

FRONTIERS

STRETCHING THE POSSIBILITIES OF SCIENCE, WE BRING THE LATEST FROM UNDER THE MICROSCOPE AND THROUGH THE TELESCOPE. BY DANIEL WEISS

EXPLOSIVE ECHOES

Around the year 1680, light from the supernova, or exploding star, Cassiopeia A passed over Earth. It apparently went unnoticed by sky-gazers at the time, but a team of astronomers recently caught glimpses of it by capturing light from the explosion that echoed off clouds of interstellar dust and is only now hitting Earth. The echoes come from multiple angles, offering an unusual multi-dimensional perspective on outer space.

"This is a really rare opportunity to look at an object from different directions," says team leader Dr Armin Rest, an astronomer at Harvard University in the United States. "Normally, we only see an object from a single direction, from Earth."

The researchers noticed that material from the explosion (which is known as ejecta) hurtled off in one direction at about 4,000 kilometres per second faster than in other directions. This makes sense, given that a neutron star produced by the explosion is thought to be heading off in the opposite direction at about 350 kilometres per second. "It was an asymmetric explosion, not a spherical fireball," says Rest.

PHOTO: NASA

This composite of infrared (red), optical (yellow) and X-ray (blue and green) images tells a story to those in the know: the red cloud maps warm dust in the outer shell, while the yellow areas mark filamentary structures of warmer gas.



ECO-AIRSHIP

Shooting up from the water like a giant leaf, this eco-airship imagined by visionary Belgian architect Vincent Callebaut could be the ultra-green answer to our future air transport needs. Called Hydrogenase, the bio-inspired ship would measure 400 metres high by 180 metres wide and dock in a biofuel-producing seaweed farm. It would fly at an average altitude of 2,000 metres, reach a top speed of 175 kilometres per hour and range over 5,000 to 10,000 kilometres.

"Hydrogenase marks a new generation of state-of-the-art hybrid airships," writes Callebaut in a statement on his architecture firm's website, vincent.callebaut.org.

The ship would consist of eight compartments protected by a waterproof, fire-resistant skin of glazed canvas. Four sections for passengers and up to 200 tonnes of freight would be interspersed with four bio-hydrogen fuel bubbles. When the craft returns to its dock, seaweed would process waste built up during the journey.

"Nothing is lost, everything is recycled and transformed!" enthuses Callebaut. "Let's take off thanks to biofuels and let's propel to the eco-responsible transport of the future!"

Sounds great, though no word yet on when or even if the giant green ship will be coming to a seaweed farm near you.

READY, AIM, SPIT!

Spitting cobras of the genus *Naja* hit their victims in the eyes about 90 percent of the time with debilitating venom, from up to 2 metres away. In a recent study to determine how they do it, Dr Bruce Young of the University of Massachusetts Lowell in the United States donned facial protection and taunted the snakes into spitting at him over 100 times. Accelerometers on Young's forehead tracked his movements while high-speed video recorded the snakes.

"In every trial, shortly before the snake spat, I made the same type of unconscious movement with my head: I moved it in one direction, then I stopped and jerked in the other direction," says Young. "It seemed to be the clue that the snake was looking for that told it, 'Now is when you want to spit.'"

The spit tended to follow after the head jerk by about 200 milliseconds, the time it typically takes to react to a visual stimulus. To account for this lag, the snake rotated its head and directed its venom where Young's eyes would be a split second later. "The snake makes a transition from tracking to predicting by accelerating the movement of its head," says Young.

The lesson? Never look a spitting snake in the eye.



PHOTOS: COURTESY BRUCE YOUNG (READY, AIM, SPIT); VINCENT CALLEBAUT ARCHITECTURES - WWW.VINCENT.CALLEBAUT.ORG (ECO-AIRSHIP); GABRIEL PEREZ / SERVICIO MULTIMEDIA INSTITUTO DE ASTROFISICA DE CANARIAS (ASTEROID ICE); COURTESY DAVID REED (LOUSY EVIDENCE); VICTOR GALLARDO (MICROBIAL MAT)

ASTEROID ICE

Scientists have found evidence of water ice on an asteroid for the first time. The thin layer of frost on 24 Themis, a 200-kilometre-wide rock orbiting between Mars and Jupiter, was detected by two separate research groups with the NASA Infrared Telescope in Hawaii and reported recently by both groups in the journal *Nature*. Hydrated compounds that include water have been previously detected on asteroids, but the discovery of intact ice was unexpected.

"We expected that some of these objects had ice on them 4.5 billion years ago, but we thought that it would have melted and reacted since then," says Dr Andrew Rivkin, a planetary astronomer at Johns Hopkins University in the United States and leader of one of the groups. "Finding the ice still there is a surprise."

