what they want to happen afterwards, the easier it is for those around them to act on

those decisions – for example, ensuring they don't die in a hospice if they would prefer to be at home.

But people near the end of their lives sometimes don't get the chance to have these conversations before it's too late, says Timothy Bickmore at Northeastern University in Boston. So Bickmore and his team – which included doctors and hospital chaplains – built a tablet-based chatbot to offer emotional and spiritual support to those who need it.

It has already seen some success in initial tests with 44 people aged 55 and over in Boston, half of whom had

terminal illnesses. After spending time talking to the chatbot, most of the participants reported that they felt less anxious about death and were more ready to complete their last will and testament.

Bickmore now plans to give a version of the chatbot to 364 people who have been told they have less than a year to live. This can also take users through guided meditation

"Talking about end-of-life decisions with people who will be affected by them is emotionally fraught"

sessions and talk to them about their health and medication. When users have made a decision, it lets designated carers know.

We have long known that talking about difficult topics with automated agents is oddly comforting, whereas talking about your end-of-life decisions with people who will be most affected by them is particularly emotionally fraught. Bickmore says the chatbot could be particularly helpful for people who are socially isolated and otherwise wouldn't be having difficult end-of-life conversations at all. Matt Reynolds ■

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There are hardly any old fish left in the sea - and that's bad

THERE aren't just fewer fish in the sea: there are far fewer old fish, too. Their numbers in fisheries around the US and Europe have fallen by an average of 72 per cent.

Lewis Barnett at the University of Washington in Seattle and his colleagues looked at records covering 63 fisheries, spanning 24 to 140 years. They used several methods to work out the age of the fish, including examining otoliths: "stones" in their ears that grow annual rings, just like trees do.

A 2010 study of 10 fisheries found a 25 per cent fall in old fish. But Barnett used models to estimate numbers

before large-scale fishing began - revealing the stark long-term decline. In some species, like Atlantic cod, populations of older fish fell over 95 per cent (*Current Biology*, doi.org/cc5t).

Losing older fish may not sound bad, as they might be near death. But old fish tend to produce more offspring per spawning. They also adapt to changing conditions better, for instance by spawning at different times and locations. This makes short-term environmental change less likely to affect the population badly.

Having only a few old fish leaves fisheries prone to collapse, but they can be saved. One way is to regularly stop fishing in certain areas to let numbers recover. Alternatively, "slot limits" could set minimum and maximum sizes of fish that can be harvested.

DNA robot delivers molecule cargo

A robot made from a single strand of DNA could one day ferry medicines to diseased cells through the bloodstream or build chemical compounds in molecular factories.

Lulu Qian at the California Institute of Technology and her colleagues have created a DNA robot that consists of a leg with two feet attached to two arms for carrying cargo. To test it, the team

created a flat 58-by-58-nanometre surface with little DNA stepping stones for it to hop between. The robot successfully picked up six fluorescent dyes – three yellow and three pink – and moved them to one of two destinations (*Science*, doi.org/cc52).

A single step between stones, which are 6 nanometres apart, takes 5 minutes, so covering the entire surface took a whole day.

But adding an enzyme could give the robot the extra thrust of a chemical motor. "This is one of the first steps towards developing general-purpose DNA robots," says Qian.

"This is the ultimate example of minuscule robotics, and yet it is still programmable and predictable," says Robert Cross at the University of Warwick, UK.

Specific signals could be used to get the bots to deliver a drug to cells that show signs of disease.

Third-hand smoke damages organs

EXPOSURE to the chemicals that cigarette smoke leaves behind on clothing and furniture seems to increase the risk of liver damage and diabetes in mice.

Manuela Martins-Green at the University of California, Riverside, and her team exposed fabric to levels of smoke similar to those found in smokers' homes. Mice living in cages with these fabrics for up to six months had more cell damage in their liver and brain than mice who weren't exposed to this third-hand smoke.

The exposed animals also had a 30 per cent rise in fasting blood glucose and insulin. Both measures are known to increase the risk of diabetes (*Clinical Science*, doi.org/cc5m).

The results are biologically plausible, says Taylor Hays at the Mayo Clinic in Rochester, Minnesota, but further study is needed before we know if it also affects humans.

Brown dwarf has star quality

A MAGNETIC disturbance has been directly observed on a brown dwarf for the first time. These objects straddle the line between stars and planets, but this slots them more in the star category.

Svetlana Berdyugina at the University of Freiburg, Germany, led a team that used observations from the Keck telescope to view the magnetism of a brown dwarf 55 times the mass of Jupiter (arxiv.org/abs/1709.02861). The field is bigger than those of strong sunspots. She says this is because brown dwarfs are relatively dense compared with stars.

This work shows that brown dwarfs exhibit strong magnetic fields and possibly, like stars, interact with the discs of gas and dust around them in their youth.

Virgin spiders are sacrificial meals

SOME spiders make phenomenal aunts. After tending their sisters' eggs and feeding the newborns, these relations offer themselves up for the spiderlings to suck dry.

"The spiders literally start feeding on the female while she is alive," says Trine Bilde at Aarhus University in Denmark. They inject enzymes to dissolve her organs and suck out the semi-digested fluids, leaving only the outer shell. "It looks as if females are almost inviting spiderlings to feed on them."

Stegodyphus dumicola are social spiders, living in large nests. In such species, mated females sometimes care for spiderlings that aren't their own - an act called "alloparenting".

Bilde and her team wondered if unmated *S. dumicola* females also perform alloparenting duties. They placed captive mated and virgin females in groups, with some spiderlings, and watched.

Both virgin and mated females performed alloparenting. They tended to egg sacs, regurgitated food for spiderlings and finally offered themselves up as a meal (*Animal Behaviour*, doi.org/cc53).

This sacrifice makes sense as the spiders in a nest are closely related and so share genes. "The more gene copies she propagates to the next generation, the better, so providing your body as food is a sensible evolutionary solution," says Bilde.



Plastic cube injections could be vaccine and booster in one

IT MAY be small, but it packs a punch. By cramming a protein into microscopic containers that release their loads at different preset times, we may have found a way to deliver a vaccine and booster shot all in one injection.

Until now, this has been out of reach as vaccines are unstable and break down at body temperature.

But Kevin McHugh at the Massachusetts Institute of Technology and his colleagues have now come up with a way of making drug-carrying particles that allow multiple doses of a

vaccine to be delivered over weeks or even months using just a single injection.

The researchers created microscopic polymer cubes, altering the thickness of their walls to stagger the time it took for them to degrade and release their contents.

Then McHugh and his team gave five mice a single injection comprising a mix of these microparticles. Each was filled with a protein that triggers a vaccine-like immune response. In tests, they found that the

protein was released in the mice nine, 20 and 41 days after the injection, just as planned (*Science*, doi.org/cc5z).

This could make it possible to deliver a vaccine and a booster in one go. The team is already working on versions of the particles that can survive for 100 or 200 days before releasing their contents.

Eventually, the technique could be used to create "omni-vaccines" that protect against a whole host of diseases in one shot, says McHugh.

Bacteria sabotage cancer drugs

TREACHERY! It turns out that chemotherapy sometimes fails because bacteria inside cells can destroy anticancer drugs, rendering them useless.

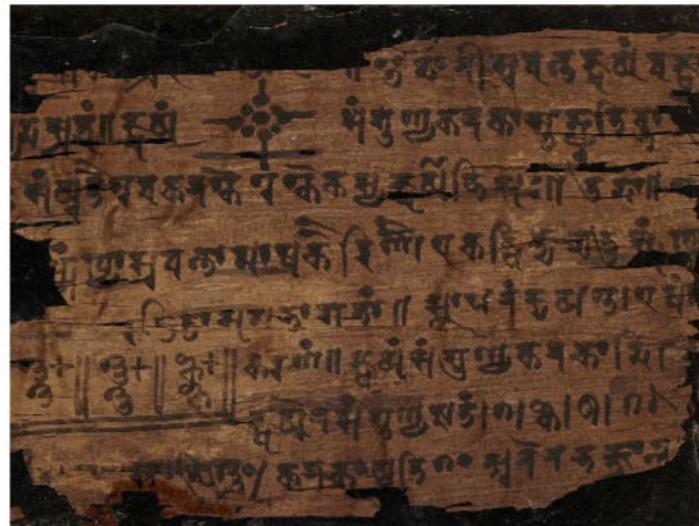
Ravid Straussman at the Weizmann Institute of Science in Israel and his team discovered that skin cells infected with *Mycoplasma* bacteria prevented chemo drug gemcitabine from killing neighbouring cancer cells.

"We found that the bacteria internalise then degrade the drug, deactivating it," says Straussman. They do this by producing a "long form" of an enzyme called cytidine deaminase.

After analysing 113 samples of pancreatic cancer tissue, the team found that 86 were infected with types of bacteria that could make the long form of the enzyme.

In further experiments, Straussman showed that antibiotics stopped bacteria with the long form from destroying gemcitabine (*Science*, doi.org/cc5n).

His team is now investigating how bacteria sabotage another anticancer drug, called oxaliplatin. "We don't think our gemcitabine discovery is an isolated phenomenon," he says.



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Zero is 500 years older than we knew

THE history of maths is being rewritten. Carbon dating has revealed zeros that date back 500 years earlier than had previously been seen.

The numbers appear in the Bakhshali manuscript, an ancient Indian text consisting of 70 leaves of birch bark filled with mathematics and text in Sanskrit. It has been in the University of Oxford's Bodleian Library since 1902, but has only now been carbon dated.

It was thought to be from the 9th century, but the dating methods show that the oldest pages are from between AD 224 and 383. In the text,

zero is denoted by a dot, which later evolved to be the symbol with a hole in the middle that we know today. It was used as a placeholder, like how "0" is used in the number 505 to show there are no tens.

Ancient cultures like the Mayans and Babylonians also used zero as a placeholder. But only the Indian dot would go on to gain true number status, first described in AD 628 by the Indian astronomer and mathematician Brahmagupta.

The concept of zero allowed for the development of calculus, and underpins the digital age.

Beating the battery barrier

Electric cars need batteries that store plenty of energy, deliver it quickly and then recharge in the time it takes to gulp a cup of coffee. BASF researchers are developing the solution

JUST a few years ago, electric cars were an option only for technology enthusiasts or hardcore environmentalists. Slow and expensive, they took several hours to recharge and their dismal range could leave you stranded before you even cleared the suburbs.

By 2020, that picture will look very different. You will be able to recharge your electric sports car in the time it takes to drink a coffee, then drive 500 kilometres before needing to top up.

The electric car revolution is upon us, spurred on by environmental regulation, government incentives and rapid innovation. The International Energy Agency predicts the number of electric vehicles on the road worldwide will increase from 2 million today to 20 million by 2020, and to 70 million by 2025. The Chinese government is set on bootstrapping its car industry into the electric age with tax breaks, research subsidies and a ruling that by 2020, 12 per cent of all vehicles sold in the country must be electric. And the UK, France, Norway, India and several other countries intend to go one better by phasing out petrol and diesel engines entirely in the coming decades.

None of this will be possible without a parallel revolution in the way we store and transport energy. An electric car's performance is driven largely by the quality of its battery. Developing powerful, long-lasting, safe batteries that can store lots of energy is crucial for this vision.

One company at the forefront of all this is BASF. The German chemicals giant supplies most leading battery manufacturers with one of their most important components: the material that makes up the cathode electrode in a

lithium-ion battery. "The cathode material determines the key properties of the battery, such as its energy content, safety and life span," says Markus Hödl, who oversees BASF's battery materials product development. "There is a huge need for improvement in this area because of the demand for low-cost, safe, fast-charging batteries with an extended driving range."

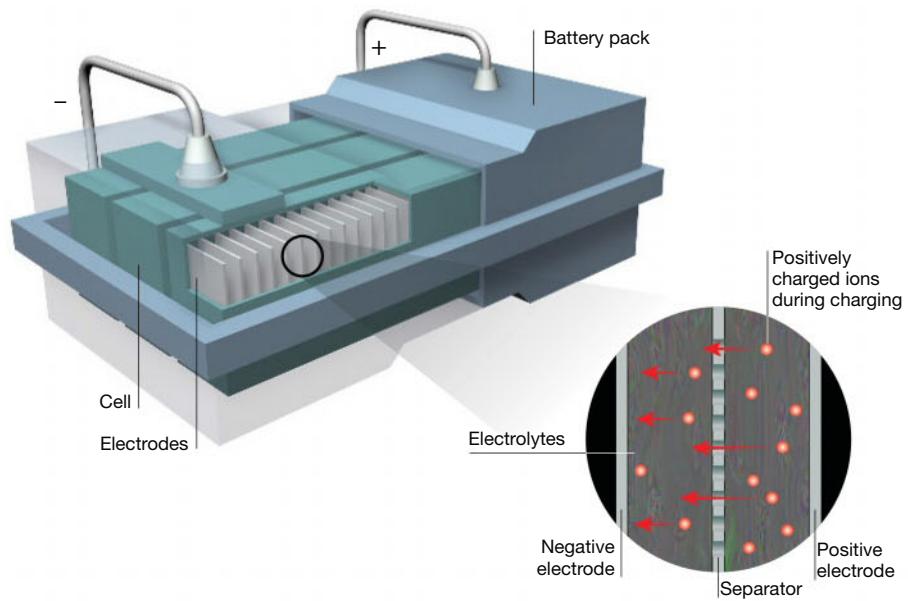
Lithium-ion batteries generate current through the movement of ions and electrons. When the battery discharges, the lithium ions move through an electrolyte from one electrode (the anode) to another (the cathode).

The lithium ions collecting on the cathode add positive charge, which attracts negatively charged electrons.



Better batteries for electric cars will improve air quality in cities and pave the way for renewable energy sources

Tomorrow's high-performance lithium-ion battery





As the electrons move through an external circuit to the ions, this creates the current that powers the car. During charging, this process occurs in reverse.

The reason the cathode material plays such a critical role is that it is largely responsible for enabling the flow of ions.

In the first lithium-ion batteries, introduced by Sony in 1991, the cathode electrodes were made of lithium cobalt oxide, which has a high energy density. But cobalt is expensive. If lithium cobalt oxide were used in a battery giving a 400-kilometre driving range, the cobalt alone would cost more than \$5000.

To make batteries more affordable, BASF replaces some of the cobalt with nickel, which is a fifth of the price. In some respects, nickel makes an even better cathode material because it has twice the energy density. But the oxygen in this mix can be released at a relatively low temperature, raising the risk of fire. The solution is to add another metal to stabilise the mix, usually manganese or aluminium, which are electrochemically less active.

BASF's researchers spend a great deal of time studying these combinations and

Metals supply

As demand for electric vehicles increases, so will the demand for the raw materials to make them. This is a major challenge for BASF, which requires regular supplies of nickel, cobalt, manganese, aluminium and lithium for its battery components.

BASF has recently announced a collaboration with the Russian mining company Norilsk Nickel, to guarantee a stable supply of responsibly-sourced nickel and cobalt.

At the same time, the company is developing ways to reduce the proportion of cobalt needed in battery components called cathodes. The current standard is 20 per cent, alongside 50 per cent nickel, 20 per cent manganese and 10 per cent lithium.

BASF's research and development team has developed new cathode materials that use only 10 per cent cobalt, and is working on reducing that further down to 5 per cent. The company plans to do this by increasing the proportions of nickel and manganese, which are cheaper and more widely available.

