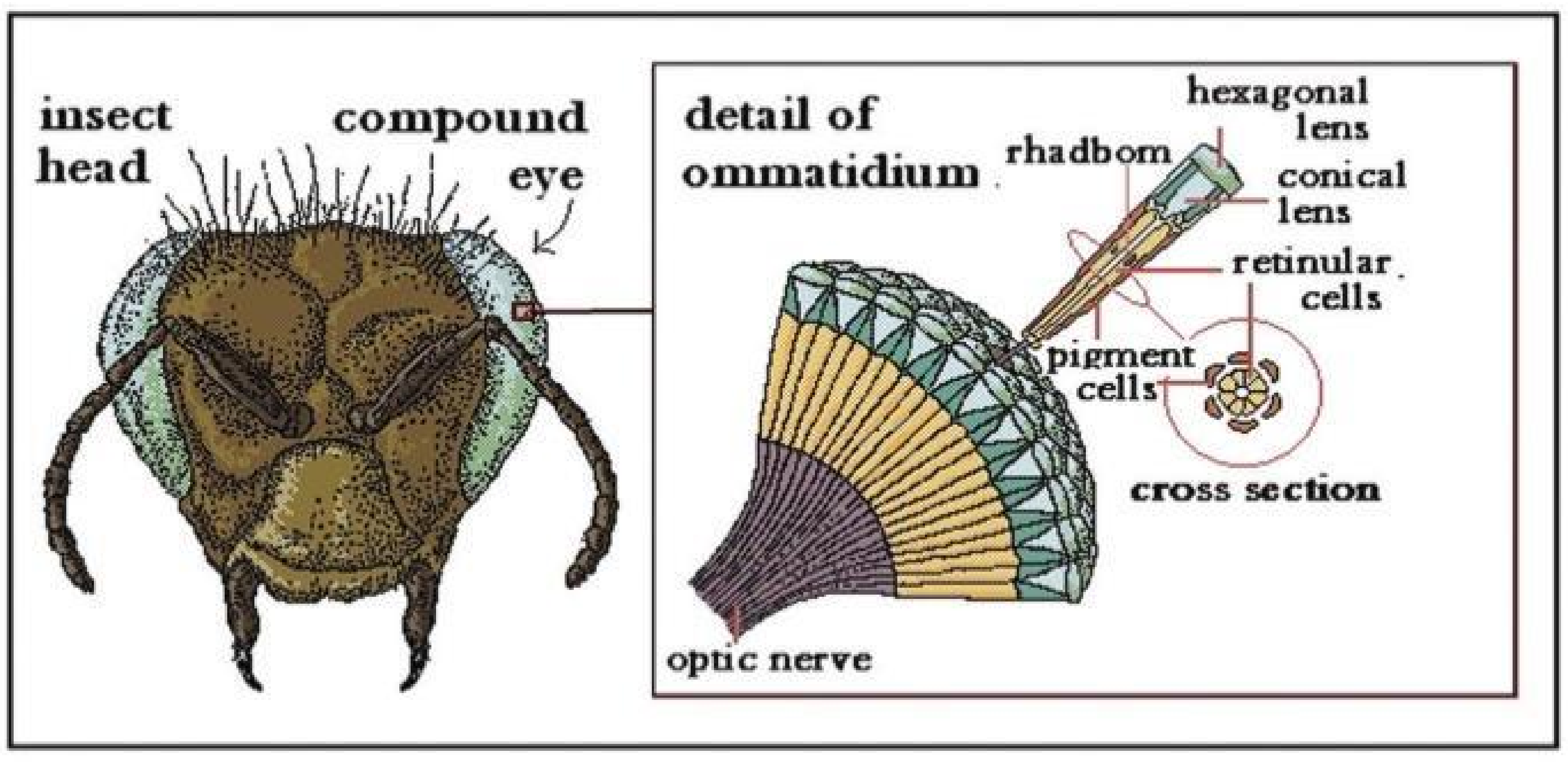
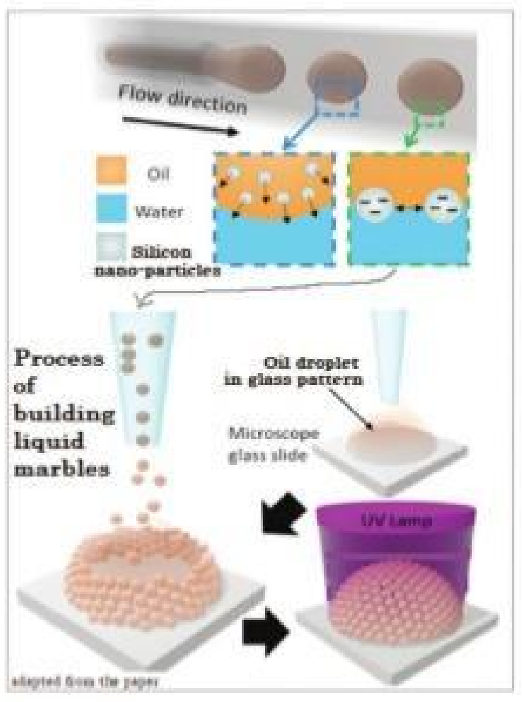
# See like a mosquito

