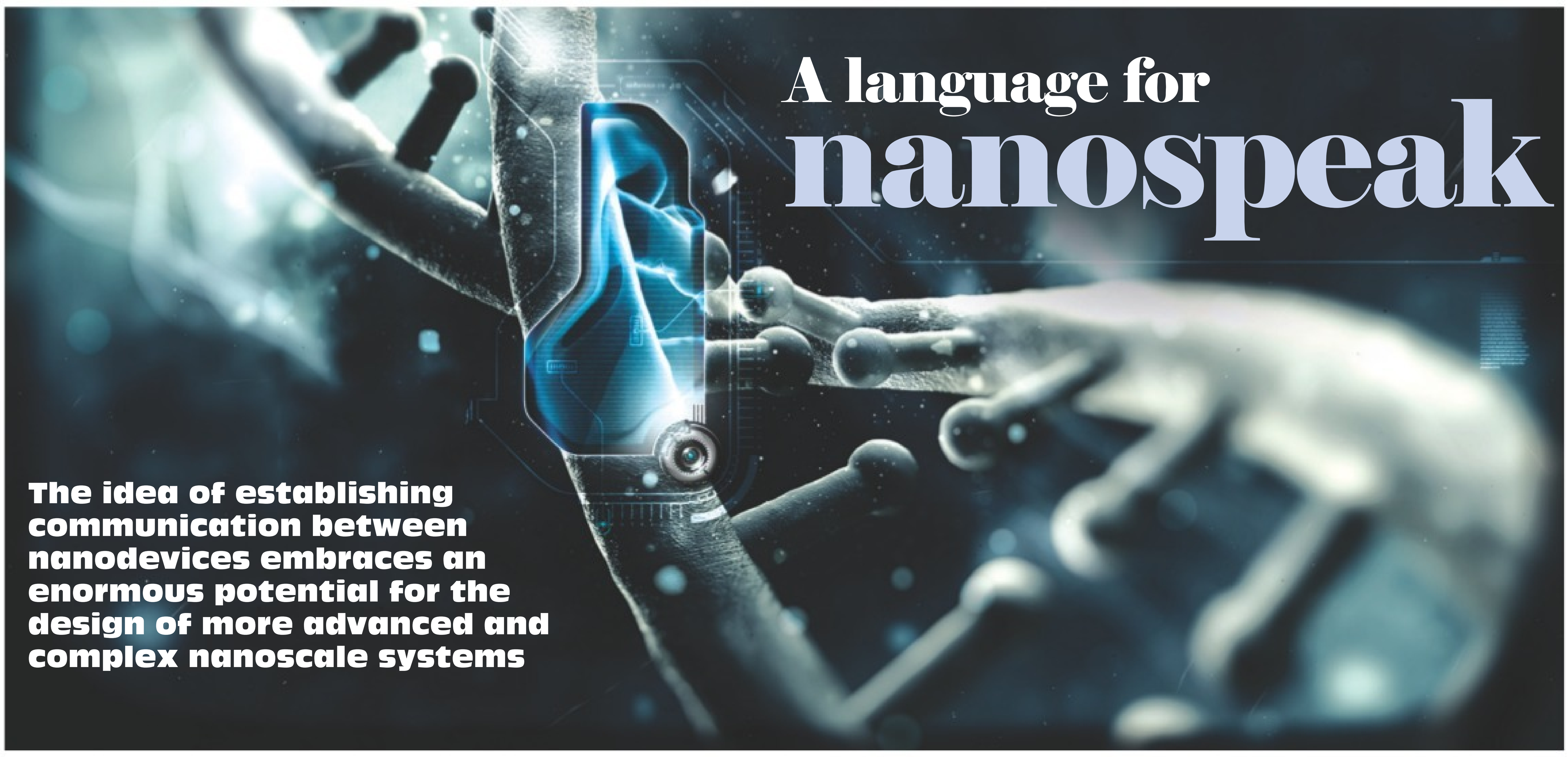


A language for nanospeak

The idea of establishing communication between nanodevices embraces an enormous potential for the design of more advanced and complex nanoscale systems