But the challenge will be to do all this while maintaining the safety of the battery.

understanding their properties. This job is made more difficult by the varied demands of battery makers. For example, different kinds of electric vehicles prioritise different features.

Fully electric cars require batteries with lots of storage capacity to maximise driving range. This requires a cathode with a high energy density – one that can absorb as many lithium ions as possible in as small a space as possible.

Nickel is great for this, and the more nickel you can pack in, the greater the driving range – but the higher the fire risk. Finding the optimal nickel content for a safe, high-energy battery is one of BASF's major research challenges. "Our aim is to achieve the maximum energy density with a material that is safe," says Hoelzle.

In contrast, for hybrid cars the rate at which the battery delivers energy is more important than storage capacity. That's because hybrids tend to use their batteries in bursts, such as when accelerating away from a stop.

To provide high power, a battery must move large numbers of lithium ions quickly from the anode to the cathode. So BASF's researchers design cathode materials using small particles, which leave gaps for lithium ions to move in and out of quickly. It helps even more if the cathode material is porous: more holes means more space and greater ion flow.

This kind of cutting-edge research should significantly lower the cost of batteries. Lithium-ion car batteries cost around \$200 per kilowatt hour of energy.

Jeffrey Lou, who runs BASF's global business unit for battery materials, thinks improved technologies will help bring that down to \$90 per kilowatt hour. "But innovation will be key on the material side, on efficient production processes and on the recycling of used batteries," he says.

The impacts will be significant. Affordable electric cars will lead to quieter, cleaner cities but will also change the way we live. For example, you should be able to drive to the supermarket and charge your car while you do your shopping, then pay for your energy and food together. "The technology is already visible on the lab benches," says Hoelzle. "In the near future, we'll be seeing a completely new type of mobility."

More at: www.automotive.bASF.com/applications

Life after the storm

Global warming means storms even bigger than Irma and Harvey are coming. We must rebuild right or risk even worse devastation, says **Michael Le Page**

HURRICANE Irma has left a trail of devastation across the Caribbean, like Harvey in Texas just days before it. The final cost won't be clear for months but it will run into billions of dollars.

In the immediate aftermath of these record-smashing storms, there is an urge to rebuild as quickly as possible. But there is also a brief window of opportunity to better prepare for future events, say disaster planners – to pause and think about what should be done differently.

So what can be done to protect these regions in the future? And perhaps just as importantly, what pitfalls should we avoid?

Thanks to better forecasting and preparedness, the death toll from most hurricanes these days is much lower than a century ago. But the damage they cause, and its financial cost, is soaring. The main reason for this is that more people are living in areas at risk, and as a result more valuable infrastructure is being built there.

In the US, for instance, the strip of land within 50 kilometres of the vulnerable Gulf and Atlantic coasts has the greatest density of housing in the country. There are now 27 million housing units in this area, up from 4 million in the 1940s, according to a study by Walker Ashley of Northern Illinois University. This rapid growth is projected to continue over the next century, particularly around Miami.

Even if the climate weren't changing, repeats of past storms like the Great Miami Hurricane of 1926 would cause far more damage, as there is more real estate. A similar event today could cost an incredible \$300 billion.

But the climate is changing.

For starters, global warming has already raised sea levels by around 20 centimetres, making all storm surges – coastal floods caused by storms pushing more seawater towards shores – that bit higher. Even this small increase can lead to hundreds or thousands more homes flooding, says Hal Needham of Marine Weather & Climate in Texas. Given the seas could rise 2 or 3 metres by 2100 as the planet warms further, there is no doubt that storm surges will get even higher.

Rising seas can also make inland flooding much worse. Even a few centimetres of sea level rise can really increase the time it takes water to drain, says Needham.

The US has many policies that essentially subsidise people living in dangerous places

Climate change is making tropical storms more destructive in several ways, such as by increasing top wind speeds. "The speed limit will go up as the climate warms," says hurricane researcher Kerry Emanuel of the Massachusetts Institute of Technology. Beside the direct

damage they do, stronger winds will pile up bigger storm surges on top of the rising seas. And as the atmosphere gets moister, storms will produce even more rainfall and flooding (see diagram, below).

The rational response would be to halt development in the areas most at risk and start a gradual process of moving people and critical infrastructure to safer regions. But people want to live near sunny beaches and warm seas, businesses make money developing such regions and local governments rake in taxes from the building boom. The prosperity of Florida and many Caribbean islands depends heavily on their beach-front real estate.

That doesn't mean nothing can be done. The US federal government could stop funding this unsustainable growth, for example. "Federal tax dollars should not be subsidising development and growth in our most vulnerable areas," says Ashley.

This happens in all kinds of ways, from support for infrastructure projects such as roads and bridges in risky areas, to a deep-in-debt federal scheme

that provides cheap flood insurance, to direct aid to help rebuilding after disasters.

"The US has many policies that essentially subsidise people living in dangerous places," says Emanuel. With many leaders in the US still denying that climate change is an issue, this is unlikely to change anytime soon.

Local plans

This makes it even more vital that local planning regulations ban development in the places most at risk from storm surges and flooding. "We need to plan for an evolving and growing risk under climate change," says Ashley.

It is the lack of such planning laws that made Houston so woefully vulnerable to Hurricane Harvey. But more is being done in Florida: its most vulnerable counties have formed the Southeast Florida Regional Compact to work together on mitigation and adaptation to both hurricanes and climate change.

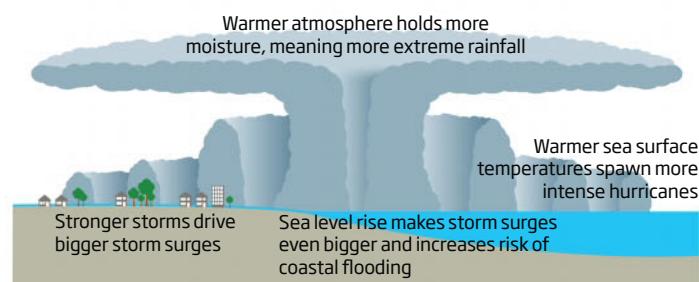
After Hurricane Andrew in 1992, Florida also tightened its building regulations. Structures in Miami-Dade and Broward counties have to be able to withstand winds of at least 210 kilometres per hour. But Irma had top winds of 295 kph.

Future storms could have even faster winds. The limiting factor is the temperature difference between the ocean and the atmosphere, and this is expected to increase further as the planet warms, says Emanuel. "We are going to be breaking records."

This is even scarier than it sounds because the destructive power of winds rises exponentially with speed. Winds of 200 kph can do twice as much damage as

Hot waters

Why global warming leads to more destructive storms





Paradise lost

CRISTOBAL HERRERA/EPA-EFE/REX/SHUTTERSTOCK

those of 160 kph.

But making buildings more storm-resistant is costly. In poorer regions such as Haiti most people can't begin to afford to pay for it, and even in rich Florida, the rules were recently relaxed to reduce costs. "Maybe weakening Florida's Building Code wasn't such a smart idea. Thank you Florida Homebuilders & Developers," tweeted the former head of the Federal Emergency Management Agency, Craig Fugate, as Irma hit.

Even if we implement tougher regulations on where and how buildings are built, that won't help those existing structures in high risk areas.

Instead, cities like Miami are turning to engineering fixes like sea walls, but these are costly to build and maintain. And with seas

set to rise, such defences will have to be made ever higher. So low-lying areas could get locked into spending bigger and bigger sums to try to hold back the seas.

"We need to have some humility around our ability to conquer nature," says Mark Stevens, a hazards mitigation planner at the University of British Columbia in Canada.

For instance, sea walls alone aren't enough in Florida, as water can flow up through the porous limestone bedrock. So Miami is also having to raise the level of roads and new developments. This process could end up turning the city into an island – assuming it doesn't run out of money first as people realise the risks and the real estate market collapses.

Going down the engineering

approach could even make future disasters worse. The problem is that building flood defences encourages more development in the area, as people assume the defences make it safe. If those defences aren't maintained, or if a storm comes along that exceeds the design specifications, the result is a much bigger disaster than if those defences hadn't been built in the first place.

"We saw that with Katrina," says Stevens. Or as Raymond Burby at the University of North Carolina wrote in a 2006 paper: "Hurricane Katrina and the flooding of New Orleans could be viewed as an

expected consequence of federal policy rather than an aberration that is unlikely to be repeated."

This "safe development paradox", as it is known, would be a problem even in a constant climate. Defences built against so-called 1-in-100 year events don't stop 1-in-500 year events.

But now global warming is changing the odds in ways we can't predict with much certainty, greatly increasing the chances of storms that could breach the defences. This is why the safest option is managed retreat as the seas rise and storms grow stronger.

But that's not a message most people are ready to hear. "It's going to take large events to convince people that retreat is the right thing to do," says Stevens. ■

"It's going to take large events to convince people that retreat is the right thing to do"

Against the grain

The latest attempt to overturn well-established dietary advice has salt in its sights, but it leaves a bad taste, says **Anthony Warner**

NEWSPAPER headlines might lead you to wrongly believe that paradigm shifts in the world of nutrition are happening all the time. Barely a week goes by without someone proclaiming that everything we know about diet is wrong.

Despite this, one truth has remained pretty much accepted. Keeping our intake of salt down to around 6 grams per day is generally acknowledged as good for health, and features in dietary advice worldwide.

Clearly this has left a gap in the market, because nothing attracts attention more than questioning the nutritional orthodoxy.

Enter James DiNicolantonio, a US-based researcher. His book *The Salt Fix* attempts to upend the standard thinking, as its subtitle makes clear: *Why the experts got it all wrong – and how eating more [salt] might save your life*.



He asserts that despite what public health organisations have been saying for decades, eating more salt than recommended is not, in most cases, linked to high blood pressure and to risk of heart disease and stroke. On the contrary, he says, it can help protect against heart disease, as well as insulin resistance, diabetes and kidney disease.

The book's references include dated research, bizarre opinion pieces and occasional anecdotes to back up the central argument that we have been getting bad advice on salt for decades. This runs counter to overwhelming evidence to the contrary. Key studies that support the book's premise have been criticised by major medical bodies.

Leading public health experts say the totality of evidence is what is important, and that this shows a still-robust link between

Notably absent

The lack of women appointed to the UK's key science committee is dire, says **Lara Williams**

WITH the announcement last week that the eight members of the new House of Commons Science and Technology Committee so far appointed were all male – and all but one white – a reaction was sure to follow. It duly did, with a string of critical tweets.

Not only had it failed to appoint any female MPs, and only one

person of colour, but of the eight, only two have a science degree: Darren Jones (bioscience) and Graham Stringer (chemistry). Stringer, by the way, is on the climate sceptic Global Warming Policy Foundation's board.

Committee chair Norman Lamb promptly spoke out, stating it is “imperative” women are on the

committee. There are still three places left to be filled – which means there is a slim space for women to potentially occupy.

Those defending an all-male line-up might make a common argument that crops up in debates on diversity in science and technology: that men dominate because too few women are qualified or interested in these professions. They might seize on recent stats from the WISE campaign for gender parity,

“In sectors such as science and technology, the gender gap exists globally and at nearly every level”

which found that women made up just 14 per cent of engineering and technology graduates.

But in order to make the broadly reductive argument that qualified or interested women just aren't there, you must ignore barriers and structures, including overt sexism, that stop women from seeing science or technology as an accessible, relevant career.

In unveiling an all-male line up for a body as important as this committee, you don't just validate that argument – you reinforce it.

The Science and Technology Committee offers an opportunity to scrutinise government policy and decision-making pertaining

a high-salt diet and ill health.

Regrettably, titles that suggest a paradigm shift are always likely to generate publicity. Because of its headline-grabbing approach, *The Salt Fix* received far more column inches than the repeated research findings that support guidelines on salt.

The public interacts with the world of nutrition to an extent that rarely occurs in other scientific fields. Despite dietary advice remaining remarkably consistent over the years, those who go against the grain tend to dominate coverage.

This matters. A recent World Health Organization report estimated that cutting salt intake to the level it recommends could result in 2.5 million fewer deaths worldwide each year. The evidence for health benefits from salt reduction is perhaps stronger than that for dietary advice on almost any other foodstuff, including sugar, saturated fat or even fruit and vegetables.

A high-profile challenge based on such underwhelming evidence is therefore at best ill-advised, and at worst dangerous. ■

Anthony Warner works as a food industry development chef and blogs about dietary science. He is author of *The Angry Chef* (OneWorld)

to many aspects of science and technology. It also offers an opportunity for representation and visibility at a very high level. Representation matters. It informs how we see ourselves and others. It makes modes of being permissible and avenues for exploring accessible. It legitimises ambition and aspiration.

And in sectors such as science and technology, in which the gender gap exists globally and at nearly every level, visible representation of that sort has never been more essential. ■

Lara Williams is a writer based in Manchester, UK

INSIGHT Limiting climate change



JGALONE/GETTY

Kicking old habits is just too hard

Meeting that 1.5°C goal could be a pipe dream

Michael Le Page

THE Paris Agreement aspires to limit global warming to 1.5°C above pre-industrial levels. But is this target at all realistic?

Climate scientists had estimated that this means we can emit no more than 70 gigatonnes of carbon (GtC) after 2015. At current emission rates, we will pass this threshold by 2022.

Now, a study is claiming that we can emit 200 GtC – nearly three times as much, pushing the deadline back to 2035. “Keeping to 1.5 [degrees] just went from impossible to very difficult,” says team member Joeri Rogelj at the International Institute for Applied Systems Analysis in Austria.

Is the team right? The first issue is how you define the pre-industrial temperature. The study uses the period 1861 to 1880, when we start to have decent temperature measurements. The UK Met Office’s record of average global surface temperatures suggests the 2010s will be 0.9°C above this period, leaving only 0.6°C of wiggle room.

But there had already been about 0.2°C of warming by 1870, according

to Michael Mann of Penn State University, which would mean there is just 0.4°C to go. “When a proper pre-industrial baseline is used, 1.5°C is virtually impossible,” he says.

Then there is the issue of why this study gives a much larger carbon budget. The team says it relied on improved climate models and more recent data (*Nature Geoscience*, DOI: 10.1038/NGEO3031).

However, the results have left other researchers scratching their heads, says Gavin Schmidt, head of the NASA Goddard Center for Space Studies in New York. “I can tell you that lots of

“When a proper pre-industrial baseline is used, 1.5°C becomes virtually impossible”

people are emailing around trying to work out why these numbers are so much higher than previous ones.”

“I am quite nervous there will be headlines that we have a significantly larger budget for 1.5°C,” says Glen Peters of the Center for International Climate Research in Norway. “But I think we need to have more

studies confirm that.”

Even if the new study is right, limiting emissions to 200 GtC still only gives us a 66 per cent chance of limiting warming to 1.5°C, it finds.

But even the best models leave out slower feedback mechanisms that lead to more warming, such as methane emissions from a melting Arctic. It is quite possible the models underestimate future warming.

In any case, it doesn’t matter. We are already on course to exceed 200 GtC. Although coal use is down, rising oil and gas use mean we are still emitting record levels of carbon dioxide.

Even if renewables grow ever faster, getting total emissions down to zero is going to be tough. Sectors like aviation and farming are producing ever more emissions that will be very hard to tackle. Discussing the carbon budget for 1.5°C may be like asking how many angels dance on a pin.

The authors of the paper say they hope the findings will inspire people to redouble their efforts to meet the Paris Agreement’s goal. Maybe. But the danger is that when the planet crosses this threshold in the next decade or three – which it will using Mann’s definition of pre-industrial – people will give up hope. We are likely to zoom past 2°C too – surprisingly, having a larger budget for 1.5°C does not mean we have a larger budget for 2°C.

