You Can Print *What?*

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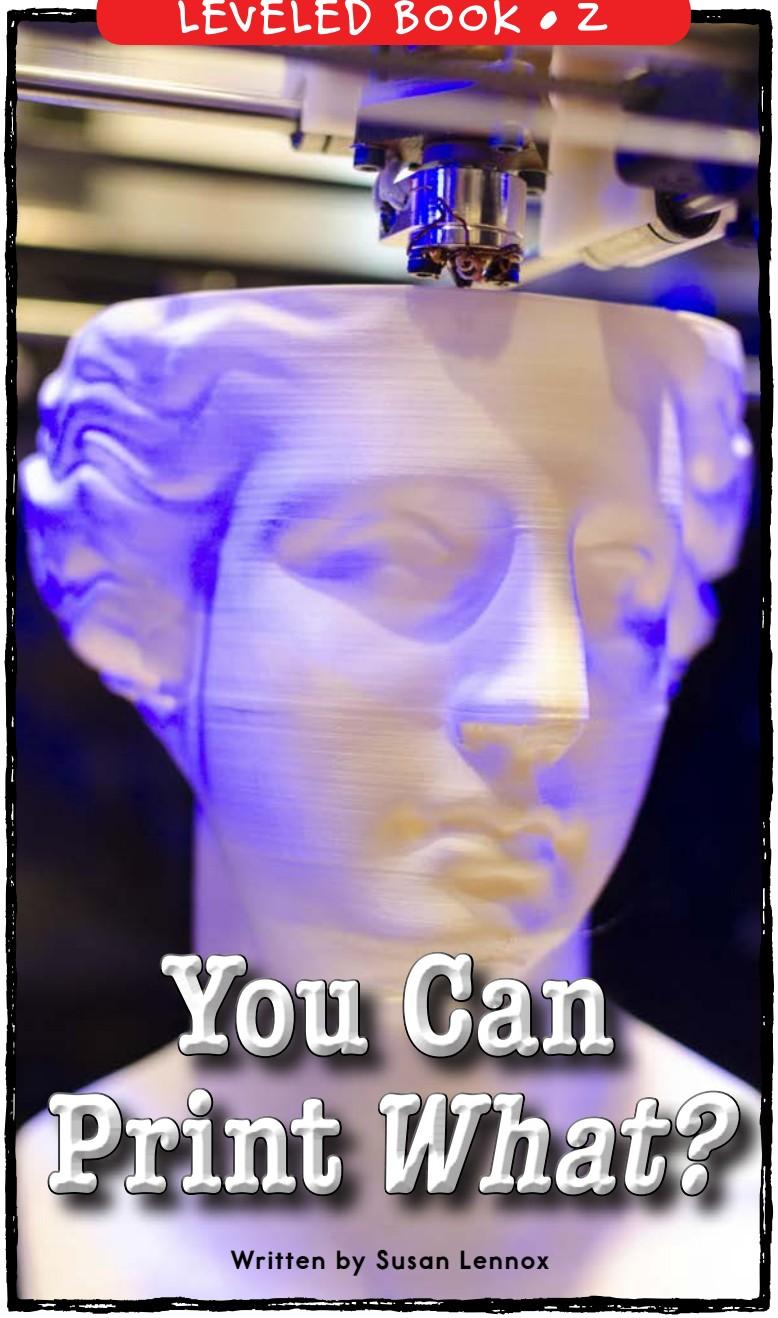

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Glossary

customized *(adj.)* made personal; made special for one person (p. 11)

data *(n.)* facts and information, such as measurements or statistics, used to analyze or plan (p. 7)

digital *(adj.)* using information stored as a series of ones and zeros for computers or other machines to read (p. 4)

engineer *(n.)* a person who designs, builds, or repairs machines, buildings, bridges, or other structures (p. 8)

industrial *(adj.)* having to do with the creation of goods, especially using machines, automation, and technology (p. 4)

innovative *(adj.)* new and original (p. 15)

laser *(n.)* a device that projects intense, focused light of similar wavelengths (p. 7)

particles *(n.)* tiny pieces of matter (p. 7)

prototypes *(n.)* an original form used as the model for later production (p. 4)

stereolithography *(n.)* a printing process that creates a three-dimensional object from a digital design (p. 8)

technology *(n.)* the use of scientific knowledge or tools to make or do something (p. 4)

three-dimensional *(adj.)* having height, width, and depth; 3D (p. 4)

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Written by Susan Lennox

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Front cover: A 3D printer replicates a sculpture head in plastic.

