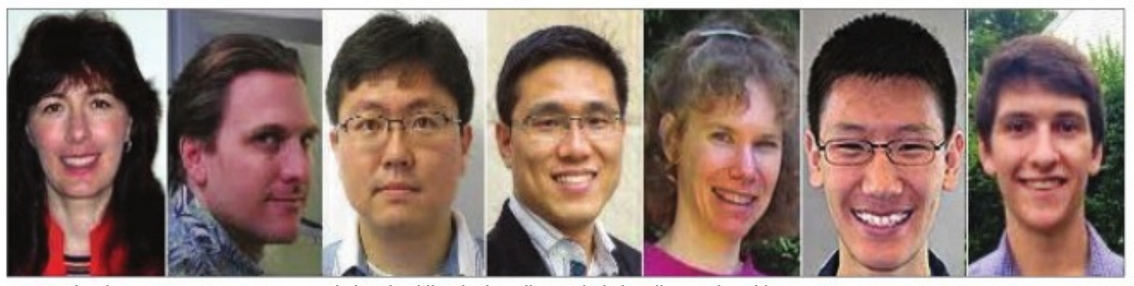
Bio-inspiration shows the way

THE BEETLE, THE CACTUS AND AN ANIMAL-TRAPPING PLANT HELP ENGINEER WATER HANDLING, WRITES **S ANANTHANARAYANAN**



Joanna Aizenberg, James C Weaver, Kyoo-Chul Park, Philseok Kim, Alison Grinthai, Neil He and David Fox.

Getting droplets of water to form from vapour and then moving the water away has industrial importance. Whether it is water-harvesting, condensation in a steam turbine or fogging of a windscreen, there is the need for a surface that combines both the ability to form droplets as well as effectively drain the condensation centre.

Kyoo-Chul Park, Philseok Kim, Alison Grinthal, Neil He, David Fox, James C Weaver and Joanna Aizenberg, at Harvard University, in their report in the journal *Nature* say that existing approaches based on very fine-scale texturing of surfaces have not been able to simultaneously optimise both how fast a droplet grows and how fast it flows away. But the example of the structure and composition used by three different biological species, the authors of the paper say, has led them to design a surface that does a lot better than synthetic ones that have been tried out so far.

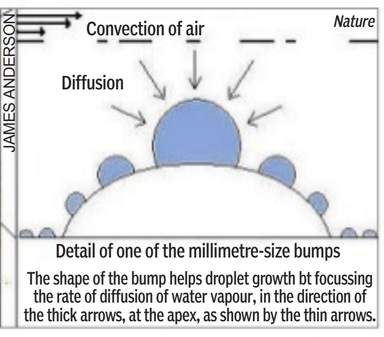
The inspiration for the drop-forming structure comes from the beetles that have evolved to squeeze water out

Bump with asymmetrical and widening slope

of the nearly moisture-free air in the Namib desert on the Atlantic side of southern Africa, an area that receives as little as one centimetre of rain in the year. With no other source of water, these beetles are known to strike a pose with their wings and rear end exposed to the fog and the wind, to harvest precious drops of water that the wings' microstructure channel to the creature's mouth.

While the backs and wings of these beetles have a distribution of small bumps, most studies have attributed their water gathering property to the surface chemistry — of the bumps being "water attracting" while the surroundings are "water repelling", rather than the topography of the surface, the *Nature* paper says. The emphasis has been on micro and

Bumps on the back and wings of *Pysosterna cribripes*, the Darkling beetles.



Detail of one of the millimetre-size bumps

The shape of the bump helps droplet growth bt focussing the rate of diffusion of water vapour, in the direction of the thick arrows, at the apex, as shown by the thin arrows.

nanoscale structure and pits or depressions have been considered to be better water gatherers than protuberances like the millimetre-sized bumps that the beetles have, the paper says.

The Harvard researchers, however, note that the entire bumpy surface has been found to be covered with water repelling wax, which means that it is not the surface chemistry that helps condensation. On the other hand, they say, even in the absence of a microstructure, the geometry of the millimetre-sized dome could be an agent of condensation by acting to concentrate the flow of vapour over the surface at the top of the dome.

To test this possibility, which was suggested by some members of the group in January 2015, an experimental bumpy surface of the same millimetre dimensions was created by pressing a thin aluminium sheet and treating the surface to be water repelling. The sheet, along with a bump-free control sheet, was then exposed to a temperature- and humidity-regulated environment where the convective movement of air close to the surface was negligible so that the main effect near the surface was a diffusion of air due to molecular movement. While there was a degree of droplet formation due to condensation, what was seen was that the largest droplets, which indicated concentration of vapour, occurred at the apex of bumps in the bumpy sheet.

