The Mole

... FOR ANYONE INSPIRED TO DIG DEEPER INTO CHEMISTRY

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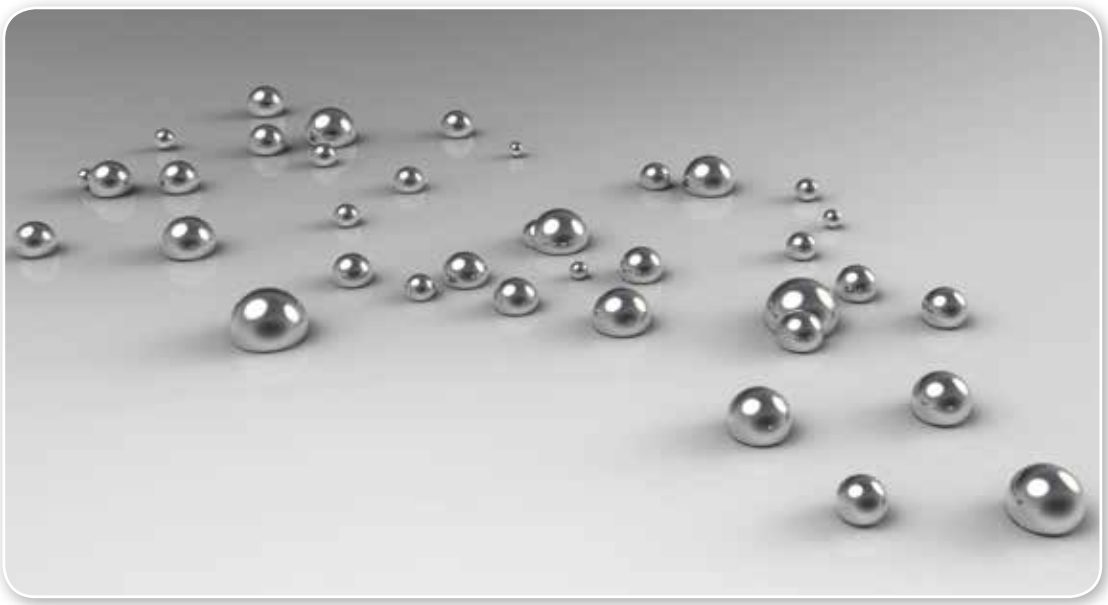
Balancing the risks of mercury

A forthcoming UN treaty aims to cut the amount of mercury used all over the world in an attempt to reduce its toxic effects. Does an outright ban go too far? Ian Farrell investigates



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Mercury is a pretty special metal. It's one of only two elements in the periodic table to exist as a liquid at room temperature, and its slippery, reflective appearance once gave it the historical nickname 'quicksilver.' It's used in all manner of applications, from producing industrial chemicals and fluorescent light bulbs to dental fillings and medical preservatives. Mercury has also been used for centuries in thermometers and barometers.

Toxicity

But there is one big problem with mercury – its toxicity. Mercury is harmful when swallowed, absorbed through the skin or breathed in, which means that chemists and engineers are always on the lookout for materials that can replace it.

Scientists have become more aware of the poisonous effects of mercury over time, but historically it was considered to have health benefits. Back in Victorian times, mercury metal was prescribed by doctors as a cure for constipation, among other things. You'd be strongly advised not to swallow or handle it today!

The United Nations (UN) has just spent six years working on a treaty that aims to eliminate or reduce mercury use throughout the world. The agreement, which is due to

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At the top of the food chain, oily fish like tuna and swordfish can be relatively high in methylmercury

be signed by all 193 UN member countries in October 2013, aims to prevent a range of health issues, the most common of which relate to the brain. Symptoms of severe mercury poisoning include: tremors and shaking; depression and insomnia; and reduced learning capabilities, especially in young children.

Methylmercury

Not all types of mercury are equally poisonous though, and experts are keen to point out that the risks posed by the metal should be properly evaluated and kept in perspective. The toxic effects of mercury depend on its chemical form and the route by which it gets into the body in the first place. The most toxic form is methylmercury, written as CH_3Hg^+.

Methylmercury affects the immune system, alters our genetic code and enzyme systems, and damages the nervous system, affecting our sense of touch, smell, taste and sight. It's particularly damaging to babies in the womb, who are 5–10 times more sensitive than adults, and it usually gets into the body through ingestion. It's so dangerous because it's absorbed more readily than other forms of mercury and excreted more slowly. It's also able to cross the blood–brain barrier very easily.

Mercury that exists as the famous liquid metal – as found in thermometers and pressure gauges – is less dangerous. If you swallowed any, it would probably pass through your digestive system without causing you too much trouble, because it's absorbed very slowly. That said, it can still be dangerous in large quantities or if exposure goes on for a long time. But the liquid metal form of mercury is much more dangerous when its vapours are breathed in. This can cause tremors, gingivitis (bleeding gums) and other neurological problems. It is a big problem in parts of the world where mercury is used in industrial processes, like mining.

The risk from fish

Mercury is found in many rocks and minerals, including coal. Although the concentrations involved are low, the amount of coal the world burns in a year is huge, which means lots of mercury is released into the environment this way. It comes back down to earth in rain and snow and finds its way into rivers, seas and oceans where microorganisms like algae and plankton absorb it and convert it to the more toxic methylmercury form.

Over time, these microorganisms are eaten by small fish that, in turn, are eaten by bigger fish, and the methylmercury accumulates in their flesh. These bigger fish are eaten by even bigger fish until we get to the top of the food chain, where oily fish like tuna and swordfish can be found to be relatively high in methylmercury. This can be a problem for families that live almost exclusively on such fish, such as Inuit and populations from the Seychelles.

The UN and the World Health Organization (WHO) are so worried about this effect that it is mentioned specifically in the treaty that is aiming to reduce mercury. They have named the treaty after the Japanese city of Minamata – one of the most famous sites of methylmercury poisoning through fish. Between 1932 and 1968, waste water containing mercury from an industrial plant was dumped in nearby rivers, where it caused horrific neurological problems in the local fish-eating population. The symptoms – which can vary from tremors and shakes to physical abnormalities – are known as Minamata disease.

Although the link between burning coal and methylmercury in fish is well established, the risks posed are not on the same scale as the Minamata disaster. While populations who eat significant amounts of fish are thought to be at risk from methylmercury poisoning, there are also arguments that the health benefits of their oily-fish diet actually outweigh the problems from the mercury.