## Nature's own tools help mimic the natural world

S ANANTHANARAYANAN




Eyes and eyesight are marvels of evolution and specialisation. Cells that were sensitive to dark and shade were refined to form images that were focused by lenses. The light-sensitive cells formed into screens that are arrays of miniature receptors of unmatched sensitivity and colour differentiation. And then, there is the processing, to make sense out of the information that the system collects.

Animals go a step further and have pairs of eyes, a feature that helps them perceive the dimension of depth. And many of the arthropod class of animals, or animals which have exoskeletons, carry this to the extreme, with pairs of compound eyes, or division of the eye into thousands of separate units, which cover a wide field of view, all at once.

Technology has harnessed sensitivity to light in the form of cameras. Camera lenses have become specialised and the complexity of the retina is matched by fine-grained photo film, or the pixels of the camera screen. And to follow the path of compound eyes, scientists have developed arrays of lenses on polymer sheets that can be shaped into a hemisphere. The lenses throw separate images on an array of silicon photo-detectors with electrical connectors. A device with 180 active lenses was less than two cm across and held out the promise of greater things. Achieving the nanometre dimensions of the segments of the eyes found in nature, and building enough of them to create a larger compound eye, however, has proved out of reach.

Donglee Shin, Tianxu Huang, Denise Neibloom, Michael A Bevan, and Joelle Frechette, from Johns Hopkins University, Baltimore, in *ACS Applied Materials & Interfaces*, a journal of the American Chemical Society, report a method that overcomes these limitations. Rather than fashion the microscopic components, Frechette and her team use nanometere-sized oil droplets to work as micro-lenses, and these are deposited as a single layer covering another droplet of oil, to serve as the flexible body of a synthetic compound eye.

The model that the Baltimore group used is the eye of the mosquito, "a source of inspiration for both its optical and surface properties,"the group says in the paper. The nanoscale features of the micro-lenses provide anti-fogging and anti-reflective properties and, as the lenses have very short focal lengths, all objects that are in view are in focus. "The hemispherical arrangement of micro-lenses captures images from all around, which the brain integrates, to achieve nearly peripheral vision while staying motionless," the paper says.

The picture shows the compound eye bulging out of a mosquito's head. We can see the segments, which are called ommatidae, of the compound eye, and that the eyes form the largest part of the mosquito head.

The structure of the ommatidae is shown in the second picture. A feature of the tiny compound eye is that the units are of low resolution and economical in terms of data. This enables the brain to deal efficiently with scanning for food or danger, while other senses, like smell take care of detail. "The simplicity and multifunctionality of compound eyes make them good candidates for miniaturised vision systems, which could be used by drones or robots to rapidly image their surroundings," says a press release from ACS.

Mimicking the structure, however, has been challenging, the paper says. While the focus has been on replicating the structure using fabricated lenses deposited on flexible substrates, the nanoscale features of the real object to replicate have been missing, as also a method to produce many artificial compound eye lenses at once. In the current work reported, the group addresses the challenge with the help of the curvature inherent to nanoparticles that are in the form of droplets, as a structure called the liquid marble.

The liquid marble is a drop of liquid whose surface has been coated with material that keeps the liquid away from other materials. A drop of water, which is naturally spherical, would spread out when placed on a glass sheet. One way of preventing this is to grease the sheet. Another would be to coat the drop with material that prevents contact with glass. The drop would then be a flexible object, which returns to being spherical, like a marble, when no forces are acting on it. When oil and water are mixed, again, the oil forms droplets, but small droplets can be dispersed uniformly, as an emulsion. The droplets, however, will progressively merge into larger droplets, unless this is prevented by adding particles that coat the droplets and keep them from direct contact.

The Baltimore group used a capillary device to generate nanometre-sized droplets of oil, and surrounded the droplets by nanoparticles of silicon. These droplets, as they do not coalesce, thanks to their coating, form themselves into a regular, patterned raft, a single layer. They are assembled as a single layer of droplets on the surface of another larger droplet -- and the result is a liquid marble, of a spherical, liquid body surrounded by droplets of the same substance, in the form of nanometer-sized spheres. It's just the structure of the compound eye!