A simpler message might be better: the more we all do to limit emissions, the better off we will all be. ■



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Hunting for WIMPs

WHENEVER the XENON1T experiment is running, this hall of funhouse mirrors becomes like a moat, protecting the search for dark matter. The 10-metre-high water tank, the inside of which is pictured, surrounds a container with 3.5 tonnes of pure liquid xenon from unwanted particles. This enables it to focus on looking for weakly interacting massive particles (WIMPs), a leading candidate to explain dark matter.

XENON1T at the Gran Sasso National Laboratory in Italy is the largest liquid xenon detector in the world. When a WIMP passes through the detector and hits xenon atoms, it will free electrons and create bursts of light.

Even though 100,000 particles of dark matter are thought to travel through each square centimetre of the detector every second, none has yet been observed. This means that if dark matter really is made out of WIMPs, those particles almost never interact with normal matter, instead passing right through like a ghostly reminder that over 80 per cent of matter in the universe remains dark and mysterious to us.

This image earned photographer Enrico Sacchetti a Gold Award in the Royal Photographic Society's annual International Images for Science competition. Along with 99 other images from the contest, it is part of an exhibition due to start a UK tour later this month. Leah Crane

Photographer

Enrico Sacchetti
es-photography.com

ACCIDENTAL ARMAGEDDON



The world is edging closer to nuclear war, but not for the reasons you might think, says Debora MacKenzie

AS YOU read this, about a dozen submarines are lurking in the world's oceans, equipped to launch nuclear missiles. Four are American; the rest might be British, French, Russian, Chinese, Indian or perhaps Israeli. Some of them are packing massive heat, equivalent to thousands of times the bomb that obliterated Hiroshima. All are being very, very quiet.

Why? In a word, deterrence. In the event of a nuclear strike or massive conventional attack on the sub's owner or its allies, that nation can unleash horrendous retaliation – so no one dares attack in the first place.

Deterrence is credited with preventing

nuclear conflict since the beginning of the cold war, but it is under increasing stress. Most obviously, North Korea has entered the game. It says it is developing nuclear weapons precisely to deter a US nuclear strike, but with the rhetoric getting out of hand, nuclear conflict could become more likely rather than less.

But beyond that headline news lies a less well-known, but potentially more disturbing, story. A series of seemingly minor technological upgrades have been destabilising the foundations of deterrence, sparking a new nuclear arms race with unforeseeable consequences. "The danger



of an accident leading to nuclear war is as high now as it was during periods of peak crisis during the cold war," says Hans Kristensen, director of the Nuclear Information Project at the Federation of American Scientists.

The rules of deterrence as formulated in the cold war depend on guaranteed retaliation to any nuclear strike. If an enemy can knock out your ability to retaliate by launching a surprise first strike on your nuclear missiles – called a counterforce attack – deterrence fails (see "Will they, won't they?", above right).

Hence the silence of the nuclear subs, and the existence of nuclear missiles on mobile launchers hidden in forests or tunnels in

Russia, China, India, Pakistan, Israel and soon, North Korea: if they cannot be found, they cannot be taken out in a first strike. Hence the US and Russian principle of maintaining a "triad" of submarine, land-based and airborne weapons: if one is knocked out, the others can strike back.

Hence also why the US and Russia keep 400 and 136 intercontinental ballistic missiles (ICBMs) in silos and on hair-trigger alert, so they can be launched at the first sign of incoming missiles that might destroy them. There used to be far more, before the Strategic Arms Reduction Treaty or START process began progressively cutting the arsenals of

WILL THEY, WON'T THEY?

The advent of nuclear bombs and their terrifying destructive capabilities turned the logic of conflict on its head. As the US military strategist Bernard Brodie wrote in 1946: "Thus far the chief purpose of our military establishment has been to win wars. From now on its chief purpose must be to avert them."

But how? The answer was developed by game theorists in the 1950s: bat the ball into your opponents' court. If you can convince them that any nuclear attack on you or your allies is suicidal, they won't try it. But you must make sure your nuclear deterrent cannot be taken out before you can retaliate, and ensure the response is automatic – if you are hit, you will hit back.

That requires a lot of warheads, and led to the cold war arms race. At its height, any nuclear exchange would have meant the mutually assured destruction of the US and Soviet Union, fittingly known as MAD. Lesser deterents, such as the UK's, merely threaten something an enemy values, like a city.

However the game is played, deterrence has kept the nuclear peace since 1945, despite some hairy moments. Yet changing technology now threatens to destabilise this improbable saviour (see main story).

the two main nuclear powers in the 1990s. But there are still so many that no counterforce attack can knock them all out.

That was the theory anyway – but it's one that seems increasingly at odds with reality. Besides its land-based ICBMs, the US packs 890 warheads on submarine-launched missiles. Of these, 506 are code-named W76, and each has the explosive power of 100 kilotonnes of TNT. The rest, called W88s, pack 455 kilotonnes. (The Little Boy bomb dropped on Hiroshima delivered 15 kilotonnes.)

Trident missiles can release up to eight of these warheads above the atmosphere, which then fly independently to preset targets. ➤



POLARIS/EYEVINE

THE KOREAN QUESTION

For all its ability to make headlines, most recently detonating what appears to have been a hydrogen bomb, North Korea is a bit player in the global game of nuclear deterrence. But its reason for going nuclear at all is to deter a first strike by the US. Like the big powers, it too worries that its nascent deterrent might be vulnerable.

North Korea has not yet attached a nuclear warhead to a missile and launched it. But it already has land-based medium-range missiles, and is developing an intercontinental ballistic missile, both of which can be moved by road. Typically countries keep these in bases, then deploy them in crises to forests or mountains where they can't be seen by remote-sensing satellites. North Korea's terrain is ideal - but moving them by road is risky.

Keir Lieber of Georgetown University in Washington DC and Daryl Press of Dartmouth College in New Hampshire have used public data from US polar-orbiting radar satellites and software such as OpenStreetMap to calculate that 90 per cent of North Korean roads are visible to satellites. The regime could move its missiles when satellites are not overhead, but Lieber calculates that 54 per cent of its

roads would still be visible via radar to aerial drones operating outside North Korean airspace. That could rise to 97 per cent with extra input from stealthy drones that can operate briefly inside the country, which the US is developing.

To keep its deterrent safe, North Korea is developing submarine-launched missiles. For now, the deterrent might seem vulnerable to a first strike. But it would have to be 100 per cent successful to preclude nuclear retaliation, and there are too many uncertainties to guarantee that, says James Acton of the Carnegie Endowment for International Peace in Washington DC. And even then there are many other ways North Korea might retaliate, with its chemical or long-rumoured biological weapons, or the hundreds of conventional short-range missiles it has trained on the South Korean capital, Seoul.

The fact that North Korea's nascent nuclear force could be vulnerable to a pre-emptive strike may just ensure that it keeps multiplying its nuclear weapons and delivery systems, and maintains other deterrents. And, as with its recent cautions about a warning shot at the US Pacific base at Guam, it will continue to find ways to let us know it has them.

North Korea's new hydrogen bomb is not the only threat to nuclear stability

Barring mechanical failure, the warheads should detonate within 100 metres of their targets. For the big W88s, that is close enough to destroy a "hard" site like a concrete ICBM silo. The smaller W76s have to land closer. As a result, W76s have previously been aimed at soft targets, like military bases, where accuracy is less crucial.

But in 1998, the US Navy started developing a "super-fuse" for the W76s that measures and corrects for their altitude at release, making them three times more likely to explode close enough to the target to destroy it. The US started deploying the super-fuse in 2009. In March this year, Kristensen and his colleagues published calculations showing that this apparently small change to US submarine-launched nuclear missiles means they can now take out all Russia's ICBM silos using just over half of the W76s, even aiming two warheads at each in case some are faulty. "That frees up the rest, and the heavier W88s, to take on harder targets such as buried command and control bunkers," Kristensen says.

All W76 warheads on the US submarine fleet are now fitted with these fuses, and they are thought to have been delivered recently to the UK's Tridents, says Paul Ingram of the British American Security Information Council, a think tank in London. A similar fuse will start being fitted to US land-based ICBMs in the 2020s.

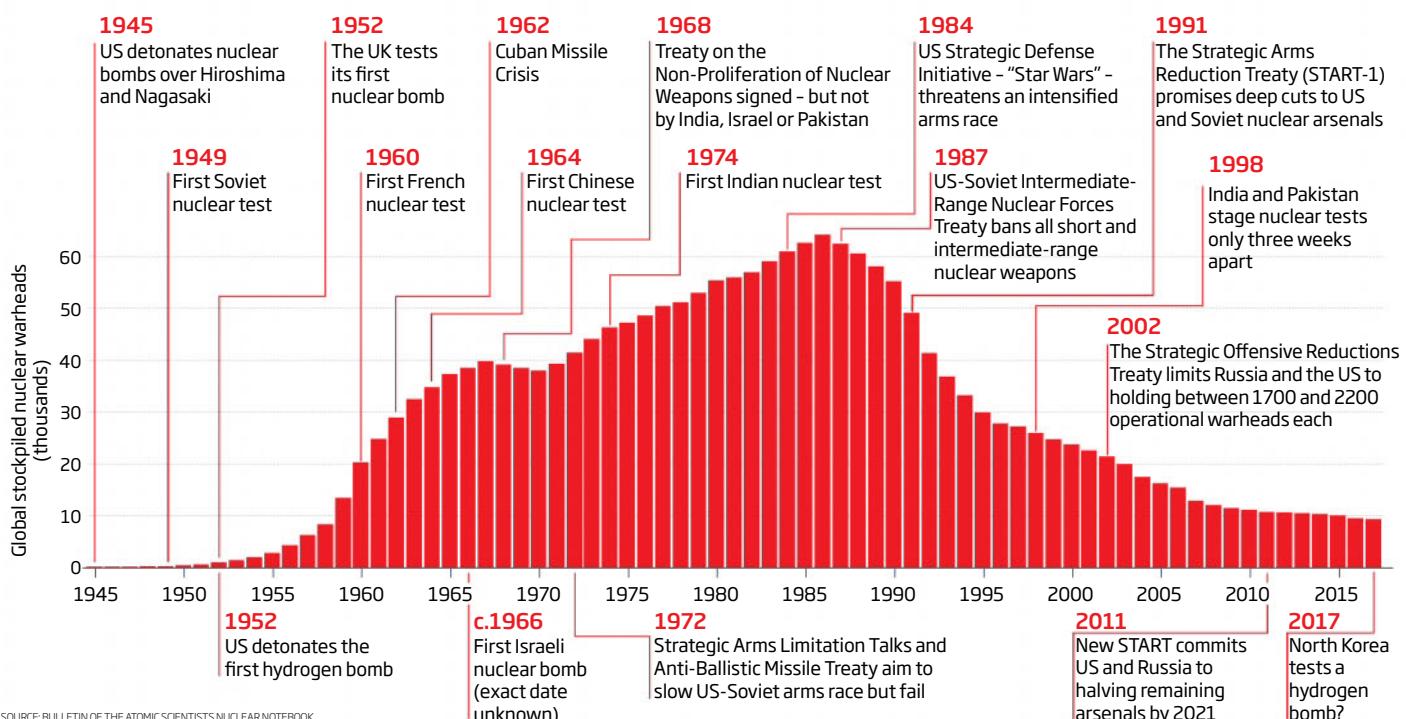
The super-fuse upgrade was part of the US nuclear modernisation programme, which is supposed to ensure the reliability of the US nuclear arsenal, not boost its capability. But after the cold war, military demands were diversifying and growing, even as the START process cut the number of warheads. So planners wanted more efficient warheads - and technology supplied that. "The super-fuse seemed such a minor change that policy-makers missed the serious implications for strategic stability and perceptions of US intentions," says Kristensen. "It's an astonishing, game-changing increase in US nuclear capability."

Escalating fears

Just because the US may now be more able to take out another country's nuclear deterrent doesn't mean it plans to, of course. But in the game of deterrence, what matters is perceptions. James Acton of the Carnegie Endowment for International Peace, a think tank in Washington DC, thinks the US would be very unlikely to try a first strike. It would not find and destroy all of Russia or China's mobile

Back from the brink

US-Russian nuclear disarmament treaties have massively reduced weapons stockpiles since the end of the cold war – but huge arsenals remain



land-based or submarine missiles, and those that survived would be used to retaliate. “But many experts [in Russia and China] are deeply, genuinely worried about the survivability of their nuclear deterrent, and even if such fears are exaggerated they can drive escalation.”

The growth in US missile defence systems is also stoking these fears. These undermine deterrence by, in theory, allowing a country to launch a first attack safe in the knowledge that it can intercept any retaliatory strikes. In May this year, apparently in response to accelerated nuclear missile development by North Korea, the US conducted the first successful test – against a simulated ICBM – of the Ground-based Midcourse Defense system it has been developing since 1999.

In response, China made angry accusations that this would “start a new arms race”. Last year the Russian president, Vladimir Putin, made the same charge, naming US “high precision weapons” – an apparent reference to the super-fuse – plus missile defence as the reason.

As worries about vulnerability have grown, all sides have beefing up their deterrents. In 2015, China caught up with other nuclear powers by deploying missiles with multiple independent warheads. In November last year, Russia started tests of an underwater drone designed to explode a radioactive “dirty bomb” in an enemy harbour to contaminate a city. The plans were deliberately leaked in

2015, experts believe, to deter US missile defence plans by demonstrating alternative forms of retaliation for a first strike.

But efforts to reinforce deterrence with a new arms race could make the use of nuclear weapons more likely, rather than less. All sides are now developing manoeuvrable hypersonic missiles, to evade missile defences and early warning radar. The US says its missiles won’t be nuclear, but an adversary about to be hit by one won’t be able to tell. China says it is

considering abandoning its policy of never using nuclear weapons first, precisely because of hypersonic missile development in the US.

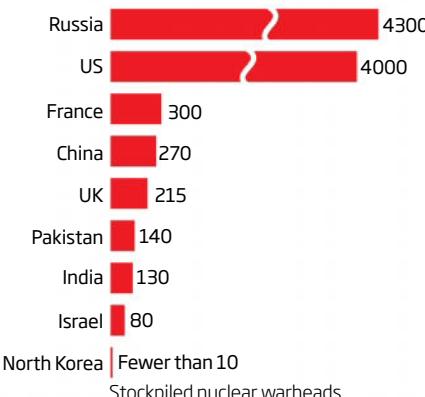
Faced with a crisis such as an incoming hypersonic missile, a country may well launch its nuclear weapons fast if it thinks it may otherwise lose them in a counterforce strike, as well as to deter further attack, says Acton. Just one missile to convince the other side to back down might provoke retaliation instead. “It’s a low-probability event, but the consequences could be catastrophic,” he says. Increasing fears that the US is aiming to be able to win a nuclear first strike could make such reactions more likely – including now from the demonstrably paranoid regime in North Korea (see “The Korean question”, left).

You don’t even need a crisis – you just have to be wrong about signals that seem to suggest imminent attack. Now that the cold war satellites that Russia once used to sense heat plumes over US missile sites and warn of ICBM launches are defunct, its radar gives only 15 minutes’ warning of incoming rockets – half the time available to the US – and Russia cannot check where they came from.