The groups also detected evidence of organic compounds on 24 Themis, raising the possibility that both the Earth's water and the raw ingredients for life arrived via asteroid impact. Within the next decade or two, Rivkin hopes that a spacecraft will be sent to 24 Themis or a similar asteroid to analyse its components. "The fact that there is potentially this 4.5-billion-year-old ice out there that we can study is exciting," he says.

LOUSY EVIDENCE

A team of scientists studying the DNA of lice that live on humans has determined that people began wearing clothing around 170,000 years ago. According to genetic analysis, that's when body lice, which are specially adapted to live in clothing, evolved from head lice. Previous estimates of when people first adopted garments have ranged from 40,000 to a million years ago.



"Body lice lay their eggs in clothing and clearly could not have survived without it," says Dr David Reed, a mammalogist at the University of Florida in the United States. "We think they evolved from a head louse ancestor."

Since modern humans only left Africa in the last 100,000 years, the study's results suggest they developed rudimentary clothing before migrating to cooler latitudes. "Modern humans had clothing technology before they really needed it," says Reed. "That allowed them to be successful when they left Africa."

According to Reed, these pesky parasites have more to teach us about our past. "Lice have been with us throughout our whole evolutionary history," he says, "and in their DNA they have recorded their own version of our history."



MICROBIAL MAT

Lurking off the west coast of South America from central Chile to Peru is a vast mat of marine microbes estimated to be the size of Greece. The mat consists of entwined microbial filaments up to 7 centimetres long and was discovered by the International Census of Marine Microbes (ICoMM), which is part of the broader Census of Marine Life (CoML). The microbes in the mat thrive on hydrogen sulphide in portions of the ocean with minimal oxygen and are thought to resemble marine life from up to 3.5 billion years ago.

"We think they are related to the first life that occupied the bottom of the ocean in the Precambrian," says Dr Victor Gallardo, vice-chair of the CoML scientific steering committee, whose team discovered the mat.

The ICoMM as a whole collected over 1,200 ocean samples and sequenced over 18 million marine microbe genomes. Still, there remains much to be learned about the world's marine microbes. A litre of seawater contains roughly a billion microbes, and scientists estimate there may be a billion or more different species in all.

POLLEN ORIGAMI

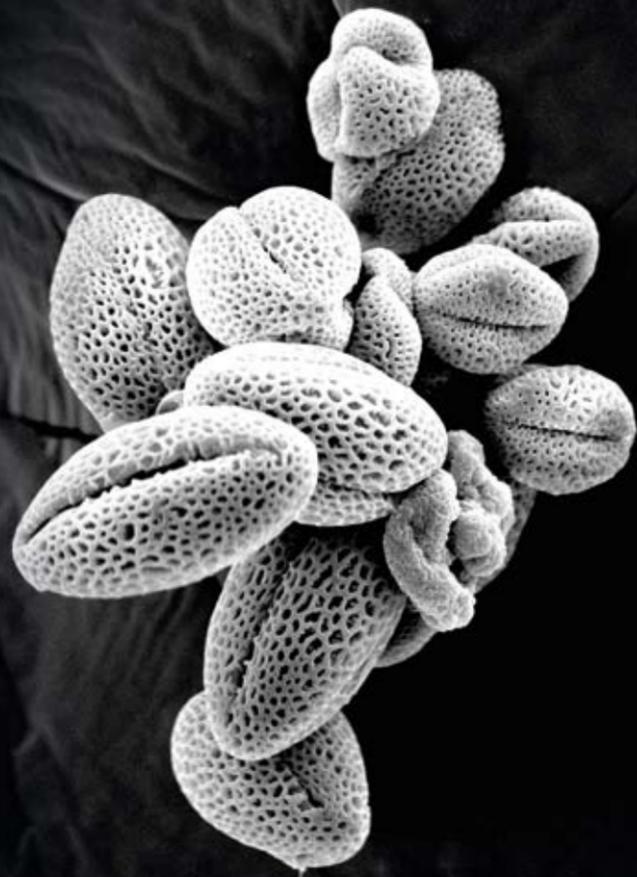
When pollen grains leave a flower, they begin to dry out. To protect themselves from death due to dehydration, many types of pollen fold up, sealing in moisture. In a recently published study, a team of scientists examined this folding process with electron microscopes and established that a pollen grain's structure determines how it folds.

"The geometric design of the outer wall guides the pollen grain to fold in a particular way so the wall is sealed," says lead study author Dr Eleni Katifori, a physicist at Rockefeller University in the United States.

