Showing the way

An artificial replication of the sunflower's motion using light-sensitive molecules could have wide-ranging applications

S ANANTHANARAYANAN

'Ah,sunflower…..
Who countest the steps of the sun
Seeking after that sweet golden clime…'
—William Blake

Blake's poem is about the legend of Clytie, a young girl who pines for Hyperion, the Sun God, but was turned into a flower that always faces the Sun. And the sunflower, or *Helianthus annus*, during its early, maturing phase, exhibits this behaviour of turning, through the day, to keep its face towards the Sun.

Xiaoshi Qian, Yusen Zhao, Yousif Alsaid, Xu Wang, Mutian Hua, Tiphaine Galy, Hamsini Gopalakrishna, Yunyun Yang, Jinsong Cui, Ning Liu, Michal Marszewski, Laurent Pilon, Hanqing Jiang and Ximin He, from the University of California at Los Angeles and the University of Arizona at Tempe, write in the journal, *Nature Nanotechnology*, of artificial devices that mimic the sunflower in pointing to the direction of heat or other radiation, without any external stimulus or power supply.

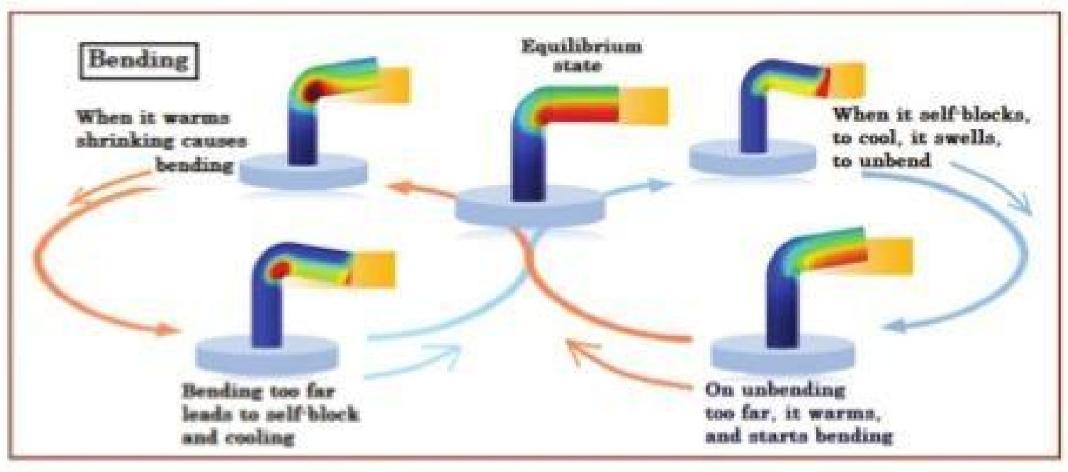
The common sunflower may get its name both from its resemblance to the radiating Sun and from the behaviour observed in its young flower stage, before maturity of the flower heads. At dawn, the flowers are seen to be pointing eastwards, to receive the rising Sun, and then they keep facing the Sun as it moves westwards. The movement reverses after sunset and at dawn the flowers are facing east again.

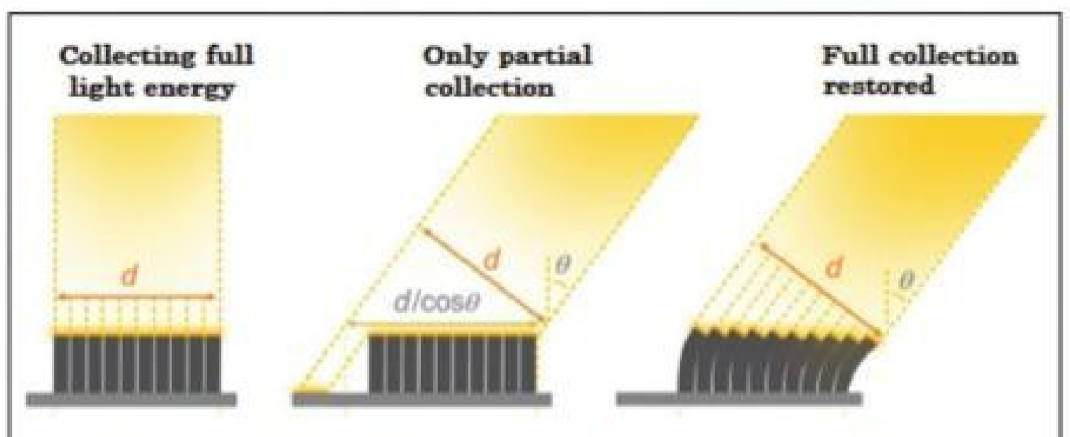
The Sun-facing motion is seen as a circadian rhythm, or an internal cycle that repeats every 24 hours, maintained by the movement of the Sun. The motion continues even when the Sun is covered by clouds or the plant is shaded for a few days. And if a young plant is turned away from the Sun, it reorients itself in a few days. The motion stops when the stalk is fully grown, the flower matures, and the mature flower stays fixed, usually facing east. Facing east makes for rapid warming in the morning and promotes visits by pollinators.