And finally, the paper says, the lenses are treated so that the assembled structure stabiliSes into a mechanically robust material -- in the form of compound eye lenses that consist of a multitude of lenses of the same material. "As a result, the assembly process demonstrates a facile fabrication strategy to create a monolayer of micro-lenses encapsulating a liquid marble without an extra process," the paper says.

Apart from being an accurately formed artificial compound eye lens system, the process overcomes a major drawback in earlier methods, of not being scalable. "The process circumvents traditional fabrication challenges and reproduces both the optical and anti-fogging properties of the mosquito eye." The process allows for the form of the liquid marble lens to be configured, which permits mobility and deformability to produce other types of lenses of this kind.

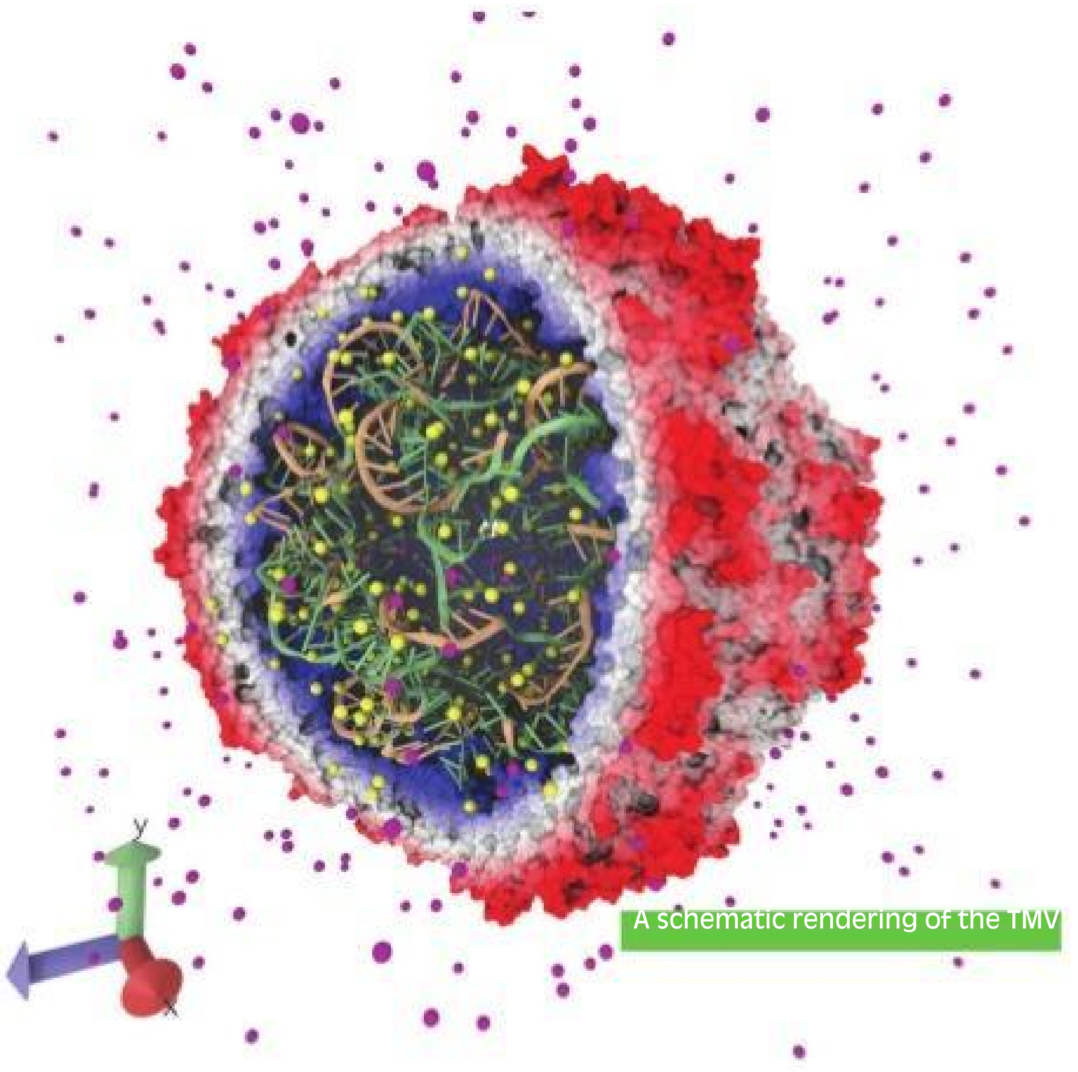
"Further development of this process will advance the miniaturisation of vision system applications, such as for medical imaging, reconnaissance devices, and robotics," the paper says.

