CATALYST

Edition 33

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Welcome

Welcome to another edition of Catalyst - aimed at young people, we're proud to bring you cutting edge research that sparks debate.

This edition features articles on: extreme survival in the Sahara and on Everest, how to recycle unavoidable food waste, the role of cheese in evolution, and we hear from Simon Wright who has been helping to build the RRS Sir David Attenborough. We hope you enjoy this edition. If you have any ideas for future topics you'd like to see covered, please get in touch via our email: **catalyst@stem.org.uk**

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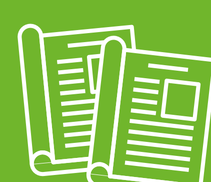

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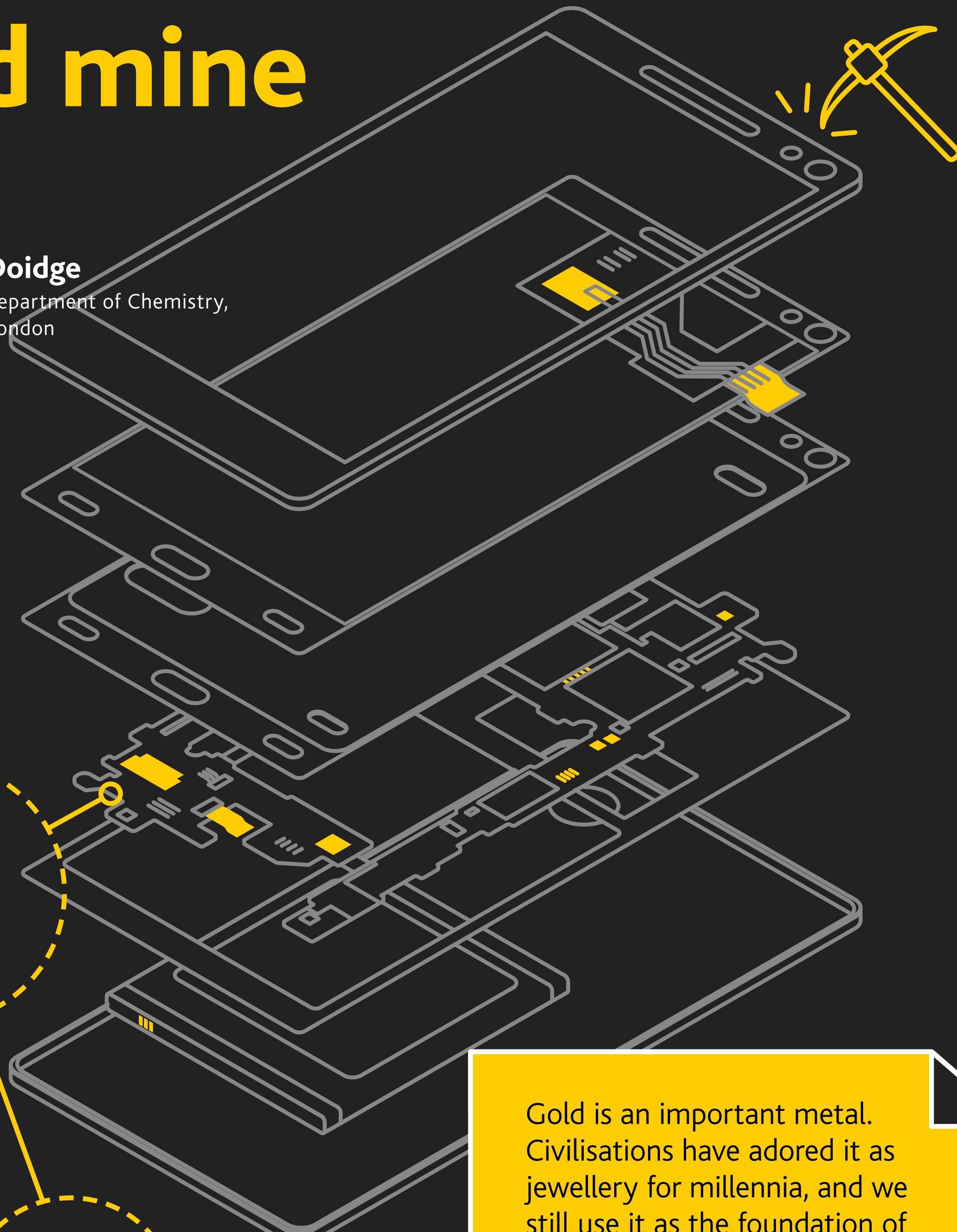

By Dr Euan Doidge
Teaching Fellow Department of Chemistry,
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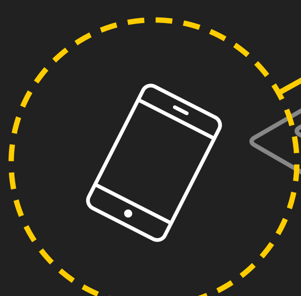


1 ton of mobile phones produces up to 300 grammes of gold.

1 ton of rocks produces up to a gramme of gold.

Gold is an important metal. Civilisations have adored it as jewellery for millennia, and we still use it as the foundation of our currencies today. Recent advances in technology now see gold used in some medicines, and notably in circuitry in contacts in modern electronics – you can even eat gold!

But where does gold come from?

Gold is found naturally in rocks and ores – around 3,000 tons of gold was mined in 2017. However, it is only found in a few places around the world, alongside other metals, and in really low concentrations – you can only get up to one gramme of gold out for every ton of rock mined.

This is a problem. We go to extraordinary lengths to get the gold we treasure.

90% of the world's gold comes from mining processes that separate out the metal by treating the crushed rock or ore with large quantities of notoriously toxic cyanide. If this leaks out, it can have a devastating effect on the local environment for wildlife and workers.

