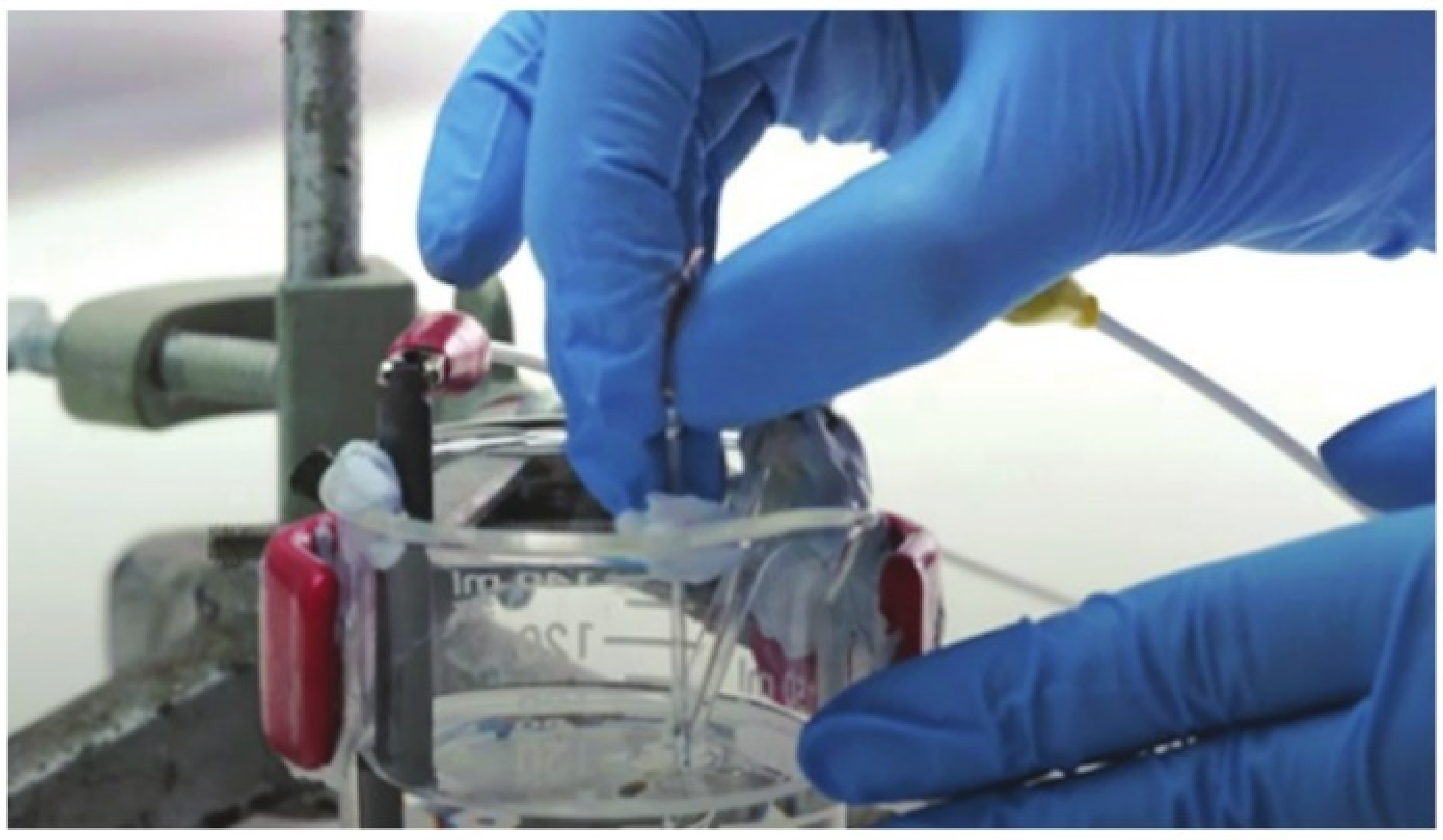
Recovering burnt toast



Electricity through Co_2, using liquid gallium as electrode, with cerium oxide nanoparticles in suspension.