The writer can be contacted at
response@simplescience.in

# Marked by spontaneity

## The tobacco mosaic virus is a case study in self-assembly but it has its limitations


A plant afflicted with TMV


A schematic rendering of the TMV

TAPAN KUMAR MAITRA

Some of the most definitive findings concerning the self-assembly of complex biological structures have come from studies with viruses. A virus is a complex of proteins and nucleic acid, either DNA or RNA. A virus is not itself alive, but it can invade and infect a living cell and subvert the synthetic machinery of the cell for the production of more viruses.

Inherent in the production of more viruses is the synthesis of the viral nucleic acid and viral proteins and their subsequent assembly into the mature virion, or viral particle. Studies of this assembly process have provided a wealth of information on structure and assembly that exceeds what we know about any other self-assembly system.

An especially good example is tobacco mosaic virus, a plant virus that has long been popular with molecular biologists. TMV is a rod like particle about 18 mm in diameter and 300 mm in length. It consists of a single strand of RNA with about 6,000 nucleotides and about 2,130 copies of a single kind of polypeptide, the coat protein, each with 158 amino acids. The RNA molecule forms a helical core, with a cylinder of protein subunits clustered around it.

Heinz Fraenkel-Conrat and his colleagues carried out several important experiments that contributed significantly to our understanding of self-assembly. They separated TMV into its RNA and protein components and then allowed them to reassemble in vitro in a test tube. Viral particles regenerated that were capable of infecting plant cells.

This result was one of the first and most convincing demonstrations that the components of a complex biological structure can reassemble spontaneously into functional entities without external information. Especially interesting was the finding that the RNA from one strain of virus could be mixed with the protein component from another strain to form a hybrid virus that was also infective. As expected, the source of the RNA and not the protein determined the type of virus that was made by the infected cells.

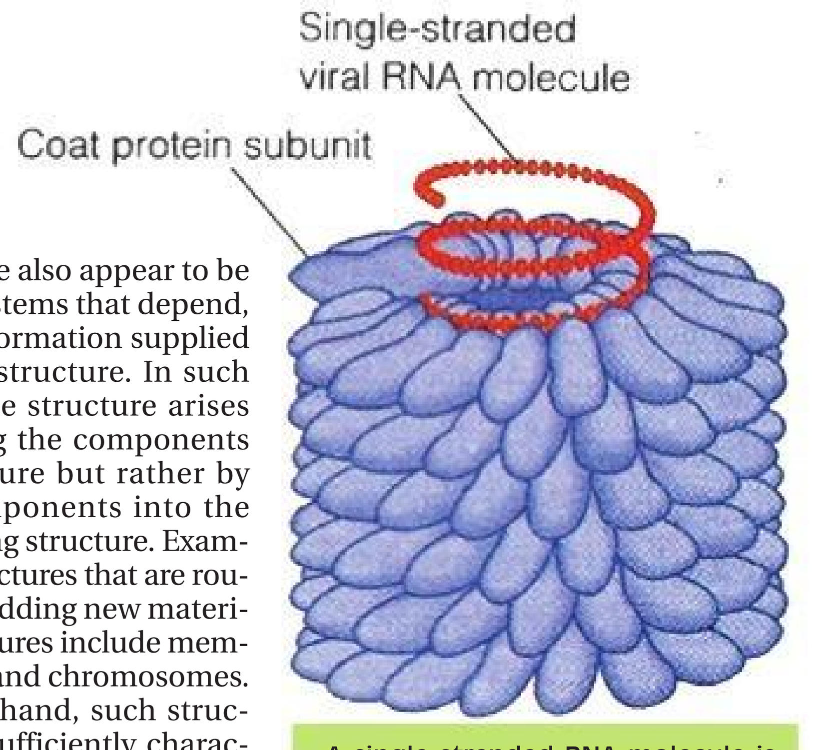
The assembly process has since been studied in detail and is known to be surprisingly complex. The basic unit of assembly is a two-layered disk of coat protein, each layer consisting of 17 identical subunits arranged in a ring. Each disk is initially a cylindrical structure but undergoes a conformational change that tightens it into a helical shape as it interacts with a short segment (about 102 nucleotides) of the RNA molecule. This transition allows another disk to bind and each successive disk undergoes a conformational change from a cylinder to a helix and binds to another 102 bases of the RNA.