A number of control trials were carried out to eliminate the role of roughness or chemical properties of the surface and it was established that it was the curvature of the bump that led to condensation, which increased if the bump was more pointed. There is, hence, an optimum size and even a variation in the shape to be rectangular for the most efficient condensation.

While this trial showed that bumps may be a good way to promote droplets, the next question was how to drain these away so that the water could be collected and was not lost to evaporation. Here again, nature showed an optimised design for drawing the water off, even against the force of gravity. The method is by using capillary forces, the kind that make the water in a glass vessel creep up at the edges, as exemplified in the *spines* found on cacti.

Cacti are a category of plants found in desert and arid regions where the priority is conservation of water. Thus, cacti have thick stalks and leaves that have less surface area as a proportion of their volume, and they are partly covered by thin spines. These spines have little water content and so present no avenue for leakage but studies by Jie Ju, Hao Bai, Yongmei Zheng, Tianyi Zhao, Ruochen Fang and Lei Jiang showed, in a paper in the journal *Nature Communications* in 2012, that the spines had barbs with a conical shape, with microscopic grooves that got smoother as they approached the base, to help channel water that may condense from fog or as dew.

Cactus spines

The Harvard researchers worked it out that when the bump had a non-symmetrical slope that grew wider as it descended, the drop that formed at the apex would move down the slope and keep moving even as it widened and grew in size as it coalesced with other droplets. The effect of guiding the droplet along the slope was regardless of even the force of gravity, if the bump was oriented so that the flow was upwards.

The effect is dependent on no friction or very little friction while the droplet moves. To simulate this property, the Harvard group relied on a stratagem of another optimisation in nature, a category of carnivorous plants that trap animal prey by luring them to the slippery rim of a deep cavity — the Nepenthes pitcher plants, so called because the insect trap is shaped like a pitcher. Following the lead, the Harvard group lubricated the bumps and the asymmetric slope so that droplets could move just as gravity and capillarity would drive them.

The result of trials with all three features — bumps, the slope and lubrication provided — was that larger drops formed faster and then slid down more effectively than with other surfaces that had not been constructed in this topography. "This combination of short response time and reliable, high-volume long-term performance are critical in numerous cases… such as heat exchange, dehumidification and desalination systems," the authors of the paper say.

THE WRITER CAN BE CONTACTED AT
response@simplescience.in

PLUS POINTS

Pinpointing the source

Scientists have found the source of the universe's most mysterious message, tracing it to two colliding stars far away from us. The hunt for the source of these fast radio bursts — strange messages that come to us from deep in the universe — has been going on for years. They sometimes last for less than a millisecond and scientists were able to learn very little about why they were happening or where they might be coming from.

The bursts were perplexing since they were first discovered in 2007 and some had strange characteristics that even led to speculation that they could be caused by alien technology.

Now scientists have found a potential source for at least one of the strange messages. It appears to be emanating from an elliptical galaxy and was probably caused by two colliding neutron stars, according to a new

The parabolic antennas of the Atacama Large Millimetre/Submillimetre Array project at the El Llano de Chajnantor in the Atacama desert, some 1,730 km north of Santiago and 5,000 metres above sea level.

report in *Nature*.

Scientists have a tendency to only spot the messages after they have been sent, meaning that they are often hard to locate or even study in any detail. But one of the messages made its way to earth in April last year, and they managed to track it down to a specific galaxy that turns out new stars rarely, which probably means the sound came from the collision of two older neutron stars that came gradually closer and then merged into one.

That explanation wouldn't solve all of the mysteries of the fast radio bursts, but it could tell us huge amounts about the make-up and the beginning of the universe. Scientists are able to look at the message and see how "smeared" it is, and by doing so work out exactly how much material it passed through on its way to earth. They could work out precisely how much of that is observable — hopefully working out how much of our universe is made up of invisible dark energy or dark matter.

They hope to build and switch on new instruments that will be able to measure the bursts, and possibly use these to learn more about where exactly they are coming from and how they are made.

ANDREW GRIFFIN/THE INDEPENDENT

Boosting resistance

Gut microbes are known to play an important role in the body's immune function, but antibiotics can deplete these bugs, leaving patients undergoing long-term treatment susceptible to infection by opportunistic, pathogenic bacteria, such as Vancomycin-resistant *Enterococcus faecium* (VRE).

Enterococcus in lung tissue.

Building on mouse studies showing that murine norovirus can enhance intestinal immune system development, a team led by researchers at the Memorial Sloan Kettering Cancer Center in New York City has now identified a norovirus-mimicking molecule that reduces VRE densities in antibiotic-treated mice. The findings were published on 24 February in *Science Translational Medicine*.

