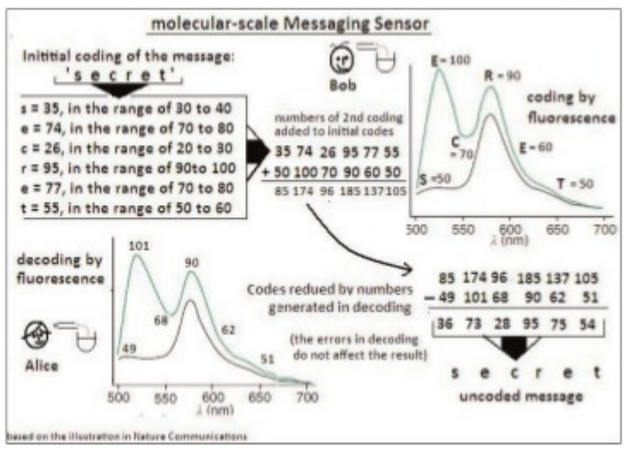
Chemical key unlocks cryptography

CODING AT THE MOLECULAR LEVEL MAY BE THE NEW INVISIBLE INK, SAYS **S ANANTHANARAYANAN**

For centuries, codes and concealment have been the means to exchange secret information. A code that was difficult to crack, however, was difficult to compose and also to read. Inks that were visible only after special treatment have lost utility after they were easily discovered. Modern commerce uses codes based on mathematics and huge calculations, but they are difficult to implement. What many current applications need is a method that is both difficult to crack and easy to use.

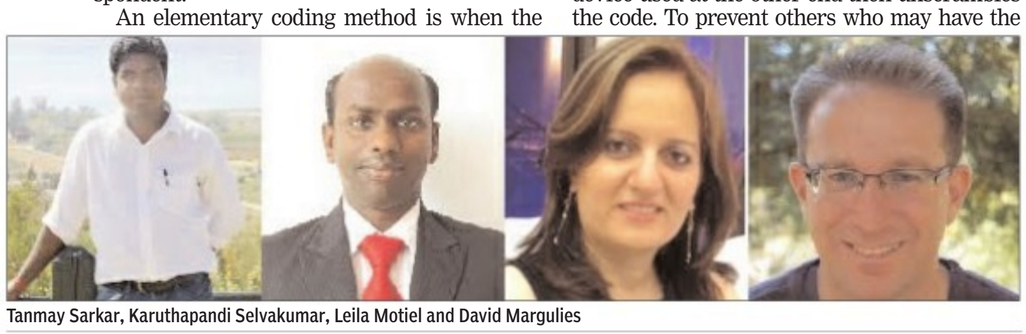
Tanmay Sarkar, Karuthapandi Selvakumar, Leila Motiei and David Margulies from the Weizmann Institute of Science in Israel describe in the journal *Nature Communications* a molecular level answer to this need. The device is a stable chemical base to which the coder adds a combination of common, everyday materials. The resulting mixture helps code the message with great security and knowing the chemicals used for coding allows easy decoding by one's correspondent.



An elementary coding method is when the letters of the alphabet are replaced by other letters or by symbols. But these codes can be cracked by intelligent inspection. Even when the code is complicated by changing the coding system in a random way, computers and statistical analysis of the coded material can break it down. While complex codes were difficult to use, invisible ink had the merit of being simple, and it was popular with international spies as lately as during World War I. The current solution, for banking and e-commerce that need messages to be conveyed with security, however, is again with the help of complex codes.

These codes generally depend on a device that generates random numbers that help scramble the letters in a message. The same device used at the other end then unscrambles the code. To prevent others who may have the same machine from eavesdropping, the sender has a secret starting point, which only the intended receiver knows. There are variations of this method, including methods based on very long prime numbers as numeric "keys". If two long prime numbers are multiplied together, the product is one from which it is fiendishly difficult to extract the original factors. A number based on the product is then published as a public key to encode a message meant for the person who has the factors and, hence, is the only one able to decode the message.

These methods, however, are cumbersome and can be used only for short exchanges or to encode the key to another conventional encryption. The method described by the Israel group in *Nature Communications*, in contrast, is an easily usable method that randomly encodes each successive character, including spaces, in a message. And then the method enables the intended receiver to reproduce the original encoding scheme with equal ease for the original message to be read out.

