Taking planets' temperature

A close look at Mars may tell us a lot about Earth and help find the directions required to design future experiments and missions to the Red Planet

S ANANTHANARAYANAN

The geologist, like the physician, learns things by watching heat flows. Just as the body is a machine whose processes generate heat, the internals of a planet are in motion and affect how heat flows out from its centre.

NASA's mission, InSight has just completed its six-month journey to our neighbour planet, Mars and on 26 November, has made a landing at a selected spot, just north of the Mars equator. And InSight carries on board, the "Heat Flow and Physical Properties Package" (HP3), a piece of equipment that can burrow into the Mars soil and measure variations in temperature, down to a depth of five metres. While Nasa has managed the launch and flight, it is the German Aerospace Center (known as DLR - for Deutsches Zentrum für Luft-und-Raumfahrt) that has constructed and would manage the penetration device, which has been evocatively nicknamed the "Mole". "It will be the deepest hole ever hammered into another celestial body using manmade technology", says the information portal that DLR has created.

Mars, the fourth planet from the sun has many things in common with the earth. While Mercury and Venus, which are closer to the sun, are much hotter, Mars has sub-freezing surface temperature. But all these four planets are similar in structure, with a metallic core, mostly iron, surrounded by a molten mantle and then a crust of minerals. The origin of the planets is considered a process of accretion, or the coming together of particles of dust that surrounded the sun during its own formation. While the fledgling planets grew and attracted more dust and rock the centres compressed to high pressures and temperatures rose enormously. There was radioactivity, in the young planets, that added to the heat and the inner region were molten and in the liquid state. In the liquid, the heavier parts, the metals, mostly iron, sank to the centre, while minerals formed the outer regions. In the case of the earth, which is the most massive of the first four planets, the pressure is so high that centre has solidified, nearly all iron, and is surrounded by molten metal and silica.

Mars is about half the size of the earth and has about a tenth of the mass. It also has an iron core, covered by a silicate mantle. The tilt of its axis of rotation is 25.2°, which is near the 23.5° of the earth. Mars, hence, has seasons, just like the earth, through the course of its year, which is 687 earth days long. But, with less gravity, Mars, like the moon, has lost most of its atmosphere. With atmospheric pressure less than 1 per cent of that of the earth, and average surface temperature of minus 60° C, there is no liquid water on Mars. Nevertheless, features like canyons and valleys suggest that there was water, ice and glaciers in the past, and the possibility that there was a form of life too.

Planets, with their hot, often molten, cores, steadily lose heat by radiation from the surface. Convection currents within the core and mantle drive heat outwards, hot material sometimes spewing out in volcanoes. The temperature, however, falls as we approach the surface. The surface itself is heated by the sun, with a day-night cycle, greatly evened out when there is an atmosphere. While there is a feeble day-night temperature wave that passes inwards from the surface, the net result is gradual cooling of the planet, with increasing temperature as one move closer to the centre.

On the earth, the structure and conditions deep under the surface have been studied through bore holes and in mine-shafts, even borings into the bed of the deepest parts of the sea. We know, now, that it gets warmer by about 1°C for every 100 metres that we go deeper into the earth. The study of earthquakes and detecting tremors in the earth have revealed something of the structure of the crust and the mantle and the movement plates of material just above the softer, outer mantle. All this leads to ideas of the formation of the earth and planets, but there is great interest in knowing how it has worked in other planets.

Comparable studies are clearly not possible in other planets, even the nearby ones. While we have detailed pictures of the chemical composition and the atmosphere of Mars and Venus, we have only visual images of surface, and nothing of what lies beneath. There have been several missions to Mars, mainly Orbiters and Landers and the Rovers, Spirit and Opportunity, which landed on the surface of Mars. But the investigations were only of the atmosphere and surface features of Mars. The only geological study outside the earth has been the Apollo programme and the Soviet Luna spacecrafts, which returned lunar rock and lunar soil for study on the earth.

Mission InSight, with DLR's HP3, the Mole, is the first time there would be investigation of the interior of a planet. And "Mars is the perfect destination, as it is relatively easy to reach and makes an ideal comparison object to Earth", the German Aerospace Center (DLR) portal says. As Mars, when it was formed, would have cooled faster than the earth, indicators of the processes involved may be better preserved on Mars, the portal says.