The human body has defence mechanisms in place against mercury, reacting it with another metal – selenium – to produce mercury selenide (HgSe). This is

The Minamata memorial, in memory of those poisoned by the 1950s industrial release of methylmercury into the bay

© JEREMY SUTTON-HIBBERT/ALAMY

totally insoluble in water, and therefore not 'biologically available' to the body. It's a neat trick, but to do it we need some selenium in our diet. And one of the best sources of selenium is (conveniently) also oily fish.

This may be why scientists have found bigger methylmercury health problems in populations that eat fish that are low in selenium (such as shark or pilot whale) than those who eat selenium-rich species (like tuna and swordfish).

Gold rush

Breathing in mercury fumes is far more dangerous than eating it, and this is worse when mercury is hot. For a metal, mercury has an extremely low boiling point, just 388˚C. This means that, as it gets warmer, the amount of mercury gas increases – just like water vapour appearing over heated water. In this situation, it's all too easy to breathe in way more mercury than your body can cope with.

Although exposure to mercury vapour is usually a result of industrial accidents, workers at gold mines in developing countries are often exposed to such hazards as part of their normal everyday job. They use liquid mercury to dissolve gold from finely powdered rock, forming a gold–mercury amalgam. The mercury is then boiled off to leave behind the gold. This process is extremely dangerous: young children and new born babies are particularly susceptible to brain damage, and exposure levels are so large that they overwhelm the body's nature defence mechanisms.

The consequences of change

Mining gold with mercury is just one of the activities that the UN's Minamata treaty hopes to eliminate, but all such changes have huge social impacts on the way that many people live and these must also be taken into account. In the case of mining, an instant ban would seriously affect the way that millions of miners all over the world work and support their families, so a gradual phase-out of the practice may be better.

Similarly, turning away from coal as a source of energy could help to reduce the amount of mercury that ends up in the environment, but doing so could harm the economic and social development of many poor countries, and the people that live in them. Energy-saving light bulbs may be a source of mercury pollution if they are dumped in landfill sites, but using them in the first place means burning less coal in power stations. Careful balances must be made.

© IAN FARRELL/MRC

Thiomersal (a compound of mercury) is added to vaccines as a preservative, to prevent the growth of fungi and bacteria

Some uses of mercury in the developing world are actually beneficial to health. Thiomersal (sodium ethylmercurithiosalicylate) is added to vaccines as a preservative, to prevent the growth of fungi and bacteria. Without it, many countries would struggle to maintain vaccination programmes that save millions of lives. Using mercury in this way is considered safe by the WHO, and is specifically excluded from the treaty.

The need to consider factors such as these when making decisions about the future use of mercury is perhaps why it has taken six years for the UN to draft the Minamata treaty. There are bound to be those that think the legislation goes too far, as well as experts who say it doesn't go far enough. The secret is balance, and compromise.

The UN's treaty is a brave and significant move, but its effects won't be seen for a long while. It will take time to phase out the industrial processes that spread mercury around the planet, and even then there is enough of the metal already in the biosphere for its effects to be seen for decades to come. However, the Minamata treaty is a step in the right direction and a recognition of the trouble that this remarkable metal can cause.

Find out more

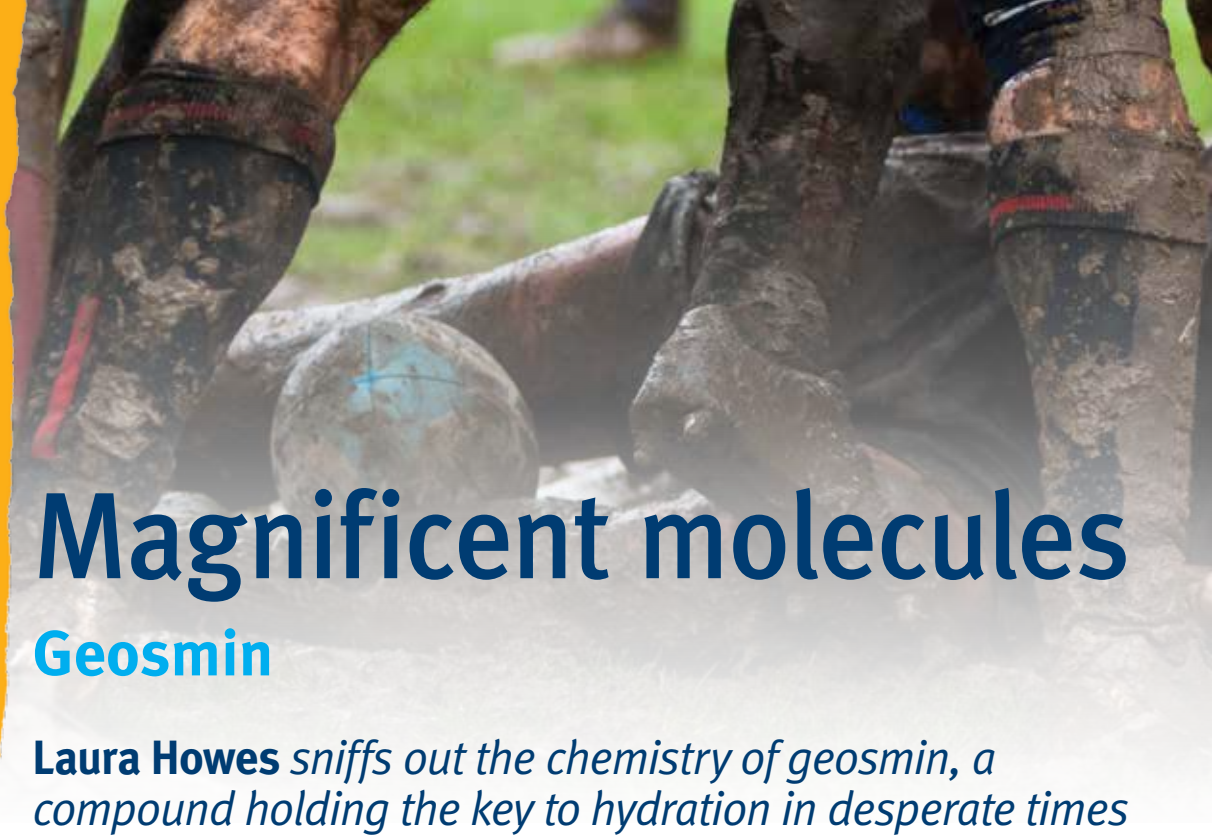
Learn more about the effects of mercury in the environment with the US Geological Survey: **http://on.doi.gov/19LjxsI**

Mercury and vaccines

In the west, we produce vaccines in single-use sealed vials that are prepared under strictly sterile conditions, but this is not the case everywhere in the world. In developing countries it's cheaper for a nurse to inject many people from a larger, multi-dose bottle of vaccine.