Reversing the process of combustion may become feasible as a team of researchers have found

S ANANTHANARAYANAN

Photosynthesis is a natural process that takes CO_2, and not oxygen, as its input. Over millenia, carbon got stored as vegetation, and then as coal underground, while the atmosphere received oxygen, for living things to flourish. And it happened thanks to the energy from the Sun.

It was when humans discovered fire that it became possible to carry stored energy, in the form of wood, or later as coal, to where it was needed, and this fuelled the growth of civilisation. The crisis created by CO_2 pumped back into the atmosphere is common knowledge. The worldwide effort, now, apart from containing generation, is to capture CO_2 and put it away.

Dorna Esrafilzadeh, Ali Zavabeti, Rouhollah Jalili, Paul Atkin, Jaecheol Choi, Benjamin J Carey, Robert Brkljac, Anthony P O'Mullane, Michael D Dickey, David L Officer, Douglas R MacFarlane, Torben Daeneke and Kourosh Kalantar-Zadeh, from the Universities of New South Wales, Melbourne, Wollongong, the Queensland University of Technology and Monash University, in Australia, Nanjing University of Aeronautics, and Astronautics, China and University of Münster, Germany, write in the journal, *Nature Communications*, that they have tested a low temperature process of converting CO_2 back to carbon. This would have great potential, where untapped, non-polluting energy sources like wind and solar could be quietly reducing the carbon content of the atmosphere.

The reason that burning carbon gives off heat is that the energy state of the carbon and oxygen atoms, together are as they are in CO_2, is lower than when the atoms are separate. There is thus surplus energy when the atoms combine, and this is given off as heat. It is like water at higher altitudes can do work, like generating electricity, while it flows down to a lower altitude. We can imagine that at least equal work needs to be done to raise the water back up. In the same way, it takes energy to split the CO_2 molecule to get back to free carbon and oxygen.

In fact, it takes a lot more than just the energy difference, because the low energy state of free carbon and oxygen is hidden behind a barrier of even higher energy, and it takes high temperatures before the separation can happen. A great many chemical processes — manufacture of fertiliser, for instance — are similarly high temperature processes. The energy for these generally comes from burning of coal. If recovery of carbon from CO_2 were to join the list, we can see that there would be nothing gained.

Photosynthesis, in green plants, gets around the high temperature demand with the help of chlorophyll. Chlorophyll provides an intermediate energy state, a by-pass route, to use energy from sunlight to go from the low energy state of CO_2 to the higher energy state of hydrocarbons, without the need for high temperature. There is much research going on to mimic the way of plants, of "fixing" CO_2 with the help of sunlight. One such is the scaffold of titanium dioxide and silicon nanowires, with the help of a specific bacterium, which breaks the CO_2 molecule using electrons that sunlight ejects from silicon.

The work of the group writing in *Nature Communications* is of using electricity to reduce CO_2, at room temperature, with the help of a metallic catalyst, or agent that helps reactions to get going in the same way as chlorophyll does in green plants. The catalyst used is a soft, silvery-white metal, cerium, whose oxide has surfaces, which act as landing stages for chemical conversions. A reaction of interest is that the oxide, Ce_2O_3 changes to CeO_2, or an increase in the level of oxidation, accompanied by reduction of CO_2, to carbon monoxide (CO) or carbon.

The trouble with using a coat of cerium on a metal surface, to support use of electricity to reduce CO_2 to carbon, is that the carbon particles adhere to the active surface and block the access of the medium that contains CO_2, a process known as coking. The surface gets rapidly coated with carbon and the conversion stops.

The team has dealt with this by two devices. The first is that the cerium is in the form of nanoparticles and the second is that the particles are not coated on a metal surface, but are suspended in a metal in liquid form. A common metal that is ordinarily a liquid is mercury. Another such, which is more active, is gallium, a metal that melts at 29.76°C. Gallium is thus solid on a cool day but would melt at body temperature, if we held it in our hand.