We also use incredible amounts of energy and resources mining and processing tons of rock to get just a few grammes of gold out. Acquiring metals requires many energy-intense process steps, including physical mining, crushing, transporting, separating, refining and many more. Metal production in general demands 10% of the world's energy supply, and generates significant quantities of carbon dioxide and other harmful emissions.

It can take 20 tons of rock to make just one gold ring.

These mining processes also generate a lot of waste. Think about how much gold we get out of these mines compared to how much rock has to be displaced, the vast majority of which is simply disposed of. In fact, it can take 20 tons of rock to make just one gold ring.

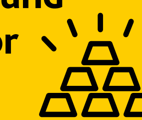
This is the severe and detrimental impact we have on the environment.

Given our reliance on gold, it is important for us to look to other sources of the metal and for more efficient metal recovery processes.

From one ton of rocks you can get up to a gramme of gold. But, you can get 300 grammes of gold from one ton of mobile phones! As there's more gold in circuitry than rocks, it's much more efficient, and environmentally friendlier to recycle gold from what we call waste electrical and electronic equipment – or WEEE – instead of mining it.

The mobile phones we all value so dearly have around 30mg of gold in them, or about 85p worth. This might not sound like a lot, but, globally, around 40 million tons of WEEE is sent to landfill every year.

Mobile phones have around 30mg of gold in them, or about 85p worth.



This is an urban gold mine – in gold alone this is worth about £9 billion annually. If we include all the metals in WEEE we send to landfill, this goes up to £22 billion. And this is only set to rise, as the amount of electronic waste we send to landfill increases every year.

Recycling gold from WEEEs is a golden opportunity – we can minimise our impact on the environment by maximising the use of metals we've already obtained.

But how do we get gold out of our phones?

This is where chemistry comes in, and the area of science known as 'metallurgy'. There are many ways of separating metals in a mixture on an industrial scale, each with their relative benefits and costs. Each relies on exploiting differences in the chemical and physical properties of the metals to achieve this.

For example, we can rely on the different reactivities of the metals at different temperatures to separate out the metals in a process called 'smelting' or 'pyrometallurgy', although this requires intense heats and energies and can be highly polluting.

'Hydrometallurgical' separations are 'greener', lower energy processes that separate the metals once they are in solution. These include the selective removal of the metal from solution as a solid based on the relative solubilities of its compounds ('precipitation'). We can also design molecules that can recognise and bind to a specific, targeted metal in solution and transfer it into a new solution and out of the mixture in a process called 'solvent extraction'.

Ideally, we can efficiently recycle all the metals in our waste products by tailoring the chemistry involved. The recycling of metals from phones has clear benefits.

After going through all the effort of getting our metals in the first place, instead of throwing our products away at the end of their lives, we should be aiming to recycle as much as possible, to the benefit of the environment, the economy and society. We call this 'closing the loop' to create a 'circular economy'.

This isn't without its difficulties, namely collecting enough waste efficiently, dealing with ever more complex waste streams, processing large volumes of material and designing molecules that can separate metals efficiently. Ultimately, the value of what we recover has to be greater than the cost of recovering it.

Chemistry, and actively choosing to recycle WEEE, is crucial to ensure we can have access to metals that don't cost us the earth.

Waste not, want not: making use of unavoidable food waste

By Elspeth Bartlet and Emma Needham
(BioVale, a partner in the Agrimax project) with support from Juliet Burns (Biorenewables Development Centre)

Tackling a global food waste problem

Most of us instinctively feel that it's wrong to waste food and yet around a third of all food produced is wasted, leading to both financial losses and environmental problems. Consumer campaigns in the UK, such as Love Food, Hate Waste, are encouraging us to become less wasteful in our everyday lives but there will always be some types of waste that are hard to avoid, particularly from farms and food processing factories; think wheat straw, potato peelings or tomato skins.

To address this global waste issue, scientists and innovative businesses are developing new ways to turn these unavoidable food wastes into a wide range of bio-based products, i.e. products that are partly (or fully) made from a renewable plant or waste material. This will reduce our dependency on petrochemicals (from crude oil), providing sustainable business income and benefiting the environment.

Developing new products for everyday use

Many crops have parts that don't bring value to the farmer, such as stalks, stubbles, leaves or seedpods. Through a European Union funded project called Agrimax, Italian company Mogu is one of many businesses attempting to create new products from such crop waste.

They have used the latest materials, science and design expertise to develop new techniques to grow fungus (yes fungus!) on wheat straw and other waste materials. They bind it together to create a light yet durable material that can be used for making a range of products including insulation, packaging and even fabrics such as leather. These new materials are the product of a natural process: the result is a 100% renewable, recyclable and compostable material which is much healthier for our planet. Even tomato skins (that are discarded when making cans of tomatoes for example) can become the raw materials for new products in the food packaging sector. They contain a waxy, water-repellent substance called Cutin that can be used to produce an inner coating for food tins, preventing the metal can from reacting with the food. So, ironically, the skins that protect the fresh tomatoes can also be used to protect the processed ones too!

A third of all food produced is wasted.

And it's not just crops where these wastes are, well, 'cropping up' if you'll pardon the pun. It's hard to believe, but there is such a thing as waste ice cream! Manufacturers have to wash the processing equipment between batches to avoid mixing the raspberry ripple with the mint choc chip. The water used to wash out the machines ends up full of sugars and fats. While this currently presents a costly waste to businesses, who have to pay the water companies for flushing this dirty water down the drain, it could become a new source of income. Increasingly, scientists are using this type of material to feed bugs and fungi, that in turn generate useful chemicals. Just in the same way that we have been using yeast to generate bread and beer for centuries, we are now using this 'fermentation' process to create all kinds of materials.