These larger bottles take up less space in cold storage and refrigerated transport, making them more practical and less expensive on a per-dose basis. The only problem is that, once they are opened, the bottles are susceptible to contamination by bacteria and fungi, which can cause all manner of health problems, and even death.

To prevent this, thiomersal is added to bottles. Its antimicrobial properties prevent the bacteria and fungi multiplying and ensure the vaccine is safe to inject. Without mercury, such vaccination programmes would have to use more expensive single-use vaccine doses, meaning fewer people could be treated. For this reason mercury-containing vaccines solve more problems than they cause and are not banned under the UN treaty.



Magnificent molecules

Geosmin

Laura Howes *sniffs out the chemistry of geosmin, a compound holding the key to hydration in desperate times*

It's a smell that I will forever associate with cold wet rugby games as our studs gripped into the pitch and the whistle blew. That unmistakeable smell of mud and earth that you might associate with weeding the garden or hiding from the rain. And the main compound responsible, rather fittingly, is called geosmin: earth odour.

Microorganisms

Geosmin is a terpene made by microorganisms in the soil, particularly the *streptomyces* family of bacteria that live in soil and decaying matter and produce most of our antibiotics. However, the biosynthesis of geosmin was only discovered in 2007 after the genetic code of *Streptomyces coelicolor*, a bacterium that munches on plant matter in the soil, was solved. It turns out that a single protein converts farnesyl diphosphate (a common starting material for the biosynthesis of terpenes) into germacradienol, which is then converted into geosmin. The resulting molecule is a volatile alcohol that you can smell at incredibly low concentrations, down to around 0.7 parts per billion. But why would you want to?

Beetroot, wine and fish

Apart from rugby fields, geosmin is the compound responsible for the earthy taste of beetroot and it can also find its way into freshwater fish, as well as wine. Somehow, what's tasty in beetroot isn't quite so good in other foods on your plate. Geosmin can be degraded with acid, which is why potentially muddy tasting freshwater fish are often liberally doused with lemon juice or vinegar. However, that option isn't really feasible for winemakers with geosmin-contaminated stock and so there's a great deal of research into other options for removing it from wine.

The most effective treatment for reducing the amount of geosmin in wine seems to be grapeseed oil, with the oil acting as a solvent for the geosmin. Unfortunately, this treatment also seems to reduce the volatile aroma compounds that you probably want to keep in the wine as well. In fact, even though you can remove much of the geosmin, the reduction in other volatiles can actually make the geosmin even more pronounced. Now that the enzyme responsible for geosmin's production has been identified, the hope is that people can find a way of stopping it being produced in the first place, rather than unsuccessfully trying to remove it later on.

Finding water

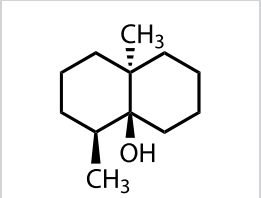
The question remains, of course, why we are so sensitive to it, considering that we find the compound so distasteful in our food and drink. One theory is that our ancestors used the odour of geosmin to identify sources of water. That might seem unnecessary in the land of wellington boots and a national obsession with the weather, but in more arid climes it could be a lifesaver. Keith Chater of the John Innes Centre in Norwich, one of the team who originally sequenced the genome of *Streptomyces coelicolor*, has suggested that camels might be so sensitive to geosmin that they can smell oases miles away, and track the scent to find water in the desert. The spores of the bacterium, in return, can then hitch a ride and travel to the next waterhole.

You might not like it in a wine glass, but geosmin is more than the smell of a wet rugby pitch: it could be the smell of survival.

Did you know?

BOTH IMAGES © SHUTTERSTOCK

Terpenes like geosmin are found throughout nature. *R*-limonene is found in orange peel and smells strongly of oranges. However, it is a chiral molecule with two optical isomers. The other enantiomer, *S*-limonene, smells of pine needles.



Geosmin is made by bacteria in the soil and is also present in beetroot. It's sometimes found in fish, but can be removed with lemon juice or vinegar.

Avogadro's lab

Vitamin C

Stephen Ashworth *asks 'how much vitamin C is in your orange?'*

We all need vitamin C to stay healthy: it is a vital nutrient. Without enough vitamin C humans develop a disease known as scurvy. Along with some other animals, we have to eat foods containing vitamin C as we can't synthesise it in our bodies.

Scurvy used to be a deadly disease for sailors and soldiers, who often had to go for long periods without fresh fruit and vegetables. One symptom of scurvy is spongy and bleeding gums. This happens because vitamin C is required for the body to make collagen, which is an important component of connective tissue. The navy found that lime juice added to rum and water (grog) kept sailors healthy and is why the English are sometimes referred to as Limeys.

Many fresh fruits and vegetables contain vitamin C. Citrus fruits, such as oranges and lemons, are especially good sources. Vitamin C may also be added to processed food as a supplement.

Ascorbic acid

Vitamin C refers to L-ascorbic acid or one of its oxidised forms. Any of these have the biological effect of vitamin C.

Ascorbic acid itself does not just have activity as a vitamin, it is also an antioxidant. The term oxidation originally referred specifically to a reaction that combined something with oxygen. However it now has a much wider meaning. If one reactant is oxidised another must be reduced, to balance out the transfer of electrons. These types of reactions are known as redox (REDuction–OXidation) reactions. An antioxidant (or reducing agent) is used to reduce another reactant while being oxidised itself (a bit like a see-saw: if one end goes up the other must come down). We can use this property of ascorbic acid to measure how much we have in a solution.

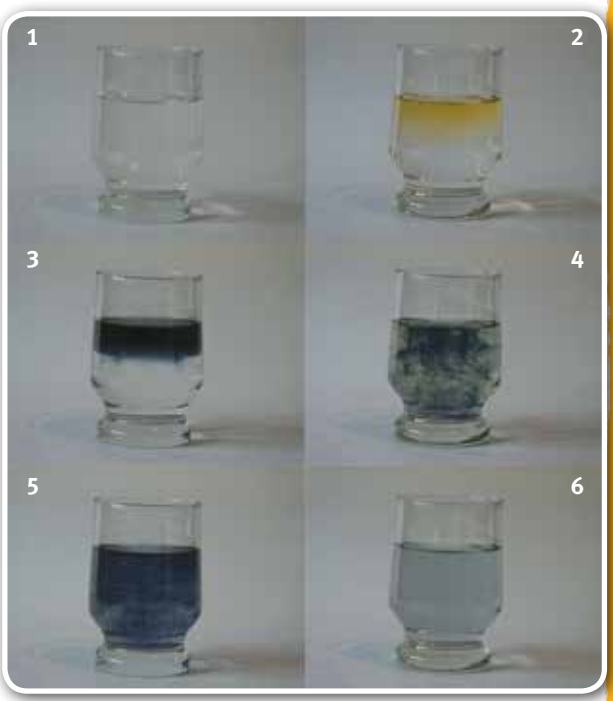
Try it yourself

Ascorbic acid reduces iodine to iodide ions, and in the process it is oxidised to dehydroascorbic acid. We can show that elemental iodine is present in solution by using starch to give a characteristic blue–black colour. An easy way to make a solution of starch is to add some boiling water to a little cornflour. Some starch dissolves and the liquid will become slightly cloudy.