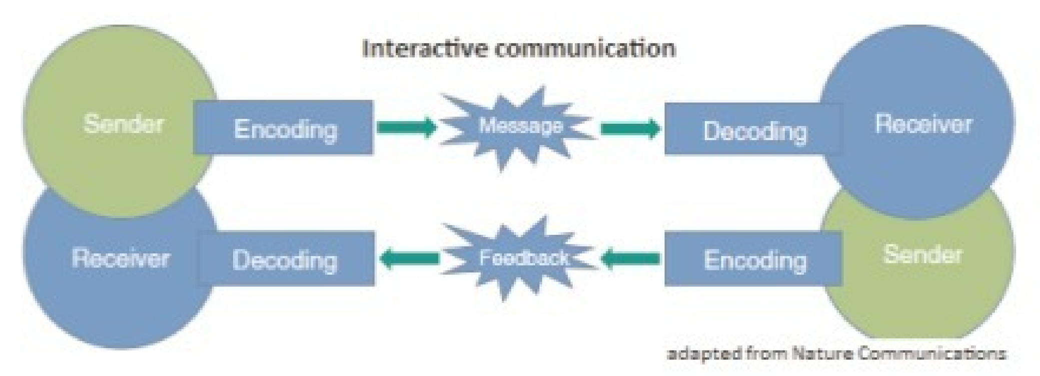
S ANANTHANARAYANAN

Manmade devices now surpass the ability of living things in data communication and machines can send messages, act on messages received and send responses to other machines. Huge data transfer, automation and complex tasks by robots have thus become possible. The same communication capability, however, cannot be transferred to the nanoscale and this limits what use we can make of nanodevices that have become feasible.

Antoni Llopis-Lorente, Paula Díez, Alfredo Sánchez, María D Marcos, Félix Sancenón, Paloma Matinez-Ruiz, Reynaldo Villalonga and Ramón Martínez-Máñez from institutes in Valencia and Madrid, in Spain, report in the journal, *Nature Communications*, that they have devised nanoparticles that use molecules, or chemical signals, for passing and receiving messages. It is the method that the smallest living things, like cells, neurons, insects and bacteria rely on, as they do not have the energy to use the methods of larger animals.

At the larger scale, the sophistication of electronics has made it possible to exercise automated, intelligent and interactive control of powerful machinery — train control and air traffic control, for instance, or even robotics that can assemble other machines or sense defects and take steps to correct them. And the machines we use have become progressively smaller. Drones, for instance, that can fly through inaccessible areas to take pictures, or even carry out operations, in electronic communication with a control centre.

While yet smaller devices are used as medical or surgical implants to carry out intelligent tasks within the bloodstream or organs of the body, it would be useful to employ drones at the level of cells, to deal with cancers, to deliver drugs or even surgery at a very fine level. At the level of very small devices, however, for measurable work, it would be necessary for groups, even swarms of nanoparticles to be in communication. The trouble is that at these dimensions, embedding electronic sensors or transmitters in the devices is not feasible.

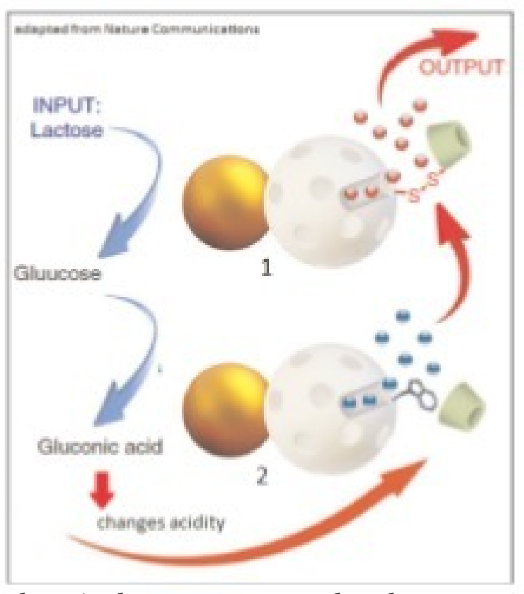


adapted from Nature Communications

What any system of communication calls for, the authors explain, is that a first entity respond to a stimulus by creating a signal. The signal should then be received by another entity and the receipt of the signal should act as a stimulus to a change in the state of the receiver. Ideally, the change includes sending a message back to the first sender, which needs to have the capacity to receive signals.

While humans have great capacity to communicate and work in teams, animals also communicate, usually with sounds or visual signals, to hunt and to find safety in large groupings. The smallest living things, however, are too small for visual signals to be seen and they cannot create sounds that carry very far. Insects thus make extensive use of chemical signals, a method also used by other animals as "scents". And the cells in the body, and single celled animals like bacteria, communicate exclusively by exchange of molecules or chemical signals. These molecules are released when electric charges accumulate within the cells and their reception by the correspondent cell usually also brings about changes in electric charges, to set off other processes.