That increases the possibility of a mistake. In 1995, Russian submarines came within 5 minutes of launching nuclear missiles after Moscow feared a Norwegian research satellite was an incoming Trident missile. Boris Yeltsin, then president, overruled his generals who advised launch, because the generally good ➤

Cold war legacy

Russia and the US still have by far the greatest nuclear firepower



SOURCE: BULLETIN OF THE ATOMIC SCIENTISTS NUCLEAR NOTEBOOK



CYBERGEDDON?

In June 2016, the British submarine Vengeance test-fired a Trident missile, the UK's nuclear deterrent. Something went badly wrong, and the missile may have veered towards the US.

The missile was not carrying its nuclear warheads and was destroyed. The UK government has remained silent on what might have caused the incident, but "the failed Trident test is consistent with cyber interference," says Paul Ingram of the British American Security Information Council, a think tank in London.

It highlights another threat to the delicate balance of nuclear deterrence (see main story): hacking. Just the possibility that the computer systems controlling deterrents could be compromised is destabilising. But in June this year Ingram and Stanislav Abaimov, a Russian-trained hacking expert, concluded that the UK Trident-based deterrent is vulnerable to the cyberwar operations of foreign governments, despite its computers being separated from the internet. This is partly because of the many subcontractors that develop them; Vengeance had just had a major refit.

The US uses similar technology, so is potentially similarly vulnerable. Meanwhile Andrew Futter at the University of Leicester, UK, raises another problem. The command and control system used to manage US nuclear weapons is currently undergoing an upgrade. Parts of the old system still relied on 8-inch floppy discs. Although outdated, this was at least relatively simple. Futter worries that the spiralling complexity of the replacement not only provides hackers more toeholds, but could lead to errors that might not be immediately obvious, for example generating false alarms that could unleash a retaliatory strike.

In June, four former high-ranking US, Russian and European defence officials called on presidents Trump and Putin to start talks about "interference in strategic warning systems and nuclear command and control" to prevent war by mistake. "That there are no clear 'rules of the road' in the strategic nuclear cyberworld", they wrote, for instance providing for consultations between adversaries, "is alarming."

HMS Vengeance is the newest of four subs that carry the UK nuclear deterrent

relations between the US and Russia at the time seemed to preclude an attack. With the current atmosphere of mutual suspicion, we may not be so lucky now. That's before you consider the increasingly real possibility of computers going haywire and launching nuclear attacks by themselves (see "Cybergeddon?", below left).

Uncharted territory

Submarine-launched nuclear missiles have long been considered the ultimate deterrent – and are the only one the UK has – because of their apparent invulnerability to pre-emptive strike. But even that now seems less certain. Persistent rumours of Soviet-era technology that allows nuclear subs to be tracked using their turbulent wakes may have something in them.

Going the other way, Ingram points to aircraft being developed for the US Navy by UK defence company BAE Systems. These can track submarines from the air using a drone to sense magnetic anomalies, then target them with air-launched missiles. If this system struck, say, a Russian submarine, the situation might not be clear in Moscow for some time, as these subs stay silent. Knowing that can happen increases Russian uncertainty, and further destabilises any potentially nuclear confrontation.

This has long been the paradox of deterrence: it is only ever a temporary stand-off, lasting just until the enemy finds a way to neutralise your deterrent. Ultimately, the technological capacity to see, hear and otherwise detect and destroy other countries' weapons could become so good that first strikes will become winnable, and deterrence will no longer work. That seems to be the dangerous, uncharted territory we are now entering.

What else will keep the nuclear peace? Optimists are promoting a UN treaty to ban all nuclear weapons, released in May. Otherwise, say weapons experts, we can talk, reassure countries that their deterrents still work, and build confidence by creating channels of communication and sharing new weapons developments. But that, says Acton, is unlikely any time soon. "Neither the Russians nor the Chinese want to talk, though the Obama administration tried repeatedly. Now that's over too." And don't even talk about North Korea. ■

Debora MacKenzie is a *New Scientist* correspondent based in Geneva

Food for thought

It's possible to have a diet that is good for you and the planet. But would you want to eat it? **Bob Holmes** finds out



DEVAN GEORGE/PLAINPICTURE

LOW fat, low salt, wholegrain, heart healthy, vegan, organic, free-range, grass-fed, low carb, no added sugar. All these buzzwords, combined with shape-shifting guidelines, befuddling labels and fad diets wrapped up in pseudoscience, can make buying groceries these days fraught. That's partly why anything that claims to cut a clear path through the confusion has ready appeal: witness the rise of the "clean eating" movement in the past few years. The rigid rules set out by self-appointed blogger gurus have since been shouted down as nonsensical notions of purity rather than coherent nutritional science. But the clean eating evangelists found a following because they promised to simplify, to make decisions about food less overwhelming – and to provide a world view to match.

I may have avoided the nonsense peddled

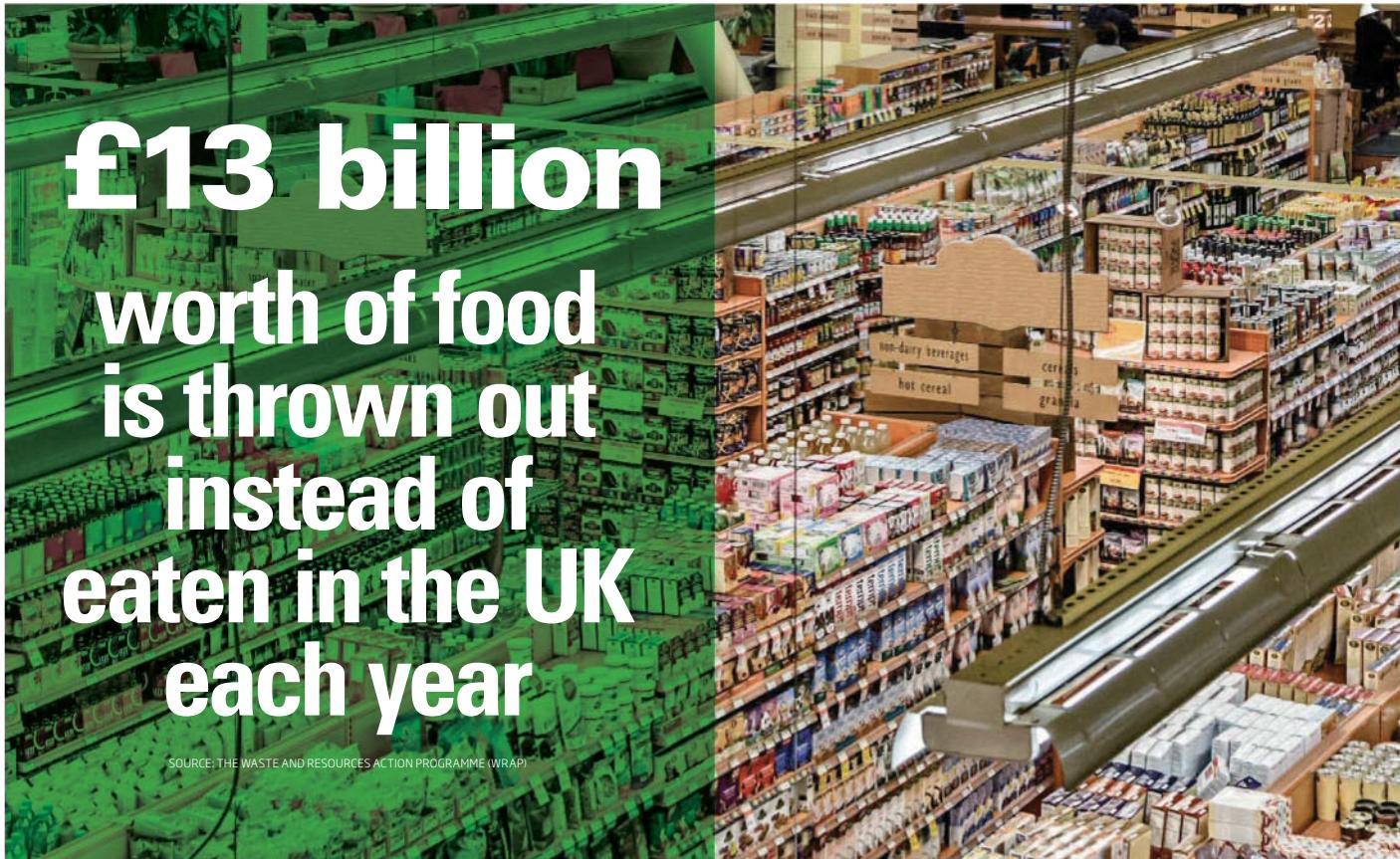
in the blogosphere, but, like many people, I find the current world of food bewildering at times. My goals are simple enough: I want to come home with the ingredients for tasty meals that will make my family healthier, without spending a fortune. And while I'm at it, I'd also like to minimise any harm I might cause to the environment and my fellow humans. That shouldn't be so hard, right?

I decided to take a close look at my food choices to see whether I could find a healthier, more sustainable diet. Could I meet both those goals, or would they pull in opposite directions? Equally important for an enthusiastic foodie like me, would I end up with a diet I would actually enjoy eating? And would the whole business be so complicated that only an obsessive would ever bother?

Although it was far more complicated than I hoped to suss the economic impact of my ➤

£13 billion worth of food is thrown out instead of eaten in the UK each year

SOURCE: THE WASTE AND RESOURCES ACTION PROGRAMME (WRAP)



DAVID MADISON/GETTY

choices on the places that grow food (see “The quinoa conundrum”, page 40), when it came to health and sustainability, what I learned was surprisingly encouraging. “Healthy diets frequently have lower environmental impacts,” says Alan Dangour of the London School of Hygiene and Tropical Medicine. Better yet, I can get to my goals without having to give up most of the foods I love.

To start, I wanted to figure out how far I could go in minimising my environmental impact. As it happens, Jennie Macdiarmid, a nutritionist at the University of Aberdeen, UK, has looked at exactly this. She and her colleagues sorted through 82 food groups and crunched the numbers to find the diet that minimised greenhouse gas emissions while meeting UK guidelines for nutrient intake and calories.

A sufficiently motivated eater could reduce their greenhouse emissions by a whopping 90 per cent, she found, by sticking to a diet consisting of just seven foods: pasta, peas, fried onions (probably because they have more calories than raw), brassicas (vegetables like cabbages, turnips and broccoli), sesame

GO ORGANIC

Choosing organic food may seem an obvious step toward a healthier, more environmentally friendly diet. But there’s little evidence that it’s any more nutritious than conventionally grown food, and pesticide residues generally aren’t a health issue when limits are enforced.

Environmental benefits are similarly elusive. Organic farms do have better soils and more native species, and may also have lower emissions per hectare because they eschew energy-intensive synthetic fertilisers. The problem is that organic crops have lower yields, so need extra land. In the UK, for example, it takes about 29 square metres to produce a tonne of tomatoes conventionally, but almost twice as much to grow it organically. If we all go organic, that would mean less land left over for forests, meadows and other natural habitats.

seeds, dry wholegrain breakfast cereal (which is fortified with lots of nutrients) and confectionery. Sweets don’t have a huge carbon footprint, so, ironically, in Macdiarmid’s analysis they are a “good” way to get enough calories once you have met your nutrient needs.

As a man who loves his wild mushroom risotto and is not a fan of dental cavities, I am dismayed, to say the least. Macdiarmid is realistic about that. “Sure, that will have low emissions and meet your dietary requirements, but who’s ever going to eat it?” she says. Phew. Fortunately, she also found that you don’t have to go to such extremes to significantly cut carbon emissions.

So I decided to give my current diet a closer look. That means dealing with the elephant in the room: meat. Like most Westerners, I eat more of it than I should, from silky prosciutto to braised lamb shanks to grilled moose steaks (one of the glories of living in Western Canada). The science isn’t fully settled yet, but diets high in saturated fats – which are found plentifully in meat and dairy – have been shown to increase the risk of heart disease.

Some of the compounds in red meat, and especially in cured meats, such as bacon and ham, also increase the risk of colon cancer. The American Institute for Cancer Research recommends eating no more than 500 grams of red meat per week, the equivalent of four hamburgers.

Meat's environmental cost may be even greater than its health risks. Today, calorie for calorie, beef causes roughly 50 times the greenhouse gas emissions of beans or grains, and requires several times more water. And that's only getting worse as the demand for

"To feed ourselves more efficiently, meat can be part of the solution"

a Western, meat-heavy diet grows throughout the developing world.

Faced with that reality, it seems my best choice would be to become vegetarian or vegan. With a little care, such diets can provide all the nutrients you need. This would reduce my environmental footprint, and with none of meat's health risks, I could end up healthier too. But not necessarily – if I were to do what many vegetarians do and switch to a cheese-heavy diet, some studies suggest all the extra saturated fat could leave me worse off.

It turns out that vegetarianism may not be the best option. After all, meat is a great protein source and full of iron and vitamin B₁₂ – nutrients that are often in short supply, especially for the world's poor. Plus, more than a quarter of Earth's surface – and 70 per cent of its agricultural land – is grazing land, most of it too steep, rocky or arid to grow crops. Grass-fed cattle or sheep are the best way for humans to get calories from this land.

Chickens and pigs can't eat grass, but they are still relatively low impact, because they more efficiently convert feed to flesh and produce no methane. They could also live happily on kitchen scraps and other food waste, though in much smaller numbers than with modern, intensive production. In a future where feeding ourselves efficiently is paramount, a little bit of meat and dairy can be an important part of the solution. But – and it's a big but – we still need to eat far less of it.

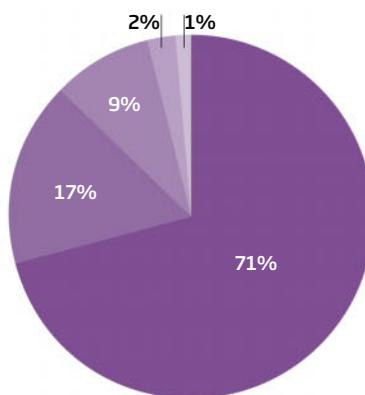
Ideally, I would buy only meat raised on "leftovers", but there's no straightforward way to do that today for chicken or pork, unless I know the farmer. For beef, I should opt for the pricey grass-fed option, which shouldn't break my budget since I'd only indulge occasionally.

That might have an impact on my carbon

Going to waste

A third of all food is thrown out globally, with households the main culprit. In the UK, for example, households account for nearly three-quarters of all wasted food

● Household
● Restaurants
● Manufacturing
● Supermarkets
● Other



SOURCE: THE WASTE AND RESOURCES ACTION PROGRAMME (WRAP)

budget, though, seeing as these grass-fed animals have a bigger carbon footprint per kilo of meat. This is because they grow more slowly than factory-farmed animals and thus emit more methane. Cutting back dramatically on meat will lessen that impact, says Tara Garnett, who heads the Food Climate Research Network at the University of Oxford. But there is no way the world can continue on today's meat-heavy path without abandoning notions of animal welfare and opting for factory farming instead. Is this a choice we really want to make?

The takeaway for me is to have more meat-free days, and when I do eat animal products, to cook smaller portions and choose kung-pao chicken or a bit of pork with sautéed greens more often than a beef steak or those braised lamb shanks.

I could also make a point of eating more fish, which can provide healthy omega-3 fatty acids as well as protein. In general, this also has a smaller carbon footprint than red meat. The catch is that some species, such as bluefin tuna, orange roughy and Atlantic halibut, are overfished; others, such as farmed shrimp and Atlantic salmon, cause immense damage to nearshore habitats and wild fish. To complicate matters even further, some species such as Pacific salmon are overfished in some places and not others. To make sense of it all, ➤



WILLIAM THOMAS CAIN/GETTY IMAGES

THE QUINOA CONUNDRUM

unfortunately there's really no choice but to do a little research before you buy. For me, that means favouring wild Alaskan salmon and Arctic char farmed in landlocked tanks.