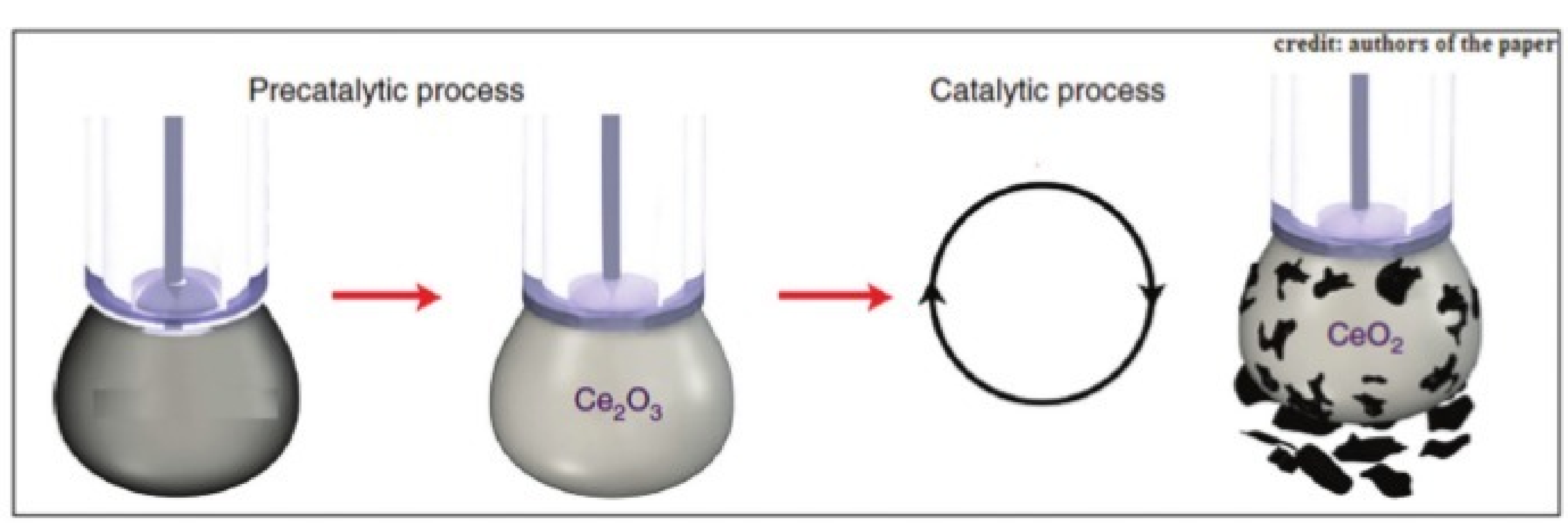
Now, the reason that flakes of carbon, which are formed at the surface of a metal, stick to the surface is that there are weak forces, called Van der Waals forces, which act very near the surface. When the metal itself is in liquid form, there are no surfaces and hence no forces, and the phenomenon of coking does not take place. The paper in *Nature Communications* says that trials with liquid gallium, saturated with cerium, with dissolved CO_2, readily passed electric current, with very efficient conversion of CO_2 to solid carbon, all at room temperature.

The strength of the current that passed was seen to indicate the extent of the electrolytic action. As the quantity of the products was too small for reliable measurement, it was this current that served to measure the efficacy of the catalyst. And it was found, the paper says, that a very substantial current was supported by the cerium in the liquid metal. To eliminate other reasons for the flow of the current, there was a control experiment with nitrogen gas taking the place of CO_2, and it was confirmed that it is the breakdown of CO_2 that gives rise to the current.