A great deal of progress has been made in the use of chemical processes to classify information or computing. Strands of DNA, for instance, are employed to recognise chemical patterns and carry out computations. Computer memories based on protein molecules have also been conjectured. A man-made nanoparticle, of submicron dimensions, which can deliver a payload and has the capacity to send and receive chemical signals, however, has been a challenge, the authors of the *Nature Communications* paper say. In the work now reported, the team recognises that what is required is a particle that can respond to stimuli in two different ways, or to "have two faces", so to speak. The team hence makes use of a class of "Janus particles" or nanoparticles that have different physical properties on opposing faces. The same Janus particle can thus allow different chemicals processes to take place.



A simplest example would be a particle that is water attracting on one side and water repelling on the other. Such particles would align themselves along an oil-water boundary for instance. Alternatively, they could attach to a "water-like" portion of so-me target molecule or structure and present the water repelling side to others that approach the target.

Following this line of thinking, the Valencia-Madrid group created nanoparticles of porous silica, to one side of which nanoparticles of gold were attached. The method described is that the silica nanoparticles were first confined to a water-paraffin interface and first coated with paraffin wax on one side. Gold nanoparticles could then be attached to the face that was not covered by paraffin and the paraffin finally washed away. The result was particles that presented a silica face on one side and a gold face on the other.

The payload, or the material to be delivered was loaded in the pores of the silicon side of a first set of particles and the holes were closed with stoppers that opened when there was a specific chemical stimulus. And the gold coated side had a function that worked with a different set of stimuli.

In a second set of particles, the gold side was sensitised to the signal sent by the gold side of the first set, and the response was for the silicon side to release the signal that induced the first set to release the payload. The payload was hence released when the carrier of the payload sent a message to another set of particles, and when a response was received from the other set. As shown in the picture, the first set of particles, which carries the payload, is stimulated by the sugar, lactose. This acts on the gold side of the particles, to release the messenger, glucose. When the second set receives the messenger, it reacts by release of a second messenger, which gets the first set of particles to release the payload.

Trials were carried out with a mixture of samples of the two kinds of nanoparticles, the first one with a load. It was clearly seen that it was only when the lactose, the stimulus for the first kind of particle, was added to the mixture that there was progressive release of the load in the first group. The trial was hence of effective, interactive communication, based on scalable chemical exchange.

The idea of establishing communication between nanodevices embraces an enormous potential for the design of more advanced and complex nanoscale systems and the development of nanodevice communities, the authors of the paper say.

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PLUS POINTS

Opinions divided

Chemicals found in fossil fuel-powered vehicle exhausts, cosmetics, electric and traditional cigarettes, glue and building materials may increase the risk of cancer because they can interfere with the body's natural repair mechanism, according to a new study.

Researchers found that formaldehyde "stalls and destabilises" structures involved in replication of DNA and "selectively depletes" the BRCA2 gene, which helps suppress tumours. They suggested the chemical and other aldehydes might trigger cancer in people with a faulty copy of the gene.

However, another scientist, commenting on the research, said it was "rather misleading" to suggest that everyday items containing the chemical, like shampoo, could be an "important cause of cancer in humans". Many things are carcinogenic but the effect is so low they are not considered major health problems. For example, toast, coffee, sunlight and granite all increase the risk of cancer.

But, writing in the journal *Cell*, the researchers said their discovery of aldehydes' effect on DNA could be important. "The public health significance of our findings is emphasised by the ubiquity of exposure to formaldehyde and acetaldehyde, particularly in the urban environment, from sources including tobacco smoke, e-cigarettes, automobile combustion emissions, building materials, and even cosmetics," they said.

Professor Ashok Venkitaraman, director of the Medical Research Council Cancer Unit at Cambridge University, added, "Our study shows how chemicals, — to which we are increasingly exposed in our day-to-day lives — may increase the risk of diseases like cancer." He said people who inherited a faulty BRCA2 gene might be particularly affected by the chemicals.

However, another scientist at Cambridge University said no one should worry about the study's findings. Professor Paul Pharoah, a cancer epidemiologist, said the link between aldehydes and the risk of cancer had been known "for a long time". He said, "This study tells us little about how important those risks are and it is rather misleading to suggest that shampoo, for example, is an important cause of cancer in humans."

Ian johnston/the independent

All it can eat

In a study published in the journal *Proceedings of the Royal Society* B, a team of researchers investigated gigantism in baleen whales, the filter-feeding leviathans that include blue whales, bowhead whales and fin whales. They found that the marine mammals became colossal only relatively recently, within the past 4.5 million years. The cause? A climatic change that allowed the behemoths to binge-eat.