Take about 250 cm^3 of water. Using an eye dropper or pipette, add a few drops (five should be enough) of tincture of iodine (you can buy this from a pharmacy) and a few drops of starch – the solution should become blue–black. Using a clean eye dropper or pipette add some orange juice to this solution and count the drops until the dark colour disappears.

One molecule of ascorbic acid converts one molecule of iodine into two iodide ions. When all the iodine has been reduced to iodide the solution loses its blue–black colour. If the same amount of tincture of iodine is used for each experiment, the amount of vitamin C in a variety of liquids may be compared. It is also possible to calibrate your solutions by using an effervescent vitamin C tablet dissolved in a known quantity (eg 1 litre) of water.

Be aware that tincture of iodine is for external use only and may stain. Also, be aware that ascorbic acid will slowly react with oxygen in the air and lose its reducing properties – one reason to eat your fruit and vegetables when they are as fresh as possible.



- **Water – (1)**
- **Add tincture of iodine – (2)**
- **Add starch solution – (3)**
- **Add orange juice until the dark colour goes – (4–6)**

Did you know?

In 1937 Norman Haworth was awarded the Nobel prize for chemistry for determining the structure of ascorbic acid. In the same year the Nobel prize for physiology or medicine went to Albert von Szent-Györgyi Nagyrápolt for his work on understanding the biological functions of ascorbic acid.

Global experiment

In the next issue you can join in with Chemistry Week activities (16–23 November) and take part in the Global Experiment to test vitamin C levels in lots of fruit and veg!

Cutting-edge chemistry

3D printed networks mimic tissue

Laura Howes *investigates networks built drop by drop that can fold themselves up*

Did you know?

Engineers have created a bionic ear that can be manufactured using a 3D printer. Find our more with this article from *Chemistry World*: **http://rsc.li/106NSet**

Watch the printer in action

Time-lapse photography shows the soft network being built drop by drop: **http://youtu.be/OU0yse-Ta34**

See the network fold

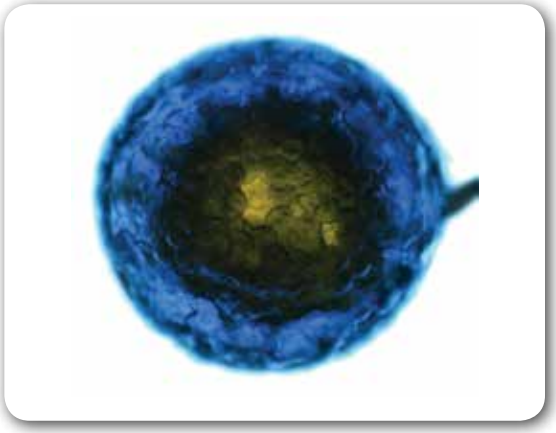
Watch the printed network fold up due to the power of osmosis: **http://youtu.be/tKHrFJ5VBKk**

Back in 2007, Hagan Bayley's lab at the University of Oxford, UK, created bionetworks made from small droplets all linked together. Each of the aqueous droplets were individually pipetted into an oily phase, where they linked together to create a chain of droplets with a lipid bilayer at each interface. Into those bilayers Bayley's group introduced a protein and showed that the linked droplets conduct a current. But making and linking these droplets together was fiddly work, requiring someone to individually pipette each droplet and then move it into place.

Fast forward five years and the Bayley lab aren't fiddling about by hand anymore. They've got a robotic printer to assemble their networks and that means the networks they are printing are not the small two-dimensional arrangements they started with. Instead they can arrange hundreds and thousands of these small droplets to create complex three-dimensional networks that can even fold up into more complicated geometries.

A printed solution

DPhil student Gabriel Villar, designed and built the machine, which prints small droplets into pre-determined arrangements. The device has two nozzles: one prints droplets, linked by protein pores, which make up the network, while the other prints the 'support' droplets that hold the droplet network in place. 'This isn't as simple as inkjet printing,' explains Villar. For a start, because the oil is so viscous the movement of the nozzles through the oil can drag the droplets with it, so that had to be factored into the program.



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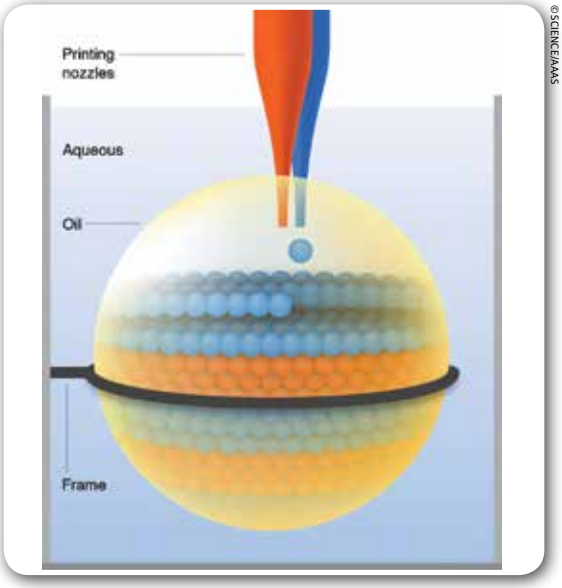
A top-down view of the folded-up network



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The resulting soft networks can be further encapsulated to create a water-in-oil-in-water system – the water droplet assembly is held together in a larger oil droplet that is then surrounded with water. This started Bayley thinking, he says, about drug delivery applications or even perhaps using the networks, which have a similar elasticity to soft biological tissues, as supports for failing organs in the body.

Folded tissues

One of the immediate applications, Bayley says, might be tissue engineering. The droplet networks can create systems with electrical or concentration gradients to direct growth. The soft systems have also been made to fold into shapes by using the power of osmosis to change the relative sizes of the droplets, suggesting that the system might one day create motors or actuators. The Bayley lab is already working on making this folding reversible, although Bayley admits this is proving difficult.