Back cover: A boy practices using his 3D-printed prosthetic hand in Haiti.

Title page: Children explore objects made by a 3D printer during an Earth Day event in New York.

Page 3: Joseph Gutenberg removes the first page proof from his printing press.

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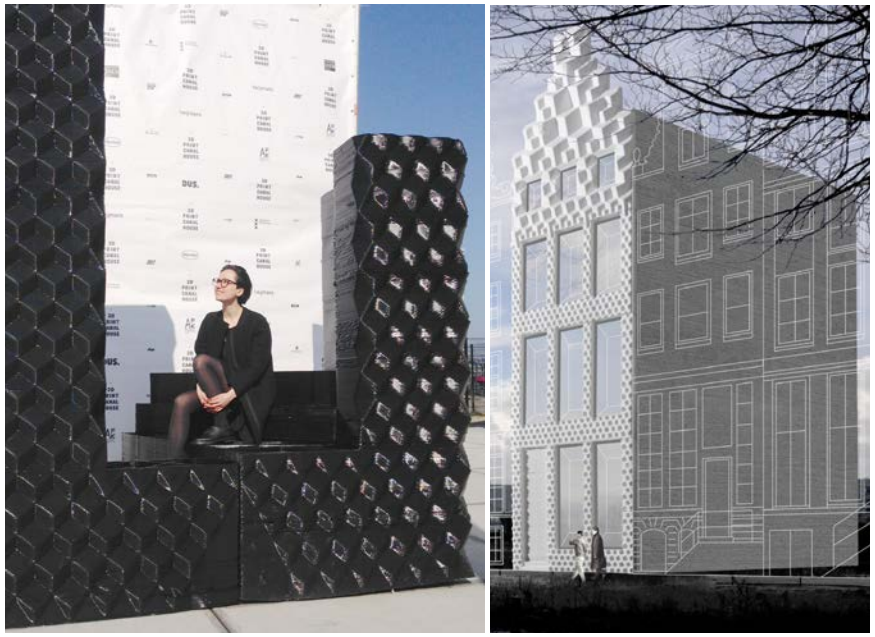
Correlation

LEVEL Z	
Fountas & Pinnell	U–V
Reading Recovery	N/A
DRA	50

Clockwise, from left: A piece of art, a chocolate lollipop, a lamp, and a dinosaur head were all created with 3D printing.

The Future

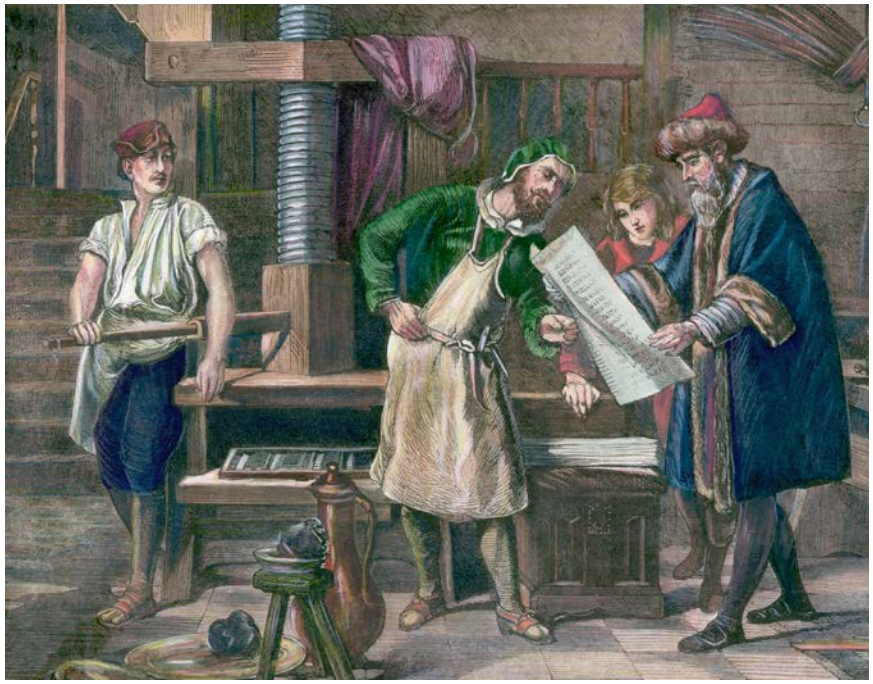
The future of 3D printing holds endless possibilities. This amazing technology allows people to customize all sorts of products, from plastic dental braces to apartment-sized furniture to buildings. As the technology continues to evolve, 3D printers may be used in rather unusual situations, such as long-term space missions. With a 3D printer on board their spacecraft, astronauts would be able to manufacture replacement parts should old parts break down, or design and create new devices to help them live in space. This **innovative** technology could help humans survive as they explore strange, new worlds!