Whales began as land-dwelling, hoofed mammals some 50 million years ago. Over several millions of years, they developed fins and became marine creatures. Between 20 million and 30 million years ago, some developed the ability to filter-feed, which meant they could swallow swarms of tiny prey in a single gargantuan gulp. But even with this feeding ability, whales remained only moderately large for millions of years.

Researchers at the Smithsonian Institution's National Museum of Natural History measured over 140 museum specimens of fossilised whales and plugged the data into a statistical model. It showed that several distinct lineages of baleen whales became giants at about the same time, starting around 4.5 million years ago. This period coincided with the time when ice sheets first began to cover more and more of the Northern Hemisphere.

Run-off from the glaciers would have washed nutrients such as iron into coastal waters, and intense seasonal upwelling cycles would have caused cold water from deep below to rise, bringing organic material towards the surface. Throngs of zooplankton and krill would have gathered to feast on the nutrients, forming vast dense patches. The oceans thus became "all you can eat" buffets for the whales.

The straits times/ann

Understanding how gravity works

The third detection of gravitational waves — generated by colliding black holes, located three billion light years away — could open up a new window in astronomy

An international team of scientists has announced the third detection of gravitational waves — ripples in space and time — demonstrating that a new window in astronomy has been firmly opened. As was the case with the first two detections, the waves were generated when two black holes collided to form a larger black hole.

The newfound black hole, detected by the Laser Interferometer Gravitational-wave Observatory, formed by the merger, has a mass about 49 times that of our sun. This fills in a gap between the masses of the two merged back holes detected previously by Ligo, with solar masses of 62 (first detection) and 21 (second detection).

The new observation was made by the Ligo Scientific Collaboration together with the European-based Virgo Collaboration, which includes Ed Daw from the University of Sheffield's department of physics and astronomy. "Because black holes don't emit light, we don't know as much about them as we do about stars that shine," said Daw, "By observing the waves of gravity that some black hole systems emit, we can infer the physics driving the emission of the gravitational waves, and probe the ideas of Einstein and others of how gravity works.

"We can also start to conduct a sort of black hole census — how many black holes are in your average galaxy and how massive are they? We currently don't really understand how the universe produced so many black hole, binaries tens of times as massive as our sun, and the quest to understand how they came about is an interesting one in its own right."

Daw added, "This latest discovery is further evidence of Ligo developing from a first-discovery instrument to an observatory that explores our mysterious universe."

The new detection occurred during Ligo's current observing run, which began on 30 November 2016, and will continue through the summer. Ligo is an international collaboration with members around the globe. Its observations are carried out by twin detectors — one in Hanford, Washington, and the other in Livingston, Louisiana — operated by the California Institute of Technology and the Massachusetts Institute of Technology with funding from the National Science Foundation.

Ligo made the first-ever direct observation of gravitational waves in September 2015 during its first observing run since undergoing major upgrades in a programme called Advanced Ligo. The second detection was made in December 2015. The third detection, called GW170104 and made on 4 January 2017, has been described in a new paper accepted for publication in the journal *Physical Review Letters*.


An artist's impression of two black holes merging.

In all three cases, each of the twin detectors of Ligo detected gravitational waves from the tremendously energetic mergers of black hole pairs. These are collisions that produce more power than is radiated as light by all the stars and galaxies in the universe at any given time. The recent detection appears to be the farthest yet with the black holes located about three billion light years away. The black holes in the first and second detections are located 1.3 and 1.4 billion light years away, respectively.

The newest observation also provides clues about the directions in which the black holes are spinning. As pairs of black holes spiral around each other, they also spin on their own axes-like a pair of ice skaters spinning individually while also circling around each other. Sometimes black holes spin in the same overall orbital direction as the pair is moving — what astronomers refer to as aligned spins — and sometimes they spin in the opposite direction of the orbital motion. What's more, black holes can also be tilted away from the orbital plane. Essentially, black holes can spin in any direction.


A bird's eye view of the Ligo centre in Hanford, Washington.

Ligo scientific collaboration spokesperson, David Shoemaker from the Massachusetts Institute of Technology said, "We have further confirmation of the existence of stellar-mass black holes that are larger than 20 solar masses — these are objects we didn't know existed before Ligo detected them.

"It is remarkable that humans can put together a story, and test it, for such strange and extreme events that took place billions of years ago and billions of light-years distant from us. The entire Ligo and Virgo scientific collaborations worked to put all these pieces together."

The new Ligo data cannot determine if the recently observed black holes were tilted but they imply that at least one of the black holes may have been non-aligned compared to the overall orbital motion. More observations with Ligo are needed to say anything definitive about the spins of binary black holes but these early data offer clues about how these pairs may form.