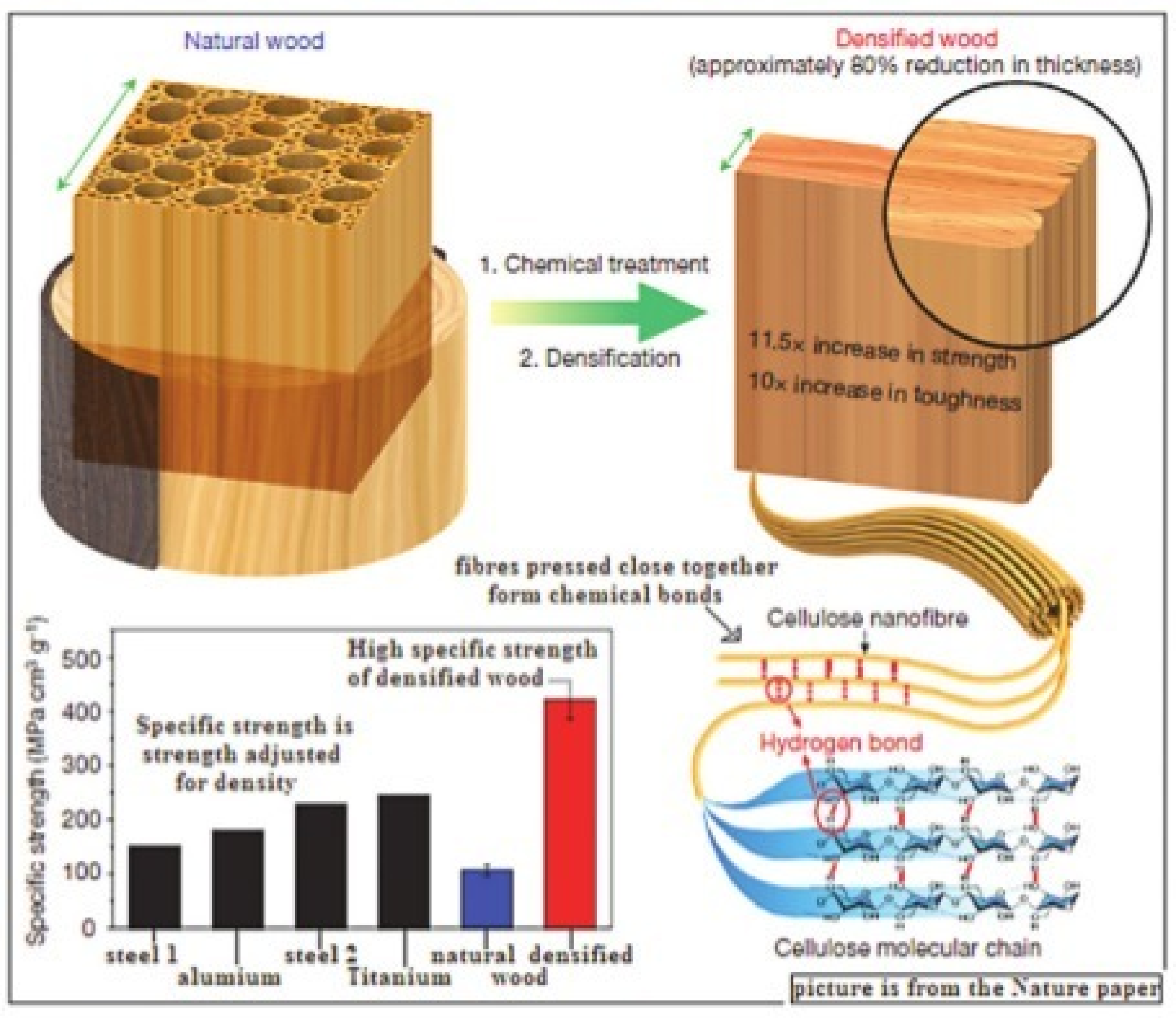
Flexing its muscles

A recently discovered process of making wood denser should set architects and designers thinking about ways to adapt to greener materials

S ANANTHANARAYANAN



picture is from the Nature paper

The expansion of civil work and tall structures in modern times is a result of the variety of shapes we can create with cement and concrete and the enormous strength concrete can have when it is reinforced by steel bars.