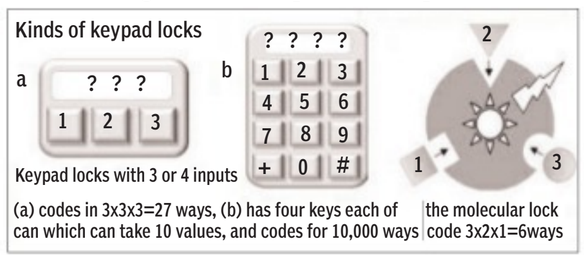


Tanmay Sarkar, Karuthapandi Selvakumar, Leila Motiel and David Margulies

Fluorescence

The Israel group's method is based on fluorescence, or the colours in the emission from some chemicals when they are bathed in light of higher frequency. The domestic tubelight is an instance of fluorescence. The electric discharge within the tube generates ultra violet light. When this strikes the coating inside the tube, the material gives off light of longer wavelengths, which add up to nearly white light.

An earlier work by some of the members of the same group had identified a chemical that could be doped with specific additives to lead to specific differences in fluorescence. The three additives would then be the key and the chemical would act like a lock that needs a specific input to open. A three-input keypad lock, like the one shown in the picture, can be set in 3x3x3=27 ways and protects against accidental opening. A larger keypad lock that can code in 10,000 ways could even provide password protection. But a simple molecular lock, if it has three inputs, would not compare, as it could code only as 123, 132, 213, 231, 312, 321, or in six ways in all.



Although apparently limited in the range of coding, a molecular lock, however, has the advantages of very compact dimensions and the robustness of the specific emission patterns, which could be read by a hand-held device and enable very easy coding and decoding. The principle of a chemical binding to different additives to generate a range of distinguishable fluorescence patterns hence suggests extension to complex coding applications with the ease of invisible ink.

The system now described by the group is a further development of not just a molecular lock but of a generator of a coding scheme using a versatile fluorescent molecule, the *molecule scale messaging sensor* or *m-SMS*, which is able to form stable links with a range of easily available reagents and generate unique emission spectra. The coder thus adds a random reagent to the base material, which gives rise to a pattern of emission at different frequencies. Each letter in the message to be encoded is then associated with successive emission levels and a code is generated. Even spaces in the original message are coded like this and anybody intercepting the message cannot even make out where the words or sentences start and terminate.

The particular additive that is used is conveyed to the proper recipient. He/she can then easily recreate the original emission pattern and use the levels of emission over the wavelengths of light to decode the message. The letters in the message are first coded by a simpler method where the representation of each character has a range or spread. In this way, even errors in the reproduced emission pattern during decoding would be accommodated, as the example in the box would show.

The actual material used is described in the *Nature Communications* paper as a kind of organic molecule that has multiple branches that take part in the fluorescence action, which is to absorb light at high frequency and then distribute the energy for emission at other frequencies. The molecule also has affinity for, or the capacity to form bonds with a variety of chemical groups, like sugars, metals, etc. The formation of such bonds affects the energy levels involved in the fluorescence action and versatility in bonding leads to great variability in the frequencies of light that is emitted. The m-SMS is thus able to combine with a variety of reagents and to respond with a specific emission spectrum for each substance. The possible reagents include easily available soft drinks, kitchen ingredients or medicines or pharmaceuticals, which have the advantage of purity.

A sender of a secret message could thus create his/her own completely unknown emission spectrum and use this as the basis for encoding a message. The intended receiver of the message, who knows which reagent to use with the m-SMS, can now read out the original emission spectrum with a simple hand-held spectrometer. For longer messages, the reagents could be used in succession, generating a fresh set of codes every time. The particular order of reagents to use could even work as an additional password protection, by using the m-SMS in the form of a keypad lock, the paper says. Apart from security of the code and password protection, even the chemical used or the m-SMS can be sent across concealed within an ordinary letter.

While coding by m-SMS would ensure secrecy, it would also guarantee that the message is genuine. Knowing how the message has been coded would also be evidence of authorship. m-SMS thus satisfies important requirements of encryption systems, in addition to its simplicity and versatility.

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Invisible ink

Writing with lemon juice is a perfect way. The trick is to write the message between the lines of an ordinary note in real ink. The lemon juice disappears as soon as it dries, but can be later brought to life either by holding the paper over a candle or pressing with a warm iron.