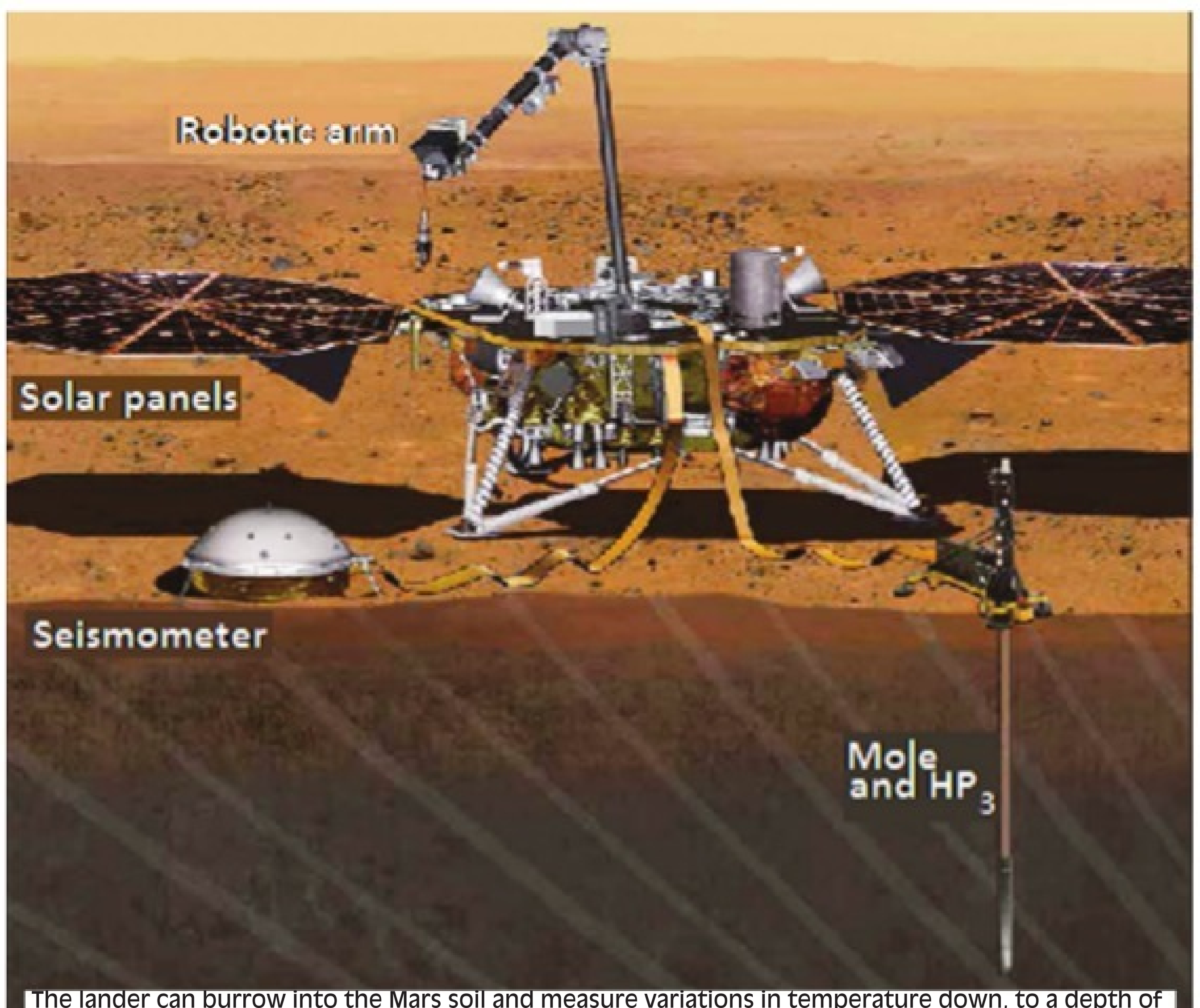
The lander itself is a platform, two metres across, that rests on three telescopic legs. Minutes after landing, the solar panels, which stretch over six metres, are deployed, to provide over 600 watts of power, on a clear day. The platform has a camera that maps the terrain to locate the best spot to place the two main equipment - an ultra-sensitive seismometer, the sensor of surface movements, and the Mole, the device to bore into the ground, with HP3, the arrangement to measure heat flow. And there is a robotic arm that would install the two pieces devices on the ground. The placement may take ten weeks, the DLR mission brochure says.

The heat sensing arrangement consists of a drilling tower, with a 40 cm long and 27 mm wide penetrating device that can hammer down to a depth of five metres into the Martian soil. And there is a casing that contains measuring and data cables, to convey data from platinum temperature sensors up to the computers in the landing craft, and thence to an orbiting relay station.