Many living things display this capacity to move "towards sources of certain environmental stimuli," the authors of the paper in *Nature Nanotechnology* say. Cells and bacteria, for instance, migrate along a chemical gradient. In the case of plants, the behaviour, which is known as phototropism, is to self-orient directly towards light sources. In many cases where movement is initiated by external stimuli, movement of organisms follows the orientation of its own anatomy, rather than the direction to the stimulus. In the case of the sunflower, the direction of movement is strictly according to the direction of the stimulus, the authors say, and "…..organisms not only sense and respond to the stimuli positions, but also spontaneously and constantly adjust their movements to tightly follow the signal directions. This presents the intelligence of self-regulation via the feedback control inherent in the dynamic interactions between their bodies and the stimulus."

The way plants do this, the authors say, is with the help of cells that detect light, present in the plant stem. As light falls on one side of the stem, plant cell hormones — called growth hormones — migrate to the opposite and shaded side. This leads to elongation of the cells on the shaded side and the stem tilts towards the illuminated side.

The authors, in their paper, present the principle of an artificial replication of the light sensitive plant, using light-sensitive chain molecules that increase or shrink their dimensions according to the light that falls on them. The system based on these molecules, the sunflower-like biomimetic omnidirectional tracker, or the "SunBOT", is able to "autonomously and instantaneously detect and track incident light in three-dimensional space at broad ambient temperatures with high accuracy and fast response, without auxiliary power supply or human intervention," the authors say.



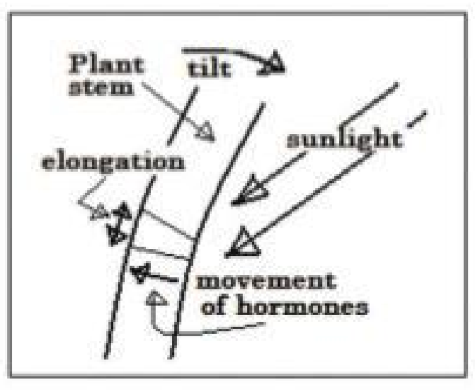


A collection of SunBOTs turn to face the source of light, so that they receive light 'face on', in place of 'obliquely'.

The core device is a stem-like cylindrical pillar shape made of reversibly photo-responsive materials. A number of materials may be suitable, the authors say, and they demonstrate the principle with four specific chain molecules. One is a hydrogel, a jelly-like material made of fibres that trap water, embedded with particles that absorb light and heat, and the others are chain molecules with either other molecules or special dyes as absorbers of light. The picture shows how the filaments of the light-sensitive material bend and straighten, to keep facing the direction of light.

The authors stress that the significant feature is the "feedback loop", which keeps trimming the tendency of the SunBOT to turn and keeps it constantly pointed towards the source of light. The other picture is of a collection of SunBOTs that turn to face the source of light, so that they receive the sun's energy "face on", in place of "obliquely".

A number of devices that depend on harvesting of sunlight could benefit from the arrangement. The authors report that in a solar-powered water vapour generation system, the SunBOT achieved a 400 per cent improvement in efficiency. With the current emphasis and importance of solar power, the value of the SunBOT becomes immediately apparent.



The authors also emphasise the fact that the SunBOT, like the sunflower, works without an external motivator, like an electronic circuit or an electric motor. It is wholly conceivable that a panel of photovoltaic cells be kept optimally oriented by an electric motor and a set of gears. But this would need orientation in two axes, one for the daily motion of the Sun and another for the seasonal. The SunBOT, in contrast, would always find the correct direction, perhaps even a direction not exactly towards the Sun, if the Sun is behind a cloud and the optimal direction is a little to the side.