German spies operating in England during World War I used this method. While correspondence of Germans, especially those under suspicion, was regularly screened by the British War Office, many letters appear to have slipped through. Till Mabel Beatrice Elliot got suspicious of a business letter written to a "friend" in Holland, by a person recently come in from New York. She applied simple chemistry in heating the letter, which revealed writing about Royal Navy ships and forces around London. Many more spies were soon caught, some convicted based on possession of lemons or corroded pen nibs!

UPENDING PHYSICS KNOWLEDGE

THE LARGE HADRON COLLIDER COULD BE ON THE VERGE OF A BIGGER FIND THAN THE HIGGS BOSON, WRITES **ANDREW GRIFFIN**

The atom smasher at Cern is getting turned back on for what could be even more important work than its biggest discovery yet since it revealed the Higgs boson four years ago. The Large Hadron Collider is being fired up at at even greater power and might be able to find particles that have previously only been hinted at. If they are found, it could lead to a rewriting of some of the most fundamental parts of physics. The Standard Model of physics, which explains how our universe is structured, has some important gaps — around dark matter, and potential other dimensions — which could be filled in by the new discovery.

When it gets switched back on, scientists will be looking to explore faint signs of a new particle that were picked up in December last year. Since then, researchers have been theorising wildly — but experts have cautioned that nothing will be known until more work can be done.

"It's a hint at a possible discovery," said theoretical physicist Csaba Csaki, who isn't involved in the experiments. "If this is really true, then it would possibly be the most exciting thing that I have seen in particle physics in my career — more exciting than the discovery of the Higgs itself."

After a wintertime break, the Large Hadron Collider reopened on 25 March to prepare for a restart early this month. Cern scientists are doing safety tests and scrubbing clean the pipes before slamming together large bundles of particles in the hope of producing enough data to clear up that mystery. Firm answers aren't expected for weeks, if not until an August conference of physicists in Chicago known as ICHEP.

On 29 April, the LHC was temporarily immobilised by a weasel that invaded a transformer that helps power the machine and set off an electrical outage. Cern says it was one of a few small glitches that will delay, by a few days, plans to start the data collection at the $4.4-billion collider.

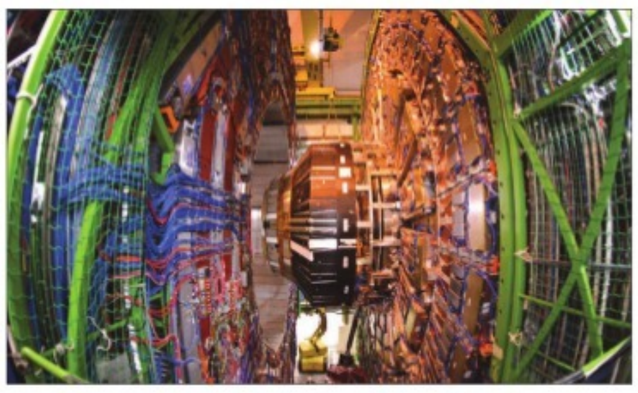
The 2012 confirmation of the Higgs boson, dubbed the "God particle" by some laypeople, culminated in a theory first floated decades earlier that the "Higgs" rounded out the Standard Model. The LHC's Atlas and Compact Muon Solenoid particle detectors last December turned up preliminary readings that suggested a particle not accounted for by the Standard Model might exist at 750 Giga electron Volts. This mystery particle would be nearly four times more massive than the top quark, the most massive particle in the model, and six times more massive than the Higgs, Cern officials say.

More data is needed to iron those possibilities out, and even then the December results could just be a blip. But with so much still unexplained, physicists say discoveries of new particles — whether this year or later — may be inevitable as colliders get more and more powerful.

Dave Charlton, an experimental physicist at the University of Birmingham in Britain who heads the Atlas team, said the December results could just be a "fluctuation" and "in that case, really for science, there's not really any consequence ... At this point, you won't find any experimentalist who will put any weight on this: We are all very largely expecting it to go away again. But if it stays around, it's almost a new ball game".

The unprecedented power of the LHC has turned physics on its head in recent years. Whereas theorists once predicted behaviours that experimentalists would test in the lab, the vast energy being pumped into Cern's collider means scientists are now seeing results for which there isn't yet a theoretical explanation.