Villar says the most satisfying part of the work was being able to simplify and automate a previously 'laborious' process. 'Something like 3D printing, which has exploded in popularity, has many more applications than anybody can think of at first,' he adds. Time will tell where these salty solutions and lipids will end up.

Shell extract rebuilds pearly whites

Emma Stoye *looks at a solution for restoring tooth enamel inspired by molluscs*

Researchers in China have shown that the organic component of mother of pearl can help repair damaged teeth, by acting as a template for the mineralisation of tooth enamel.

Tooth enamel is made up of rod-like crystals of hydroxyapatite, a calcium phosphate mineral. It is the hardest tissue in the body, but is susceptible to erosion by food and bacterial acids. Once gone, it never naturally reforms, and cavities must be fixed using manmade materials. Methods of artificially rebuilding enamel often involve extreme temperature, pressure or pH conditions that make them impractical for clinical use.

Mother of pearl

Researchers from the Chinese Academy of Sciences and Fujian Medical University, both in Fuzhou, are working towards a more feasible solution using the natural composite nacre (mother of pearl) from the inside of mollusc shells.

Nacre is composed of layers of aragonite, a form of calcium carbonate, separated by an organic matrix of proteins and biopolymers called the water soluble matrix (WSM). The WSM acts as a template for aragonite crystal growth during nacre formation, so the researchers thought it might also be able to influence the structure of hydroxyapatite crystals in enamel. They tested this using extracted human molars that had been deliberately damaged with a strong acid.

Growing crystals

The teeth were immersed in a solution containing the isolated nacre WSM from mussel shells, along with calcium and phosphate ions, for three days. Scanning electron microscope images revealed that hydroxyapatite crystals with the correct shape and orientation formed on the surface of the tooth. The new 'enamel' was also similar to the real thing in terms of smoothness and hardness. Without the WSM, the crystals that formed were randomly orientated.

'Our study demonstrates that the WSM is an effective template for hydroxyapatite remineralisation,' says Zanyong Zhuang, one of the researchers involved. 'It is much cheaper and easier to extract than other protein templates, and is a natural agent that would be physiologically safe in clinical restoration.'

A long way off

Zhuang admits, however, that there are many other things to consider when dealing with teeth in situ. Paul Anderson from the Institute of Dentistry at Queen Mary University of London, UK, agrees that further research is needed. 'This work is intriguing,' he says, 'but the mechanism of enamel growth has been well studied, and the [template] mechanism proposed here seems to contradict that. Clinical enamel repair is still a very long way off.'

©ISTOCKPHOTO

Tooth enamel is made up of rod-like crystals of hydroxyapatite, a calcium phosphate mineral

Did you know?

©SHUTTERSTOCK

Thinking of becoming a dentist?

Most universities require you to have an A-level in chemistry (together with biology) in order to study dentistry.

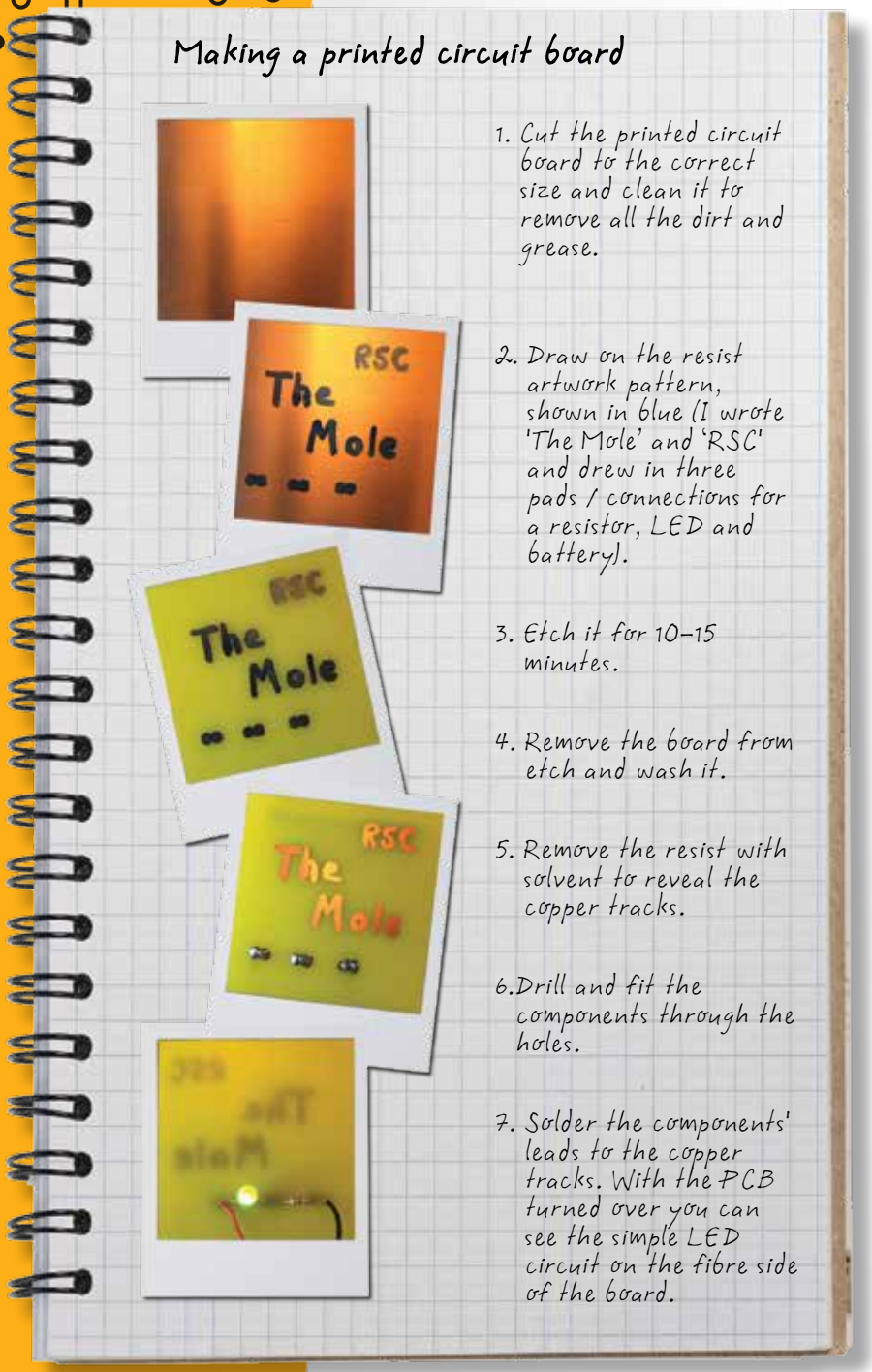
Find out more

Learn more about novel materials that could be coming to a dental surgery near you, with this article from *Chemistry World*: **http://rsc.li/11CVv1f**

Trade secrets

How to make a printed circuit board

Jonathan Hare *explores the chemistry behind your favourite gadgets*



Printed circuit boards (PCB) are found in almost all electronic devices including mobile phones, iPods, computer motherboards, TVs, calculators, washing machines, radios and car electronics. A PCB is a rugged and effective way of wiring-up electronic components to create electronic devices.