But what of the rest of my dinner plate, the starches and vegetables? Should I be making changes there, too? Unfortunately some of the best foods for my health, such as avocados and tree nuts – excellent sources of healthy fats – are among the worst crops environmentally, often grown with irrigation in arid climates. When it comes to growing food, the bottom line is that the environmental impact depends on how and where, which seems worryingly difficult to keep track of. We often think of rice as a water-hungry crop compared with wheat,

A critical variable in creating a truly sustainable diet is how our food choices impact the livelihoods of the people growing what we eat. Unfortunately, that's very hard to pin down. "There's a lot of huff and puff about these questions, and there's very little data," says Alan Dangour of the London School of Hygiene and Tropical Medicine.

Disruption is inevitable: if we were to eat much less meat, for instance, that's bound to be bad news for cattle ranchers, but might be good news for vegetable farmers. Plus, with less grain going to feed livestock, wheat prices would probably fall – a huge benefit for the world's poor.

Importing food grown in poorer countries enables their farmers to earn extra cash, but by bidding up the price, it may also be taking food out of the mouths of the poorest people there. To eat more plant proteins, for example, I could buy quinoa more often; lots of people are doing that, and its price has shot up in recent years. Some worry that this has priced quinoa out of the reach of poorer people in Bolivia and Peru, and indeed, consumption has fallen there (though this may reflect a shift away from traditional diets to more "modern" fare). "Unintended consequences of good intentions are very common," says Ana Islas Ramos of the UN Food and Agriculture Organization.

"The idea that local produce is best is actually a misconception"

for example, but in India, most rice is grown with rainwater and most wheat irrigated.

So is it fish all over again? Do I have to investigate each item I want to eat? Fortunately, no. "Scientists will always argue the toss on whether a Brussels sprout is better than an asparagus," says Macdiarmid. "But how deep do you want to get? My feeling is we have to have some relatively simple messages." She and the other researchers I spoke to say it boils down to this: eat a wide range of fruits, vegetables, whole grains and legumes. That way I'll be more likely to cover my nutrient requirements, and I'd hedge my bets on environmental impact by not eating



too much of any one food. So guacamole can stay on the menu, now and then.

Of course, I should be getting all of this stuff as locally as possible, right? I love a stroll around the farmers' market, but the idea that buying local produce is paramount for environmental sustainability is actually a misconception, says Sue Dibb, executive director of Eating Better, an advocacy group in the UK. Growing tomatoes in UK hothouses uses four times the energy of growing them in Spain and shipping them to the UK, for instance. "If you care about sustainability, you care how hard it is to produce something, more than where it is produced," says Daniel Mason-D'Croz, a development economist with the International Food Policy Research Institute in Washington DC.

In terms of keeping it local, what that really means is that you can have more of certain foods when they are in season nearby. Out of season, you should cut back on foods that are so perishable that they must be transported by plane, such as the Peruvian asparagus I can buy in the Canadian winter. It's not always easy to know which vegetables are flown and which come by road, rail, or ship, but as a general rule, the quicker it will spoil in your fridge, the more likely it is to have arrived by air.

Most of my dinners, to my great enjoyment, also include a glass of wine or beer. There's

UK households waste the equivalent of 6 meals per week

SOURCE: THE WASTE AND RESOURCES ACTION PROGRAMME (WRAP)

JONATHAN KNOWLES/GETTY



1/3 of all of the food produced on the planet each year gets lost or wasted

SOURCE: UN FOOD AND AGRICULTURE ORGANIZATION

eating a standard, meat-heavy UK diet, for example, would reduce their greenhouse gas emissions by 17 per cent just by consuming fewer animal products and more fruit and vegetables, in keeping with healthy diet recommendations from the World Health Organization. Push just a little harder, and they could achieve a 40 per cent reduction. Macdiarmid, too, found that such simple steps could cut emissions by more than a third.

"The surprising truth is, it's easy to make a difference - without becoming a fanatic"

But the truth is, the two most important steps I could take toward a healthy, sustainable diet require even less drastic measures: eat less and waste less. UN statistics show that the average North American or European has access to more than 3100 calories per day, far more than the 2500 that the UK's National Health Service recommends for the average man. (For women, the recommendation is roughly 2000 calories per day.) That's why my waist – like that of most people in wealthy countries – has thickened a bit over the years.

And a quarter of all the food purchased in the UK gets thrown out uneaten, according to the Waste and Resources Action Programme (see pie chart, page 37). In the US, it's one-fifth. About two-thirds of that waste is avoidable, thrown out mostly because it has spoiled (like the leftover rice and half-loaf of mouldy bread I just binned), or because people have cooked or served too much. So if I want to trim my own food waste, I merely need to pay closer attention to how much I buy and how much I cook at each meal.

If I'm honest, I began this project braced for disappointment. Diving into the morass of messages about food, sustainability and health, I worried I would come away more confused than I started, or faced with a diet I just wouldn't want to eat. But the surprising – and reassuring – truth is that it's easy to make a difference, even without becoming a fanatic about it. I don't have to turn vegetarian or vegan, because I can reduce my environmental footprint almost as much just by cutting back on meat and other animal products. And I can bring a little more awareness to where my food comes from and how it got to my plate. That's a pretty good recipe for a healthier planet – and a healthier me. ■

research to suggest that alcoholic drinks, in moderation of course, may have some health benefits. But do I really need it? "Arguably, these are all unnecessary foods," says Garnett. She has calculated that alcoholic beverages contribute about 3 per cent of the UK's food-related greenhouse gas emissions.

But she and other researchers acknowledge that, like eating meat, alcohol is deeply embedded in culture, and that trampling

THE FIGHT FOR SUSTAINABILITY

Governments aren't shy about trying to shape people's food choices to improve their health, but they are less practised at nudging people to prioritise the environment as well (see main story). Only Sweden, Germany, Brazil and Qatar consider sustainability in their dietary guidelines, and Brazil falls short of explicitly recommending that people eat less meat. Elsewhere, the food industry has pushed back against any efforts to curb consumption. "I've worked in nutrition for 25 years, and it still amazes me how powerful the food companies are," says nutritionist Jennie Macdiarmid of the University of Aberdeen, UK.

When the US reviewed its dietary guidelines in 2015, for example, the review committee initially proposed telling

Americans to eat less meat. Heavy lobbying by meat producers nixed that idea, and the guidelines now advise only that people eat "a variety of protein foods" and limit saturated fat. Similar lobbying in Australia relegated any mention of sustainability to an appendix in its national guidelines.

Local efforts may be more successful. Many school systems have taken the lead in serving healthier and more environmentally friendly foods, for instance. That could help shape the attitudes of younger generations. "One of the things that gives me hope is I see younger people who have changed their behaviour," says Alan Dangour of the London School of Hygiene and Tropical Medicine. "They're eating different things. They're more conscious of their impacts."

Bob Holmes is the author of *Flavour: A user's guide to our most neglected sense* (W.H. Allen)



Absent minded

Ever spotted a face in a door handle, or accidentally called your boss “mum”? Sometimes your brain just takes a leave of absence, but these brain farts are side effects of our extraordinary minds, discovers Helen Thomson

WHY DO I FORGET THE REASON I WALKED INTO THE ROOM?

This brain fart is so common it even has its own name: the “doorway effect”. Intrigued by this frustrating experience, Gabriel Radvansky at the University of Notre Dame, Indiana, and his colleagues asked people to navigate a virtual environment. Occasionally the participants would pick up an object, causing it to disappear from view. Now and again they would be asked what they were carrying. If they had moved into a different room, they were slower and less accurate at remembering what the object was. Radvansky repeated the experiment in genuine rooms and found the same thing: people’s powers of recall are worse after they pass through a doorway than when they walk the same distance within a room.

What’s going on? As we move around the world, our brain is thought to construct what Radvansky calls a temporary “event model” of our environment and our

thoughts and actions in it. But storing several event models at once is inefficient. “New environments may require new sets of skills, and so it is best to focus our memory on what is currently at hand,” says Radvansky.

Doorways seem to trigger the replacement of one event model with another. This swap makes us more likely to forget what happened in the first room. It’s not just doorways that trigger this shift – passing from rural fields into a town can do it too, or from highways to backstreets, upstairs to down.

WHY DO RANDOM NOISES TURN INTO WORDS?

Is it just me or does my printer say “cold feet, cold feet”, every time it turns on? This strange perception actually hints at something fundamental about the way the brain creates our whole reality.

The world around us bombards us with

sensory information. The brain doesn’t process every little detail – that would be very inefficient. Instead, it makes educated guesses.

When it comes to sound, the primary auditory cortex processes the rawest elements, such as pitch. Higher brain regions further up the chain process more complex features such as melody and meaning.

But rather than every detail being relayed up, the brain takes the rudimentary elements and combines them with memories and experience to make a prediction of what you might be hearing.

That prediction passes into the frontal lobes, which perform a kind of reality check. If that judges it to be sensible, we consciously perceive the sound. If not, then the information is sent up to the higher regions, which adjust subsequent predictions.

Because of the way the brain fills in these blanks, neuroscientist Anil Seth at the University of Sussex, UK, calls our reality “a controlled hallucination, reined in by our senses”. Indeed, when this goes wrong and the brain’s predictions are no longer kept in check, people can experience hallucinations.

As for my printer moaning about cold feet, what was once random noise must at some point have reminded my brain of the words “cold feet” – perhaps it was its pitch or rhythm, or maybe I had cold feet at the time. Whatever it was, my frontal lobe gatekeeper deemed it an acceptable prediction and it floated into my consciousness. Once I had spared some conscious thought to my printer’s chatter, my brain had even more information on which to base future predictions. Now, it’s hard not to hear these words every time the machine switches on.

You can test this out for yourself. Listen to sine-wave speech, a sonically degraded version of speech (visit the online version of this story for an example). All you will hear is beeps and whistles. But if you listen to the ➤

original recording and return to the degraded version, suddenly you will be able to make out what is being said. Nothing has changed apart from your brain's expectations – it now has better information on which to create your reality.

WHY DOES STARING AT A WORD TURN IT TO NONSENSE?

Coffee. Coffee. Coffee. Read a word enough times and not only does the spelling seem impossible but the word starts to lose meaning. This peculiar feeling was first described in 1907 by psychologists Elizabeth Severance and Margaret Washburn. Fixate on a printed word for too long, they wrote, and "it will be found to take on a curiously strange and foreign aspect..."

"Reality is a controlled hallucination, reined in by our senses"

sometimes making it look like a word in another language... or a mere collection of letters." The phenomenon was later named semantic satiation by psychologist Leon Jakobovits James.

This well-studied form of mental flatulence is thought to be a result of "cellular fatigue". When a brain cell fires, it uses energy. It can usually fire a second time immediately, but if it keeps on firing it eventually tires and must take a short break to do so again.

When we read a word over and over, the brain cells responsible for processing all aspects of it – its form, meaning and associations – tire. And so the word stops making sense.

To prove this theory, Jakobovits James and his colleagues had students repeatedly read and speak words and numbers two or three times a second for 15 seconds. They were then asked to rate how meaningful they were on a scale, either straight away or after reading or speaking a different word or number. The numbers and words became less meaningful after continuous repetition, but increased in meaning after a short interruption.

Some words are more conducive to the illusion. More meaningful or emotional words, such as "massacre", for instance, may take longer to appear alien because your brain cycles through several different associations that it attaches to the word before fatiguing completely. A less evocative word such as "coffee" may take only a few repetitions to turn into gobbledegook.



HOW CAN YOU SUDDENLY FORGET YOUR PIN?

They are a handful of simple digits you've been using on autopilot for years... and then one day at the ATM, all of a sudden you get your PIN wrong. To make matters worse, the harder you try, the more remote those magic numbers feel. How can something so familiar just vanish?

Our memories are thought to live at synapses, the gaps between neurons where electrical impulses jump from one cell to the next. Each firing strengthens the connection between the pair of neurons concerned, making any further activity in the first neuron more likely to stimulate the second. For instance, if we think about an image of a flower and its name, the network of neurons responsible for those two concepts will activate and strengthen. When we later recall the image, the flower's name is now more likely to be retrieved at the same time. This is the foundation for how we store information long term, such as our PIN.

Besides serious illness, there are two main reasons why our memories occasionally fail us. Connections between neurons weaken over time if not frequently activated – by recalling

the memory, for example. This may be why your PIN occasionally flies out of your head; perhaps you just haven't used it in a while.

The other reason is interference. When we recall a memory, it also becomes malleable and prone to change. In the case of the forgotten PIN, you may have used those numbers in some other way, mixing up the digits to create a new online password, for example – replacing the original number in your mind. Or perhaps you recently received a PIN for a new card. The memory of your original PIN has been contaminated with new information.

Your frame of mind could also be to blame: stress, in particular, is known to flood the brain with chemicals that can mess with memory. But it's unlikely that a number you use as often as your PIN has left your memory bank completely, so take a break and try again later.

If that fails, try to recall your PIN using visual imagery – the line your finger usually takes to type it on the keypad, for instance. Studies have shown that associating things we want to remember with images makes them easier to recall.



WHY IS THE DOOR HANDLE SMILING AT YOU?

Kate Middleton recently turned up in a jelly bean, and Jesus has appeared in everything from a roughly plastered wall to a jar of Marmite.

Seeing faces in inanimate objects is a well-known phenomenon called pareidolia. You've probably experienced it yourself, in the form of the man in the moon. Even monkeys get it. But why?

Our brain is primed to see faces from an early age. Fetuses can recognise the shape of a face from inside the uterus – scans show that they turn

reported seeing a face a third of the time.

During the task, regions at the front and back of the brain involved in memory, planning and decision-making appeared to cause activation of the right fusiform gyrus, our face-processing region.

We know that the brain makes predictions about what we might see on the basis of prior knowledge (see "Why do random noises turn into words", page 41).

The fact that the right fusiform gyrus becomes active suggests that the expectation of seeing a face is priming the brain to create one from even the most minimal information.

But why do we see faces even when we're not expecting to?

Evolutionarily, it makes sense for the brain to be on high alert for faces. We need to be able to detect one and understand its motives – whether it is friend or a foe – in order to react.

That we are occasionally too good at it, spotting a screaming banshee in half a pepper or the Virgin Mary in grilled cheese is of little consequence compared with failing to spot a face hidden in the woods.

"Fetuses can recognise a face from inside the uterus"

towards dots of light shone into their mother's belly that resemble a face, but ignore random shapes.

To investigate pareidolia, Kang Lee at the University of Toronto, Canada, scanned people's brains while they watched clips of random static. He told them that half of the time a face would appear.

Despite this being untrue – the screen always displayed static – participants

WHAT CAUSES FREUDIAN SLIPS?

In 2012, CBS news anchor Robert Morrison referred to Prince William as the "douche of Cambridge" rather than the duke. It was an unfortunate slip of the tongue, but did it reveal any private opinions about William?

Freud would have said that Morrison's slip gave away his thoughts, but there could be a more forgiving explanation. When we speak, the brain calls up numerous areas – networks that consider all the possible word choices, those that process meaning, and those that help us form individual sounds. With all this processing going on, the brain occasionally makes a mistake, failing to suppress an alternative choice of word or activating the sounds for one word instead of another.

