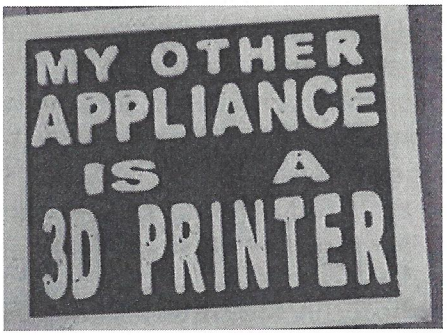
Overview



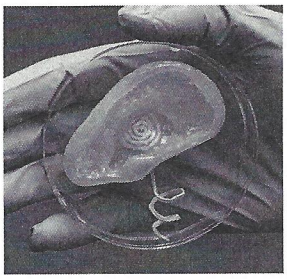
The 3D printing revolution has begun. Also known as additive manufacturing, 3D printing involves the layer-by-layer creation of a three-dimensional object from a digital model. It can be used to manufacture prosthetics, spare parts, food items, toys, and even on-demand organs. This exciting technological breakthrough is rapidly spreading across the globe. The positive impact that 3D printing may have on society appears to be limitless. Its range of applications is vast. The cultural contributions of 3D printing may ultimately prove to be even greater than futurists previously imagined.

Additive manufacturing would not have expanded without major advances in technology and computer-directed modeling. In recent years, digital design software has evolved and become more accessible. Today, scanners are more powerful, affordable, and easier to use than ever before. Nevertheless, many people are only now hearing about 3D printing technology. They do not realize that engineers and designers have already been using large, expensive 3D printers for nearly three decades. Their efforts have produced parts for aerospace, automotive, and defense companies. Ten years ago, it took weeks to generate a digital 3D model. Now, it takes only hours.

There are a number of steps in the 3D printing process. First, the object must be digitized. When creating a completely new object, the virtual design of the object is made through a Computer-Aided Design (or CAD) file using a 3D modeling program. For an object that already exists, a 3D scanner can be used to create the digital file. Engineers or product designers can scan an existing object by shooting thousands of points of light at it and loading its "point cloud" into a computer. (The point cloud is a 3D ghost image of the original object.) No matter how it is created, once a digital file is available, printing begins. During printing, successive layers of material are repeatedly laid down, under computer control. The process continues until an entire object is created. Each layer can be thought of as a thinly sliced horizontal cross-section of the final object. Some 3D printing methods use melting or softening material to produce the layers.

Some of the most promising applications of 3D printing are emerging in medicine. For example, the printing of cartilage, organs, skin, and tissue holds great promise for transforming healthcare and extending life. So far, there has been mixed success in printing organs. Constructing organs by hand is hard work, and it is plagued by human error. A few handmade, printed bladders have been functioning in several patients for many years. Currently, scientists at the Wake Forest Baptist Medical Center's Institute for Regenerative Medicine are working with other labs to systematically find ways to print muscle, kidneys, and bones.

Other research is focused on improving the organ transplant process. This involves using a patient's own tissues to print organs for transplantation. Once perfected, it promises to reduce the risk of a body rejecting implanted organs. Waiting times for kidneys and other donor organs will decrease. Organ traffickers may be put out of business. However, researchers are still years away from perfecting the printing process for organs and tissue.



Doctors around the world are now using 3D printing to create customized body parts for their patients. Entrepreneur Daniel Stolyarov is experimenting with 3D printing using graphene for applications in the human body. Graphene is a flexible, transparent substance that is a hundred times stronger than steel. Researcher Carlos Kengla has spent the last few years focusing on the production of ears. He prints them using cells taken from human ear cartilage. The Alfred duPont Hospital for Children is working with engineers to build durable exoskeletons using 3D printers. Experts predict that 3D bioprinting will completely reshape modern healthcare. In part, that is because prescription drug companies are eager to test new drugs and therapies on rapidly prototyped organs and tissues, rather than on animals or human subjects.

In the technological arena, futurists predict that handheld devices such as smartphones will soon contain integrated 3D scanners. That will make digitizing real objects into 3D models as easy as taking a picture. Already, prices of 3D scanners range from very expensive industrial models to $30 do-it-yourself devices for the home. The Ford Motor Company uses 3D printing to make prototypes of parts for its vehicles. Brake rotors, cylinder heads, shift knobs, and vents are all made with 3D printing. Yahoo! is teaching blind children to search the internet using a machine called Hands On Search. It combines voice recognition technology with a MakerBot 3D printer to turn spoken queries into physical objects. In the aerospace industry, NASA is making history with its 3D printed rocket engine injector, which passes major hot fire tests. In a recent test, the injector generated ten times more thrust than any previous injector made from 3D printing. Astronauts on the International Space Station successfully printed a wrench in space after engineers on Earth emailed the design file to them.

It is predicted that nano-3D printing will be the next big thing in 3D printing. This involves applying 3D printing concepts to nanotechnology. Doing so is expected to make nanofabrication faster, cheaper, and more efficient sooner than many futurists originally envisioned. Batteries the size of a single grain of sand can be used to power 3D printed miniature medical devices, compact electronics, and tiny robots. Princeton University scientists have already created a bionic ear using nano-3D printing. The goal of their experiment was to find an efficient way to merge electronics with tissues.

Thanks to 3D printing, ordinary individuals around the world continually enjoy a wider range of impressive devices, innovations, and opportunities. It is clear, however, that 3D printing will not be restricted to just business applications or available only to the wealthy. Instead, technologists claim that 3D printing will soon be so accessible that the public will be freed from the dominance of mass manufacturing. Rather than products being mass-produced, manufacturing is expected to become personal and customized.

