Home

[Site Map]

Departments

[What is Progressive Engineer?]

[Engineer's Job Market]

[Advertising, Directory Listing, and Job Posting Information]

[Engineering Resources and Weblinks]

[Engineering Firm Directory - Find a Firm]

[How Engineering Firms Operate and How to Select One]

[Sustainability Firm Directory]

[Back Issues]

[Engineering Schools]

[Online Engineering Education Programs]

[Tom Gibson's Consulting Services and Green Building Technologies Portfolio]

[Can We Write an Article About You?]

Profile

Rich McFarland:
HVAC technician invents an instrument to test pressure switches in furnaces and goes entrepreneurial with it.

Profile

Nick Fenelli:
Mechanical engineer heads Vehicle Technologies, a company pioneering a novel omni-directional wheel for forklifts and myriad other

Progressive ENGINEER
COMPANY PROFILE

Organovo

Tissues Made to Order

Applying the 3D printing process used for rapid prototyping in manufacturing to creating human tissues will facilitate organ transplants and help pharmaceutical companies test new drugs, among other benefits.

By Steve Murray

Organovo chairman and CEO Keith Murphy has a chemical engineering background.

By 2007, Keith Murphy wanted a change. After working 17 years for large biotech companies, the chemical engineer and MIT graduate sought an entrepreneurial opportunity. "I needed something more fast-paced and that really involved innovation," he says. At the same time, Dr. Gabor Forgacs, a biophysicist at the University of Missouri-Columbia, had developed a new 3D printing technology for biological materials and was looking for a way to commercialize it.

The two met, saw the potential in collaborating, and started Organovo, a San Diego, California company that may represent the future of regenerative medicine. Organovo is using 3D printing to fabricate human tissues, an advance that could lead to faster drug development and eventually to artificial organs that save lives.

Three-dimensional printing has been around since the 1980s as a rapid prototyping and manufacturing tool. These printers work essentially like their inkjet counterparts, with a few important additions. A computer applications.

Company Profile

Organovo:
Applies the 3D printing process used for rapid prototyping in manufacturing to creating human tissues.

program guides an inkjet printer cartridge to locations on a sheet of paper, where the tip deposits ink. Color printing employs several cartridges, each with a different ink color, and additional computer instructions about which ink to deposit at which location. Inkjet printing generates a single layer of text and images on a flat page and, because the page is two-dimensional, the computer program only needs a two-dimensional model of the output to control the job.

On the other hand, 3D printer cartridges typically contain plastics in place of ink. The material is softened by heating and then deposited onto a flat surface, where it solidifies. However, 3D printers perform this operation again and again, going over the surface repeatedly and leaving additional layers of material until the final object has a vertical, as well as horizontal, shape.

Biological printing is an extension of the 3D printing process used to quickly build prototypes in manufacturing.
Courtesy ProtoCAM

Printing more complex objects also employs multiple cartridges, each with a different material. Differences can involve physical properties or just color, but at least one material is used as a temporary scaffolding to support the main structure during fabrication and is removed at the end of the printing operation. These types of printers can build very delicate and intricate objects with interlocking or moveable parts. Because 3D printing generates three-dimensional objects, the controlling program needs a three-dimensional model such as a CAD file to guide the cartridges.

Such 3D printing technologies have several advantages for sustainable manufacturing. The building approach is additive; 3D printing deposits only the material needed for construction. More conventional machining tools such as mills and lathes are subtractive, cutting material away from stock and generating scrap. Printing with controllable cartridges also avoids many of the tooling and setup costs of other manufacturing methods, so the approach is ideally suited for small or complex production runs. Finally, the technology is versatile; the same 3D printing machines can be used to make such things as furniture, structural walls for houses, clothing, toys, and even food products. Some innovative companies are even beginning to explore the use of recycled materials as feedstock for 3D-printed products.

Link to Life Sciences

Medical applications of 3D printing are largely extensions of manufacturing concepts. Computer models are generated with X-ray or MRI scanning of a patient and used to print products tailored to that individual, such as replacement teeth and bridgework. The technology will likely streamline some current medical procedures, and improve their outcome, through fabrication of very complex body structures. Ball-and-socket joints used in hip replacements, for example, can be printed as an integrated assembly, avoiding the need to cut a patient’s bone to match the prosthetic.

The leap to tissue engineering probably occurred when a researcher noticed that drops from an inkjet cartridge were about the same size as human cells, and this is where the Organovo story picks up again. The new company built its first 3D bioprinter in 2009 with support from Invetech, a Melbourne, Australia-based engineering firm with experience in life science applications. Their NovoGen MMX was the first commercial 3D printer technology proven to fabricate actual tissue from cells and the first to work across tissue types such as muscle, heart, and lung. Time Magazine included the achievement on its list of Best Inventions of 2010.

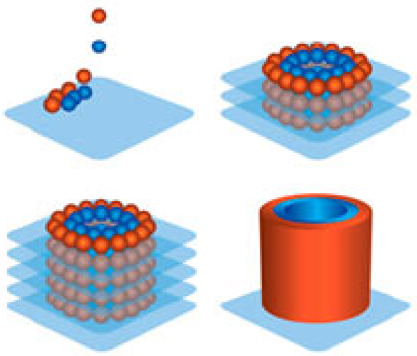

Company co-founder Gabor Forgacs developed the 3D printing technology for biological materials.