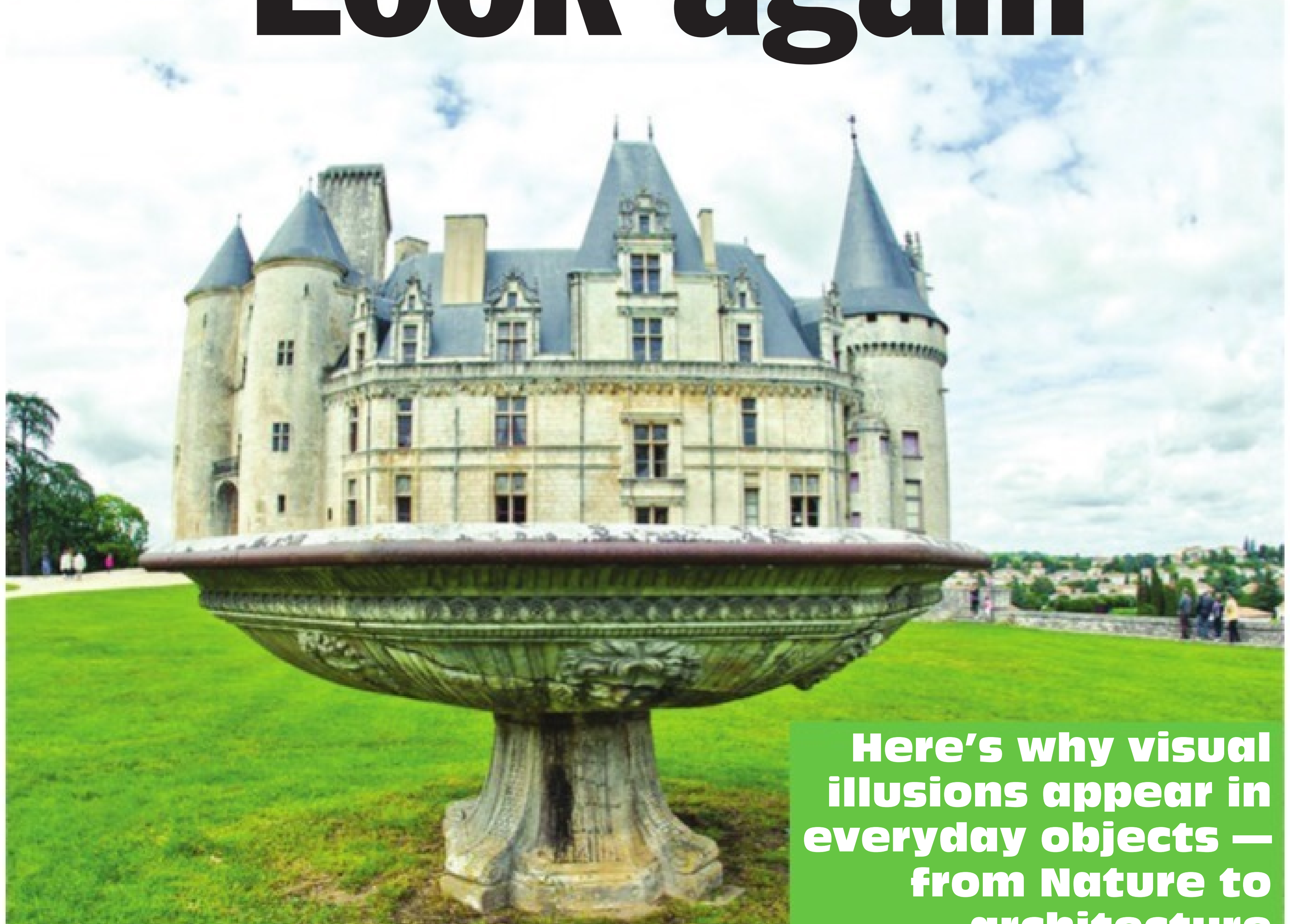
To study the mechanism of the specific exchanges that took place at the cerium nanoparticle surface, the particles were bathed in laser light and Raman Effect changes in the scattered light were examined. The Raman Effect is the slight changes that come about in photons of light scattered by molecules of a substance. Molecules consist of atoms connected by electrical forces, and they vibrate with specific frequencies. The energy that a molecule would absorb or impart to a scattered photon is thus characteristic. Observing the scattered frequencies during the catalytic action provided a sensitive window to identify molecules in the process, and the action of cerium to reduce CO_2 was established.

The process of reducing CO_2 to carbon, or reversing the process of burning, will always consume energy, as it is the CO_2 state that is at the lower level. The methods available so far, however, have involved very high temperatures, calling for high energy use. The work now reported suggests that a room temperature method, which can be sustained by renewable energy sources, even off-grid sources, which are not available for other applications, could be the means of extracting carbon from the atmosphere. If it is not just carbon, for storage, but other chemicals that are produced, the method could be regarded as a negative carbon technology, the paper says.