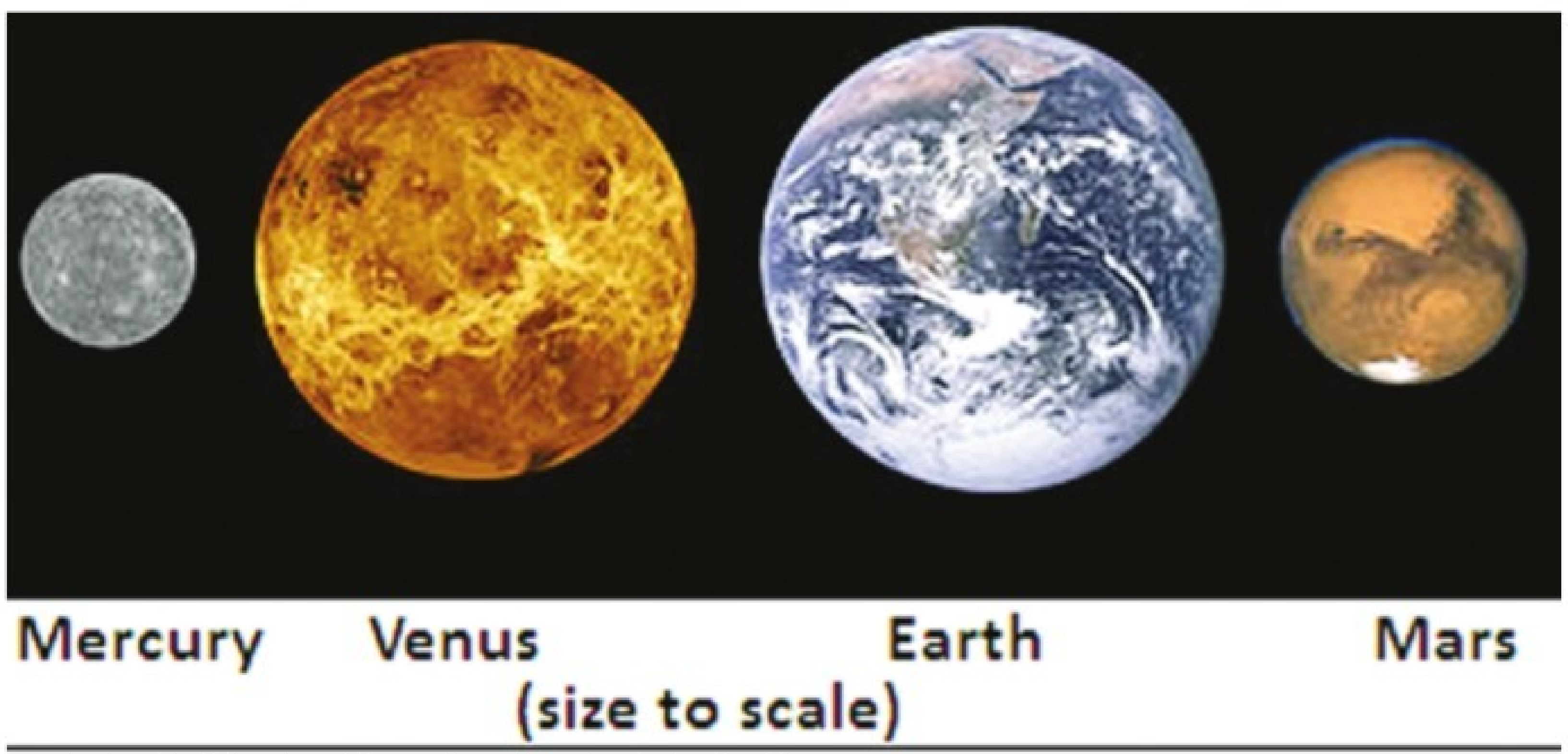
The measuring accuracy of the sensors is a thousandth of a degree. The objective is to measure the heat flow from the interior of the planet to the surface. The change in the temperature as the depth increases is called the geothermal gradient. If we know the gradient and also how well the material of the soil conducts heat, which would be measured during the time it takes for the Mole to drill into the ground, we could work out the amount of heat that is flowing to the surface.

