Processing of blood at Sankalp Blood Centre, Bengaluru

LAB-GROWN LIQUID LIFE

As global shortages persist, researchers race to craft artificial blood that works as well as nature's own

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PHOTOGRAPHS: GOUTHAM V

The sight of blood has a way of unsettling people. It can make one dizzy or glued to the seat during a slasher flick. But beyond fear or fascination, blood is life itself—the body's constant messenger and rescuer. It carries oxygen, removes waste and sustains every living tissue. Yet hospitals and blood banks are in a state of perpetual crisis, often running dangerously low.

This unending shortage has fuelled one of medicine's most ambitious pursuits: to create artificial blood. But after years of false starts, breakthroughs in molecular biology, nanotechnology and stem-cell science are offering hope that science may finally manage to bottle life.

THE LIQUID ORGAN

To make synthetic blood is to attempt to mimic a miracle. Blood is, in essence, a 'liquid organ'. It is not just a fluid; it is a living tissue in motion—carrying nutrients, fighting infection and repairing the body. Its complexity is immense, making duplication exceptionally difficult.

"Even though it is complex, these are all solvable problems, with enough time, money and the right people involved," says Dr Allan Doctor, professor of paediatrics and director of the Centre for Blood Oxygen Transport and Haemostasis at the University of Maryland. He also co-founded KaloCyte, a firm working on artificial blood products.

Each component of blood performs distinct and delicate tasks. Plasma contains thousands of proteins; platelets form clots to stop bleeding; and red blood cells (RBCs) ferry oxygen through haemoglobin—a molecule that must be both stable and safe.

Artificial substitutes must do all this while avoiding immune rejection and breaking down harmlessly once the job is done. The challenge, as Dr Allan puts it, is to replicate what evolution perfected.

LONG & BLOODY QUEST

The idea of replacing blood is not new. In 1960s, scientists astonished the world by showing that a mouse could survive immersed in oxygen-rich perfluorocarbon liquids. This experiment gave birth to the first artificial oxygen carriers. They worked briefly but were inefficient and soon discarded.

The next wave focused on haemoglobin-based oxygen carriers (HBOCs)—injecting chemically modified haemoglobin rather than intact RBCs. This proved disastrous. Free haemoglobin, outside the protective membrane of RBCs, scavenges nitric oxide, a molecule vital for relaxing blood vessels. This scavenging led to high blood pressure, vessel constriction and organ stress.

"There's a reason it [haemoglobin] is inside RBCs," says Dr Allan. "It's toxic if it's free in your bloodstream. Evolution determined that the best way to move oxygen is with haemoglobin, and the best way for haemoglobin to move in the bloodstream is to be inside a cell."

After a series of failures, including some fatal trial outcomes, research in this area nearly stopped by the early 2000s. It is only now, with new scientific tools, that the field has begun to recover.

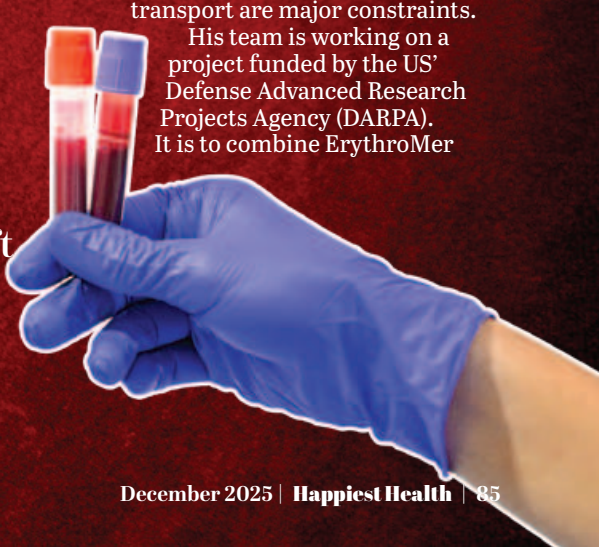
BUILDING BIO-INSPIRED PARTICLES

Dr Allan and his collaborator, Dr Dipanjan Pan of Penn State University, are among those leading this revival. Together, they developed ErythroMer, a microscopic, cell-like particle designed to carry oxygen safely through the bloodstream.

Each ErythroMer particle consists of a lipid membrane that encapsulates haemoglobin, mimicking the natural RBC. The membrane prevents haemoglobin from reacting harmfully while allowing it to pick up and release oxygen efficiently.