The writer can be contacted at response@simplescience.in



Look again



Here's why visual illusions appear in everyday objects — from Nature to architecture

KIM RANSLEY

Optical illusions are cleverly designed to distort reality, but did you know that the same distortions occur frequently in everyday life?

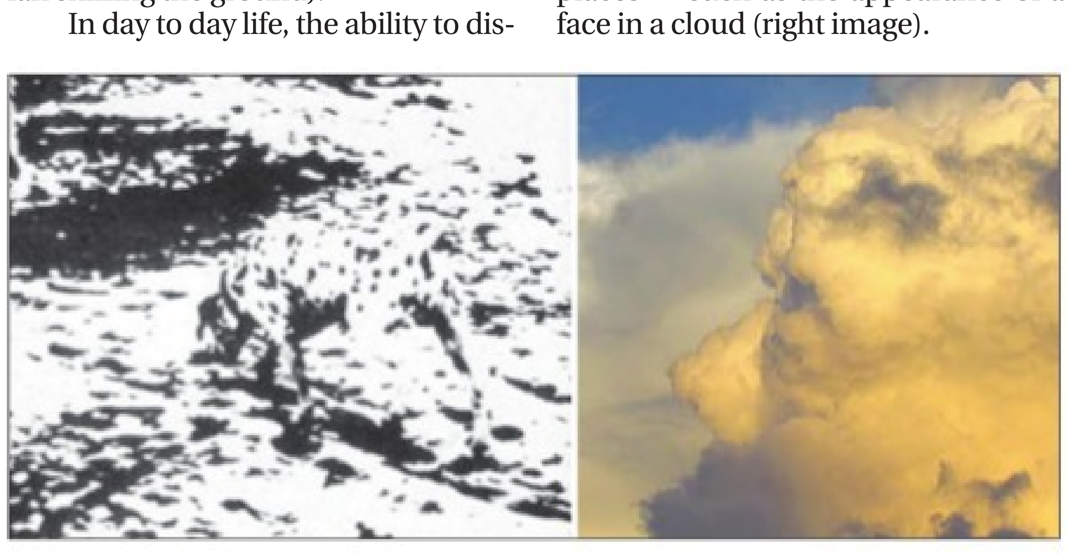
Our ability to see involves the brain moulding raw sensory data into a refined form. Some of the refinements are deliberate — they're designed to help us survive. But the process also requires a surprising amount of guess work. And while our brains have evolved to guess right most of the time, certain patterns regularly trip it up. That's when we might see an optical illusion.

These patterns can have the same illusive effect whether encountered in a book of optical illusions, or on your way to the train station.

Hidden objects

A bunch of random blotches can sometimes be interpreted as complicated visual objects, as shown in the classic illusion below. (Don't see it? Keep looking! You might see a Dalmatian sniffing the ground).

In day to day life, the ability to distinguish objects helps us work out what is around us when parts of the scene are covered or lighting is poor. But, visual patterns that occur by chance can also trigger the system, causing us to see familiar objects in very strange places — such as the appearance of a face in a cloud (right image).