Although the Organovo process mirrors each of the major steps of other 3D printers, including use of the right “inks” and use of different materials to provide supporting structure, it’s considerably more involved. Cells are first grown in a culture to increase the amount of material stock. They are then harvested, formed into a basic bio-ink, and incubated so they will grow together. Finally, the cells are inserted in a cartridge, loaded into the printer, and deposited under computer control into the desired tissue shapes. Cells then mature in a bioreactor that simulates the environment of the human body. The final product is functionally identical to human tissue. In fact, cardiac tissue developed at the Organovo labs began to beat like a human heart when the growth process was completed.

Organovo scientists are quick to acknowledge the big role nature plays in completing the printing process. As cells mature, they also specialize and migrate to where they would be located on the tissue structure if they had developed in the human body. In other words, the cells complete the development job on their own, much the way cells change and form structures in a growing embryo.

The company recently succeeded in fabricating hollow blood vessels. Obtaining a tissue shape like this requires the same multi-material methods used for other complex 3D printing jobs. Organovo uses a collagen hydrogel as the scaffolding material, and after the cell tissue has grown, this material is removed. In the case of blood vessels, the scaffolding gel is formed into cylinders, and the tissue cells are deposited around it.

Organovo received patents in July for its multilayer vascular tissues and a core technology that produced them. These accomplishments also earned Organovo a spot on the MIT Technology Review’s TR50 list of the most innovative technology companies of 2012.



This simplified model of the bioprinting process shows how cells are deposited on a scaffolding material, which is later removed to leave the desired tissue shape.

Tissue engineering is an interdisciplinary effort involving biologists, biophysicists, physicians, and engineers. Organovo is a small company of about 30 employees, including a core group of biomedical engineers who stretch to perform a variety of technical duties. Invetech augmented the bioprinter development team with expertise in automation and system control. The firm tackled one of the biggest challenges to practical 3D bioprinting: precision. Human cells are measured in microns (millionths of a meter), so the cell dispensing tip of the bioprinter cartridge had to be consistently positioned for work at these scales. Invetech engineers solved the problem in only nine months with a computer-controlled, laser-based calibration system that kept the robotic cartridge controllers precisely aligned.

A Boon to Pharmaceutical Companies

Organovo's near-term goal is to produce tissue platforms that drug companies can use to determine the potential benefits or harm to humans of new drugs in advance of full clinical trials. Drug development is a high-risk, high-payoff enterprise, heavily weighted on the high-risk side. Although drugs are first tested in animals, their responses don't always match those of humans, and up to 65 percent of the drugs found effective with animals must be abandoned once human clinical testing begins. Identifying and dropping likely failures would save considerable time and money for the pharmaceutical industry and shorten the timelines for successful drug development.

Organovo's testing platforms can be used to assess drug reactions of human tissue at an early stage, to determine whether full testing is warranted. The company recently signed a partnership arrangement with Pfizer to further evolve this approach. Teaming with Pfizer will enhance drug testing and provide funds to move Organovo closer to their long-term goal: printing replacement organs.

Over 100,000 people in the United States are currently waiting for transplant organs, and18 die every day without one. Insufficient donors and immunological rejection of many transplanted organs conspire to widen the gulf between supply and demand.

A technician at Organovo demonstrates the NovoGen MMX Bioprinter.

Although public information programs have succeeded in expanding the number of willing donors, only one to two percent of the population dies in a way that yields viable transplant organs. Anne Paschke, spokesperson for the United Network for Organ Sharing, notes, “Any technology . . . that ends up reducing the need for donated organs will simply save a lot more lives.” Organovo is working on that solution.

Bioprinting can address the two central issues with organ transplants, namely availability and viability. Even successful organ transplants can be rejected by a patient’s immune system, endangering the patient’s health and losing a donated organ. In contrast, bioprinted organs can be autologous. That is, because replacement organs are grown from a patient’s own cells, the likelihood of tissue rejection drops dramatically. Combining patient-derived source cells with print-on-demand organs could essentially decouple the need for transplants from the size of the donor population. Fabricating entire replacement organs will push the limits of 3D bioprinting, of course, but the company has already faced a critical first hurdle – providing a blood supply to maintain an organ – with its recent vascular tissue printing success.

It’s hard to predict how much money could be saved with a consistent supply of printed organs, but current transplant procedures in the United States cost anywhere between a quarter million dollars to five times that much. The benchmark shouldn’t be difficult to beat.

Organovo is looking to 2015 for human trials with printed tissue products, with actual organ testing some time beyond that. It’s possible, however, that the timeline might be shortened. Manufacturing applications of 3D printing grew exponentially when machines became available to a wide community of companies and entrepreneurs. Keith Murphy believes the same path will be followed in the life sciences. “Ultimately,” says Murphy, “the best way to do that is get a number of bio-printers into the hands of researchers.”

Murphy’s desire for a change, Dr. Gabor Forgacs’ need to commercialize an invention, and the engineering support of Invetech have transformed a manufacturing technology into a significant new capability well on its way to improving the quality of human life. With time, engineering-science collaborations like this should find even more uses of 3D printing in the life sciences.

For more information on Organovo, visit www.organovo.com

A licensed engineer and Ph.D. in Industrial and Systems Engineering, Steve Murray flew F-14s in the Navy and then spent a career in a federal lab doing human factors and systems engineering. He has also served as an adjunct and visiting professor at the University of San Diego and now works as a freelance science writer (www.stevemurrayink.com).

Progressive Engineer
Editor: Tom Gibson
2820 Mexico Rd., Milton, PA 17847
570-713-4812 * tom@progressiveengineer.com