The use of cement and steel, and even plastics, which have now appeared, however, involves huge energy input and carbon emission in their production. In contrast, the use of wood as the main building material in earlier times was eco-friendly, even if wood, as a material, has less strength and durability. A technique to process wood to grow many times in strength and resilience, even higher than other materials, would hence be of great interest.

Jianwei Song, Chaoji Chen, Shuze Zhu, Mingwei Zhu, Jiaqi Dai, Upamanyu Ray, Yiju Li, Yudi Kuang, Yongfeng Li,Nelson Quispe, Yonggang Yao, Amy Gong, Ulrich H Leiste, Hugh A. Bruck, JY Zhu, Azhar Vellore, Heng Li, Marilyn L Minus, Zheng Jia, Ashlie Martini, Teng Li and Liangbing Hu, of the University of Maryland, Northwestern University, University of California at Merced and the Forest Products Laboratory, Wisconsin, report in the journal, Nature, a method to compress natural wood and make it stronger,weight for weight, than steel.

The strength of materials arises mainly from the strength of the atom-level bonding between the microscopic components of the material. Denser materials, whose composing units are closer packed, would hence be stronger, and this is true in the transition from the less-dense wood, an organic material, to denser cement, which is composed of minerals, and then to the densest, the metals.

In the case of wood, its structure has evolved specifically to include channels for water and nutrients and to have strength only enough to support the weight of the tree. Wood thus contains voids, has low density and little capacity to withstand a crushing load. However, as it has fibres that run along the direction of growth, which help a tree withstand high winds, wood can stand bending or stretching forces. This is the property that has made wood useful in constructing beams that support each floor of a building. Very tall structures made of wood, however, have not been possible.

Cement and concrete, in contrast, have high compression strength and can work as the supports for beams, which, as cement and concrete cannot bear bending or stretching, have necessarily been of wood. Steel, however, has high compressive strength as well as the capacity to resist bending, a capacity that is called tensile strength. While steel structures, like some bridges or the Eiffel Tower, could hence be very strong, metals have high density (steel is 7.5 to 8 gms per cc) and add to the weight of the structure, which tends to limit how high any structure can be.

Reinforced concrete is a mixture of cement, sand and gravel that contains steel rods that that bind firmly to the cement. While concrete can bear compression, the steel rods provide the capacity to bear bending forces and the combination, although only part of its volume is steel, has great overall strength. The production of the materials, cement and steel, however, consumes energy and the use of reinforced concrete is a cause of pollution.

Special plastics and petroleum-based substances have also found application as building material, especially when given tensile strength by reinforcement with glass fibre. Even with plastics, however, the financial and environment costs are high and do not allow these materials to be widely used.

Coming back to wood, we have noted that a reason for its limitations is that it is not dense and its structure has voids. A method to remedy this has been by steam treatment and compression. Methods like this, the authors of the paper in *Nature* say, are still not able to eliminate the voids completely. While there is improvement in strength, the result is not durable, particularly in response to humidity.

The authors discuss the structure of wood, as containing tubular channels, whose cells consist mostly of cellulose, along with material called "hemicelluloses" and "lignin". Cellulose is a long chain molecule, thousands of units long, and contributes to the tensile strength of wood. Hemicellulose has little strength to contribute and lignin helps in structural stability.

When wood is chemically treated, there is great reduction of hemicelluloses and lignin but the cellulose largely remains. This reduction makes the cell walls porous and less rigid. As a result, on hot-pressing, the tubular structures and the cell walls collapse and wood can be compressed down to 20 per cent of the original thickness, with a three-fold increase in density.

"The fully collapsed wood cell walls are tightly intertwined along their cross-section and densely packed along their length direction," the paper says. And at a finer scale, the cellulose nanofibres are aligned and also densely packed. This increases the area of contact between neighbouring nanofibres and promotes chemical bonds to form, which leads to more than 10 times higher mechanical strength of densified wood. A record high tensile strength of densified wood is 587 MegaPascals, which is greater than that of structural steel (400-550 MPa), the paper says.

While densified wood attains high mechanical strength along the direction of alignment of cellulose nanofibres, the authors went one better by laminating two layers of natural wood with the orientation of wood fibres crossed, and then carrying out the process of leaching and hot compression. The result was a composite, which showed high tensile strength (~ 225MPa) in all directions. Densified wood has also shown good performance in toughness, impact resistance and in high humidity, the paper says. Wood could hence become a viable alternative material to use for structural members, even for containers or other areas where metals are used.