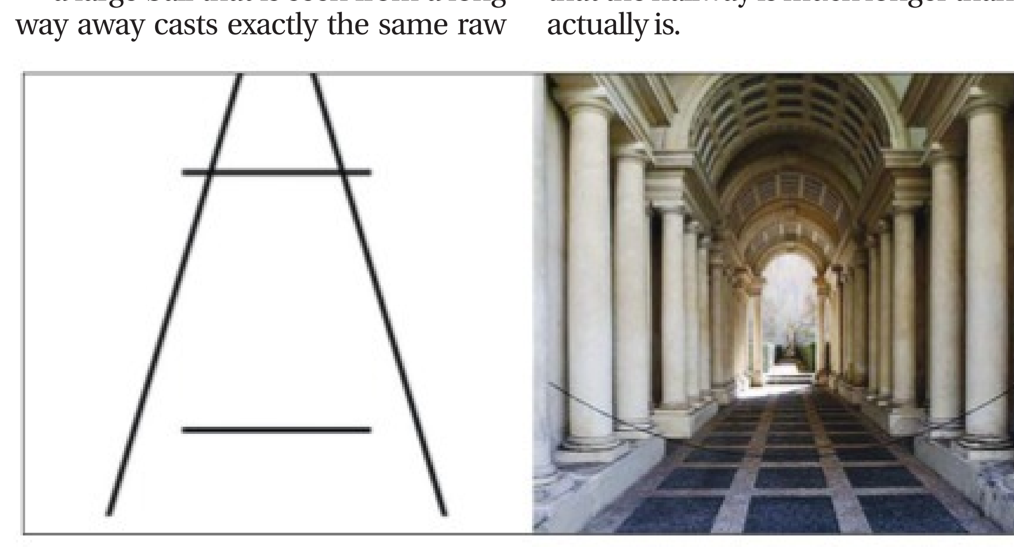
Distorted dimensions

The two horizontal lines in the Ponzo Illusion (left image) are actually the same length, but to most people, the lower line seems shorter. The illusion works by using converging lines to mimic the appearance of parallel lines extending into the distance (train tracks often give this appearance).

Because the brain interprets the top line as being further away, it judges that the line must be bigger than it actually is, and inflates the appearance of the line accordingly.

Size and distance are difficult for the brain to work out at the same time — a large ball that is seen from a long way away casts exactly the same raw image as a small ball seen up close. The brain relies on many different cues to work this out, and usually does a pretty good job. But it can make errors when the context is misleading. This principle has been exploited by designers for centuries now, as seen in this classic example of roman architecture (right image). Here, the ancient designers put a pint-sized statue (60cm tall) at the end of the corridor (nine metres long) in the Palazzo Spada.

Because we are used to seeing life-size human forms, viewers assume that the statue must be human-sized and a long way away, giving the impression that the hallway is much longer than it actually is.



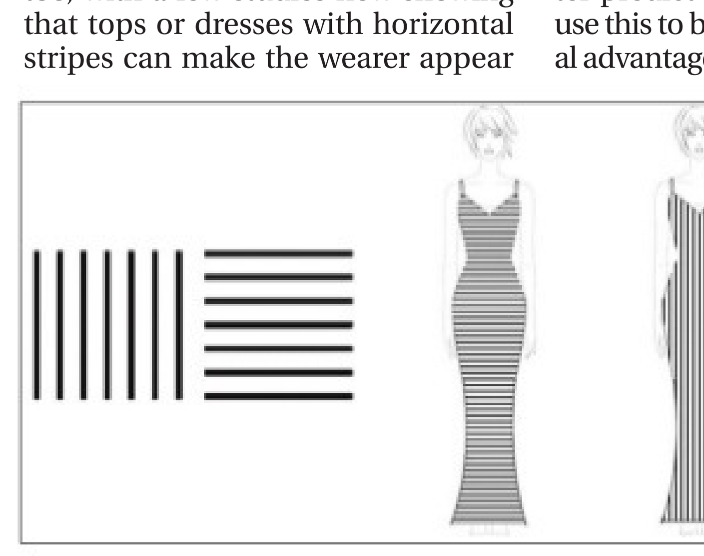
Slimming stripes

Scientists have long known that objects bearing stripes may appear wider or taller than they really are, though scientists are yet to fully explain why the brain produces this particular distortion. The Helmholtz illusion (left image) shows this with two squares. Many people report that a square with vertical stripes appears too wide, and a square with horizontal stripes appears too tall.

The effect may work for clothing, too, with a few studies now showing that tops or dresses with horizontal stripes can make the wearer appear slimmer than the same item with vertical stripes (right image).

Unfortunately, a recent study suggests that this effect may rely on the wearer being slim to begin with. The bigger the wearer, the less likely the illusion is to work. As we can see, our experience can differ from reality in many ways. What's more, it's likely that the visual distortions we don't notice far outnumber those that we do.