I mean goxi furl

Sometimes an entirely inappropriate word pops out, as when you call your boss "mum". This can happen because the word shares some context with the one you intended – your boss might look like your mother, or their names may both trigger the idea of an authority figure. As the brain shuffles through these associations to come up with the right word, once in a while it trips up.

"I used to constantly tell my class about piss and stretch when I was supposed to be talking about pitch and stress," says Michael Motley, emeritus professor of communication at the University of California, Davis. The linguistic blunders we make are non-Freudian on the whole, says Motley. "They are simple conflicts between different word choices."

That said, there is some evidence to support Freud's ideas. In 1979, Motley's team asked groups of heterosexual men to read pairs of words silently to themselves until a buzzer sounded, at which point they were told to read the words aloud.

One group had been greeted by Motley, a middle-aged man at the time. Another group was met by a good-looking, provocatively dressed young woman. "We wanted to influence what their thoughts might be," says Motley.

They found that the men all made the same number of slips, but in different ways. The men greeted by the woman made more sex-based slips, reading "goxi furl" as "foxy girl", for instance. So on occasion, our thoughts do seem to influence our linguistic stumbles. Maybe there was more to Morrison's slip up after all. ■

Helen Thomson is a consultant for *New Scientist*. For more brainfarts, see this article online

The original chancer

Jerome Cardano's compulsive gambling inspired mathematical inventions that paved the way for quantum physics

ON 8 September 1526, the Blessed Virgin's birthday, Jerome Cardano was in Venice. While others were praying, Cardano was playing cards at the house of senator Thomas Lezun. He was confident that his recent invention – the mathematics of probability – was about to pay off. As well as money, he was hoping to win a night with a beautiful prostitute. Such an experience, he thought, might be just the thing to end his four-year streak of impotence.

He was nearly 25, and had recently graduated from medical school. Though Cardano would later become renowned across Europe for his skills as a physician, as well as a celebrated author, astrologer and mathematician, right now what he needed was money. The Milanese College of Physicians had denied him a licence to practice, possibly because of his illegitimate birth, although his rude, confrontational personality certainly didn't help. It was this need for funds that drove him to gamble – and sparked his interest in all things mathematical.

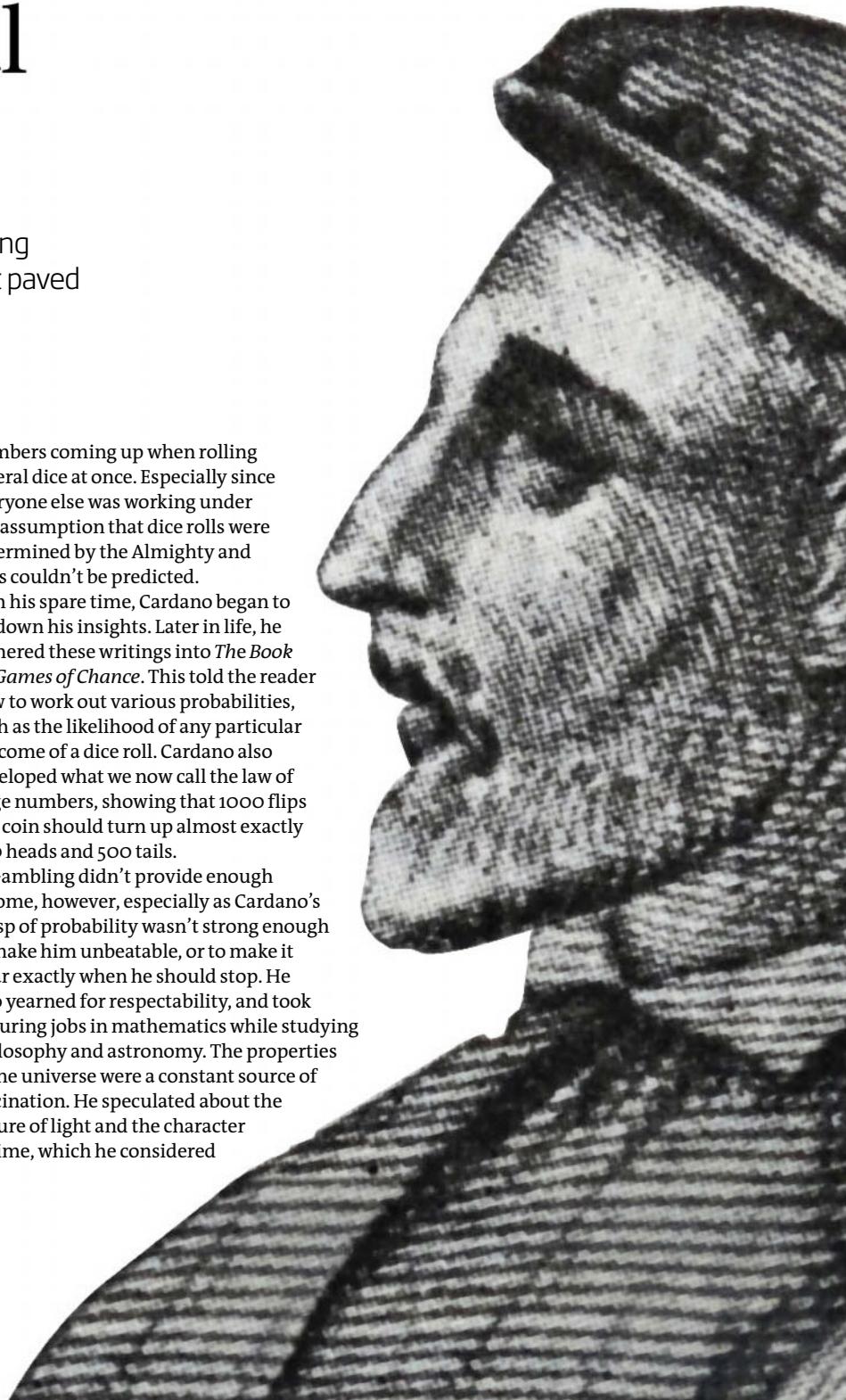
Cardano grew up in Renaissance Milan, the son of a lawyer who counted Leonardo da Vinci among his associates. As a child, Cardano sometimes sat on da Vinci's floor while the adults talked philosophy, law and culture. He was even taken to see *The Last Supper*, freshly painted on the wall of the convent of Santa Maria delle Grazie; when he saw it again years later, he was amazed at how "blurred and colourless" the once-vivid fresco had become.

It was as a student, during one of many nights in the local tavern playing dice and cards, that Cardano realised his time could be spent much more lucratively if he thought about stakes and the likelihood of certain

numbers coming up when rolling several dice at once. Especially since everyone else was working under the assumption that dice rolls were determined by the Almighty and thus couldn't be predicted.

In his spare time, Cardano began to jot down his insights. Later in life, he gathered these writings into *The Book on Games of Chance*. This told the reader how to work out various probabilities, such as the likelihood of any particular outcome of a dice roll. Cardano also developed what we now call the law of large numbers, showing that 1000 flips of a coin should turn up almost exactly 500 heads and 500 tails.

Gambling didn't provide enough income, however, especially as Cardano's grasp of probability wasn't strong enough to make him unbeatable, or to make it clear exactly when he should stop. He also yearned for respectability, and took lecturing jobs in mathematics while studying philosophy and astronomy. The properties of the universe were a constant source of fascination. He speculated about the nature of light and the character of time, which he considered





to be something that only flows within our universe. In the region outside, it “remains eternal”, he wrote in *On Subtlety*, his “complete account of the universe”.

He was granted a medical licence eventually, and soon gained a reputation as a skilled and innovative physician. His mathematical skills meant he was repeatedly offered work in military research, though he always turned it down, and his texts teaching the basics of astronomy sold in significant numbers. Such was the demand that European publishing houses sometimes pirated his works. Shakespeare scholars even suggest that much of Hamlet’s “To be or not to be” speech is inspired by Cardano’s book *Consolation*, a lament on the death of his eldest son.

Cardano lived at a time when the works of great Islamic mathematicians such as Omar Khayyam had recently become widely available in Latin translation. He was entranced by them, and became obsessed with creating a guide to algebra – the Great Art, as he called it. It would explain how to solve quadratic equations (containing x^2 terms), as well as cubic (x^3), quartic and quintic equations. These weren’t only of interest to mathematicians: they had applications in the military and financial sectors, and solutions were highly prized – and carefully guarded.

Cardano’s big problem was that the books available only provided a method for solving quadratic equations. Eventually (by somewhat questionable means) he “borrowed” a solution for the cubic equation and used this to develop solutions for the quartic and quintic equations. Along the way, Cardano discovered a puzzling phenomenon even more abstract than probability: imaginary numbers.

The most basic imaginary number, now denoted as i , is the square root of -1. It was even more alien and confounding then than it is to countless schoolchildren today. Negative numbers were themselves still a somewhat suspicious concept, and zero had only just become accepted as a mathematical object.

Cardano encountered square roots of negative numbers halfway through some of his algebraic workings. It didn’t really matter: he could keep them in, and since they were squared later in the process, the problem disappeared. But he found their existence curious, labelling them “impossible quantities”. In *The Great Art*, he declares they are neither positive nor negative, but “some

GEROLAMO CARDANO/UNIVERSAL HISTORY ARCHIVE/AUG/BRIDGEMAN IMAGES

recondite third sort of thing”.

These days, they are far from recondite. Engineers use i to develop electronic circuits, compression algorithms and myriad other facets of 21st-century life. Together with probability theory, i is also essential to our manipulations of the Schrödinger equation of quantum theory. Cardano’s two major mathematical finds have turned out to be the supporting pillars for our best explanation of how everything in the universe works.

Cardano’s lack of fame today may have something to do with his arrest by the Inquisition in 1570. The most likely reason is because he had presented a previous pope with a horoscope of the Son of God. At the time, astrology was widely accepted, and though Paul III had welcomed this gift from someone regarded as a talented astrologer, the papacy had since passed to Pius V, who had outlawed the practice. A horoscope of Christ was viewed

“Cardano realised he could win more often at dice if he thought about probability”

by many in Pius’s court as an attempt to subjugate the Creator to his creation: if the stars foretell the life of Christ, that leaves no room for God to act as He chooses.

After a few months of incarceration, Cardano was released to house arrest. But he was forbidden to teach, publish books or even talk about why he had been arrested. He had to pay a significant lump sum to the church for this “freedom”, from which he received a meagre monthly income. With the smell of the Inquisition’s bonfires hanging around him, none of his former associates were comfortable in his company ever again, and his fame and esteem quickly waned.

It was during this time that Cardano wrote the autobiography that tells, among other tales, of that night’s gambling in Venice. He used his sense for probability to guess that his opponent was cheating by using marked cards. Having carefully won back the money he had lost, he drew his dagger and slashed Senator Lezun’s cheek in retribution before vanishing into the night. He didn’t mention what happened about the prostitute. ■

By Michael Brooks

The Quantum Astrologer’s Handbook, Michael Brooks’s book about Jerome Cardano, is published by Scribe on 12 October

Energy's deadly race

We could outrun environmental disaster by ditching fossil fuels, but will we? **Fred Pearce** explores a very uncertain future

Energy and Civilization: A history
by Vaclav Smil, MIT Press
Behind the Carbon Curtain: The energy industry, political censorship, and free speech
by Jeffrey A. Lockwood, University of New Mexico Press
Climate of Capitulation: An insider's account of state power in a coal nation
by Vivian E. Thomson, MIT Press

FOR aficionados of megatrends in human affairs, Vaclav Smil has long been a favourite. Now in his 70s and still thinking and writing with huge vigour, Smil has gained a whole new audience in recent years thanks to Bill Gates describing him as his favourite source of new facts.

Unlike many big-picture gurus, Smil is not a determinist. *Energy and Civilization* is a magisterial history of how advances in energy technology – from fire and packhorses to solar panels and the hydrogen bomb – have driven and underpinned the advances of humanity. But he never argues that anything is predestined: we make it up as we go along, says the Czech environmental scientist, who moved to Canada after Soviet tanks rolled into Prague in 1968.

The biggest choice we face today is whether, and how, to make the “epochal transition” from fossil fuels. They gave us two centuries of industrialisation and urbanisation, but their emissions now threaten climate catastrophe. Even now, Smil says, we haven’t really got to grips with how

profound this change will be. We may not make it.

The world is awash with eco-pessimists who see us as doomed by our addiction to the fuels that are wrecking our planet. Meanwhile, set up in opposition are super-optimists like the late Julian Simon and recent acolytes such as Matt Ridley. They insist that our future is assured because *Homo sapiens* has always used ingenuity to get out of a jam, finding new materials or tech to

“The conversion of energy is our planet’s ‘universal currency’, starting with photosynthesis”

do stuff better. Smil sits in neither camp. He sees the task, but refuses to predict the outcome.

The conversion of energy is our planet’s “universal currency”, he says, starting with photosynthesis to turn solar energy into biomass. Human societies have progressed and grown by finding ever more

and better ways to convert energy for our own purposes.

Human muscle can only deliver about 100 watts of power. But early water wheels for irrigation and grain-milling gave us 500 watts. Then came 100,000-watt steam engines – so good their inventor James Watt gave his name to our unit of power. Not that they are a patch on the billion-watt steam turbines generating electricity in modern power stations.

Such changes transformed the world. You probably never thought much happened to US agriculture between 1800 and 1900. Wrong, says Smil. Better ploughs and replacing sickles with harvesting machines raised the food output of energy and labour more than 20-fold – thereby releasing both to make America the 20th century’s greatest superpower.

As energy production has grown, it has mostly become cheaper and more efficient.



PETER VAN ACTMAEL/MAGNUM PHOTOS

A candle converts 0.01 per cent of the energy released by burning into light; modern electric light bulbs are a thousand times more efficient. We all complain about high energy bills, but Smil chastises us. “In the year 2000, a lumen of light in Britain cost a mere 0.01 per cent of what it did in 1500 and about 1 per cent of what it did in 1900.”