"If you put it inside an artificial membrane, then it could be safe," he explains. The innovation does not stop there. ErythroMer can be freeze-dried, stored at room temperature, and reconstituted when needed—an advantage in emergency medicine or war zones, where blood storage and transport are major constraints.

His team is working on a project funded by the US' Defense Advanced Research Projects Agency (DARPA). It is to combine ErythroMer



with freeze-dried plasma and synthetic platelets to create an artificial form of whole blood. "It works on small animals. We think we are about two years away from human trials," he says.

Japan has seen similar progress, with researchers testing encapsulated haemoglobin and lipid shells reported to function across various blood types, and offering longer shelf-life than standard red blood cells.

THE LIVING FACTORY

A different approach is taking shape at the University of Cambridge. Prof Cédric Ghevaert and his team are growing RBCs from stem cells. Unlike synthetic materials, these lab-grown cells are living and function exactly like those in our veins.

"They simply mimic better the systems we currently enjoy naturally. Enclosed in a cell, active molecules like haemoglobin or clotting factors are protected from destruction and are not toxic. They last much longer after administration. A red cell has a life span of 120 days, while HBOCs last only hours," says Ghevaert.

His team recently conducted the RESTORE trial, the world's first clinical study to compare lab-grown red cells with donor blood. "The trial was designed so that several recipients received both the stem-cell-derived RBCs and donor RBCs, enabling a statistically significant comparison," he explains.

"Patients with thalassaemia, sickle-cell disease or incredibly rare blood groups, for whom finding matched red cells is an awful challenge, stand to benefit the most," says Ghevaert.

If all goes well, he estimates, "We're talking about five to 10 years when these products could become available. First for specific patient populations, then widened to larger groups such as those with sickle-cell anaemia and thalassaemia."

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director, Centre for Blood Oxygen Transport and Haemostasis, University of Maryland

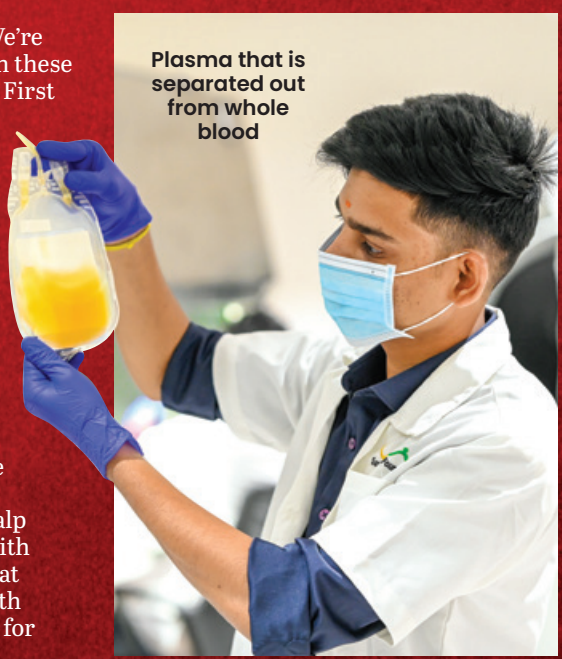
VIEW FROM THE FRONT LINE

That timeline matters deeply in countries like India, which has among the world's highest burdens of thalassaemia. Individuals with the condition rely on frequent transfusions, and a shortage of safe, compatible blood is a constant danger.

Rajat Agarwal, president, Sankalp India Foundation, which works with people with thalassaemia, says that while India is becoming better with voluntary donations, the demand for blood is still increasing.

"The collection is not keeping pace with demand, and we still have a huge amount of disparity when it comes to availability of blood from place to place within the country," Agarwal says.

He believes synthetic blood could be transformative if it becomes safe, universal and affordable. "If you could make blood that's affordable and universal—not dependent on donor matching—it would be a blessing. But the economics must work," he says.



For now, he sees the most immediate potential in synthetic platelets—simpler cells that may be easier to manufacture—and in universal substitutes that bypass the need for blood grouping.

THE ROAD AHEAD

From encapsulated haemoglobin to lab-grown cells, the quest for artificial blood is finally moving from the speculative to the tangible. The ultimate goal, as Dr Allan puts it, "is to prevent people from dying before they can get to a hospital".

For Ghevaert, it is the thrill of seeing the first manufactured cells enter a patient's vein. "I remember the first time I injected manufactured cells, that feeling of 'wow, this is truly a giant leap'," he says.

And for people like Agarwal, who see the human cost of blood shortages every day, the prospect of synthetic blood brings hope. "Artificial blood won't replace donors anytime soon. However, if it becomes safe, universal and affordable, it could save countless lives over time."