The idea of "autonomous maximisation of the input power density,"which the SunBOT embodies, could be used in a great many areas, the authors say. In robotics like in complex tasks in changing environments, is one. The use in solar harvesting and solar cells, of course, is self-evident. There could also be "smart windows", signal receivers, like antennas, which adapt orientation to seek the strongest signal; use in devices like guided surgery; in detection of emissions, enabling telescopes, or even a radar beam or a receiver of sounds, to stay pointed to a given object, the authors say.

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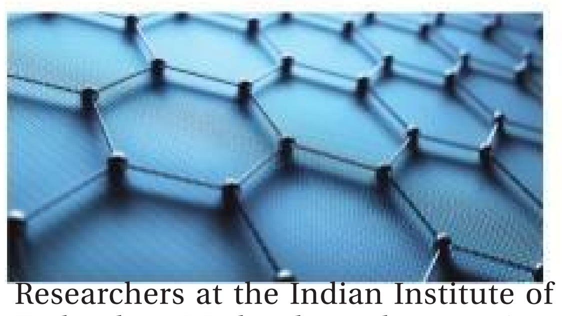
PLUS POINTS

Making graphene



Researchers at the Indian Institute of Technology-Madras have shown a simple route to producing graphene platelets from graphite. They have found that when graphite is suspended in an appropriate fluid and subjected to intense shearing force of machining, the layers of graphite separate into graphene platelets.

The research was led by Sathyan Subbiah, associate professor, department of mechanical engineering, IIT-Madras and his research student, Wazeem Nishad. Their work has recently been published in the peer-reviewed international journal, *Manufacturing Letters*.

Graphene is a form — an allotrope, to use the technical term — of carbon, that shot into fame in 2010 through the Nobel Prize it earned for Sir Andre Geim and Sir Kostya Novoselov of the University of Manchester. The idea of graphene is, however, not new. The history of this two-dimensional honeycomb shaped carbon spans more than a century of worldwide research. Graphene is the building block of the more commonly known graphite; a one millimetre-thick sheet of graphite is made of three million layers of graphene.

The researchers suspended graphite in a lubricant liquid containing sodium cholate to prevent the graphite particles from clumping together and subjected the suspension to machining of mild steel using oscillations of a carbide tool. As Subbiah had expected, the oscillations trapped the graphite to produce graphene flakes as a by-product of the lubricant with thicknesses in the range of a few nanometres.

Graphene is one of the strongest materials known; puncturing a pristine single layer of graphene with a pen would require the pen to be pushed by a large car in fifth gear. In addition, it conducts electricity 13 times better than copper, forms an excellent barrier layer and has an extremely high surface area — six grams of graphene could cover an entire football field, a property that makes it extremely useful in applications like catalysis.

Treatment breakthrough

Scientists have identified a new potential treatment pathway for cardiovascular disease. Their research has shown for the first time that a protein expressed in a subset of immune cells contributes towards the build-up of fatty deposits in arteries, which leads to cardiovascular disease.

These fatty deposits are caused by macrophages, a subset of immune cells known to take up surplus cholesterol. When this is present in excess, they mature into larger cholesterol-laden cells known as foam cells, which accumulate and cause blockages inside arteries.

The study published in *Science Advances*, shows for the first time that levels of a protein called Tribbles-1 (TRIB1) inside macrophages controls the amount of cholesterol taken up by foam cells. The research shows that higher levels of TRIB1 increased specific cholesterol uptake receptors, promoting arterial disease, whereas decreasing TRIB1 reduced disease.