A circular approach to the future

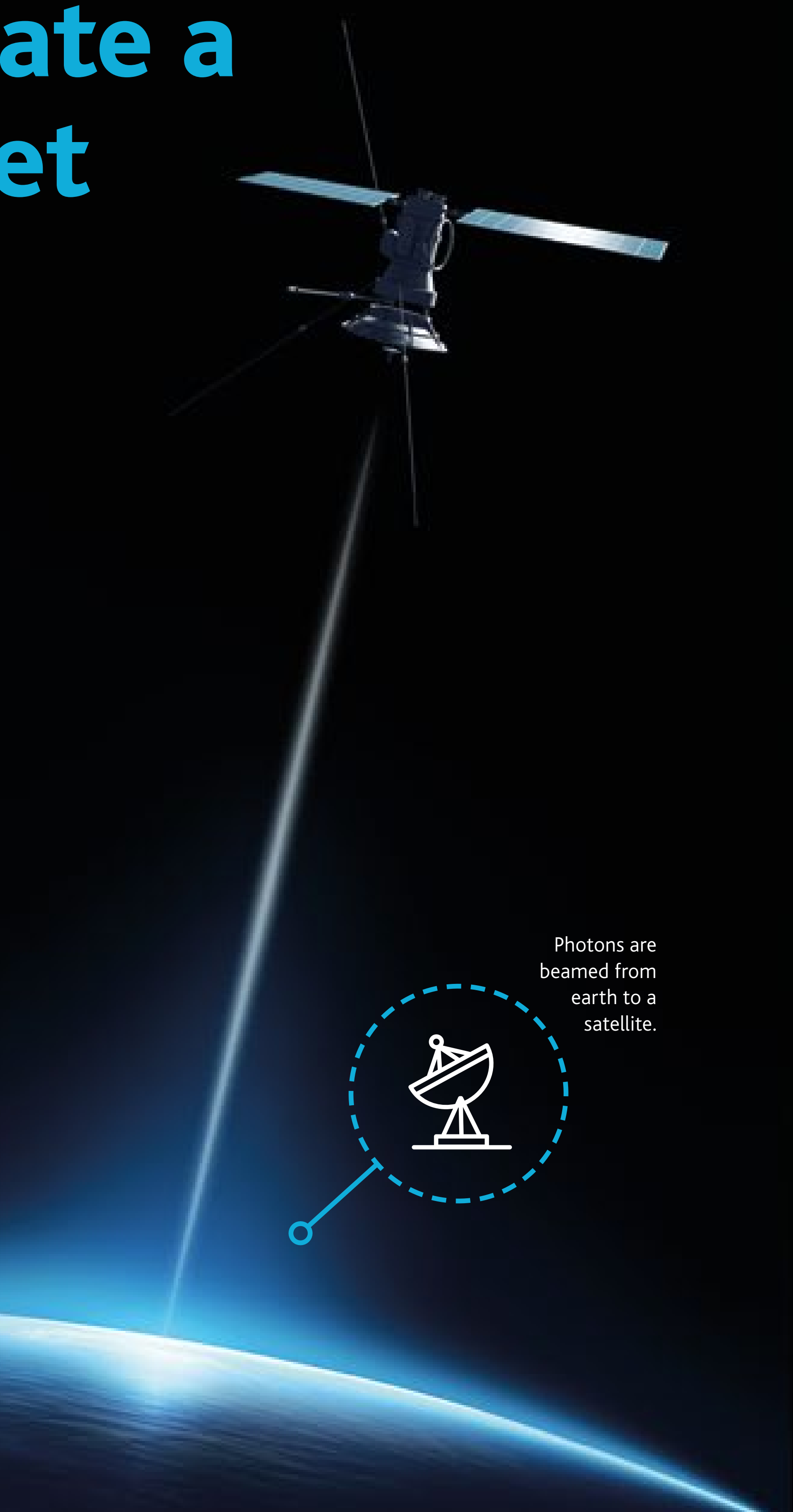
The ability to make products from unavoidable waste and renewable materials is a rapidly developing area, and we are seeing more of these products in our local shops as well as in well-known supermarket chains. With the help of the latest scientific and technological developments, high value chemicals, construction materials, packaging, toys, fabrics and energy can all be made from crop and food processing waste. In the future, we could see the creation of 'biorefineries' (like an oil refinery but using bio-based starting materials) that create a range of products from waste streams before using what remains to generate energy for our homes and schools, or to fertilise the soil in which our crops grow. This brings the use of waste full circle, using leftovers to make new materials – in contrast to our current linear process which generates enormous volumes of waste.

With these types of biorefineries now emerging we can not only avoid waste, but also become more economically effective and help save the planet in the process.

Teleportation is real and it's being used to create a new internet

By Thomas Hird
PhD Student in Quantum Technologies, University of Oxford and University College London

Since Captain Kirk was first 'beamed up' by Scotty over 50 years ago, teleportation between Earth and space had been restricted to the world of science fiction. But since last year scientists have been teleporting quantum particles to space!



Photons are beamed from earth to a satellite.

Although its name conjures up futuristic images, quantum teleportation is relatively commonplace in physics labs around the world.

To clarify, no people or things are teleported in the traditional sense of the word. The properties of a photon (a particle of light) are transferred from one to another by making use of the phenomenon known as quantum entanglement. This allows two particles to share the same state, irrespective of the distance between them. Imagine the two particles as a pair of coins that always 'agree' which face they show when looked at or measured. This means if one shows heads (H), then the other will also show heads, and similarly for tails (T). This interaction between the two happens instantly, regardless of distance, and was famously described by Einstein as 'spooky action at a distance'.