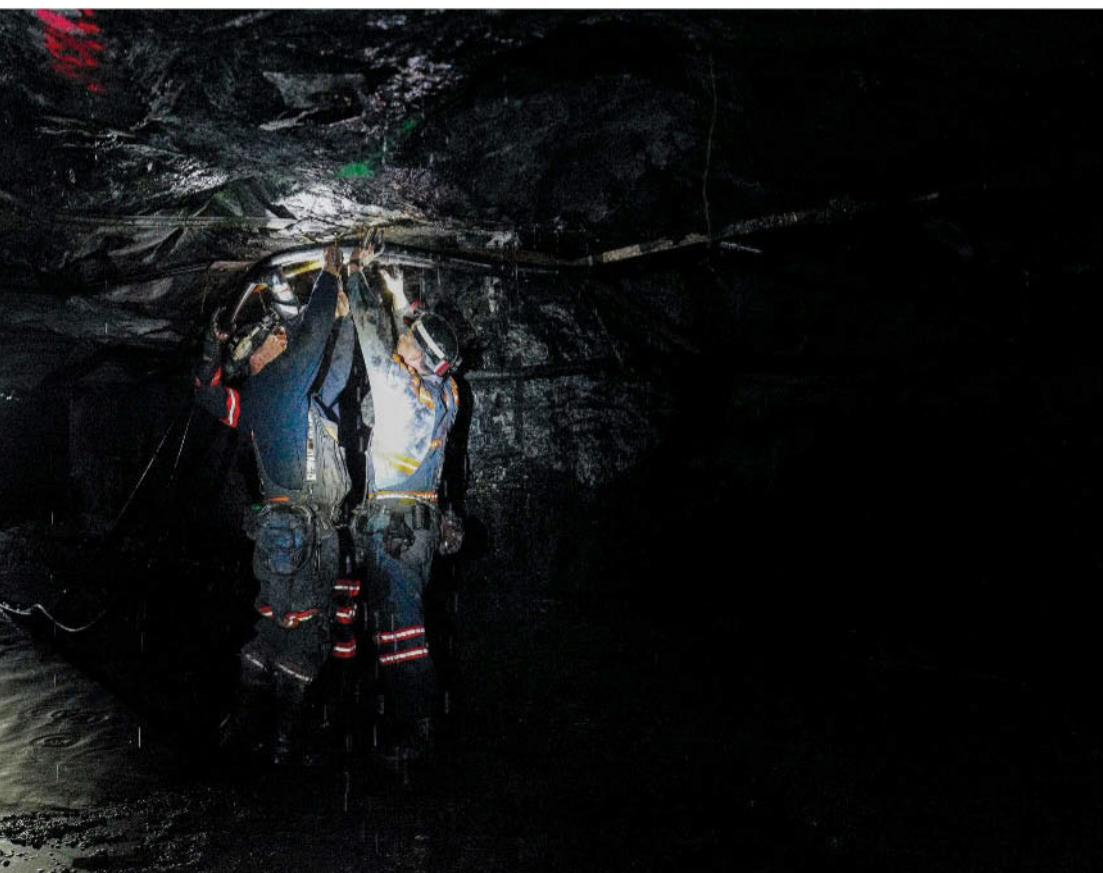
Presented with such facts, it would be easy to become a facile techno-optimist. But Smil is having none of that. Cheaper energy means we use more of it, with often absurd consequences. What sense, he asks, does it make for “tens of millions of people to take intercontinental flights to generic beaches in order to acquire skin cancer faster”?

And while we generally think that cheap energy allows us to save time, that idea can often be illusory. Smil revives an old statistic from a 1970s guru, Ivan



STUART SEITTEY/VEINNE

A return to building nuclear power plants may be key to our future



Drilling deep: are we up to the task of banishing the black stuff?

upbeat assessment of the potential of renewables technologies to rapidly take over from fossil fuels. He predicts that the US will meet its Paris Agreement climate targets in spite of the accord's repudiation by Donald Trump.

But reading two other books gives us pause. Technologically it is doable. But politically? There's the rub. And it isn't just the White House that might undo the commitment. There are many, in US society especially, who will go to any lengths to avoid making the decision. *Behind the Carbon Curtain* by Jeffrey Lockwood and *Climate of Capitulation* by Vivian Thomson both call them out by drilling down to state-level politics, where coal money talks very loudly.

Lockwood, who teaches environmental ethics, charts how fossil fuel companies in Wyoming silence dissent, from getting museums to destroy artwork to modifying school curriculums. And he follows in detail the travails of one boat-rocking researcher who was squeezed out of academic life for questioning corporate reassurances about their activities being safe for underground water reserves.

Meanwhile, Thomson gives an insider's account detailing the corruption of Virginia's environmental regulation. She sat on the state's Air Board, and saw at first hand how clean-air decision-making fell foul of industry lobbying there and in other states.

Against the backdrop of Smil's big story, such mendacity may look too small-scale and local to make a difference. But the real lesson from the great man's book isn't that the reactionaries will be trampled by history, but that, against all sanity, they could win. ■

Illich, about how fast a car really goes. Once you take into account all the time needed to earn the money to buy and run it, the answer is 5 kilometres per hour, or an average walking pace. That paradox still pervades energy and environmental policy-making.

Energy-transforming technologies up the stakes, whether the catapult or the steam engine, sailing ships or water wheels, the flintlock or splitting the atom. But Smil sees no general rule that more energy produces better societies: "Higher energy use by itself does not guarantee anything except greater environmental burdens." We do things differently, we get more bangs for our joule, but it isn't axiomatic that this is always a good thing. In any case, those who see "a future of unlimited energy", whether from nuclear fusion or solar panels, are dealing in "nothing but fairy tales".

This is a very human story of fallible technologies and societal dysfunctions. But Smil is in little doubt that we now face a genuine crossroads, and only one right road. In the next few decades, we have to ditch fossil fuels and embark on what he calls "the unprecedented quest to create a new energy system compatible with the long-term survival of high-energy civilization".

First up, we will need a return to building nuclear plants and a breakthrough in cheap ways to store wind and solar energy. Not either/or, but both.

Will we succeed?

That's the cliffhanger. Smil ends with questions rather than answers. This could end in Malthusian tragedy, as envisaged recently by systems theorist Geoffrey West, who argued that innovation can't keep up with our runaway population: that we are not just on a treadmill; we have to

keep jumping off one treadmill onto an even faster one. Or it might end in Simon-ite triumph, in which innovation continues to keep ahead of calamity.

Smil concludes that "the only certainty is that the chances of succeeding... remain uncertain". Should we feel cheated? Didn't

"Al Gore is offering a surprisingly upbeat assessment of the potential of renewables"

the futurologist just duck out? I think not. To be told that there is all to play for is liberating and democratic.

But there is work to be done. Coal-burning, once the great driver of prosperity, has become our curse. Are we up to the task of banishing the black stuff? Some believe so. Former US vice president Al Gore has recently been offering a surprisingly

Fred Pearce is a consultant for *New Scientist*

A typewriter like no other

Douglas Heaven on how China saw off technological imperialism

The Chinese Typewriter: A History
by Thomas S. Mullaney, MIT Press



IN 1900, readers of *The San Francisco Examiner* were alerted to a monstrous new contraption that had been installed in two knocked-through rooms in a newspaper office in the city's Chinatown. An accompanying cartoon illustrated the 5000 keys of its 3-metre-wide keyboard being operated by four typists frantically taking dictation from someone with a megaphone. In 1903, one typist was even given a fake Chinese name: Tap-Key.

And so the idea of the Chinese typewriter entered the world – as a racist joke. A typewriter for a language with tens of thousands of characters? No such devices existed. Decades later, with the appearance of real Chinese typewriters, *The Times* compared a Chinese keyboard to a strange lunar surface, and called the act of typing Chinese an “operation similar to landing on the Moon”.

Yet here we are in 2017 and China leads the way with typing. How so? Thomas Mullaney, a historian at Stanford University specialising in Chinese IT, has written a deep account of China’s struggle against prejudice and technological colonialism. It is as much a meditation on the Chinese language and its writing system as a history of technology.

Chinese is the only major language with nothing like an alphabet. Unlike Thai or Japanese, it doesn’t even use consonant-

vowel sequences written as a unit – alphasyllabaries – but consists of many and varied characters. The typewriter jokes derive from 19th-century social Darwinists who saw Chinese as more primitive than Indo-European languages, and the opposite of English, with its neat set of 26 characters. And printers long complained about the incompatibility of Chinese script with movable type, forgetting it was invented in China 400 years before Johannes Gutenberg introduced it to Europe.

Even so, adapting a Western invention to Chinese was a challenge. As Remington and Olivetti rapidly iterated through designs of their typewriters from the 1880s, the concept quickly became fixed: some 40 keys arranged in rows in easy reach of fingers, right-to-left movement of paper, and a carriage return at the

end of the line. And above all, the rat-a-tat-tat, a sound so culturally embedded the Tommy gun was known as the Chicago Typewriter.

Early models were marketed as “universal typing machines” because it was easy to adapt them to most languages, often just by relabelling keys. But a few languages needed changes under the hood: Hebrew, for example,

“19th-century social Darwinists saw Chinese as more primitive than Indo-European languages”

is written right to left, requiring the carriage return to be reversed. Thus it became known as English backwards; Arabic, English in cursive; Russian, English with different letters; French, English with accents – and so on.

But not every language could be so accommodated. As Mullaney

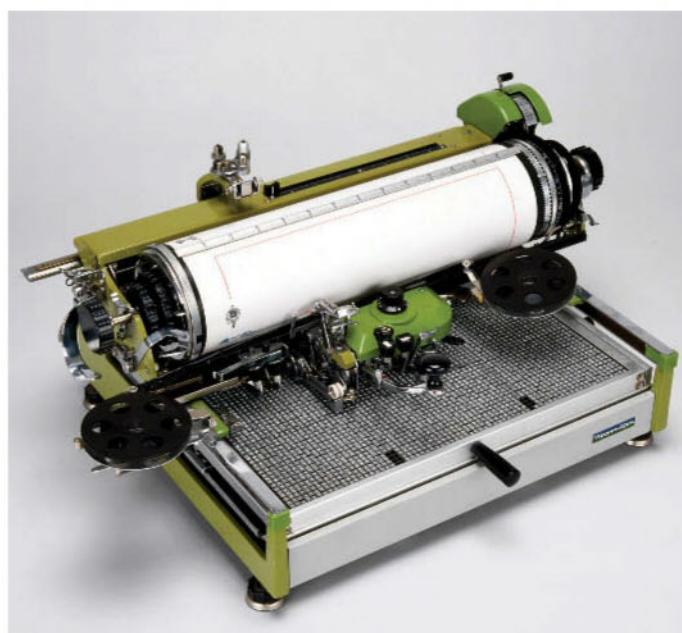
writes, this universality worked only if Chinese script was erased from the story. Each expulsion from the “universal” reminds us not just about the arbitrariness of Chinese but of all writing. For Mullaney, this is Semiotics 101: “There is no inherent, invariant or natural relationship between the signifiers we use and those concepts we wish to signify.”

This insight underpins China’s escape from Western expectations of a typewriter. By abandoning a correlation between what you type and what you see on page or screen, Chinese inventors devised increasingly sophisticated ways of mapping key presses to text. To produce Chinese on a typewriter or digital device, you type a “temporary and disposable set of instructions”, which are then converted into the script you see.

QWERTY keyboards and “typing” are now dead in China, replaced by smart input systems: predictive text, autocomplete, and “cloud input”, where ever better suggestions are produced by comparing your keystrokes with other Chinese users, pulled from the internet as you write.

While the full history of China’s information revolution is the subject of Mullaney’s next book, *The Chinese Typewriter* takes us up to the 1950s and the dawn of computing, as he thoroughly pulls the subject inside out to get at its heart. At best, this gives us a fresh view of the issues, and I particularly liked his dissection of our notion of a typewriter. But the academic preamble can feel like throat-clearing that delays an otherwise fascinating story. ■

In China, typing is replaced by ever more sophisticated input systems



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Douglas Heaven is a consultant for *New Scientist*

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EDITOR'S PICK

Democracy needs more than a technical fix

*From Michael Leonard,
Stoke-on-Trent, Staffordshire, UK*
Niall Firth mentions voter apathy harming democracy and reports on a "liquid democracy" app (9 September, p 8). But if I'm a person who doesn't vote in elections or referendums, I'm less likely to download an app to help me to vote more. If someone is willing

to pay me to download the app and put votes down for one of their interests – on which I have no opinion of my own – the right amount of money could persuade me to make a few taps on my phone screen.

I can't see any way the technology could prevent this. Some would argue that democracy already goes to whoever can afford to pay, but this proposal is certainly no improvement.

*From Ron Todd,
Yate, Gloucestershire, UK*
One of the main requirements of any voting system is that people have confidence that the votes counted match the votes cast. Regardless of how secure the software is, if people don't understand how it works, it would take only a plausible-sounding rumour of hacking to spread doubt.

Sweet, sweet poison that is perfectly slow

*From Frank Aquino,
West Leederville, Western Australia*

I congratulate Tiffany O'Callaghan for keeping the warning about the hazards of sugar alive and in our faces (9 September, p 42). It's all too easy to say, "Oh, I know all that. One jelly bean won't hurt." The undeniable science now is that it will hurt.

Sucrose is the perfect slow poison – a 40-year poison. Not even Hercule Poirot could have connected the dots, the effect being so delayed. But sucrose is toxic; make no mistake. Before 1874, when the UK abolished a tax on sugar and was suddenly flooded with it, myocardial infarction was extremely rare in the literature. By 1900, we see the first myocardial infarction ever recorded. There was no name

for type 2 diabetes before 1900 because it was so rare as to be considered a medical curiosity. By the early 20th century, there were over 30 million cases in sugar-rich countries. Nowadays, we don't have to wait 40 years to see sucrose's effects: childhood obesity is pandemic.

*From Brian Wood,
Lenzie, East Dunbartonshire, UK*
The interesting interview with Robert Lustig reminds me of John Yudkin's book *Pure, White and Deadly*, first published in 1972 to amusement and some derision from many experts, particularly those working in food-related industries. If we had been more open-minded back then, Yudkin's warnings about sugar might have reduced the problems.

As scientists, we ought to avoid reinventing the wheel quite so frequently. But students are

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"A problem for those living with chronic pain: can't be seen on the face as they're used to it"

Elizabeth Turp is sceptical about software rating the pain people are in from their faces and catching out fakers (9 September, p 12)

increasingly taught that there is no point in reading material that is more than 10 years old.

The safest childbirth and the healthiest babies

From Kate Evans,
Street, Somerset, UK

Clare Wilson describes the Royal College of Midwives removing such advice to members as "wait and see – let natural physiology take its own time" as "back-pedalling" (19 August, p 23). As I understand it, the RCM changed from a "Campaign for Normal Birth" to a "Campaign for Better Births" because it wanted to campaign for improved care for the small proportion of expectant mothers for whom medicalised birth is indicated, as well as for the majority, for whom physiological birth is the preferred outcome. Referring to physiological birth as

"normal" may unfortunately have made women who give birth with medical assistance feel that doing so was in some way "abnormal", when that isn't the case.

The latest guidelines from the UK National Institute for Health and Care Excellence recommend that for low-risk, multiparous women, the first choice of birthplace should be the home or a midwife-led unit.

For women who are likely to give birth easily, being in a major obstetric unit may result in interventions that make their birth less straightforward. There is no reason why, if we staff and fund such units properly, this should be the case.

From Soo Downe,
Preston, Lancashire, UK

Wilson refers to infant deaths at the Morecambe Bay health trust in north-west England. The

investigation into these wasn't a formal inquiry. It reported that over-prioritising natural childbirth was one of five elements of dysfunctionality that contributed to these deaths. The others were: a lack of effective teamwork; skills and practice that had "drifted"; a failure to recognise or admit incidents; and deficient and self-justificatory investigation with failure to learn. It made no attempt to apportion adverse outcomes to individual elements of dysfunctionality.

These are not the infinite paradoxes you seek

From Gabriel Carlyle, St Leonards-on-Sea, East Sussex, UK

Stuart Clark writes that set theory has never managed to deal with contradictions such as the fact that sets of whole numbers that have apparently different sizes

can both, on close inspection, be infinite (26 August, p 39). Many people find it counterintuitive or even paradoxical that infinite sets can be paired off with "proper subsets" of themselves – defined as subsets that are not equal to the full set. It even led the polymath Galileo Galilei, in his 1638 work *Discourses and Mathematical Demonstrations Relating to Two New Sciences*, to the erroneous conclusion that "we cannot speak of infinite quantities as being the one greater or less than or equal to another".