"This particle — if it's real — it would be something totally unexpected that tells us we're missing something interesting," Charlton said. Whatever happens, experimentalists and theorists agree that



When the LHC at Cern gets switched back on, scientists will be looking to explore faint signs of a new particle that were picked up in December last year.

2016 promises to be exciting because of the sheer amount of data pumped out from the high-intensity collisions at record-high energy of 13 Tera electron Volts, a level first reached on a smaller scale last year, and up from eight TeVs previously. (Cern likens one TeV to the energy generated by a flying mosquito: That may not sound like much, but it's being generated at a scale a trillion times smaller.)

In energy, the LHC will be nearly at full throttle — its maximum is 14 TeV — and over 2,700 bunches of particles will be in beams that collide at the speed of light, which was "nearly the maximum", Cern spokesman Arnaud Marsollier said. He said the aim was to produce six times more collisions this year than in 2015. "When you open up the energies, you open up possibilities to find new particles," he said.

"The window that we're opening at 13 TeV is very significant. If something exists between eight and 13 TeV, we're going to find it." Still, both branches of physics are trying to stay skeptical despite the buzz that's been growing since December. Csaki, a theorist at Cornell University in Ithaca, New York, stressed that the preliminary results didn't qualify as a discovery yet and there was a good chance they may turn out not to be true. The Higgs boson had been predicted by physicists for a long time before it was finally confirmed, he noted.

"Right now it's a statistical game, but the good thing is that there will be a lot of new data coming in this year and, hopefully, by this summer we will know if this is real or not," Csaki said, alluding to the Chicago conference. "No vacation in August."

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THE INDEPENDENT

Cellular digestion

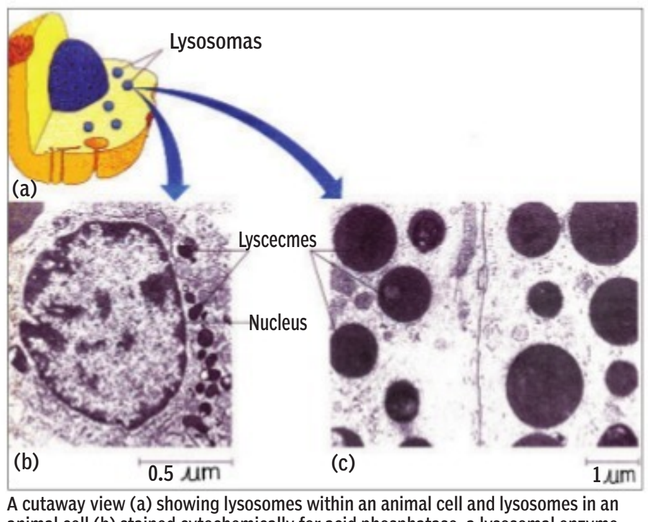
TAPAN KUMAR MAITRA EXPLAINS THE FUNCTIONS OF LYSOSOMAL ENZYMES

Discovered in the early 1950s by Belgian Nobel Prize-winning biochemist Christian de Duve and his colleagues, lysosomes are organelles about 0.5-1 µm in diameter and surrounded by a single membrane. The story of that discovery has gone on to underscore the significance of chance observations made by astute investigators and it also illustrates the importance of applying newer techniques to the progress of science.

Lysosomes are used by the cell as a means of storing hydrolases, which are enzymes capable of digesting specific biological molecules such as proteins, carbohydrates or fats. It is important for cells to possess such enzymes, both to digest food molecules that it may acquire from its environment and to break down cellular constituents that are no longer needed. But it is also essential that they be carefully sequestered until actually needed, lest they digest cellular components, not meant for destruction.

The lysosomal enzymes are somewhat similar to secretory proteins in their synthesis and packaging. They are synthesised on the rough endoplasmic reticulum and transported to the Golgi body, where a mannose-six-phosphate tag is added to mark them as lysosomal enzymes. They are then packaged into vesicles that transport them to organelles called early endosomes, which subsequently mature into late endosomes. A late endosome is therefore a collection of newly synthesised digestive enzymes packaged in a way that they protect the cell from their activities until they are required for specific hydrolytic functions.

A late endosome, in turn, either matures to form a new lysosome or delivers its enzyme complement to an active lysosome.