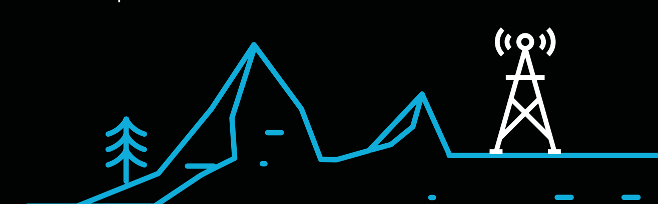
Unlike a coin, the state of a quantum particle does not need to be well defined – it can be in a superposition (combination) of heads and tails simultaneously. For example, 50% H + 50% T. Technology exploiting superposition and entanglement of particles would allow the construction of a 'quantum computer', which could outperform all current technology.

Quantum internet would allow us to send 'unhackable' data.

However, there is a downside. Quantum particles are fragile, and building this type of computer has proved difficult. The act of observing a particle can destroy its quantum behaviour. This 'observation' can happen when the particle interacts with the environment. Practically, this means quantum systems need to be precisely controlled, thus restricting the distances we have been able to send the states.

To perform teleportation from Earth to space, scientists need to create a pair of entangled photons, keeping one on Earth and beaming the other to the satellite. To improve the photon's chances of reaching space, the researchers use special transmitters located in the mountains. The high altitude decreases the amount of air between the transmitter and the satellite which is equipped with a very sensitive photon detector.

Because of the entanglement between the photons, a measurement on the ground-based photon instantly changes the state of the photon at the satellite. In this way, the state of the photon (its properties) are transferred from Earth to the satellite. The result is that the photon on the satellite has become the photon that was previously on the ground – it has been teleported.



Quantum internet would send information using quantum signals instead of radio waves.

What does this have to do with a quantum internet?

At its heart a quantum internet would be one that uses quantum signals instead of radio waves to send information. The internet we know and love uses radio waves to connect multiple computers through a 'worldwide web' in which electronic signals are sent back and forth. In a quantum internet, signals would be sent through a network using quantum particles. Being able to transport quantum particles to space allows for the possibility of having two particles entangled on opposite sides of the world, a key step in creating a worldwide network.

How will this change my internet?

As far as typical internet surfing goes, probably not much. It's highly unlikely that you'll be using the quantum internet to update Twitter for example. The quantum internet would excel, however, at sending information securely. Through what's known as quantum encryption or quantum cryptography, people would be able to send 'unhackable' data over a quantum network. This is because quantum cryptography sends an encrypted message and its keys separately. Quantum physics means that tampering with the keys or message (observing the quantum states) causes it to change – something both the sender and receiver can detect.

The future

A quantum internet could also speed up access to a working quantum computer by putting quantum computing in the cloud. Instead of trying to get your hands on a physical quantum computer (which is fragile and hard to make), you could access one through the cloud or interface separate quantum computers around the world to boost computing power. Whilst the reality of a quantum internet is perhaps decades away, scientists have already held the first 'quantumly-unhackable' video call between Beijing and Vienna. So strides are definitely being made towards this future of communication and computation.

Career journey with

Simon Wright

Polar oceans, plastics and penguins – Simon Wright tells us all about his world of work.

Q Tell us a bit about yourself

A I'm Simon Wright, I normally work at sea on a scientific research ship operated by the British Antarctic Survey (BAS) as the Deck Engineer. Though for the last two years I've been on dry land assisting with the build of Britain's new polar research vessel, the RRS Sir David Attenborough.

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

A Strange as it might seem for someone growing up about as far from the sea as you can get (I grew up in Leicester), I always wanted to go to sea. I have always enjoyed understanding how things worked, so becoming a marine engineer seemed the best choice. It also allowed me to travel around the world and see many different places, especially now when I'm able to see places and things that very few people get the chance to.

Q How does your work impact the world around us?

A The scientists that I work with onboard the ship study the properties and currents of the polar oceans, the marine biology and the seabed itself. These investigations help us understand more about the polar regions, which affect what is happening to the entire planet.

When at sea, it is my job to assist scientists trying to understand many different things, but much of the work is focused on studying environmental change and the potential impacts. More recently, there is the additional focus on microplastics that has been very much in the news. Having an interest in all things STEM has helped me in my job to understand what is happening and how best to help.

"I have always enjoyed understanding how things worked, so becoming a marine engineer seemed the best choice."

Q What do you do to help the scientists?

A The ship is equipped with lots of machinery, such as winches and cranes, that allow us to lower scientific equipment to the bottom of the ocean, which may be up to 6,000m deep. The equipment can sample what is on the seabed or anywhere in the water in-between. It is my job to ensure that all the equipment required is maintained, repaired and ready to work when needed. I then assist the rest of the ship's company to carry out the scientific operations safely.

Q What are the best things about your job and are there any downsides?

A I have an interest in science generally so to be able to work with scientists and get to understand some of what they are doing is fantastic. I also enjoy taking photographs, particularly wildlife, so getting to see so many amazing creatures is fantastic – just don't ask how many penguin photos I have!

On the downside it can be not very nice if a problem happens when you are in bed. You then have to get up and go outside, having just woken up, to fix it. It is especially unpleasant if it is cold, windy and rainy, if not snowing as well.

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

A Having an interest in how things work and wanting to work with your hands is an advantage. Living on a ship is different to a job on land as it means that you work and also live with the same people for long periods of time, so being able to get on with everyone is important.

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

A To become an engineering officer, you would need to apply to a marine engineering or shipping company to be sponsored through your training. The training would lead to a higher qualification in marine engineering. It would also include the Certificate of Competency, which says you are qualified and safe to work at sea.

The training route you take would depend on the qualifications you have already and any experience. To get onto a training course, you would normally need GCSEs (grades 4 to 9) including Maths, English and a science (preferably Physics), and possibly one or two A Levels or equivalent qualifications.