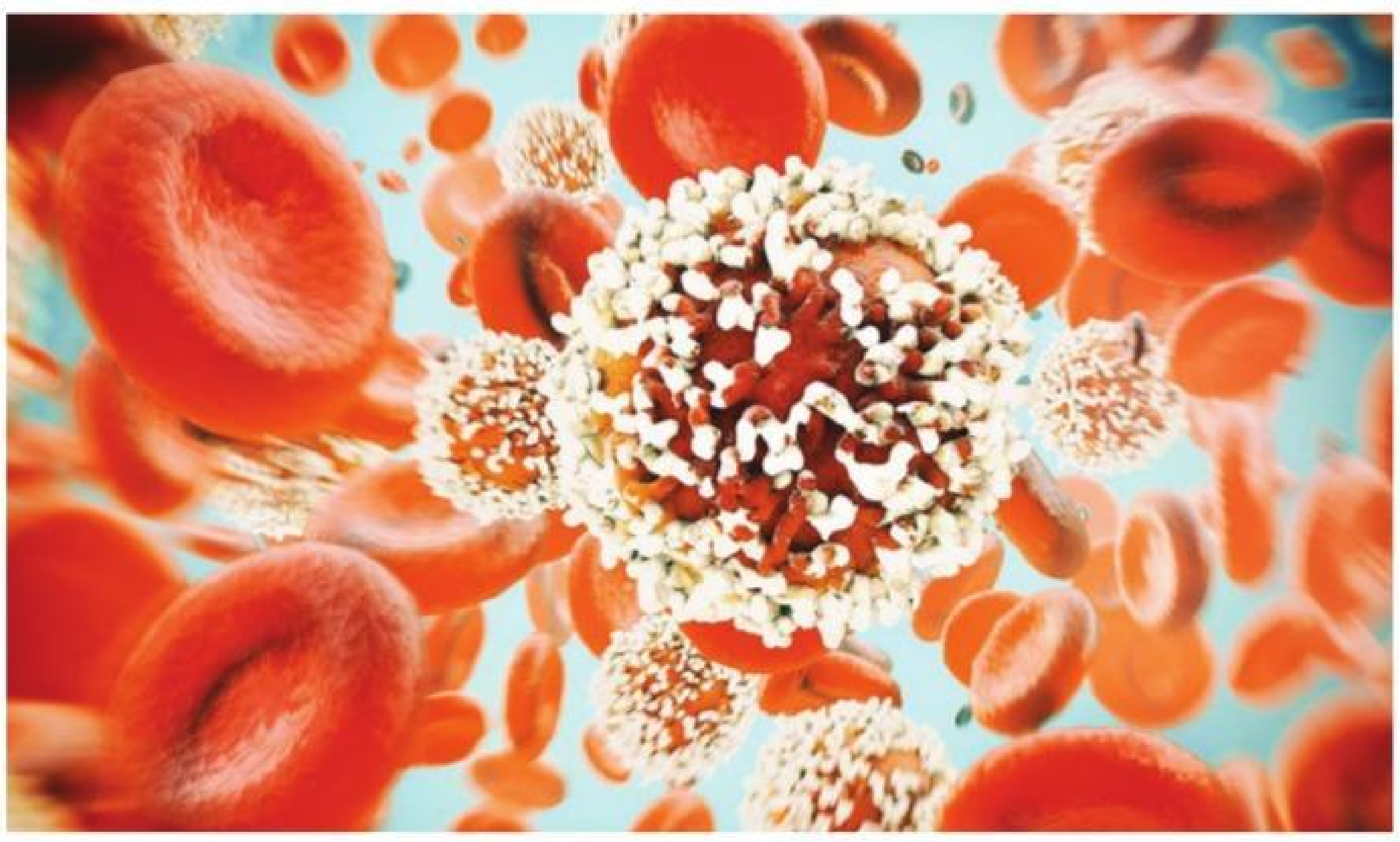
The findings of this early translational study, which involved the University of Sheffield, Leicester and scientists from Hungary and the US, suggest that inhibiting TRIB1 in macrophages could be a viable therapeutic target in treating cardiovascular disease. Researchers have long been trying to identify the proteins regulated by TRIB1 to understand their effects, and whether they are of benefit or are detrimental to disease development.

Jessica Johnston from the department of infection, immunity and cardiovascular disease at the University of Sheffield was first author of the study and her PhD research focused on the project. She said, "The role of TRIB1 in macrophages has remained elusive for some time. Our research provides the missing link and highlights the importance of cell-specific expression in cardiovascular disease."

Professor Endre Kiss-Toth, also from the department of IICD, led the study. He said, "The research into this mechanism has not yet translated into novel medical interventions. However, we now have pre-clinical proof that it would be beneficial to build on this research and see which patients with cardiovascular disease would benefit from the development of treatments to manage their lipid-laden foam cell formation."

Triggering mutations

Several substances including chemical carcinogens lead to cancer often after metabolic activation in the liver



TAPAN KUMAR MAITRA

The idea that certain chemicals, such as those found in tobacco smoke, can cause cancer was first proposed more than 200 years ago. In 1761 a London doctor, John Hill, reported that people, who routinely use snuff (a powdered form of tobacco that is inhaled), experience an abnormally high incidence of nasal cancer, suggesting the presence of cancer-causing chemicals in tobacco.