While it is possible that wood could take the place of steel in many applications, one could also say that this would lead to increased felling of trees. This question could be put in context by considering that the manufacture of a kilogram of pig iron takes about half a kg of coke and emits about two kg of CO_2. An average tree fixes some 1100 kg of CO_2 in a lifetime. The loss of a tree could thus be acceptable if it led to saving about 550 kg of steel, which appears to be feasible. Another aspect is that 1100 kg of CO_2 emission is avoided as soon as 550 kg of steel is replaced by the wood from one tree, whereas the tree would take many years to fix the same CO_2. And then, the tree could be replanted!

The process reported in the *Nature* paper should set architects and designers thinking about ways to adapt to greener materials.

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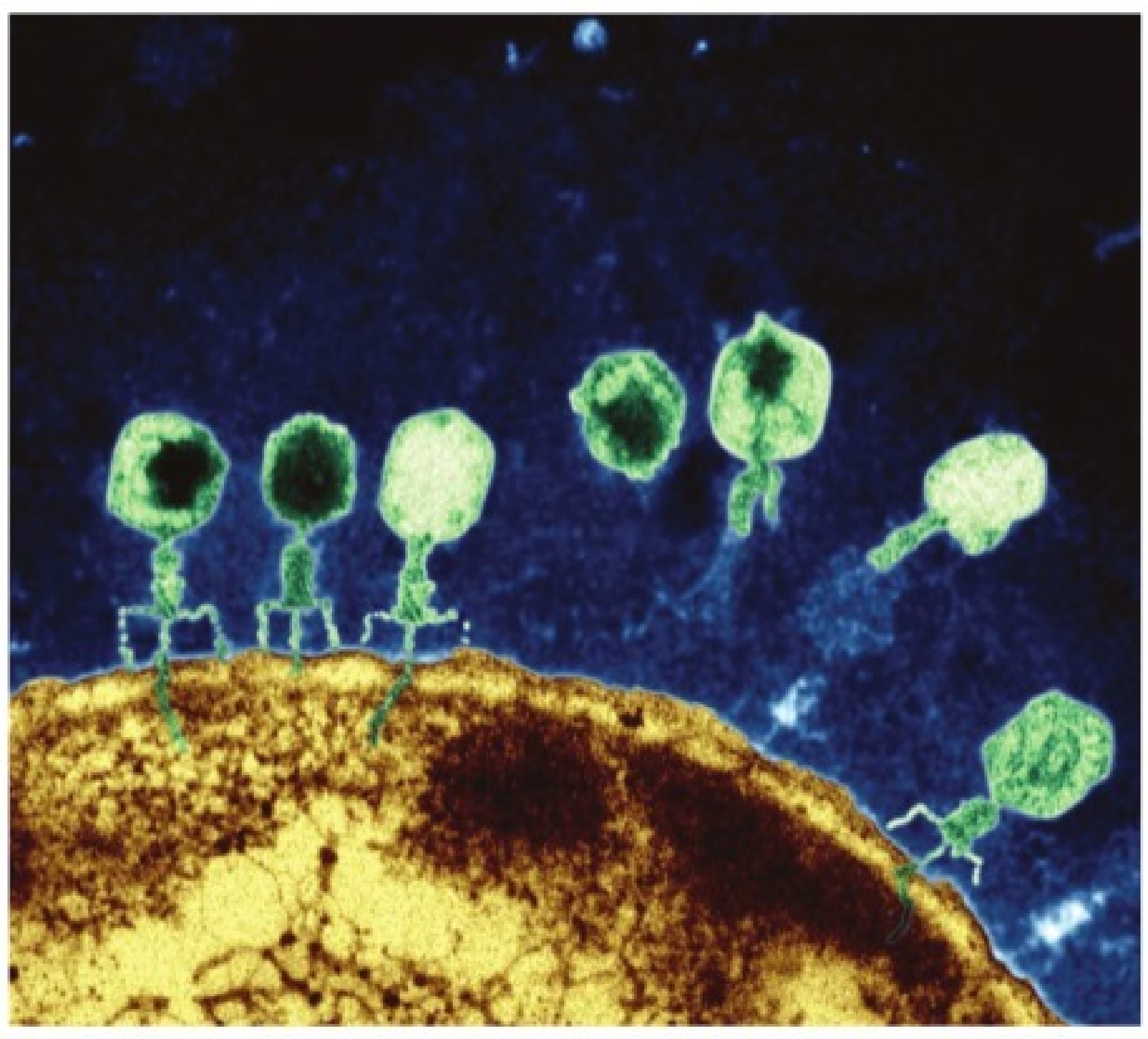
Storing vital information

Alfred Hershey and Martha Chase showed that DNA is the genetic material of viruses



TAPAN KUMAR MAITRA

Bacteriophages are viruses that infect bacteria. They have been objects of scientific study since the 1930s, and much of our early understanding of molecular genetics came from experiments involving these viruses.