"My job is to ensure that all the equipment on the ship is maintained, repaired and ready to work when needed."

Q What's next for you?

A Well the RRS Sir David Attenborough will put to sea in 2019 and then we'll learn how to operate the ship and get it ready for its first Antarctic voyage.

How robots will help you grow your greens!

By Samuel Oliver Wane
Senior Lecturer, Harper Adams University

The role of precision agriculture is utilising technology to gain efficient use of the land.

Throughout history, the majority of people lived outside towns and cities, but since 2008 the world's urban population has exceeded the number of those living rurally. As our planet's population continues to grow at an alarming rate, housing and industry mean effective use of the remaining rural land becomes a challenge. Human labour is difficult to recruit and the pattern of recruiting from poorer countries is temporary. But the future looks bright...

The role of precision agriculture is utilising technology to gain efficient use of the land. The role of robotics in agriculture is the next essential step and a natural progression of agricultural development. There is a strong case for mobile robots working in fields; their lighter weight would mean reduced compaction of land, they could work in fleets and through the night, waiting for the optimal low-wind conditions for spraying, and they could manage autonomous weeding and pest control. Selective spraying and harvesting and reduced reliance on imported labour has made the use of robotics in agriculture an essential option. The rise of the population requiring healthier diets, and the decreasing land mass has alerted the governments in many developed countries to the need for automation.

Here are some examples of how robots are innovating the future of farming.

Preparation

Ploughing is the inversion or mixing of topsoil to prepare a suitable seedbed. It also has the ability to bury surface crop residues and to control weeds; this involves pulling a plough at great force through the soil. The biggest challenge we have, particularly in the UK, is working the soil whilst it is dry enough, in-between rain. The soil is sensitive to damage from tyre pressure, particularly when wet. Heavy tractors can pull larger implements and get the work done faster, but at the expense of crushing the soil substructure. Small, light, unmanned robots could collaborate to cover the area quickly in a swarm whilst the conditions are right, resulting in less soil damage. Obstacle sensors on the front of the vehicle could detect the location of obstacles and these could be stored in the mapping system so future planning would compensate for them.

Seeding

Seed mapping is the concept of passively recording the position of each seed as it goes into the ground. It is relatively simple in practise as a real-time kinematic (RTK) GPS is fitted to the seeder and infrared sensors are mounted below the seed chute. As the seed drops, it cuts the infrared beam and triggers a data logger that records the position and orientation of the seed. The seed co-ordinates can then be used to target subsequent plant-based operations. Re-seeding is the concept of being able to identify where a crop plant has not emerged and a machine can automatically place another seed in the same position. A re-seeder would have the ability to insert individual seeds or plants without disturbing the surrounding crop.

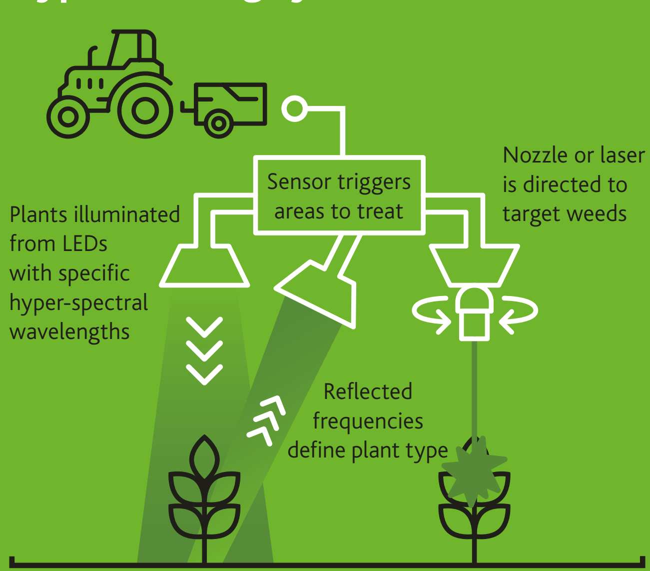
Weeding

Last century's approach to weeding through spraying was to douse the whole field and allow the chemical to be selective on the plants it attacks. This has led to weed resistance, damaging of watercourses, damaging the soil and spraying the crops we eat.

The environmental impact of herbicide chemicals such as glyphosate is often questioned, and the consumer preference for organic farming is continuously increasing. Mechanical human weeding is approximately 20 times more costly than using chemicals.

An innovative laser weeding system has been trialled at Harper Adams University, in Shropshire. This consists of a box on the back of a tractor with a camera, computer and laser on a moving gimbal. The box is open to the ground and uses machine vision to recognise the location of weeds as it passes over them. Once located, the computer controls the gimbal and moves the laser to focus a short laser dose on the sensitive growing part (the meristem) of the weed. The cells rupture with the heat and it ceases to grow.

Hyperweeding System



Extreme survival: from the Sahara to the summit of Everest

By Ricky Munday
Founder of Inspire Alpine

The human body is an amazing thing and it is incredible how it can survive the most extreme of climates. Ricky Munday tells us his experience of running across the world's largest desert and climbing the tallest mountain on earth.

After a rough period in my life I knew that I needed something really positive to focus on, so I took a major risk and entered the Marathon des Sables, a 150-mile ultramarathon across the Sahara Desert, known as the 'toughest footrace on earth'.

The Marathon des Sables is a stage race, which takes place over seven days – it's the equivalent of running seven marathons in seven days, although the stage lengths do vary. The longest stage is 50 miles and the shortest stage is a half-marathon. Daytime temperatures in the Sahara touched 50°C, and at night the temperature dropped to zero. Competitors carry all of their clothing, sleeping bag, stove and food.