There is no contradiction here. Modern set theory deals quite easily with both Galileo's paradox and the Hilbert Hotel that Clark mentions. Though if the currently (widely) accepted axioms of set theory (the so-called Zermelo-Fraenkel axioms plus the axiom of choice) are themselves inconsistent, all bets are off. ➤

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Let's all write numbers the right way round

From Alec Cawley,
Penwood, Berkshire, UK

Gilbert Ramsay remarks that numbers are written from left to right in Arabic, which surprises him given that Arabic text runs right to left (Letters, 9 September). But I suggest that numbers are written from right to left in both Arabic and Western scripts – logically for those using Arabic, less so for Westerners. Reading from the right, you immediately know what value each digit represents. Reading from the left, you don't know if the first digit is units, tens, hundreds, thousands or millions until you reach the end.

The advantages of life alongside a food fad

From Dawn Nelson,
Henderson, Nevada, US
Anthony Warner is right to criticise food fads (5 August, p 24). But one enormous benefit has come from the gluten-free craze.

I have coeliac disease. In my case, a single crumb of gluten-

containing food causes symptoms ranging from debilitating to almost deadly. Gluten can hide in innumerable and unlikely foods.

It is improbable that the food industry would have started adding gluten allergy warnings to packaging or begun producing gluten-free foods solely for those of us with the genuine condition. But because of the fad, it is now much safer for me to purchase foods and there is a far greater variety available. Thank you, hypochondriacs!

Two views on culture stabilising gender

From Jon Arch, Welwyn Garden City, Hertfordshire, UK

Gina Rippon gives a fascinating perspective on gender differences in behavioural traits, with insights from studies in both humans and other species (2 September, p 24). She describes recent work that can be modelled in terms of biology being the source of differences between sexes in average behavioural traits, and environment stabilising these differences.

I find this a welcome balance to an article by Lara Williams arguing against biological determinism (19 August, p 22). Those of a conservative mindset may regard the stabilising effect of human culture on gender differences as a force for good. Liberals will see it as unfairly limiting opportunities for both women and men. But the main influence on our attitude to gender stereotyping is the age and society in which we live.

My experience of 'menopause' as a man

From David Matheson,

Walsall, West Midlands, UK

A sidebar to Jessica Hamzelou's article on the menopause queried whether men have an equivalent (2 September, p 36). Many men who undergo treatment for prostate cancer have hormone therapy that quickly reduces their testosterone to extremely low levels. As my oncologist said to me, "It'll be like having a menopause."

She wasn't joking: from hot flushes, through mood swings

to emotional fragility, I had a plethora of menopausal symptoms. Had I had to continue this treatment for longer, I would have been at risk of osteoporosis. The andropause may or may not exist, but for those men whose prostate cancer is treated this way, the menopause is a reality. It did, however, get me in touch with my feminine side.

Steam had a go on London's streets too

From Jonathan Swan,
Chelmsford, Essex, UK

Mick Hamer recalls competition between electric and petrol-driven buses in London early last century (9 September, p 35). He mentions only in passing that this was a three-way race. Between 1907 and 1912, the Metropolitan Steam Omnibus Company ran 63 Darracq-Serpollet steam buses. In 1908, the London General Omnibus Company had 35 steam buses and the following year Thomas Clarkson founded the National Steam Car Company here in Chelmsford, which by 1914 had 184 in London.

Despite them being quiet, efficient and economical, the last steam bus was withdrawn in November 1919, and our roads have since been dominated by the internal combustion engine.

TOM GAULD



For the record

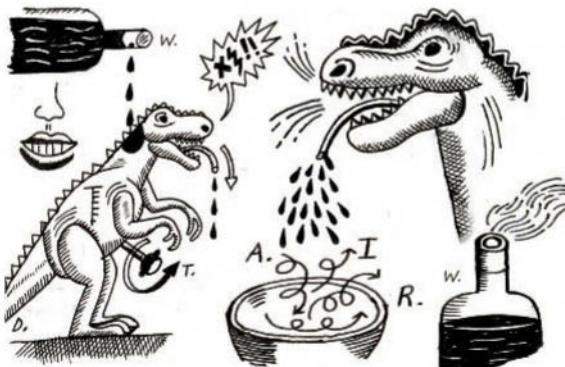
- Sticky problem: Earth's mantle layer flows slowly but is solid (2 September, p 40).
- North Korea also fired a ballistic missile across Japan in 1998 (2 September, p 4).

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MAKE

Do try this at home



A roaring good way to drink

Crack open a bottle and let this prehistoric sommelier do the rest – it'll let you know when the first glass is poured

"Red wine tastes better when it's had time to breathe, but decanting is dull and pouring is boring," writes Barry Onyx. "Can you make the process as smooth as a Spanish Syrah?"

For wine that will leave you breathless, you must first let it breathe. My boyfriend agrees that this is a tedious job. We need a device that aerates and pours all in one – and adds a dash of excitement. "I like wine and I like dinosaurs," is what he said. So now we have a new pet: the winosaur.

Mixing air into wine is behind the flavour-boost, so I need to maximise contact between the two. My first thought was to use a paint sprayer to atomise the wine. Very Heston Blumenthal. However, painting the town red on a night out is one thing; painting the kitchen red on a night in is another.

An upended drinks bottle with a hole cut in the cap does the same thing without the mess. Like a grown-up egg timer, wine dripped from one bottle to another. All we needed was a way to know when it was ready to drink. What better

than the roar of a dinosaur?

First, I dismembered a toy dinosaur and removed its electronic voicebox. To trigger the roar I turned to a float switch. This clever device lets you mix water and electronics, and trips a switch once the liquid level raises it high enough. I mounted it inside the wine-receiving vessel, at the 550 millilitre mark, along with an overflow tube mounted under a dinosaur skull (sadly, my skull is only plastic).

Why stop at 550ml? Because a bottle of wine is 750ml and my favourite glass holds about 200ml. Once the carafe is full, the remainder of the bottle trickles into my waiting glass with a fearsome roar.

Finally, I added the tap from a box of wine to the bottom of the decanting vessel. It's not quite a fire-breathing dragon, but it's far more practical.

With this dino-decanter you can simply upend your chianti and walk away. Just remember to use the right size wine glass, or you may end up with an angry dinosaur dribbling wine all over your kitchen.

Hannah Joshua

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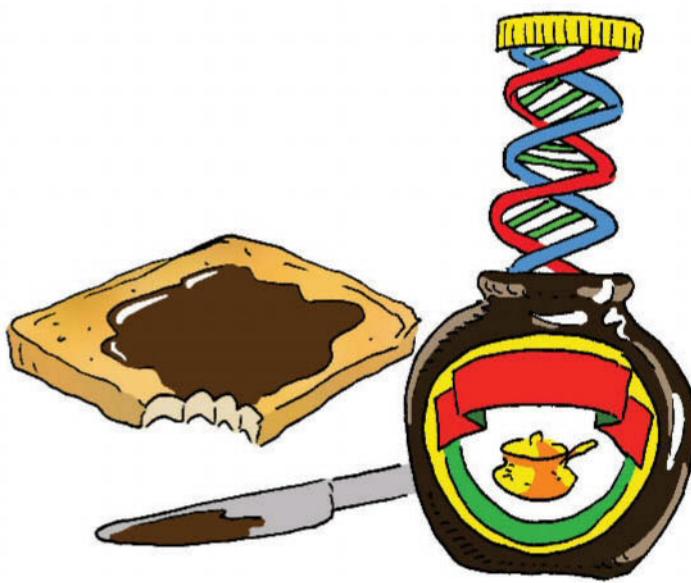
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ADVERTISING a product using a flimsy scientific premise: it's a ploy you either love or hate, and our colleagues are firmly in the latter camp. So it's no surprise that they felt a press release claiming a genetic basis for a Marmite preference was not an idea worth spreading. Many other media outlets did, however, and it falls to Feedback to unpick the notion.

The work in question, by genetic testing company DNAFit, purports to explain a liking (or lack thereof) for the popular yeast-based spread. Genetic samples from 261 people were examined for single nucleotide polymorphisms (SNPs), bits of the genome where one letter varies from person to person. They found five SNPs that were common to self-described Marmite lovers.

But a study like this can't prove that genes have an effect on breakfast spread preferences. Even if there was no genetic component to people's reaction to Marmite, you could still find SNPs shared by those who love to put Marmite on their toast. And who better to share SNPs than family

members? It could be that people simply develop a taste for things their parents have on the kitchen table.

To really find out if an SNP makes a difference, you would need to put each version of it into mice and study their breakfast habits. That's a much more complicated endeavour than just doing a quick bit of genetic testing in a bid to score headlines.

The press release ends by mentioning that for just £89.99, interested readers can order their own genetic scan from DNAFit and "discover for themselves if they were born Marmite lovers or haters". Those on a budget might consider a cheaper test - a small jar of Marmite and a spoon.

AWAKENING the spirit of Feedback in a new generation, physics teacher Rebecca Cornwell asked her students to estimate the distance in kilometres from Earth to various objects in orbit, including the moon.

"A pupil spontaneously asked if they could measure in 'subways'

instead, as they could visualise that more easily," she writes. It took her a moment to work out that the student meant the products of a baguette-based sandwich chain.

"It did prompt an interesting discussion, however, about the need for a standard 'subway,'" says Rebecca. Truer words were never spoken, thinks Feedback: only last year, the company settled a class-action lawsuit after it was revealed that many of its "Footlong" sandwiches measured only 11 inches.

PREVIOUSLY, Feedback asked you in what ways we might adapt humans to better survive climate change (2 September). "Protection of the human species has already started," says Roger Denison, who correlates the increasing frequency and severity of obesity with the increasing frequency and severity of flooding. "A good layer of blubber tends to keep us warm in the water and aids buoyancy," he says, "which must help us survive tidal surges and flooding from torrential rain."

Roger also suggests that the resulting increase in the surface area of human bodies might even tip the balance in favour of photosynthetic skin. Feedback thinks getting humans fat enough to cross this threshold would probably sequester so much carbon that climate change itself could be averted.

RESPONDING to our cost-saving strategies for homeopathic remedies (9 September), Barrie Barton writes in with a further suggestion. "I simply omit the active ingredient, as per the best tradition of homeopathy, and also leave out the carrier substance, the container and even the label."

Barrie says this is "the ultimate homeopathic preparation available and is also very cheap". And, he adds, it's just as effective as the shop-bought version.

FURTHER to the West Yorkshire medical practice known as the Kilmeny Surgery (9 September),

Michael Hitchman reports the existence of the Amwell Group Practice in Islington, London. "Possibly another example of the North-South divide?" he asks.

HOPING to find a new USB charging cable for his phone, Richard Mellish is snagged by some truly unbelievable hardware from AudioQuest. "Is digital audio really just ones and zeroes?" the site asks. "We don't believe so."

In Feedback's experience, the audiophile market usually contains quite a lot of zeroes. AudioQuest's "Diamond USB Type A to Type Mini B Cable" is 75 centimetres long, has "solid 100% perfect-surface silver conductors", and costs a cool £499.

What do you get from a USB cable that costs as much as the phone it's connected to? *Hi-Fi+* magazine said this was an



"audibly superior USB cable that offers exceptional retrieval of low-level details and three-dimensional soundstaging cues in the music, which also conveys a heightened – indeed, almost 'sculptural' – sense of rock-solid imaging".

Not mentioned: the remarkable efficiency with which cables like these can siphon money from audiophiles' bank accounts.

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The UK's £10 notes are being replaced. Barbara Wager is left cheered, if sceptical, by the Bank of England's claim that the old banknotes will "retain their face value for all time"

Not my cup of tea

I live in a hard-water area and find that vinegar is a cheap and effective way to descale my kettle. But no matter how much I rinse afterwards, I won't get a decent cuppa for a week. Given that the kettle is stainless steel and plastic, why does the taint stay so long? A proprietary citric acid descaler presents no such problem, but is less effective and more expensive.

■ Plastics can absorb organic chemicals and impurities, so kettle descalers have to be non-toxic. Acetic acid is the organic component of vinegar and can be absorbed. It is then slowly released after descaling, tainting tea and coffee. Citric acid will also be absorbed and then released, but has a much less pungent flavour than vinegar, so is less likely to be noticed – rather like a tiny slice of lemon in tea.

A kilogram of citric acid powder can be purchased fairly cheaply, and two tablespoonfuls to a litre of hot water can be used as a descaler, or for lots of other cleaning jobs.

David Muir
Edinburgh, UK

■ Kettle descalers are useless. Instead, just cut a whole fresh lemon into several pieces and boil it in the kettle for a few minutes. Then rinse carefully. It is cheap, safe and effective, and in my experience does not leave an aftertaste.

The aftertaste you get may, however, be due to your metal

kettle – in which case, buy a glass one and use a lemon to clean it.

Ann Williams
Chichester, West Sussex, UK

Let's be blunt

How do metal blades in wet shavers lose their sharpness so easily on human hair and how can I avoid this?

■ Being related to a family that owns and operates a cutlery-grinding business, I've learned a few things about keeping cutting edges sharp: start with good steel, handle it carefully and dress, or cover, it frequently. If you do this, you can have knife edges that you can actually shave with – I've seen it.

"Losing the edge", as it is known, is a bit of a misnomer. What actually happens is that the microscopically sharp extreme edge of the freshly sharpened blade gets bent or rolled over, largely depending on the item contacted. A butcher carving up a roast can therefore go a while if cutting through meat, but as soon as they strike a bone, it's time to find the honing steel. This will restore the edge with a few strokes.

But back to the shaver: it is impractical to rehone the blade, so perhaps the problem can be addressed by making what is being cut as soft as possible. A nice soak in a hot shower or a minute with a hot cloth on the face before shaving might help the blade last longer.

Roger Seymour
Spring Green, Wisconsin, US

■ Wet shavers must maintain microscopically fine cutting edges to remain effective. Even razors with multiple square-ended blades rely on sharp corners, so erosion of just a fraction of a micrometre causes drastic blunting. The sharper the edges, the faster they erode.

It is a sort of surface tension effect: the atoms comprising any sharp edge are most exposed to chemical attack and poorly supported against abrasion. Suitably designed dry blades can sharpen in action by grinding each other, but that doesn't work well in corrosive liquid. Certain metal surfaces can be protected by a layer of resistant oxide, but that works less usefully under water. Furthermore, wet muck between sliding surfaces forces blades apart, preventing crisp cutting and demanding frequent cleaning.

Jon Richfield
Somerset West, South Africa

■ My dad used to work for a large razor blade manufacturer. He told me that the firm had done tests showing that by alternating blades, more clean shaves could be completed per razor than if you used the same blade every day.

He said this was why expensive cutthroat razors came in sets of seven – and why using a "magic pyramid" (popular in the 1970s), whereby a razor blade was placed under the pyramid for a few days and apparently resharpener itself, seemed to work.

David Clarke
Seaford, East Sussex, UK

Does any reader know why alternating blades makes each one last longer? – Ed

This week's questions

IN BLACK AND WHITE

Both Friesian cows and zebras are black and white. Does that mean both animals have identical code in their DNA that specifies "black and white"?

Robert Watson
Jesmond, New South Wales, Australia

STOP THE ROT

Certain animal carcasses can become so quickly infected with dangerous bacteria that they pose a significant threat to human health – for example, pork and chicken. Yet soon they will become alive with fly maggots competing for protein. Why are the maggots immune to the bacteria and their toxins, and why can't this be harnessed for human protection?

Bryn Glover
Kirkby Malzeard, North Yorkshire, UK

BARMY RUBBLE

When there is an archaeological find, earth has to be carefully removed to expose buried artefacts or building structures. Excluding nearby volcanic disasters, what causes a site to fill up with rubble and debris over time? Where does it come from?

George Agius
Mississauga, Ontario, Canada

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