What does the future of 3D printing look like? Biz Stone, Twitter's co-founder, recently predicted that Nike could be a pure software company in ten years, with consumers printing its footwear at home. Before long, products will be at an individual's disposal. Imagine a woman is at home when she realizes that one of the wheels on her dishwasher has broken. She easily looks up the part on the Internet and then prints a replacement at home, or at a neighborhood printer using the 3D Hubs network. What if a child outgrows his current pair of customized 3D printed shoes? Simply drop the old pair in the material recycler and print out a new pair in a larger size.

With 3D printing, the future lies at the fingertips of those with innovative ideas. How will 3D printing be used to improve the lives of others or change the world? The answers may be just a few clicks on a computer and a quick print away.

Terms and Definitions

2-dimensional (2D): a shape that has width and height, but no thickness or depth

3-dimensional (3D): an object that has height, width, and depth

4-dimensional (4D): a dimension in addition to length, width, and depth, to be able to employ geometrical language in discussing phenomena that depend on four variables

3D Hub: an online 3D printing service platform which connects 1 billion people around the world to a network of 3D printers

3D printing: a manufacturing process in which a three-dimensional object is created layer by layer from a digital model; also known as **additive manufacturing**

aerospace: the branch of technology and industry concerned with aviation and spaceflight

alternative-printing technique: any non-traditional or non-commercial photographic printing process

automation: the use of electronic devices and machines to reduce the need for human involvement in manufacturing and other processes

biomimetic: human-made processes, substances, or devices that imitate nature

bioprinting: the 3D printing of biological tissue and organs through the layering of living cells

Computer-Aided Design (CAD): the use of computer systems to create, modify, or improve graphic designs of physical objects

consumer: a person who purchases goods and services for personal use

cross-section: the surface or shape that is revealed when a straight cut is made through an object

digital manufacturing: a method of production in which computer technology is responsible for producing products with little or no involvement from humans

digitize: the process of changing pictures or sounds into electronic forms that can be processed by a computer

entrepreneur: a person who organizes and operates a business, or businesses, and takes on greater than normal financial risks in order to do so

fabrication: the act of making a product from raw materials

filament: the type of material, similar to ink in a traditional printer, used to construct objects in 3D printing

insourcing: a business model in which all of a business's activities are completed within the business without the help of another company

intellectual property (IP): creations of the mind such as inventions, artistic works, designs, symbols, and images

layering: a concept used in 3D printing where an object is designed and printed in small, stacked pieces that come together to form the full object

machining: a form of manufacturing used to create objects by braiding, cutting, drilling, grinding, and/or shaping the material

manufacturer: a person or company that makes goods for sale

mass production: the production of high volumes of standardized products, typically performed on assembly lines

nanofabrication: the design and manufacture of devices with dimensions measured in nanometers (1 nanometer is 10^{-9} meter, or a millionth of a millimeter)

nanotechnology: the branch of technology that focuses on the manipulation of individual atoms and molecules

on-demand: a technology in digital printing in which a product can be printed or created at the click of a button

open source: software or designs that are freely available and can be accessed, distributed, and modified by anyone

outsourcing: a business model in which an outside company is responsible for some of the primary business's activities

photopolymer: a material used in 3D printing that changes characteristics when exposed to light

polyethylene terephthalate (PET) plastic: a clear, tough, and shatterproof material that is commonly used in fibers for clothing, containers for liquids, and as filament for 3D printing

polymer: a substance that has a molecular structure consisting chiefly or entirely of a large number of similar units bonded together

printhead: a moveable part in a printer that holds the material that will be used for printing

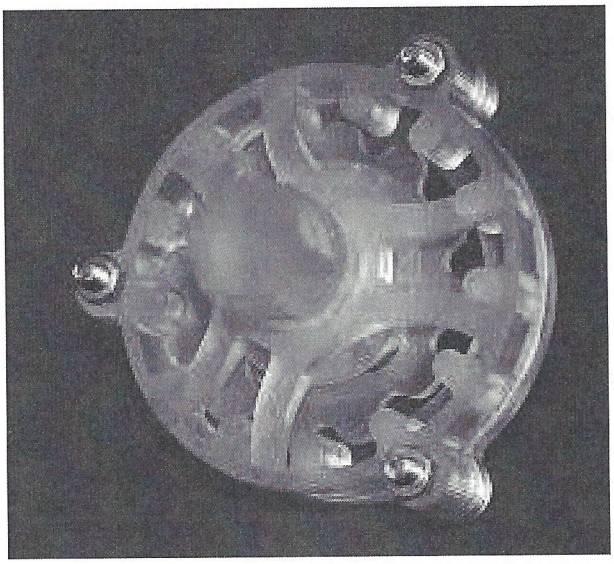
prosthetic: an artificial device used to replace a missing or defective body part, such as a limb or a heart valve

prototype: a sample or model of a product that is built as a test to be learned from or copied

rapid prototyping: the use of 3D Computer-Aided Design (CAD) data to quickly produce a 3D printed model

resin: a sticky, flammable substance produced by plants and trees that is insoluble in water

stereolithography: a 3D printing technique in which structures are built from liquid polymers that harden when they come into contact with computer-controlled laser light



textile: a type of cloth or woven fabric

thermoplastic: a plastic material, or polymer, that can be easily molded or shaped at high temperatures and becomes solid at cool temperatures