As the external temperature increases, your body tries to dump excess heat to maintain a normal body temperature of 37°C; your heart rate increases to pump more blood to your skin, and you sweat. Cardiovascular exercise creates additional metabolic heat and adds to the body's heat burden. In very hot environments, the rate of 'heat gain' is greater than the rate of 'heat loss' and the body temperature begins to rise, which can result in heat illnesses such as heat exhaustion or the more serious heatstroke.

Daytime temperatures in the Sahara touched 50°C, and at night the temperature dropped to zero.

Preparing your body for such a range of temperatures is daunting. Some runners train on a treadmill or stationary bike in a sauna. Hot yoga is a modern practice that can help with acclimatising to the extreme heat.

On day two of the race I suffered from severely infected blisters. The medics sliced off the blisters, applied iodine to the raw flesh, and then Compeed and tape, which allowed me to continue. On day four – the long stage – I ran with two highly experienced runners from Italy. I overextended myself and became severely dehydrated. At 40 miles, I began dry vomiting. At the checkpoint, the medics gave me rehydration salts, which I drank and then vomited straight back up. The only option left was intravenous (IV) fluids – I received three bags of fluid via IV and camped at the checkpoint. In the morning I finished the stage, and two days later I crossed the finish line, and experienced such an intense feeling of elation, and relief. I had pushed my physical and mental boundaries far beyond what I had believed to be possible.

Completing the event totally changed my mindset, and I turned my attention to the world's high mountain ranges. Fourteen years and 18 expeditions later, I was climbing high on the summit ridge of Mount Everest.

At 7,000m, my oxygen saturation was measured at 52%, which is almost half of the sea level value. On the summit of Everest at 8,848m, the oxygen pressure is only 30% compared to sea level. Many climbers have entered the Death Zone and never returned – on the northeast ridge of Everest we passed many bodies as we climbed high on the ridge. To prepare for this very low oxygen level, we had spent six weeks slowly climbing up to the North Col at 7,000m and above, then descending back to base camp to rest.

These acclimatisation 'rotations' gave our bodies time to adapt to the lower oxygen levels by generating more red blood cells, to allow our bodies to make more efficient use of the reducing oxygen in the atmosphere. Our breathing rate also increased as we climbed higher – a shorter term response to low oxygen levels. The downside of this increase in respiration was that we were losing a significant amount of water vapour in our breath and would easily become dehydrated. To compensate, we tried to drink at least five litres of fluid every day.

On the summit of Everest the oxygen pressure is only 30% compared to sea level.

I was wearing a down suit, triple high-altitude boots and high-altitude mitts. I carried two oxygen cylinders in my rucksack and I wore an oxygen mask on my face. I carried only one litre of water inside my down suit, and two energy gels. That is all I would eat or drink for the next 17 hours. Every step required a monumental effort of will.

After an exhausting climb, we had passed the three main obstacles on the northeast ridge – the first, second and third steps. These steps are vertical boulders, up to 40m high. As I climbed the steep snow slope in the pre-dawn twilight, I saw a shape fluttering in the wind, 50 steps ahead. It looked like a prayer flag, which Sherpas place on the summit of mountains in Nepal and Tibet.

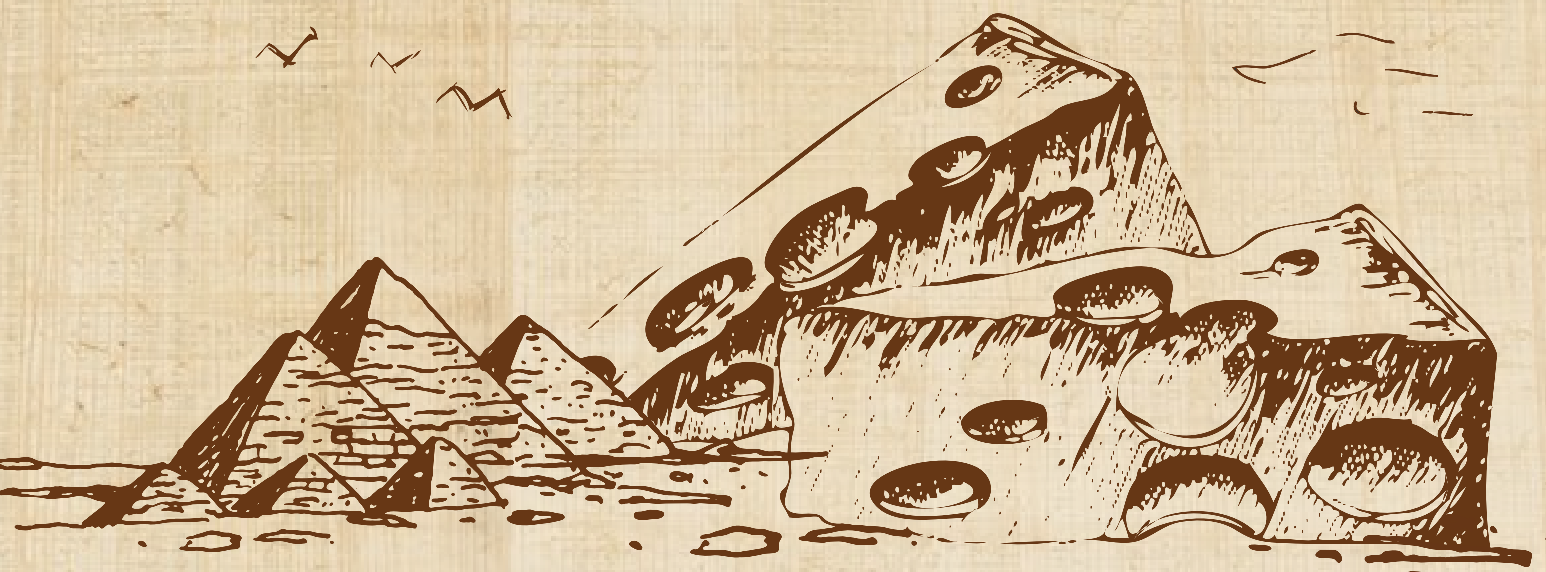
The light of my head torch picked out a few more fluttering shapes, and I was hit with an overwhelming realisation. For a moment, I stood absolutely still. I was in shock. I turned to my Sherpa guide Phurba:

"Phurba, this can't be the summit."