Understanding the processes used by our brains can allow us to better predict sensory experiences, and use this to build objects with functional advantages and intriguing forms.



The writer is a postdoctoral researcher, University of Sydney, Australia. This article first appeared on www.theconversation.com

PLUS POINTS

'Electrogenic microbes'

Tiny creatures that can "eat" pollution and generate electricity in the process have been captured for the first time. Scientists trekked into the depths of Yellowstone National Park in the US to extract these bacteria, which are adapted to living in geysers and hot springs that can reach over 90°C. The so-called "electrogenic" microbes were targeted due to their ability to produce power, which experts hope could be harnessed in the future to drive devices.

However, publishing their findings in the *Journal of Power Sources*, the scientists admitted this could be tricky because of the extreme environments the bacteria live in, which is why they had to test their abilities in the field. "This was the first time such bacteria were collected in situ in an extreme environment like an alkaline hot spring," said Abdelrhman Mohamed, a PhD student at Washington State University who led the research.

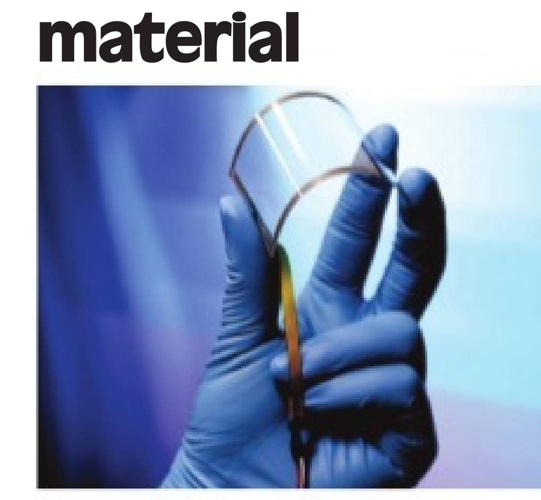
The team stuck electrodes into the water of four hot springs, and left them for a month to be colonised by the bacteria. "The natural conditions found in geothermal features such as hot springs are difficult to replicate in laboratory settings," said Haluk Beyenal, who supervised the study. "So, we developed a new strategy to enrich heat-loving bacteria in their natural environment."

Some of these electricity-producing bacteria have the power to convert toxic pollutants into less harmful substances. As they do so, the electrons passing through their body as they digest their food are dumped outside their bodies on minerals or metals, using hair-like structures that protrude from their bodies like wires. This produces a stream of electricity in an efficient process that can conceivably be used in low-power applications.

While scientists hope that the microbes could one day power all kinds of systems, they have been limited by the handful of varieties that have been grown in labs.

The independent

New 'meta' material



Physicists from the University of Sheffield, UK, in close collaboration with the University of Manchester, Ulsan National Institute of Science and Technology (Republic of Korea), National Institute for Materials Science (Japan) and the University of Oxford, have discovered that when two atomically thin graphene-like materials are placed on top of each other their properties change, and a material with novel hybrid properties emerges, paving the way for design of new materials and nano-devices. This happens without physically mixing the two atomic layers, nor through a chemical reaction, but by attaching the layers to each other via a weak so-called van der Waals interaction — similar to how a sticky tape attaches to a flat surface.

In the study published in *Nature*, scientists have also found that the properties of the new hybrid material can be precisely controlled by twisting the two stacked atomic layers, opening the way for the use of this unique degree of freedom for the nano-scale control of composite materials and nano-devices in future technologies.

The new structures nicknamed "van der Waals heterostructures" open a huge potential to create numerous "meta"-materials and novel devices by stacking together any number of atomically thin layers. Hundreds of combinations become possible, which are otherwise inaccessible in traditional three-dimensional materials, potentially giving access to new unexplored optoelectronic device functionality or unusual material properties.

Professor Alexander Tartakovskii, from the department of physics and astronomy, at the University of Sheffield, said, "The materials influence each other and change each other's properties, and have to be considered as a whole new 'meta'-material with unique properties — so one plus one doesn't make two."

The researchers would like to do further studies and explore more material combinations to see what the capabilities of the new method are.