As they lose water and contract, some pollen grains fold along thinner, weaker portions of their walls called apertures. Other grains that lack apertures simply collapse like deflated beach balls, although these tend to travel short distances and face less threat from dehydration.

The study examined three folding patterns that are common to many different types of pollen, although a bewildering variety of alternative patterns exist as well. "There are some very bizarre ones," says Katifori.

The goal of the study was primarily theoretical, although its findings could have applications to drug design. "It might be inspiring to engineers to design smart microcapsules that could do targeted drug delivery," says Katifori.



TIBETAN ADAPTATION

Tibetan highlanders function perfectly well at altitudes whose lack of oxygen can make lowlanders severely ill. A new study has pinpointed for the first time some of the genetic variations that allow highlanders to thrive where others gasp.

In the study, genome scans were performed on blood samples from 31 Tibetans living in a village over 4,400 metres above sea level. In comparison with closely related lowland Chinese and Japanese, most of the Tibetans were found to differ at 10 points on the genome thought to relate to oxygen processing. Two of these genes are associated with haemoglobin, the protein that binds to oxygen so the blood can transport it, and may help explain why Tibetans do not overproduce blood cells in reaction to oxygen deprivation.

"What's unique about Tibetans is they don't develop high red blood cell counts," says study co-author Dr Josef Prchal of the University of Utah School of Medicine in the United States. "If we can understand how they do this, we can develop therapies to treat human disease."

The genetic adaptations may also explain the highlanders' resistance to swelling of the lungs and brain that afflict many others upon arrival to high elevations. The researchers estimate that the adaptations have been developed over 5,000 to 20,000 years of living on the Tibetan plateau.



MAMMOTH BLOOD

A team of scientists has manufactured a key component of woolly mammoth blood and demonstrated that it was specially designed to help the extinct beasts thrive in frigid Arctic winters. Mammoths' haemoglobin, the protein in red blood cells which binds to oxygen, was adapted to continue delivering oxygen to tissue even as its temperature plummeted to near-freezing. This means that mammoths didn't have to waste too much of their precious energy keeping their extremities warm.

"If you can reduce your energy requirement when it's cold, clearly that will be a big benefit," says team leader Dr Kevin Campbell of the University of Manitoba in Canada. "It's like turning your house temperature down at night in the winter."

Using DNA harvested from three mammoths preserved in Siberian permafrost for 25,000 to 43,000 years, the scientists compared the genes responsible for making haemoglobin with the same genes from Asian elephants living today and found that they differed at just a few points. They then altered the elephant genes so they were functionally identical to those of the mammoth and inserted the altered genes into bacteria, which produced the mammoth haemoglobin. When the scientists tested the mammoth haemoglobin's ability to release oxygen at low temperatures, they found that it did so much more efficiently than elephant haemoglobin.

"It's as if I took a blood sample from a 40,000-year-old mammoth," says Campbell. "We brought it back to life and measured it as if the animal was still alive."

PHOTOS: REDUX (TIBETAN ADAPTATION); COURTESY ELENI KATIFORI (POLLEN ORIGAMI); PHOTO RESEARCHERS (MAMMOTH BLOOD); JAXA (MOONBOT BASE)



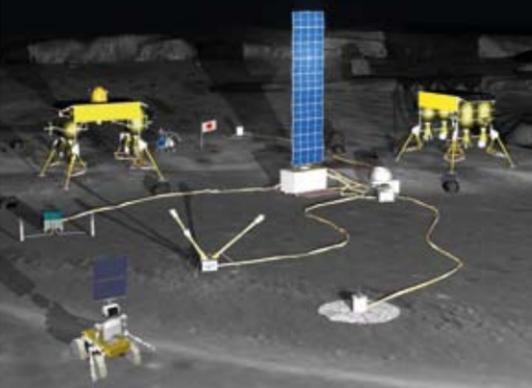
MOONBOT BASE

Japan has seen the future of the moon! A government study group recently released a draft report with plans to land a fleet of robots near the moon's south pole where they would build a research and exploration base to be staffed entirely by ... robots.

The moonbots would fan out from the base, gather an array of lunar rock samples and bring them back for further study. "We would like to collect and analyse valuable samples which nobody else has ever obtained and to learn about the evolution of the moon," the group's leader Katsuhiko Shirai, president of Japan's Waseda University, wrote via e-mail.

The robots would be equipped with solar panels, cameras and arms to collect their rock samples. Their total running distance would be about 100 kilometres. The location of the base has been chosen for its exposure to plentiful sunshine as well as the opportunity it affords for study of the moon's inner structure through observation of moonquakes.