"Yes, summit."

I was hit by a wave of euphoria and disbelief, and I fought to hold back my tears. I stepped onto the summit of Everest at 6.15am, with Phurba one step behind. The wind was howling. We clipped into the fixed rope and embraced again. I had achieved my lifelong dream.

The summit of Everest is 8,848m above sea level.



The surprising role cheese played in human evolution

By Penny Bickle
Lecturer in Archaeology, University of York

A solid white mass found in a broken jar in an Ancient Egyptian tomb has turned out to be the world's oldest example of solid cheese.

Probably made mostly from sheep or goat's milk, the cheese was found several years ago by archaeologists in the ancient tomb of Ptahmes, who was a high-ranking Egyptian official. The substance was identified after the archaeology team carried out biomolecular identification of its proteins.

This 3,200-year-old find is exciting because it shows that the Ancient Egyptians shared our love of cheese – to the extent it was given as a funerary offering. But not only that, it also fits into archaeology's growing understanding of the importance of dairy to the development of the human diet in Europe.

Dairy in diets

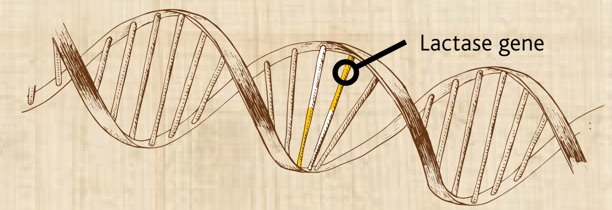
About two-thirds of the world's population is lactose intolerant. So although dairy products are a daily part of the diet for many living in Europe, Northern India and North America, drinking milk in adulthood was only possible from the Bronze Age, over the last 4,500 years.

For most of human history, adults lost the ability to consume milk after infancy – and the same is true of people who are lactose intolerant today. After weaning, people with lactose intolerance can no longer produce the enzyme lactase. This is necessary to break down the lactose sugars in fresh milk into compounds that can be easily digested. People with lactose intolerance experience unpleasant symptoms if they consume dairy products, such as bloating, flatulence and diarrhoea.

Drinking milk in adulthood was only possible from the Bronze Age, over the last 4,500 years.

Ancient DNA analysis on human skeletons from prehistoric Europe places the earliest appearance of the lactase gene (LCT) – which keeps adults producing lactase – to 2,500BC. But there is plenty of evidence from the Neolithic period (around 6,000–2,500BC in Europe) that milk was being consumed.

This is not totally surprising though, as the Neolithic marks the start of farming in most regions of Europe – and the first time humans lived closely alongside animals. And although they were unable to digest milk, we know that Neolithic populations were processing milk into substances they could consume.



Archaeological evidence

Using a technique called 'lipid analysis', shards of ancient pottery can be analysed and fats absorbed into the clay identified. This then allows archaeologists to find out what was cooked or processed inside them.

We have ancient ancestors to thank for the cheese we eat today. Although it is not yet possible to identify the species of animal, dairy fats can be distinguished. It is also challenging to determine what techniques were being used to make dairy products safe to consume, with many potential options. Fermenting milk, for example, breaks down the lactose sugar into lactic acid. Cheese is low in lactose because it involves separating curd (from which cheese is made) from whey, in which the majority of the lactose sugars remain.

Clay sieves from Poland, similar to modern cheese sieves, have been found to have dairy lipids preserved in the pores of clay, suggesting that they were being used to separate the curds from the whey. Whether the curds were then consumed or attempts made to preserve them by pressing into a harder cheese is unknown.

Early cheese making

While the techniques from bioarchaeology have provided this fantastic detail on Neolithic diets – where the science stops, experimental archaeology can explore what was possible.

We have been making cheese using the utensils, plants and techniques available to Neolithic farmers. The aim of the experiments is not to faithfully recreate early cheeses, but to begin to capture some of the decisions available to early cheese makers – and the experiments have thrown up some interesting results.

By using these ancient techniques, we have discovered that a wealth of different means of curdling the milk would have been possible, each producing different forms, tastes and amounts of cheese.

And such specialist knowledge may have been akin to the spread of bronze smelting at the end of the Neolithic. Dairy may have had a special status among foodstuffs, for example, at the major late Neolithic feasting site of Durrington Walls, not far from and contemporary with Stonehenge, dairy residues were found in a particular kind of pottery vessel and concentrated in the area around a timber circle – a form of Late Neolithic monument.

From the Bronze Age, however, lactase persistence offered an advantage to some people who were able to pass this on to their offspring. It also seems that this advantage was not solely because of increased calorie and nutrient intake alone, but because of the special status dairy foods may have had. The development of this biological adaption to fresh milk took place after humans had already found ways to safely include dairy products in the diet.

This shows that humans are not only able to manipulate their food to make it edible, but that what we consume can also lead to new adaptations in our biology.

The oldest discovery of solid cheese was most likely made from sheep or goat's milk.

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Competition winner!

By Ellen Flewitt

Ellen Flewitt

Aged 17

Currently studying Biology, Chemistry, Physics and Maths at Peter Symonds College in Winchester.