A cutaway view (a) showing lysosomes within an animal cell and lysosomes in an animal cell (b) stained cytochemically for acid phosphatase, a lysosomal enzyme. The cytochemical staining technique results in dense deposits of lead phosphate at the site of acid phosphatase activity (TEM); and an electron micrograph (c) of lysosomes in two adjacent cells of human epididymal epithelium.

Equipped with its repertoire of hydrolases, the lysosome is able to break down virtually any kind of biological molecule. Eventually, the digestion products are small enough to pass through the membrane into the cytosol of the cell where they can be utilised for the synthesis of macromolecules — recycling at the cellular level.

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PLUS POINTS

Our best chance

It seems like the Kepler space telescope is very, very good at its job, even though it's technically broken, and the three exoplanets described on 2 May in the journal *Nature* manage to stand apart: According to the scientists who discovered this trio, their earth-like worlds might represent our best-ever shot at finding signs of alien life.

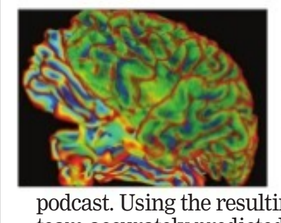
These planets were detected based on the dimming of the star they orbit, which has been named Trappist-1 for the TRAnsiting Planets and PlanetesImals Small Telescope it was discovered with. As they orbit, transiting in front from the telescope's perspective, the star blinks and dims out of view. Scientists use this dimming to calculate the size of the planets and their distance from their host star.

The three worlds are close by, located just 40 light years away in the constellation Aquarius — the water-bearer – but the fact that they're earth-like and promising doesn't mean they actually hold water. The researchers, led by Michael Gillon and Emmanuel Jehin of the University of Liège in Belgium, believe the worlds are tidally locked, which means they have one hot side that faces their star and one cold side plunged in eternal darkness. They're incredibly close to their sun, orbiting it in just a matter of days and they don't receive more than a few times as much radiation as earth does, but the first two planets are still probably a smidgen too close to have water covering their surfaces. Still, it's possible that certain regions of the others are just right for water, which could allow some simple life to evolve. Other factors, such as cloud cover and geothermal activity, could tip the scales toward habitability as well. And the third, most-distant planet's orbit has yet to be determined, meaning it could fall into the perfect orbital range for water and life.

But it's the star at the centre of this foreign system that makes the planets so exciting. The three worlds orbit an ultra-cool dwarf star – which is just one-eighth the mass of our sun, and much cooler. It's more similar to Jupiter, which is so massive that it's almost star-like as opposed to to our own sun.

RACHEL FELTMAN/THE INDEPENDENT

Within the brain



To better understand how the brain processes language, researchers from the University of California, Berkeley, and their colleagues used functional Magnetic Resonance Imaging to map the brains of people listening to a storytelling podcast. Using the resulting maps, the team accurately predicted the study participants' neural responses to hearing new stories. And these responses were surprisingly consistent across individuals, according to the team's study published on 27 April in *Nature*.

To map the brain's semantic representation more broadly, study co-author Jack Gallant and colleagues scanned the brains of seven graduate student volunteers while the study participants listened to more than two hours of stories from "The Moth Radio Hour". They then quantified the response of small chunks, or voxels, of brain tissue to different concepts in the stories by measuring blood flow. First, they computed how often certain words in the stories occurred alongside a set of 985 common English words (for example, "month" and "week" are often found together). They then used a regression model to estimate how these common words produced responses in each voxel for every volunteer.

THE SCIENTIST

Expression recognition

Researchers from Soongsil University in South Korea and Vietnam National University in Ho Chi Minh City have developed a new facial expression recognition system that can tell, with almost 99 per cent accuracy, if you are happy, sad or showing any other emotion. Fundamentally, it uses mathematical processing to measure eyebrow position, openness of the eyes, mouth shape and other factors in order to correlate those with basic human emotions: anger, disgust, fear, joy, sadness, surprise and a neutral expression. It can even work on images of faces just 48 pixels square. Facial expression recognition has been the focus of much research in recent years, thanks to the emergence of intelligence communication systems, data-driven animation and intelligent game applications.

"When facial expressions recognition of players is applied in an intelligent game system, the experience can become more interactive, vivid and attractive," the researchers said. The study was published in the *International Journal of Computational Vision and Robotics*.