This disk-by-disk elongation process continues, with the successively stacked disks creating a helical path for the RNA strand. The process eventually gives rise to the mature virion, its RNA completely covered with coat protein.

In many cases, the information required to specify the exact configuration of a cellular structure seems to lie entirely within the polymers that contribute to the structure. Such self-assembling systems achieve stable three-dimensional configurations without additional information input because the information content of the component polymers is adequate to specify the complete assembly process. Even in assisted self-assembly, the molecular chaperones provide no additional information.

However, there also appear to be some assembly systems that depend, in addition, on information supplied by a pre-existing structure. In such cases, the ultimate structure arises not by assembling the components into a new structure but rather by ordering the components into the matrix of an existing structure. Examples of cellular structures that are routinely built up by adding new material to existing structures include membranes, cell walls, and chromosomes.

On the other hand, such structures are not yet sufficiently characterised to determine whether the presence of a pre-existing structure is obligatory or whether, under the right conditions, the components might be capable of self-assembly. Evidence from studies with artificial membranes and with chromatin (isolated chromosomal components), for example, suggests that a preexisting structure, though routinely present in vivo, may not be an indispensable requirement for the assembly process. Additional insight will be necessary before one can say with certainty whether, and to what extent, external information is required or exploited in cellular assembly processes.




A single-stranded RNA molecule is coiled into a helix, surrounded by a coat consisting of 2,130 identical protein subunits. Only a portion of the entire TMV virion is shown here, and several layers of protein have been omitted from the upper end of the structure to reveal the helical RNA molecule inside

The writer is associate professor and head, department of botany,
Ananda Mohan College, Kolkata

PLUS POINTS

## Uncharted territory

Nasa is close to finding life on Mars, but the world is not ready for the "revolutionary" implications of the discovery, the space agency's chief scientist has said.

Jim Green has warned that two rovers from Nasa and the European Space Agency could find evidence of life within months of arriving on Mars in March 2021. The ExoMars Rover, which has been dubbed "Rosalind" in memory of British chemist Rosalind Franklin, will search for extra-terrestrial life by drilling 6.5 feet down into Mars' core to take samples. Those samples will then be crushed up and examined for organic matter in a mobile laboratory.

Green compared the potential discovery to when the astronomer Nicolaus Copernicus stated that the Earth revolves around the Sun in the 16th century. "It will start a whole new line of thinking. I don't think we're prepared for the results," he told *The Sunday Telegraph*. "I've been worried about that because I think we're close to finding it and making some announcements."

Nasa's rover Mars 2020 will drill into rock formations on the planet before sending test-tubes of rock samples back to Earth -- the first time material from Mars will have been brought onto this planet.

Green added that the discovery of life on Mars will give scientists a new set of questions to explore. "What happens next is a whole new set of scientific questions. Is that life like us? How are we related?" he said. "Can life move from planet-to-planet or do we have a spark and just the right environment and that spark generates life — like us or do not like us — based on the chemical environment that it is in?"

Recent research has shown that planets, which were previously thought to be uninhabitable, may have once had suitable conditions for life. Earlier this year, scientists discovered that there may be a vast and active system of water running underneath the surface of Mars.

A study released this month also claimed that Venus may have been habitable for two to three billion years before its atmosphere became incredibly dense and hot about 700 million years ago. Recent research suggests that civilisations could exist on other planets, according to Green. "There is no reason to think that there aren't civilisations elsewhere, because we are finding exoplanets (planets outside the solar system) all over the place, he said.

His comments came less than 24 hours before technology entrepreneur Elon Musk unveiled a SpaceX spacecraft designed to carry crew and cargo to Mars or other planets in the solar system before returning to Earth. Musk said the company's Starship was essential for the viability of space travel by introducing a spacecraft that can be reused. The ship is expected to take off for the first time in about two months and reach 65,000 feet before it lands back on Earth.

The Independent

## Learning from snot

Whale snot — the spray that comes out of the mammal's blowhole — is a treasure trove of DNA, hormones and bacteria. Marine biologists study samples to analyse each whale's hormone levels, and gather information about its reproductive cycle and stress levels. Since whales are increasingly affected by human activities such as pollution, their snot also stores toxins, which give conservationists clues about the ocean's health.

The United States-based marine conservation organisation Ocean Alliance uses drones to collect the snot. It tracks the health of whales around the world with environmental group Parley for the Oceans. Appropriately named Parley SnotBot, the drones hover about four metres above each whale's blowhole. As the whales exhale, the spray is caught by sponges and petri dishes attached to the drones.

The Straits Times/ANN