A few years later another British physician, Percival Pott, observed an elevated incidence of scrotum cancer among men who had served as chimney sweepers in their youth. It was common practice at the time to employ young boys to clean chimney flues because they fit into narrow spaces more readily than adults. Pott speculated that the chimney soot became dissolved in the natural oils of the scrotum, irritated the skin, and eventually triggered the development of cancer. This theory led to the discovery that scrotum cancer could be prevented among chimney sweepers through the use of protective clothing and regular bathing practices.

In the years since these pioneering observations, the list of known and suspected carcinogens (cancer-causing agents) has grown to include hundreds of different chemicals. Chemicals are usually labelled as carcinogens because humans or animals develop cancer when exposed to them. This does not mean, however, that each of these substances causes cancer through its own direct action.

For example, consider the behaviour of 2-naphthylamine, a potent carcinogen that causes bladder cancer in industrial workers and is present in tobacco smoke. As might be expected, feeding 2-naphthylamine to laboratory animals induces a high incidence of bladder cancer. But if 2-naphthylamine is implanted directly into an animal's bladder, cancer rarely develops.

The explanation for the apparent discrepancy is that when 2-naphthylamine is ingested (by animals) or inhaled (by humans) it passes through the liver and is metabolically converted into chemical compounds that are the actual causes of cancer. Placing 2-naphthylamine directly in an animal's bladder bypasses this metabolic activation and consequently cancer does not arise.

Many carcinogens share this need for metabolic activation before they can cause cancer. Substances exhibiting such behaviour are more accurately referred to as pre-carcinogens, a term applied to any chemical that is capable of causing cancer only after it has been metabolically activated. The activation of most precarcinogens is carried out by liver proteins that are members of the cytochrome P450 enzyme family. Members of this enzyme family catalyse the oxidation of ingested foreign chemicals, such as drugs and pollutants, to make the molecules less toxic and easier to excrete from the body. However, in some cases these oxidation reactions inadvertently convert foreign chemicals into carcinogens — a phenomenon known as carcinogen activation.

Once it had been determined that chemicals can cause cancer, the question arose as to how they work. The idea that carcinogenic chemicals act by triggering DNA mutations was first proposed around 1950, but there was little supporting evidence at that time because nobody had systematically compared the mutagenic potency of different chemicals with their ability to cause cancer.

The need for such information inspired Bruce Ames to develop a simple, rapid laboratory test for measuring a chemical's mutagenic activity. The procedure he developed, called the Ames test, utilises bacteria as a test organism because they can be quickly grown in enormous numbers in culture. The bacteria used for the Ames test are a special strain that lack the ability to synthesise the amino acid histidine.

The bacteria are placed in a culture dish containing a growth medium without histidine, along with the chemical being tested for mutagenic activity. Normally, the bacteria would not grow in the absence of histidine. However, if the chemical being tested is mutagenic, it will trigger random mutations, some of which might restore the ability to synthesise histidine. Each bacterium acquiring such a mutation will grow into a visible colony, so the total number of colonies is a measure of the mutagenic potency of the substance being investigated.

Because many chemicals that cause cancer only become carcinogenic after they have been modified by liver enzymes, the Ames test includes a step in which the chemical being tested is first incubated with an extract of liver cells to mimic the reactions that normally occur in the liver. The resulting chemical mixture is then tested for its ability to cause bacterial mutations. When the Ames test is performed in this way, a strong correlation is observed between a chemical's ability to cause mutations and its ability to cause cancer.

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Ames test

The Ames test is based on the rationale that most carcinogens are mutagens. The ability of chemicals to induce mutations is measured in bacteria that lack the ability to synthesise the amino acid histidine. When placed in a growth medium that lacks histidine, the only bacteria that can grow are those that have acquired a mutation that allows them to make histidine. The number of bacterial colonies that grow is therefore related to the mutagenic potency of the substance being tested.

Chemicals being investigated with the Ames test are first incubated with a liver homogenate. Substances that exhibit strong mutagenic activity in the Ames test also tend to be strong carcinogens. Among this particular group of substances, aflatoxin is the most potent mutagen and the most potent carcinogen.