The basic PCB consists of a thin laminate or fibreglass board covered on one side with a thin layer of copper. The copper is etched to form a complex circuit of 'tracks' that are used to wire-up and interconnect the electronic components attached to the board. Modern PCBs in mobile phones and computers usually consist of a number of very thin boards sandwiched together to make a complex multilayer PCB.

Etching a connection

The PCB track pattern is made by etching away the unwanted copper to leave the desired interconnections. Firstly an etch-resistant pattern – the resist – is drawn on to the copper. This can be painted on using a suitable marker pen or screen print techniques can be used. The PCB is then placed in an etch that removes all the bare uncovered copper, leaving the covered copper (the tracks) untouched.

Various chemicals can be used as an etch to remove the copper. Nitric acid and ammonium persulfate can be used but iron(III) chloride is standard. The reaction of copper with $FeCl_3$ is a two step redox reaction:

$FeCl_3 + Cu \rightarrow FeCl_2 + CuCl$

$FeCl_3 + CuCl \rightarrow FeCl_2 + CuCl_2$

Warming and agitating the etch solution (using vibrations and air bubbles) can greatly speed up the process and produce a cleaner finish. After etching, cleaning and drilling, the PCBs are often dipped in a tin(II) chloride ($SnCl_2$) compound to deposit a thin film of tin on the copper tracks. This provides a surface that does not tarnish as quickly as the pure copper but is still easy to solder. In addition to the chemical etching methods, modern CNC micro-milling machines are also being used to create PCBs. Channels can be cut into the bare copper using a tiny cutting tool to create complex tracks and wiring circuitry.

Books for summer

Whether you're looking for something interesting to read this summer, or thinking about your university application, here are some books for the holidays

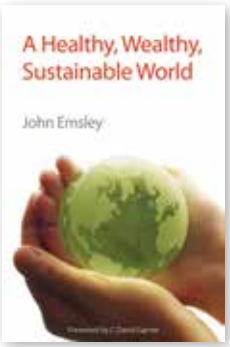
Scientists don't work in isolation: they communicate with others to keep abreast of the latest developments and exchange ideas. This extends beyond their own subject too – chemists work with physicists, biologists, engineers and more.

If you're thinking of studying science at university, you will need to do more than just pass exams. It's important to read around your subject. University admissions tutors look for evidence that applicants show a genuine interest in the course they wish to study, and independent reading is a great way to demonstrate this.

To expand your knowledge and awareness of science in general, here are some books we recommend:

A healthy, wealthy, sustainable world

John Emsley
Hardback: £18.99
http://rsc.li/11GJ1Wq



This book reflects two major current issues. One is that we face a major crisis because of the way humans have been using the world's resources in a way that is totally unsustainable. The second is that although this is a major problem, there is hope, and much of that centres on chemistry. This is an important message. Of course chemistry is even-handed, and sometimes its applications have caused damage to people and places. Yet its successes often go unnoticed, and the prospects for future prosperity are dismal without it.

John's book is divided into chapters according to major areas of application of chemical sciences: food, water, health, fuels, plastics, cities and sport. Within each of these contexts, a case is made for how chemistry can make a continuing major contribution to maintaining and developing standards of living for present and future generations. John discusses what has already been achieved, what is under development, and what chemists can reasonably hope to aspire to.

A key theme is that despite the bad press often given to 'chemicals', especially those judged not to be 'natural', chemists have already done a great deal to help people become healthier and safer, as well as having increasingly sophisticated 'kit' to house, clothe and entertain us.

It is packed with facts, and John is relentless in supporting his argument with engaging and relevant examples. This book is highly recommended for chemists, however it would make an even better present for those misguided enough to see chemistry as inherently a 'bad guy'.

Keith S Taber

An optimist's tour of the future

Mark Stevenson
Paperback: £8.99 | Kindle: £4.63
http://amzn.to/11GKFr6

In this book, humorous scientist Mark Stevenson tours the globe in search of groundbreaking thinkers and scientists, bumping into a few free radicals along the way. The narrative is split into four distinct (but linked) sections: man, machine, Earth and re-boot.

Theories constantly bounce off the walls – from Aubrey de Grey's radical transhumanism and ascension from our mortal bodies, to the genetic infrastructure of said bodies and how we can force small bespectacled men in basements to write the next generation of artificial intelligence – this book has it all.

Stevenson never meets an idea with scepticism, instead preferring to visit the theorist or engineer behind it, obtain their point of view and then make some rather humorous points of his own. I find this a refreshing take on most scientific reads that focus too much on the facts and not on the theories. He focuses on what will be coming to the home in the not too distant future, rather than penning an epic love letter to the failed prototypes of yesteryear.

Not all is fun and games, however, as Stevenson highlights some of the dangers of future technology. He remarks that technology will be misused and that the next Chernobyl or 9/11 disaster is never far off. Do not let this put you off, though! No new scientific or technological cause is without drawbacks, be they mortal or ethical.

This is a volume filled with hope, optimism and wondrous bouts of side-splitting, scientific punchlines. This book makes for an excellent and insightful read for anyone doubtful about the future of innovative science.

Callum Saunders

Try these too

Will we ever speak dolphin?
Mick O'Hare (ed)
Paperback: £4.28 | Kindle: £3.67
http://amzn.to/19sS5jo
The latest in the series from New Scientist: 130 science questions (and answers!) you've never thought of.

Deceived wisdom
David Bradley
Hardback: £11.99 | Kindle: £5.76
http://amzn.to/19ERX0s
Why what you thought was right is wrong – an evidence-based scientific approach to debunking urban myths.

Tribal science
Mike McRae
Paperback: £15.15
Kindle: £7.96
http://amzn.to/18Q4hfm
This thought-provoking book attempts to examine the interactions between humans – as emotional, social creatures – and the cold logic of science. An enlightened view of the way science works.