The collected data of the surface conditions and the rate of cooling, by flow of heat from the interior, on Mars, along with data of the seismic, or Marsquake-like, activity, would open a new chapter in our understanding of the structure of Mars. And hence of interpreting what we know about the earth. And then, in what directions we need to design future experiments or missions to Mars!

The writer can be contacted at response@simplescience.in



The lander can burrow into the Mars soil and measure variations in temperature down, to a depth of five metres



Mars is about half the size of the Earth and has about a tenth of the mass

Unravelling the structural components

Here's how the three enzymes called RNA polymerases I, II, and III carry out transcription in the eukaryotic nucleus

TAPAN KUMAR MAITRA

Some of the properties of the three RNA polymerases that function in the nucleus of the eukaryotic cell, as well as two others found in mitochondria and chloroplasts. The nuclear enzymes are designated RNA polymerases I, II, and III. As the table indicates, these enzymes differ in their location within the nucleus and in the kinds of RNA they synthesise. The nuclear RNA polymerases also differ in their sensitivity to various inhibitors, such as -amanitin, a deadly toxin produced by the mushroom Amanita phalloides (known commonly as the "death cap" or "destroying angel").

RNA polymerase I resides in the nucleolus and is responsible for synthesising an RNA molecule that serves as a precursor for three of the four types of rRNA found in eukaryotic ribosomes (28S rRNA, 18S rRNA, and 5.8S rRNA). This enzyme is not sensitive to -amanitin. Its association with the nucleolus is understandable, as the nucleolus is the site of ribosomal RNA synthesis and ribosomal subunit assembly.

A prominent structural component of the eukaryotic nucleus is the nucleolus, the ribosome factory of the cell. Typical eukaryotic cells contain one or two nucleoli, but the occurrence of several more is not uncommon. The nucleolus is usually a spherical structure measuring several micrometers in diameter, but wide variations in size and shape are observed. Because of their relatively large size, nucleoli are easily seen with the light microscope and were first observed more than 200 years ago. However, it was not until the advent of electron microscopy in the 1950s that the structural components of the nucleolus were clearly identified. In thin-section electron micrographs, each nucleolus appears as a membrane-free organelle consisting of fibrils and granules. The fibrils contain DNA that is being transcribed into ribosomal RNA (rRNA), the RNA component of ribosomes. The granules are rRNA molecules being packaged with proteins (imported from the cytoplasm) to form ribosomal subunits. As we saw earlier, the ribosomal subunits are subsequently exported through the nuclear pores to the cytoplasm. Because of their role in synthesising RNA, nucleoli become heavily radiolabeled when the cell is exposed to radioactive precursors of RNA.

