3-D printing the human heart

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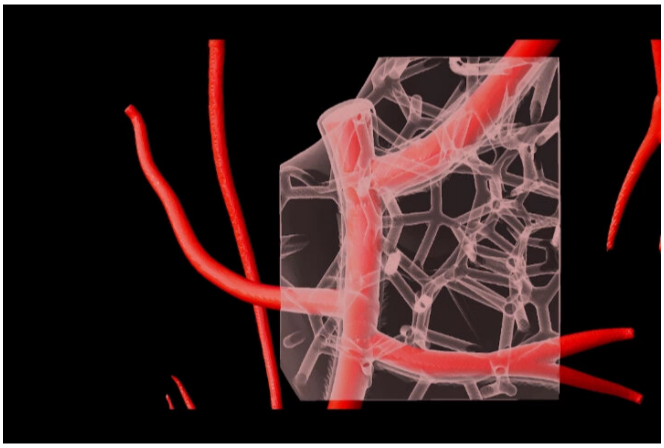


Carnegie Mellon University researchers have developed a technique to 3D bioprint collagen, allowing them to fabricate fully functional components of the human heart. Credit: Carnegie Mellon University College of Engineering

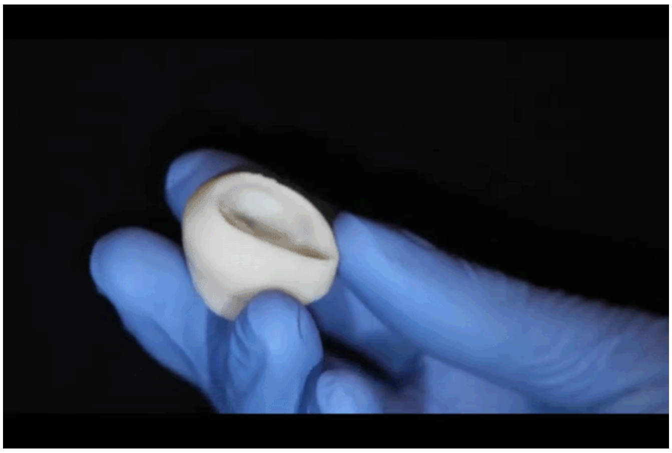
A team of researchers from Carnegie Mellon University has published a paper in *Science* that details a new technique allowing anyone to 3-D bioprint tissue scaffolds out of collagen, the major structural protein in the human body. This first-of-its-kind method brings the field of tissue engineering one step closer to being able to 3-D print a full-sized, adult human heart.

The technique, known as Freeform Reversible Embedding of Suspended Hydrogels (FRESH), has allowed the researchers to overcome many challenges associated with existing 3-D bioprinting methods, and to achieve unprecedented resolution and fidelity using soft and living materials.

Each of the organs in the human body, such as the heart, is built from specialized cells that are held together by a biological scaffold called the extracellular matrix (ECM). This network of ECM proteins provides the structure and biochemical signals that cells need to carry out their normal function. However, until now it has not been possible to rebuild this complex ECM architecture using traditional biofabrication methods.

"What we've shown is that we can print pieces of the heart out of cells and collagen into parts that truly function, like a heart valve or a small beating ventricle," says Adam Feinberg, a professor of biomedical engineering (BME) and materials science & engineering at Carnegie Mellon, whose lab performed this work. "By using MRI data of a human heart, we were able to accurately reproduce patient-specific anatomical structure and 3-D bioprint collagen and human heart cells."

Over 4000 patients in the United States are waiting for a heart transplant, while millions of others worldwide need hearts but are ineligible for the waitlist. The need for replacement organs is immense, and new approaches are needed to engineer artificial organs that are capable of repairing, supplementing, or replacing long-term organ function. Feinberg, who is a member of Carnegie Mellon's *Bioengineered Organs Initiative*, is working to solve these challenges with a new generation of bioengineered organs that more closely replicate natural organ structures.



A researcher displays the pliability of a trileaf heart valve bioprinted in collagen. Credit: Carnegie Mellon University College of Engineering

"Collagen is an extremely desirable biomaterial to 3-D print with because it makes up literally every single tissue in your body," explains Andrew Hudson, a BME Ph.D. student in Feinberg's lab and co-first author on the paper. "What makes it so hard to 3-D print, however, is that it starts out as a fluid—so if you try to print this in air it just forms a puddle on your build platform. So we've developed a technique that prevents it from deforming."

The FRESH 3-D bioprinting method developed in Feinberg's lab allows collagen to be deposited layer-by-layer within a support bath of gel, giving the collagen a chance to solidify in place before it is removed from the support bath. With FRESH, the support gel can be easily melted away by heating the gel from room temperature to body temperature after the print is complete. This way, the researchers can remove the support gel without damaging the printed structure made of collagen or cells.

This method is truly exciting for the field of 3-D bioprinting because it allows collagen scaffolds to be printed at the large scale of human organs. And it is not limited to collagen, as a wide range of other soft gels including fibrin, alginate, and hyaluronic acid can be 3-D bioprinted using the FRESH technique, providing a robust and adaptable tissue engineering platform. Importantly, the researchers also developed open-source designs so that nearly anyone, from medical labs to high school science classes, can build and have access to low-cost, high-performance 3-D bioprinters.

Looking forward, FRESH has applications in many aspects of regenerative medicine, from wound repair to organ bioengineering, but it is just one piece of a growing biofabrication field. "Really what we're talking about is the convergence of technologies," says Feinberg. "Not just what my lab does in bioprinting, but also from other labs and small companies in the areas of stem cell science, machine learning, and computer simulation, as well as new 3-D bioprinting hardware and software."

"It is important to understand that there are many years of research yet to be done," adds Feinberg, "but there should still be excitement that we're making real progress towards engineering functional human tissues and organs, and this paper is one step along that path."

More information: A. Lee el al., "3D printing of collagen to rebuild components of the human heart," *Science* (2019). science.sciencemag.org/cgi/doi … 1126/science.aav9051

Q. Dasgupta el al., "A FRESH SLATE for 3D bioprinting," *Science* (2019). science.sciencemag.org/cgi/doi … 1126/science.aay0478

Provided by Carnegie Mellon University