One of the most thoroughly studied of the phages that infect the bacterium *Escherichia coli* is bacteriophage T2. During infection, this virus attaches to the bacterial cell surface and injects material into the cell. Shortly thereafter, the bacterial cell begins to produce thousands of new copies of the virus. This scenario suggests that the material injected into the bacterial cell carries the genetic information that guides the production of the virus.

What is the chemical nature of the injected material? In 1952, Alfred Hershey and Martha Chase designed an experiment to address this question. Only two possibilities exist because the T2 virus is constructed from only two kinds of molecules — DNA and protein. To distinguish between these two alternatives, Hershey and Chase took advantage of the fact that the proteins of the T2 virus, like most proteins, contain the element sulphur (in the amino acids methionine and cysteine) but not phosphorus while the viral DNA contains phosphorus (in its sugar-phosphate backbone) but not sulphur.

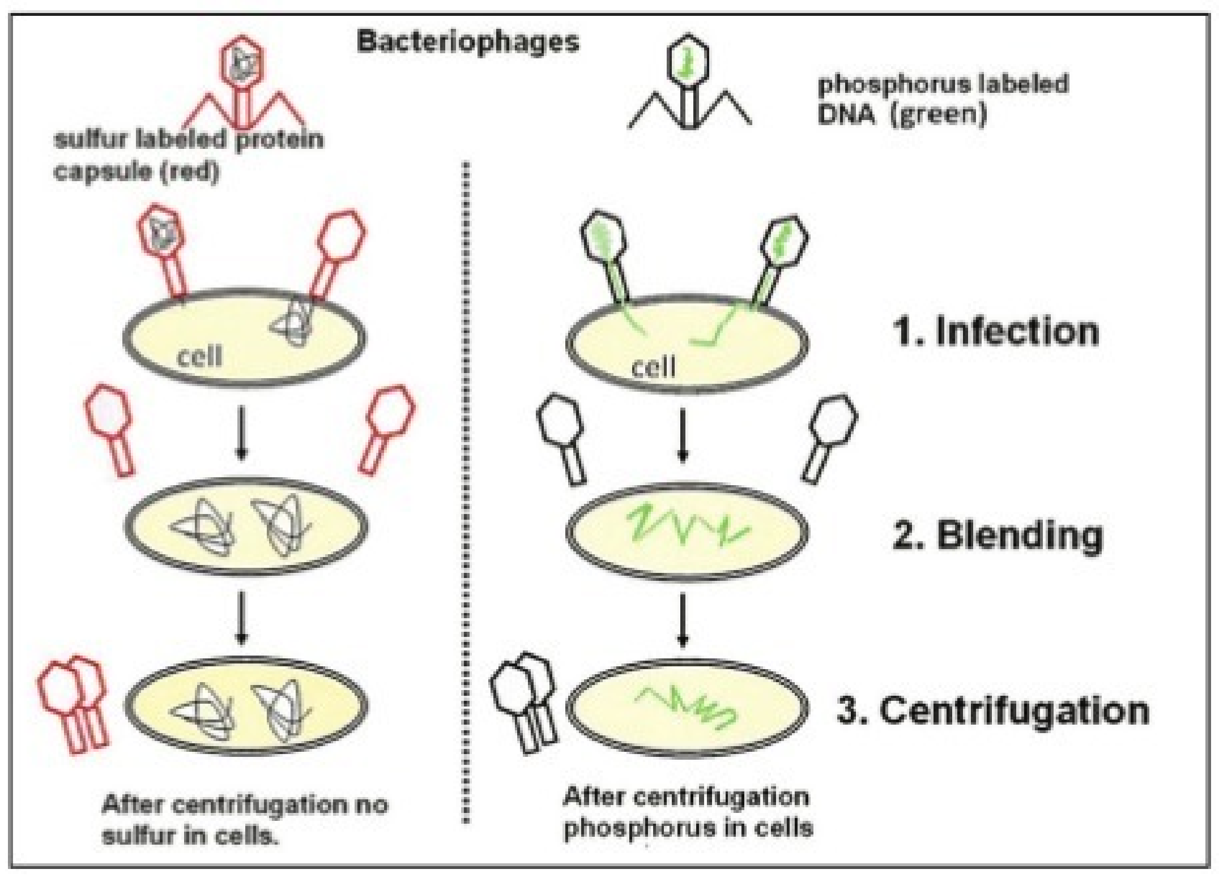
Hershey and Chase therefore prepared two batches of T2 phage particles (as intact phages are called) with different kinds of radioactive labelling. In one batch, the phage proteins were labelled with the radioactive isotope ^{35}S; in the other batch, the phage DNA was labelled with the isotope ^{32}P.