"They showed not only that this (norovirus) was protective against VRE — which is a very serious, hospital-acquired pathogen — but that they could also mimic the effect of the virus using a drug," said Kenneth Cadwell, an assistant professor of microbiology at New York University's Skirball Institute of Biomolecular Medicine, who was not involved in the research. "That's pretty amazing." Inspired by recent research in mice demonstrating that murine norovirus can enhance antibacterial defences in the intestine, the team tested whether inoculations of norovirus could reduce VRE densities in antibiotic-treated mice. They found that in cases where inoculations led to infection, the norovirus induced elevated expression of a gene coding for Toll-like receptor 7 (TLR7) — a protein involved in both antiviral and antibacterial immune pathways. In these cases, the mice began synthesising antimicrobial peptides in the intestine, and regained partial resistance to VRE colonisation.

CATHERINE OFFORD/THE SCIENTIST

REMARKABLY CONSTANT

TAPAN KUMAR MAITRA EXPLAINS THE SOURCES AND CONSEQUENCES INVOLVING CHROMOSOMAL STRUCTURE AND NUMBERS

Wherever adequate genetic data have been obtained, the general features of inheritance in both plants and animals have been found to be remarkably constant. This fact has, of course, enormously simplified the study of inheritance because the basic principles derived from experiments on favourable organisms can then be generally extended to the great majority of species that do not lend themselves to laboratory study. To be sure, differences exist, but in the main the physical features of meiosis-synapsis, crossing over and segregation are sufficiently constant to permit generalisations to be made from the cytological fact to the genetical interpretation, and vice-versa. Indeed, modern cytogenetic interpretation is a composite derived from the observations of many species.

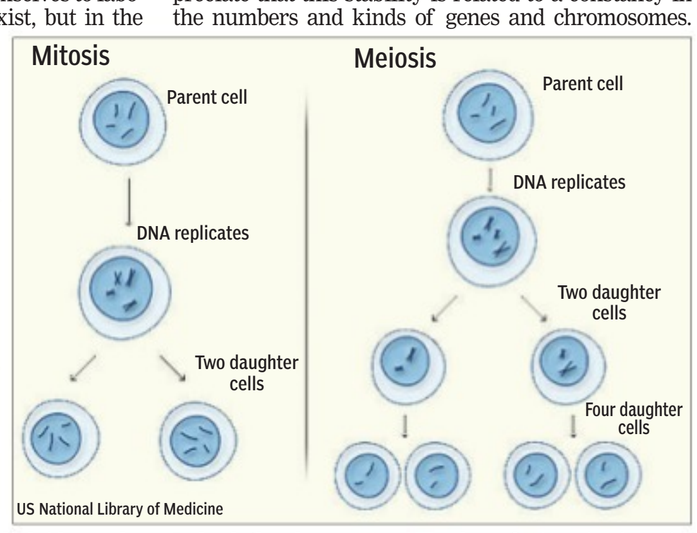
Cell division, whether mitotic or meiotic, is a series of events coordinated in both time and space to give a reasonably predictable result: two genetically identical daughter cells if mitotic, a variety of gametes or asexual spores if meiotic. Thus, an organism heterozygous for a given gene produces gametes carrying each of the alleles with a frequency of 50 per cent. Mendelian ratios demonstrate this equality, as does the constancy of allelic frequencies from one generation to the next in normal diploid populations. Both, of course, depend on the regularity of the meiotic process.

Mitosis, at both morphological and molecular levels, provides a mechanism for the maintenance of precise quantitative and qualitative genetic continuity; that is, the daughter cells are the genetic equivalent of the mother cell from which they arose. Meiosis, on the other hand, while providing for genetic continuity, also injects variation into patterns of inheritance through the segregation of alleles, the disruption of linkage groups by crossing over, and the union of gametes of dissimilar genotype. When meiosis is regular, however, these variations occur in predictable ratios, but we find also that additional variation can be introduced by other means. These departures from a regular inheritance have evolutionary significance.

The constancy of the chromosome as a structural entity lies in its capacity to reproduce itself at each cell division with extraordinary precision. However, chromosomes can undergo change spontaneously even as genes mutate, and the newly constructed chromosome, like its original counterpart, is replicated exactly at each cell division thereafter. Under natural conditions, such changes in chromosomal structure are rare events; they can, on the other hand, be induced with relative ease by ionising radiations such as X-rays and by chemicals.

Chromosomal aberrations leading to rearrangements in the linear order of genes may be grouped into four classes: deletions or deficiencies; duplications; inversions; and translocations. The first three, as a general rule, affect only single-chromosomes, whereas translocations may involve one, two, or more chromosomes. Their detection can be made both cytologically and genetically in favourable material; in less favorable material, certain aberrations can be inferred from the chromosomal configurations found at metaphase and anaphase of meiosis.