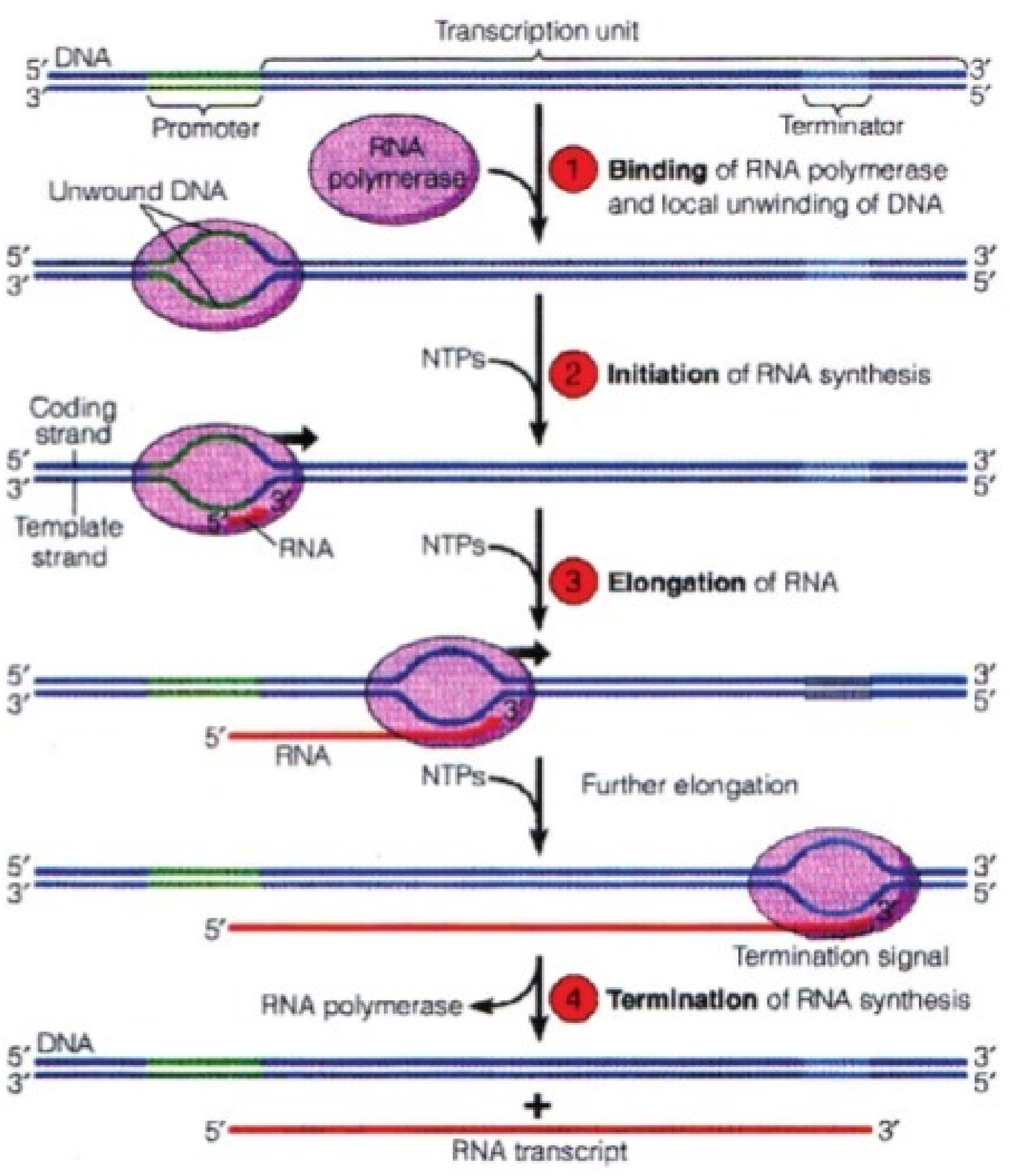
RNA polymerase II is found in the nucleoplasm and synthesises precursors to mRNA, the class of RNA molecules that code for proteins. In addition, RNA polymerase II synthesises most of the snRNAs-small nuclear RNAs involved in posttranscriptional RNA processing. Thus, polymerase II is responsible for the synthesis of the greatest variety of RNA molecules. The enzyme is extremely sensitive to -amanitin, which explains the toxicity of this compound to humans and other animals.

RNA polymerase III is also a nucleoplasmic enzyme, but it synthesises a variety of small RNAs, including tRNA precursors and the smallest type of ribosomal RNA, 5S rRNA. Mammalian RNA polymerase III is sensitive to a-amanitin, but only at higher levels of the toxin than are required to inhibit RNA polymerase II. (The comparable enzymes of some other eukaryotes, such as insects and yeasts, are insensitive to -amanitin.)

Structurally, RNA polymerases I, II, and III are somewhat similar to each other as well as to prokaryotic core RNA polymerase. The three enzymes are all quite large, with multiple polypeptide subunits and molecular weights around 500,000. RNA polymerase II, for example, has more than ten subunits of at least eight different types. The three biggest subunits are evolutionarily related to the prokaryotic RNA polymerase subunits , ?, and / ?'. Three of the smaller subunits lack that relationship but are also found in RNA polymerases II and III. The RNA polymerases of mitochondria and chloroplasts resemble their prokaryotic counterparts closely, as you might expect from the probable origins of these organelles as endosym-biotic bacteria. Like bacterial RNA polymerase, they are resistant to -amanitin.

Transcription in eukaryotic cells involves the same four stages but the process in eukary-otes is more complicated than that in prokaryotes. The main differences are as follows:

- Three different RNA polymerases transcribe the nuclear DNA of eukaryotes. Each synthesises one or more classes of RNA.
- Eukaryotic promoters are more varied than prokaryotic promoters. Not only are different types of promoters employed for the three polymerases, but there is great variation within each type, especially among the ones for protein-coding genes. Furthermore, some eukaryotic promoters are actually located downstream from the transcription start-point.
- Binding of eukaryotic RNA polymerases to DNA requires the participation of additional proteins, called transcription factors. Unlike the bacterial sigma factor, eukaryotic transcription factors are not part of the RNA polymerase molecule. Rather, some of them must bind to DNA before RNA polymerase can bind to the promoter and initiate transcription. Thus, transcription factors, rather than RNA polymerase itself, determine the specificity of transcription in eukaryotes. In this chapter, we limit our discussion to the class of factors that are essential for the transcription of all genes transcribed by an RNA polymerase.
- Protein-protein interactions are very important in the first stage of eukaryotic transcription. Although some transcription factors bind directly to DNA, many attach to other proteins-either to other transcription factors or to RNA polymerase itself.
- RNA cleavage is more important than the site where transcription is terminated in determining the location of the 3' end of the RNA product.
- Newly forming eukaryotic RNA molecules typically undergo extensive RNA processing (chemical modification) both during and, to a larger extent, after transcription.