By using radioactive isotopes in this way, Hershey and Chase were able to trace the fates of both protein and DNA during the infection process. They began the experiment by mixing radioactive phage with intact bacterial cells and allowing the phage particles to attach to the bacterial cell surface and inject their genetic material into the cells. At this point, Hershey and Chase found that the empty protein coats (or phage "ghosts") could be effectively removed from the surface of the bacterial cells by agitating the suspension in an ordinary kitchen blender and recovering the bacterial cells by centrifugation. They then measured the radioactivity in the supernatant liquid and in the pellet of bacteria at the bottom of the tube.

The data revealed that most (65 per cent) of the ^{32}P remained with the bacterial cells, while the bulk (80 per cent) of the ^{35}S was released into the surrounding medium. Since the ^{32}P labelled the viral DNA and the 35S labelled the viral protein, Hershey and Chase concluded that DNA, not protein, had been injected into the bacterial cells and hence must function as the genetic material of phage T2.

This conclusion received further support from the following observation — when the infected, radioactive bacteria were resuspended in fresh liquid and incubated longer, the ^{32}P was transferred to some of the offspring phage particles, but the ^{35}S was not.

As a result of the experiments, by the early 1950s most biologists came to accept the view that genes are made of DNA, not protein. Unfortunately, Oswald Avery, the visionary most responsible for the complete turnabout in views concerning the function of DNA, never received the credit he so richly deserved. The Nobel Prize Committee discussed Avery's work but decided he had not done enough. Perhaps Avery's modest and unassuming nature was responsible for this lack of recognition. After Avery died in 1955, the biochemist Erwin Chargaff wrote in tribute, "He was a quiet man; and it would have honoured the world more, had it honoured him more."



Schematic diagram of the Hershey-Chase Experiment

Why did the Hershey-Chase experiments receive a warmer welcome than Avery's earlier work on bacterial transformation, even though both led to the same conclusion? The main reason seems to have been simply the passage of time and the accumulation of additional, circumstantial evidence after Avery's 1944 publication. Perhaps most important was evidence that DNA is indeed variable enough in structure to serve as the genetic material. This evidence came from studies of DNA base composition.

Despite the lukewarm reaction initially received by Avery's work, it was an important influence on several other scientists. Among them was Chargaff, who was interested in the base composition of DNA. Between 1944 and 1952, Chargaff used chromatographic methods to separate and quantify the relative amounts of the four bases — adenine (A), guanine (G), cytosine (C), and thymine (T) — found in DNA.

Several important discoveries came from his analyses. First, he showed that DNA isolated from different cells of a given species have the same percentage of each of the four bases, and that this percentage does not vary with individual, tissue, age, nutritional state or environment. This is exactly what would be expected of the chemical substance that stores genetic information because the cells of a given species would be expected to have similar genetic information.

However, Chargaff did find that DNA base composition varies from species to species. Comparison of such data revealed to Chargaff that DNA preparations from closely related species have similar base compositions, whereas those from very different species tend to exhibit quite different base compositions. Again, this is what would be expected of a molecule that stores genetic information.

But Chargaff's most striking observation was his discovery that for all DNA samples examined, the number of adenines is equal to the number of thymines (A=T), and the number of guanines is equal to the number of cytosines (G = C). This meant that the number of purines is equal to the number of pyrimidines (A + G = C + T).

The significance of these equivalencies, known as Chargaff's rules, was an enigma and remained so until the double-helical model of DNA was established by Watson and Crick in 1953.