If the chromosome numbers of a randomly selected group of individuals of a particular species were determined, in all likelihood they would be the same. This situation is to be expected, for species are reasonably constant biological entities and it is not difficult to appreciate that this stability is related to a constancy in the numbers and kinds of genes and chromosomes.



US National Library of Medicine

Indeed, the chromosome number of a species is a significant biological datum. But even as the genes mutate or change in number through loss or addition, so also do chromosomes. The process is sporadic, for cell and chromosome divisions are remarkably regular phenomena, but variations do occur and are sometimes perpetuated to give rise to new chromosomal races.

Variation in chromosome number produces two types of individuals or cells, namely those whose somatic complements are exact multiples of the basic haploid number characteristic of the species, and those whose somatic complements are irregular multiples of the basic number.

Individuals or cells of the first type are termed euploid. They may be haploid (monoploid), diploid, triploid, tetraploid, and so on, with the higher multiple members above the diploids being referred to collectively as polyploids. A tetraploid plant, for example, could produce diploid gametes and gametophytes in much the same manner as a diploid plant produces haploid gametes and gametophytes. However, an irregular meiotic distribution of chromosomes in polyploids due to irregular synapsis and metaphase orientation often leads to comparable irregularities in chromosome number in the gametes and resultant offspring. In many polyploid series, therefore, the initial point of reference is the basic haploid complement of chromosomes, and the term diploidy, for example, implies that each chromosome of the haploid set is represented twice, even though homologous chromosomes may differ from each other in genie content as a result of deficiencies or duplications.

THE WRITER IS ASSOCIATE PROFESSOR, HEAD, DEPARTMENT OF BOTANY, ANANDA MOHAN COLLEGE, KOLKATA, AND ALSO FELLOW, BOTANICAL SOCIETY OF BENGAL, AND CAN BE CONTACTED AT
tapanmaitra59@yahoo.co.in

Isolated for 50,000 years

STEVE CONNOR REPORTS ON A DNA STUDY THAT CLAIMS THERE IS NO DIRECT EVIDENCE THAT ABORIGINAL AUSTRALIANS EVER INTERMARRIED WITH SOUTHEAST ASIANS, AS SOME HAD SUGGESTED

Aboriginal Australians have been genetically isolated from the rest of humanity for 50,000 years, with a DNA study determining that a detailed analysis of the male Y chromosome from 13 Aboriginal men found no traces from other ethnic groups, such as people from the Indian subcontinent who were thought to have migrated to Australia about 2000 BC.

Geneticists have calculated from mutations present in the Aboriginal Y chromosome that the first inhabitants of Australia had separated from other members of Homo sapiens living elsewhere in the world about 50,000 years ago — probably long before our species had arrived to live in Europe. The findings of the study, however, failed to explain the arrival of the dingo wild dog in Australia, which is not a native species and was almost certainly brought by humans to the continent from other parts of Southeast Asia.

Previous genetic studies, along with archaeological evidence of imported tools and a change in language, had suggested that the dingo had arrived with Southeast Asians who had settled in Australia and interbred with local Aboriginals. However the latest study, published in the journal *Current Biology* by an Anglo-Australian team of researchers, ruled out any interbreeding with non-Aboriginals, at least down the male line of descent, said Chris Tyler Smith, an evolutionary geneticist at the Wellcome Trust Sanger Institute in Cambridge.

The researchers liaised closely with Aboriginal communities to carry out the DNA analysis and had already shared their results with them, he said. "We were effectively telling them what they already knew. They were the least surprised by the findings."

Lesley Williams, an Aboriginal elder, said that "science has confirmed what our ancestors have taught us over many generations — that we have lived here since the Dreaming".

Meanwhile, a discovery that rewrote Australian history and made headlines around the world concerned a 42,000-year-old skeleton found in a dry lake bed that revealed that the continent had been occupied for twice as long as previously believed. That was in 1974, and since then "Mungo Man" — he was found in an area of outback New South Wales known as Lake Mungo — had been kept in a cardboard box at the Australian National University in Canberra.

That greatly distressed Aboriginal tribal groups from Lake Mungo, and in November last year, after years of negotiations, the bones were finally handed back to the area's traditional owners to be returned to their original burial place. "I think it's terrible that they were taken in the first place," one elder, Lottie Williams, told Australia's *ABC*. "We weren't even told... Now we're picking them up to take them back to where they belong."

Aboriginal Australians on the Tweed River, New South Wales, Australia, circa 1880.

It was an ANU geologist Jim Bowles who discovered the skeleton in the arid, remote region. Now 85, Professor Bowles — who found a partially cremated female skeleton, dubbed "Mungo Lady", in the same region seven years earlier — was present at the ceremony in Canberra on 6 November 2015.

THE INDEPENDENT