The current plan is to launch an investigative mission in 2015 followed by a mission in 2020 to construct the base. The estimated cost of the entire project is US\$2.2 billion. Aspiring astronauts may be disappointed, though, as there are no plans for any humans to visit the robots on the moon.





QUANTUM RANDOMNESS

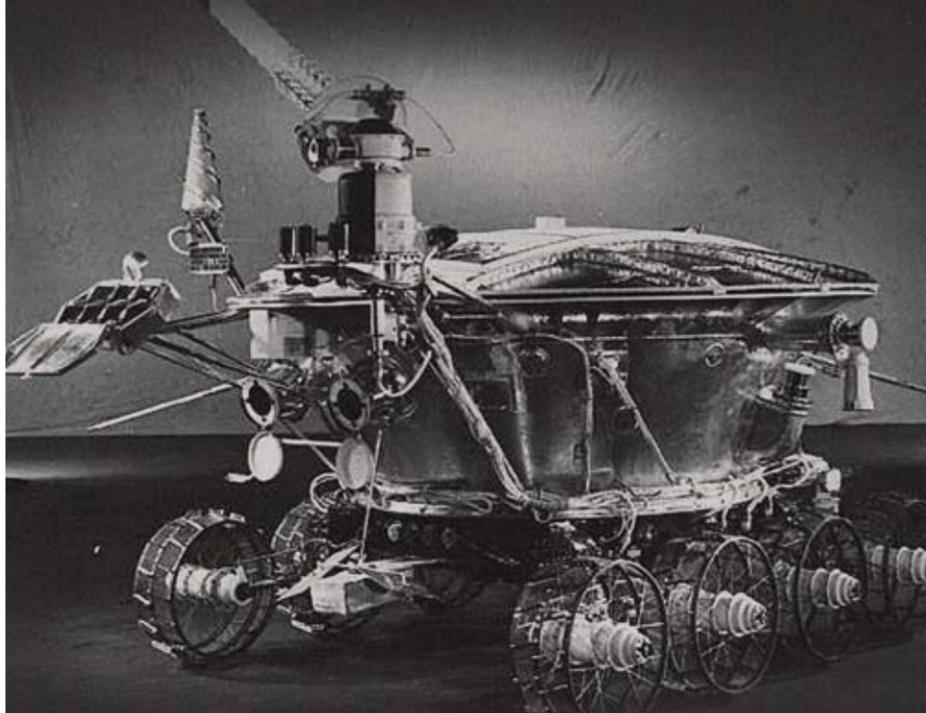
A team of researchers has developed a way of generating random numbers - and proving that they are truly random - using principles of quantum mechanics. Many "random" phenomena like rolled dice, flipped coins and spun roulette wheels yield results that can be predicted using the initial positions and velocities of objects involved.

"In classical physics, any randomness that we see is due to our ignorance," says Antonio Acín, a physicist at the Institute of Photonic Sciences in Spain.

To attain truly random results, Acín and his colleagues fired laser pulses at a pair of ytterbium ions kept in separate vacuum chambers a metre apart. Depending on the ions' energy state, they either discharged a photon, representing 1, or remained dark, representing 0.

The scientists used a test called Bell inequalities to prove that the two ions were linked in a system known as entanglement, which means that measuring one affects the other. Since entanglement is impossible according to classical physics, they concluded the ions must be obeying quantum rules and producing random results.

This type of random number generator could be useful in applications like cryptography, when true randomness is essential, although it will need to be faster. In a month of operation, Acín's set-up yielded just 42 random numbers. "We are far from competitive," he says, "but in principle it is the best random-number generator on Earth."



LOST LUNAR REFLECTOR

A lunar light reflector has been found after having been lost for almost 40 years. The reflector, named Lunokhod 1, arrived on the moon with the unmanned Soviet Luna 17 mission in November 1970, but was last heard from in September 1971.

This March, researchers examining images captured by NASA's Lunar Reconnaissance Orbiter noticed a sunlit speck that turned out to be Lunokhod 1. The imagery narrowed the lost reflector's location to within 100 metres and showed it was several kilometres from its last known coordinates. Armed with this new information, a team of physicists led by Dr Tom Murphy of the University of California, San Diego, in the United States, pinpointed Lunokhod 1's position with a telescope on April 22. Murphy plans to use the reflector in his research, which involves tracking the moon's orbit to within a millimetre by firing laser pulses at lunar reflectors and timing their return to Earth.