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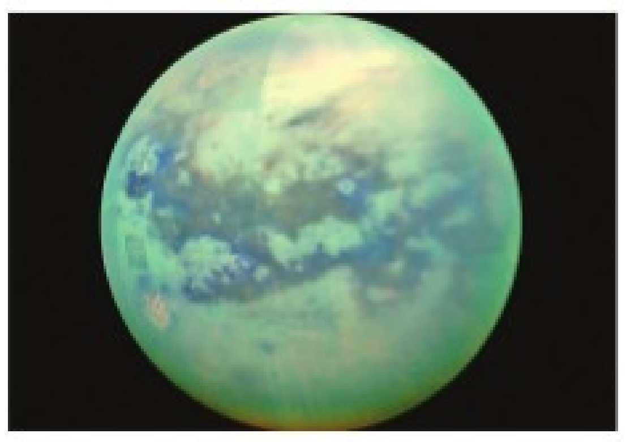
PLUS POINTS

Titan on Earth



A Nasa handout image of Titan

An artist's impression of the submarine

An "alien" ocean has been built on Earth by researchers. The simulation of another world could help us explore more of our solar system and understand the strangeness that lurks within it.

Scientists one day hope to be able to plunge a submarine under the surface of Titan, Saturn's biggest moon. Nasa hopes to be able to do so within the next 20 years.

But doing that is going to be tough, given that the surface is very cold, at around -300 Fahrenheit, and the ocean is made of methane and ethane. It's those characteristics that make it so interesting to researchers — unlike anywhere else in our solar system, it has oceans, rivers, clouds and rain like our own, but emerging from a cycle based on methane not water — but it's also what makes it such a hard place to explore.

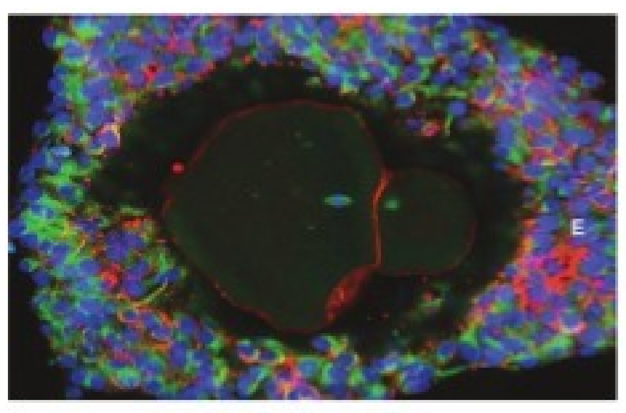
It will be important to make sure that anything we build can withstand the difficult and dangerous environment on the planet. It will not only have to survive moving around Titan's seas but even taking video from them, which can be used by scientists back at home on Earth to understand more about the strange world's atmosphere.

To do that, a researcher at Washington State University built a small version of Titan's seas, allowing for the testing of a heated submarine of the kind Nasa might send along. They built a small chamber that housed the liquid mixture that is found on the planet and simulated its low temperatures, and they also built a small model that was able to simulate the same heat the submarine will give off.

"My research just took a right turn, and I went with it," said Ian Richardson, a former graduate student in the University's School of Mechanical and Materials Engineering who worked on the effort.

The Independent

Born in the lab



Scientists have succeeded for the first time in growing human eggs in a laboratory from the earliest stages in ovarian tissue all the way to full maturity — a step that had previously been taken in mice.

Publishing their result in the journal *Molecular Human Reproduction* last week, scientists from Britain and the US said that it could one day help in developing regenerative medicine therapies and new infertility treatments. In previous studies, scientists had developed mouse eggs in a laboratory to the stage where they produced live offspring, and had also matured human eggs from a relatively late stage of development.

This latest work, by scientists at two research hospitals in Edinburgh and the Center for Human Reproduction in New York, is the first time human eggs have been developed outside the human body from their earliest stage to full maturity.

Independent experts not directly involved in this work praised it as important, but also cautioned that there is much more to do before lab-grown human eggs could be safely be made ready for fertilisation with sperm.

"This early data suggests this may well be feasible in the future," said Ali Abbara, a senior clinical lecturer in endocrinology at Imperial College London. "(But) the technology remains at an early stage, and much more work is needed to make sure that the technique is safe and optimised."

If success and safety rates were improved, it could in future help cancer patients wishing to preserve their fertility while undergoing chemotherapy treatment, improve fertility treatments, and deepen scientific understanding of the biology of the earliest stages of human life.

The straits times/ann