Paradox
Jim Al-Khalili
Paperback: £6.74 | Kindle: £6.17
http://amzn.to/10VApGM
Jim describes nine well-known enigmas that have puzzled many, until scientific analysis showed how to resolve them.

Book prices were taken from Amazon.co.uk in June 2013.

Help from ChemNet

- Talk to other chemistry students about any worries you're having in the RSC ChemNet discussion forum **http://rsc.li/chemnet-group**
- Ask Dr ChemNet about revision topics you're having difficulty with **http://rsc.li/dr-chemnet**
- Check your knowledge with quizzes on Learn Chemistry **http://rsc.li/ZI26Fb**

Did you know?

RSC ChemNet is free to join for anyone aged 14–18. Tell your friends! **http://my.rsc.org/chemnet**

To book a place on an RSC ChemNet event:
E: chemnet@rsc.org
T: 01223 432276
or book online and find more info about all the events at:
http://my.rsc.org/chemnet

Higher apprenticeships

Want to earn while you learn? Higher apprenticeships could be your debt-free route to chemistry graduate status. **James Mitchell Crow** *takes a look.*

Emma Brown is the envy of her friends. She is three quarters of her way to earning a chemistry degree, and she's getting paid to do it. Emma is an 'R&D apprentice' at Unilever's Port Sunlight plant, from which she attends the University of Liverpool about two days a week. Unilever pay Emma a salary, and also cover her tuition fees. For Emma, the decision on whether to take a conventional university degree, or take the apprenticeship route, was a simple one. 'To get all my degree paid for, have no debt at the end and four years of work experience, it was a no-brainer really!' she says.

As well as her debt-free degree, Emma will come out of the programme with another key attribute – four years' worth of work experience. Taking a university degree was once a sure route to a job, but times have changed, and today's graduates face a crowded job market. Individuals with extensive work experience can really stand out from the crowd. 'So many people I know have graduated and not been able to get jobs, because it's all about having work experience,' says Emma.

Pathways to a degree

When Unilever launched its R&D apprenticeship programme three years ago, it was a step ahead of the game. At that time, very few apprenticeships in the UK went beyond the equivalent of late secondary education. Other countries, particularly Switzerland, had much more extensive schemes – and much lower levels of youth unemployment. The UK government took notice, and in 2012, a national scheme of higher apprenticeships for chemistry was launched across England – an alternative way to achieve chemistry graduate status than the traditional university route, and without the associated fees. Within science, the apprenticeship can be taken as one of six possible pathways: chemical science, life science, food science, process development, packaging development and healthcare science.

Choice and flexibility

The higher apprenticeship programme has been designed to offer employers and apprentices as much choice and flexibility as possible. For example, to complete their 'level 5' qualification, chemistry apprentices can study for a foundation degree via distance learning, or attend a local further education college to do a HND. Depending on the employer, some higher apprenticeships end at this point, while others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continue on to the full degree, which can be completed part-time at any university.

Unilever now offers the formally recognised higher apprenticeship at its Leeds site, and a growing list of other companies are starting to offer the scheme, including pharmaceutical companies such as GSK, and Takeda Cambridge, UK research arm of Japanese drug company Takeda.

'Our entry level criteria are the same as those for university entry,' says Linda Millett, head of human resources at Takeda Cambridge. 'We still recruit graduates, I was just interested in offering a different career pathway for young people into our industry,' she adds.

Career prospects

But for those who do choose a higher apprenticeship, Linda sees their career prospects as equal to a university graduate, if not better. 'Some of the graduates we take in can take a while to settle into the work environment. Someone who has been in the workplace for three years, I think they've got an edge – even over a graduate with an industrial placement year.'

Higher apprenticeships aren't for everyone, says Emma. Juggling work with study requires excellent time management skills, for example. 'I have to be strict with myself as to when I get things done,' she says. But Emma adds that although she has less free time than her university friends, she hasn't found the gap to be too great. 'I haven't really struggled with that too much, I've still got a life.'

Charlotte Vincent

Technician at LGC Forensics

From hair and beauty to identifying remains from the first world war, Charlotte tells **Ian Le Guillou** *how apprenticeships have been a great route into chemistry*

Charlotte had little idea of what she wanted to do after finishing her GCSEs. She was a bright pupil but did not like the thought of staying in school to do A-levels. However, finding work would not be easy with few qualifications and no experience. As a compromise, she enrolled on a course at a hair and beauty college while working part-time at a hairdressers.

Enjoying science

A year after her course finished, now working full-time at the hairdressers, Charlotte began to think further ahead. She still was not sure what she wanted to do, but had the feeling that science might hold the answer: 'I enjoyed science at school – it was one of the few subjects that I thought was quite interesting. On the hair and beauty course, we had a course on physiology and that was the part I enjoyed the most.' After a conversation with her dad, who used to be a fire investigator, she began to like the sound of forensic science.

'I thought about going back to college to do a forensic science subject but they said I didn't have enough science background or grades to get on the college course.' However, Charlotte heard about a new apprenticeship scheme starting at LGC Forensics, a company that provides a range of forensic services for police forces and civil cases.

Identifying soldiers

Apprenticeships are quite hard to come by and the scheme at LGC Forensics is one of the first of its kind. They took on 22 apprentices that year, including Charlotte, based around the country. The apprentices were assigned to different areas of forensics, from toxicology to radiochemistry. Charlotte went straight in as part of the DNA analysis team: 'I worked on civil paternity cases [and] I also had quite a lot of involvement on the Fromelles project. That's a project to identify soldiers who were killed in the battle of Fromelles in the first world war. We send kits to people in Australia and the UK so that they can send us their DNA and we can process that and compare it to unidentified remains.'

The unique aspect of the apprenticeship scheme is the balance between working and studying. 'Four days a week you're working in the office or the lab, and then we had a college day where you do the theory work. You have to do quite a lot of work, like essays and assignments.' This is one of the aspects that Charlotte appreciates the most: 'I prefer to work and do college work at the same time, rather than just college work. I think it's much more interesting if you can see where the theory is being applied.'

Qualifications

The course that the apprentices go through leads them to obtain BTEC and NVQ qualifications in forensic science. The syllabus, set out by Birmingham Metropolitan University, covers a wide range of forensics from photography to analysing blood patterns to court procedures.

Charlotte is now working at LGC Forensics full-time, having just recently finished her 18 month apprenticeship. 'I enjoyed it a lot, for me it was more than I expected really.' She'll now be working in the radiochemistry department and picking up a whole new set of techniques.