PHOTOS: GETTY IMAGES (QUANTUM RANDOMNESS); LAVOCHKIN ASSOCIATION (LOST LUNAR REFLECTOR); JONATHAN WEBB (TASTE TRAINING); COURTESY TIM BERRA (DARWINIAN INBREEDING); COURTESY UCF CARACOL ARCHAEOLOGICAL PROJECT (LASER ARCHAEOLOGY)



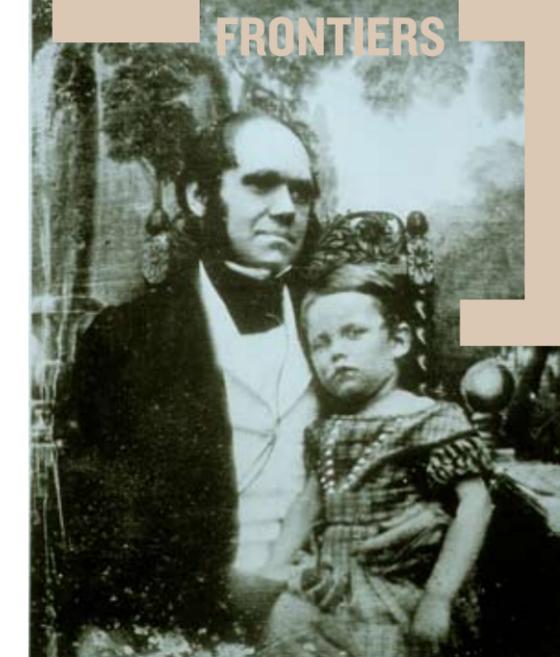
TASTE TRAINING

Australian ecologists are using a method called conditioned taste aversion to dissuade endangered northern quolls (*Dasyurus hallucatus*) from eating poisonous cane toads (*Bufo marinus*). The toads, introduced to Australia in the 1930s, have spread across the country and ravaged northern quoll populations, rendering the cat-sized marsupial locally extinct in some areas.

"The quolls are naïve to the fact that cane toads are poisonous," says Dr Jonathan Webb of the University of Sydney. "The toad looks like a giant frog, so they just attack it and then discover that it's poisonous."

In a first attempt at taste training, Webb and his colleagues fed each of 31 young quolls a small toad laced with a nausea-inducing chemical. They then released these trained quolls along with 31 untrained quolls into the wild. The results were striking: the trained quolls tended to avoid the cane toads and survived up to five times longer than their untrained counterparts, some of which downed a fatal meal within hours of release.

"The trained animals would encounter a toad and be obviously interested, but as soon as they sniffed it at close range, they lost interest, which was really encouraging," says Webb.



DARWINIAN INBREEDING

A new study finds evidence that Charles Darwin's children may have suffered ill health and infertility due to inbreeding. Darwin and his wife, Emma Wedgwood, were first cousins, and there was a history of intermarriage between their families. Three of their 10 children died before the age of 10, at least two from infectious diseases. Of six surviving children who had long-term marriages, three had no children.

"If it were just one child who left no offspring, we might dismiss that for a variety of reasons," says lead author Dr Tim Berra, emeritus biology professor at Ohio State University in the United States. "Two, you begin to wonder what's going on, but three out of the six leaving no offspring raises the spectre of unexplained infertility."

Berra and his co-authors fed data on 25 families from four generations of Darwins and Wedgwoods into a computer program, and found that Darwin and his wife had a 6.3 percent chance of passing on identical copies of a gene to their children. When offspring receive identical copies of a deleterious recessive gene, increased susceptibility to bacterial infection and infertility can result.

However, Berra points out that several of Darwin's children were highly successful. "Three of Darwin's sons were elected fellows of the Royal Society," he says. "They were extremely accomplished in the sciences and were knighted by Queen Victoria."

LASER ARCHAEOLOGY

For over 25 years, anthropology professors Arlen and Diane Chase of the University of Central Florida in the United States laboured to uncover the ruins of Caracol, a Mayan city in Belize. Their efforts yielded a map of 23 square kilometres. In the last year, they have increased this total more than eightfold using imagery gathered from an airplane with Light Detection and Ranging (LiDAR) equipment.

"Our problem was that Caracol is a huge site," says Diane. "There was no way we could effectively map it using traditional archaeological techniques."

LiDAR - which involves bouncing laser beams off the ground - detected structural outlines hidden beneath thick foliage. The results revealed 11 roadways and tens of thousands of terraces used to grow crops. The data also determined that the city covered 177 square kilometres and confirmed the Chases' estimate that it had at least 115,000 residents in the year 650. But the results have raised new issues. "We can start to ask how the city was organised, who lived where and what the political unit looked like," says Diane. "The questions are endless."