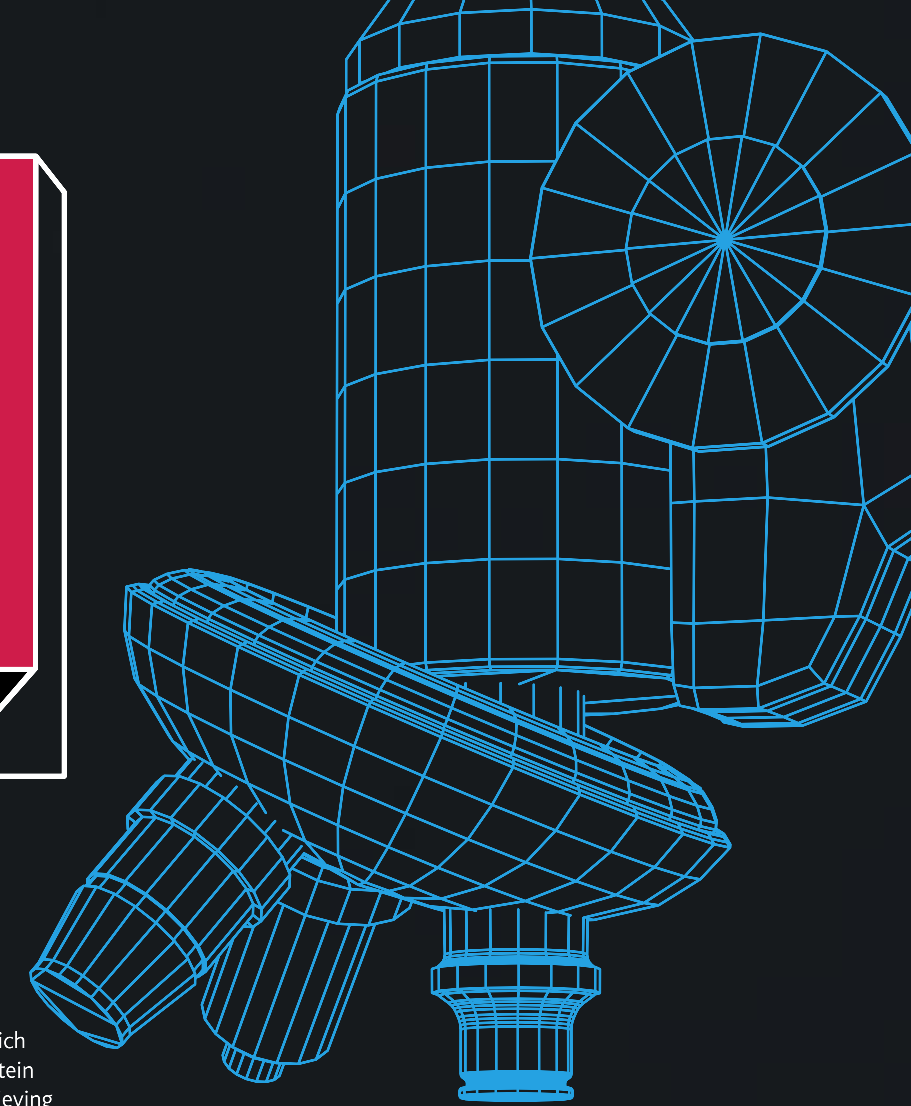
"I love figuring out how things work! Whether it's something as large-scale as astrophysics or as tiny as microbiology, I'm always keen to understand what's going on behind what we see."

Chemist Friedrich Miescher used pus covered bandages from local hospitals for his research.

Biochemist Chargaff identified that DNA showed variation between species.

Ellen discusses the famous discovery of the double helix – the twisted ladder-structure of DNA which marked a milestone in the history of science. However, Ellen dives deeper into this discovery and questions how much credit we can attribute to renowned scientists Francis Crick and James Watson.

Crick and Watson - two very famous names with a single important discovery.



But how much did they really uncover?

Despite the official discovery of DNA as we know it coming in 1953, the groundwork for these findings was laid way back in 1869, with a Swiss chemist named Friedrich Miescher. Miescher set out to find what he called the 'protein component' of white blood cells, or leukocytes. After retrieving the pus covered bandages from local hospitals, he cleaned and filtered the white blood cells, then separated out the leukocytes into the constituent proteins. Through this process, Miescher discovered a protein that was completely unlike proteins discovered before: it had more phosphorus and was resistant to protein digestion. The significance of Miescher's work was not realised for many more years, and even now only a tiny fraction of people have heard his name.

Russian chemist Phoebus Levene was the next part of the journey. Through countless experiments and years of research, he made a number of discoveries. Levene used hydrolysis, the addition of water, to break down yeast. What he found was that nucleic acids (a catch-all name for all types of DNA) were partly composed of four nitrogen containing bases: adenine, guanine, cytosine and thymine. He also found that each base was attached to a sugar molecule, and that sugar molecule to a further phosphate. This configuration of molecules would be called the nucleotide, which we now know to be the basic building block for DNA.

Although Levene was correct in many of his findings, new discoveries changed his theories slightly. For example, he said that the four bases were always in the same order - but this was too simplistic and failed to account for the complexity of even a simple organism's characteristics. In other ways, Levene was very accurate; for example his model of the nucleotide is still in use today. The biochemist Chargaff expanded on Levene's work. Firstly, he identified that DNA showed variation between species. Before long, he had also observed that amounts of certain bases were roughly the same. Adenine was always equal to thymine, and guanine equal to cytosine. Although Chargaff couldn't explain the findings himself, this information helped Crick and Watson.

Chargaff's work, and that of his fellow scientists, finally gave Crick and Watson the insight they needed. Using cardboard cutouts and their knowledge of possible bond angles and molecular distances, they began to piece together the puzzle. After initial failure, a colleague called Jerry Donohue suggested they should try different configurations of the bases thymine and guanine.

Brilliantly, everything now fell into place and the molecules fit perfectly - the structure of DNA as we know it had been discovered.

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