During her apprenticeship, Charlotte was asked to come along to an LGC Forensics event at a school. As Charlotte describes, the A-level students there 'were shocked to see that I didn't have a science background and that I worked in a lab environment. They weren't even aware of apprenticeships.

'I think I'm quite a good example of getting into science without a typical science background.'

Pathway to success

- 2013–present
  Technician, LGC Forensics, Teddington
- 2011–2013
  Apprentice, LGC Forensics, Teddington
- 2010–2011
  Working as a hairdresser, Teddington
- 2008–2010
  Hair and beauty course, Brooklands College
- 2008
  GCSEs, Sunbury Manor School

RSC ChemNet Events

- **Taster day at Queen's University Belfast**
  26 August 2013 09:30–16:30
  Visit the school of chemistry and chemical engineering for a flavour of undergraduate life at QUB.
  http://rsc.li/17VEoNj
- **What's it like to study chemistry at university?**
  17 July 2013 10:00–16:00
  Newcastle
  An opportunity to find out first-hand what it's like to be a chemistry student at Newcastle University.
  http://rsc.li/17VEHpE
- **Chemistry by the seaside**
  17 July 2013 09:30–15:00
  Newquay
  Come and find out about the chemistry of the ocean from Simon Ussher (Plymouth University) and Chris Hines (founder of Surfers against Sewage).
  http://rsc.li/17VFWFt

£50 of vouchers to be won

Puzzles

Wordsearch

Find the 35 words/expressions associated with fingerprinting research hidden in this grid (contributed by Bert Neary). Words read in any direction, but are always in a straight line. Some letters may be used more than once. When you have found all the words, use the remaining letters to make a nine-letter word.

S	F	C	N	I	Z	U	D	A	T	A	B	A	S	E	B	T
A	L	K	A	N	E	T	H	I	O	L	C	D	H	D	S	P
S	A	S	N	V	P	O	W	D	E	R	I	T	O	I	H	H
E	K	E	O	I	O	E	I	R	I	C	S	F	T	R	O	Y
Y	E	M	P	S	L	G	P	M	A	E	A	N	T	T	T	S
D	D	I	A	I	I	A	E	O	U	T	E	R	K	I	G	I
T	A	C	R	B	C	M	N	Q	T	I	L	E	Y	N	U	C
N	L	O	T	L	E	I	I	Y	C	E	A	A	B	I	N	A
E	U	N	I	E	M	N	A	S	O	D	T	G	A	D	C	L
C	M	D	C	A	H	C	C	I	P	I	E	E	R	R	A	R
S	I	U	L	C	I	I	A	O	P	X	N	N	R	U	R	E
E	N	C	E	D	S	C	E	N	E	O	T	T	I	F	T	A
R	I	T	S	N	O	I	T	E	R	C	E	S	E	L	R	C
O	U	O	E	S	E	G	D	I	R	O	N	T	R	U	I	T
U	M	R	S	T	L	A	S	M	A	T	C	H	P	S	D	I
L	O	F	I	N	G	E	R	M	A	R	K	S	I	I	G	O
F	E	U	D	I	S	E	R	Y	L	I	O	E	T	D	E	N

ALKANETHIOL
AMINO ACIDS
COPPER
CRIME
DATABASE
DISULFUR DINITRIDE
FATTY ACIDS
FINGERMARKS
FLAKED ALUMINIUM
FLUORESCENT DYE
FORENSIC SCIENTIST
IMAGE
INVISIBLE
ION
IRON
LATENT
MATCH
NANOPARTICLES
OILY RESIDUE
OXIDE
PHYSICAL REACTION
POLICE
POWDER
REAGENT
RIDGES
SALTS
SCENE
SECRETIONS
SEMICONDUCTOR
SHOTGUN CARTRIDGE
SHOTTKY BARRIER
TECHNIQUES
TIP
WIPE
ZINC

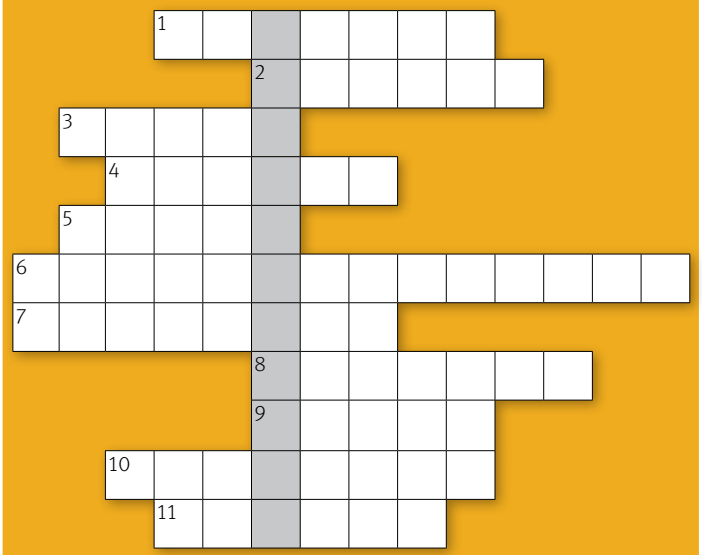
May wordsearch solution and winner

The winner was Adam Hilton from Richmond. The 10-letter word was CROSSLINKS.

Submit your answers online at
http://svy.mk/TM413ans
by **Monday 12 August.**
A correct answer for each puzzle, chosen at random, will win a £25 Amazon voucher.

Chemical acrostic

Complete the grid (contributed by Simon Cotton) by answering the 11 clues to find the answer in the shaded box, which is the name given to the functional group formed when an organic acid is neutralised.



1. A starting material for making esters

2. You might test for this functional group with bromine water

3. Type of compound often associated with a fruity smell

4. Essential element in organic compounds

5. Functional group often associated with explosives

6. You can test for this group with sodium carbonate (10,4)

7. This group reacts with both 2,4-dinitrophenylhydrazine and ammoniacal silver nitrate

8. Family name given to a cyclic ester

9. This group can be diazotised

10. Type of alcohol that is very difficult to oxidise

11. Type of compound that is weakly acidic and often associated with antiseptics

			L	I	T	H	I	U	M
			I	O	D	I	N	E	
		A	S	T	A	T	I	N	E
				C	A	E	S	I	U	M
		O	X	Y	G	E	N		
B	E	R	Y	L	L	I	U	M	
P	L	A	T	I	N	U	M		
		S	O	D	I	U	M		

May acrostic solutions and winner

The winner was Jessica Wang from Tenbury Wells.