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

PLUS POINTS

Curbing the heat

Spraying sun-dimming chemicals high above the earth to slow global warming could be "remarkably inexpensive", costing about US$2.25 billion a year over a 15-year period, according to a study by US scientists.

Some researchers say the geo-engineering technique known as stratospheric aerosol injection (SAI) could limit rising temperatures that are causing climate change.

As yet unproven and hypothetical, it would involve the use of huge hoses, cannons or specially designed aircraft to spray large quantities of sulphate particles into the upper layer of the atmosphere to act as a reflective barrier against sunlight.

Total costs to launch a hypothetical SAI effort 15 years from now would be US $3.5 billion, scientists at Harvard University said in a report published in the journal, Environmental Research Letters.

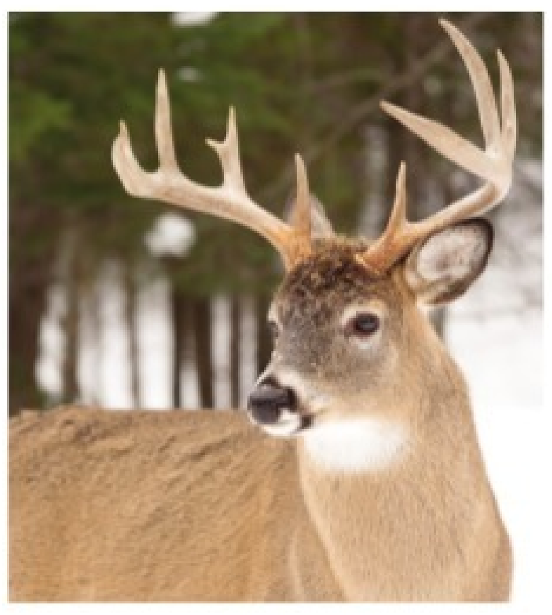
Discounting other methods of deployment because of cost and feasibility, the research assumes a special aircraft can be designed to fly at an altitude of about 20km and carry a load of 25 tones.

After direct input from several aerospace and engine companies, the scientists said they have developed a design that could be suitable and could be ready to be deployed in 15 years, aiming to cut the rate of temperature change in half. The scientists emphasised that this is merely a hypothetical scenario.

There are risks to such unproven potential technologies. Scientists have said SAI could result in negative consequences such as causing droughts or extreme weather in other parts of the world, harm crop yields as well as potential public health and governance issues. It also does not address the issue of rising carbon dioxide emissions, the main greenhouse gas blamed for global warming.

The straits times/ann

Rapid regrowth



Every spring, male deer undertake a unique biological ritual: sprouting and rapidly regrowing their massive, spiky antlers. A complex matrix of bone, living tissue and nerve endings, deer antlers can reach 50 inches long and weigh more than nine kilogram. Not only are the antlers useful in attracting mates and fighting, they qualify deer as the only mammal that can regrow lost body parts.

Researchers say that they have identified the two genes primarily responsible for antler regeneration in one species, fallow deer. The study, reported recently in the Journal of Stem Cell Research and Therapy, notes that these genes are also found in humans, potentially opening new avenues of research into bone trauma and diseases.

Peter Yang, an orthopaedic researcher at the Stanford University School of Medicine and senior author of the study and his colleagues travelled to a deer farm in California to take samples of early antler tissue, which consists primarily of stem cells from male red deer.

After analysing the genes in the samples, the researchers tried shutting down some and revving up others to determine which function they controlled. They compared samples of RNA from the antlers with human RNA in search of overlaps. They then tinkered with the relevant genes in mice to see how they affected tissue growth.

The team eventually narrowed their focus to two genes, "uhrf1" and "s100a10", both of which have previously been linked to bone development in humans. Yang and his team concluded that the two genes work in tandem to generate rapid antler growth in deer.

The Independent