A building block made by a 3D printer is used in the construction of the 3D Canal House in Amsterdam, Netherlands (left). An artist's sketch shows the completed house (right).

A Home Like No Other

Some 3D engineers have taken this technology to new heights—literally! A team of architects in Amsterdam is using a giant, portable version of a 3D printer to build a three-story house out of plastic. The machine creates interlocking bricks from layers of melted plastic that will be assembled into thirteen rooms. Construction will take three years—a long time by house-building standards. The team hopes this experiment will open the door to new ways of thinking about home construction using manufacturing processes such as 3D printing.



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These customized shoes were designed and created using a 3D printer.

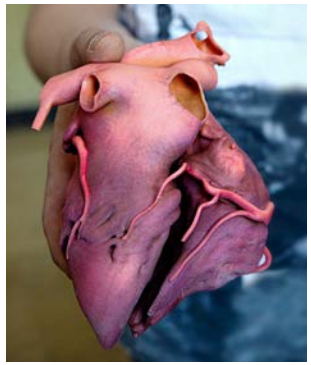
Introduction

An **industrial** designer is hard at work creating a **digital** plan for a shoe you won't find in any store. She peers at the image on her monitor while using a special computer program to modify the shoe's shape and size. When she's satisfied with her work, she hits the "print" command. The printer at the other end of the room springs into action, whirring and humming. But it isn't printing just a picture of the shoe—it's creating an actual shoe!

Welcome to the world of **three-dimensional** (3D) printing—the latest **technology** for making models, or **prototypes**, of almost anything imaginable! What comes out of a 3D printer is quite different from what comes out of a conventional computer printer. However, both types of printers use the same concept—layering—to make their final product.

Have a Heart—or a Liver!

Engineers and scientists are developing a way to create real human organs using the layering technique to fuse living cells and form human tissue. A gel containing special cells taken from a patient's body is layered to form the correct shape, then incubated for a time to let the cells mature and bond to each other. Scientists have made ears, lungs, and livers using this technique. Researchers are now working on creating a human heart made of both natural tissue and artificial materials.



A 3D model of a human heart is used for medical education.

People who receive 3D organs may avoid the usual problem faced by transplant patients—rejection of the new organ. Whenever a foreign object is introduced into the body, the immune system treats it as a threat and attacks it. Transplant patients must take special medicine after surgery so their immune system doesn't destroy the transplanted organ. This medicine may also make patients more prone to infection. However, if the organ is made from the patient's own cells, rejection is less likely to occur. Patients may not have to take as much medicine, and they heal and recover more quickly with fewer complications.

Beauty the bald eagle before and after her new beak was attached.

3D Printing Is for the Birds!

The ability to create customized 3D objects affordably has led to some amazing applications. When an engineer visited a wildlife rehabilitation center, he was struck by the plight of a bald eagle named Beauty. A hunter had shot off Beauty's top beak, making it impossible for her to hunt, eat, or preen herself. The engineer believed he had a 3D solution to Beauty's problem.

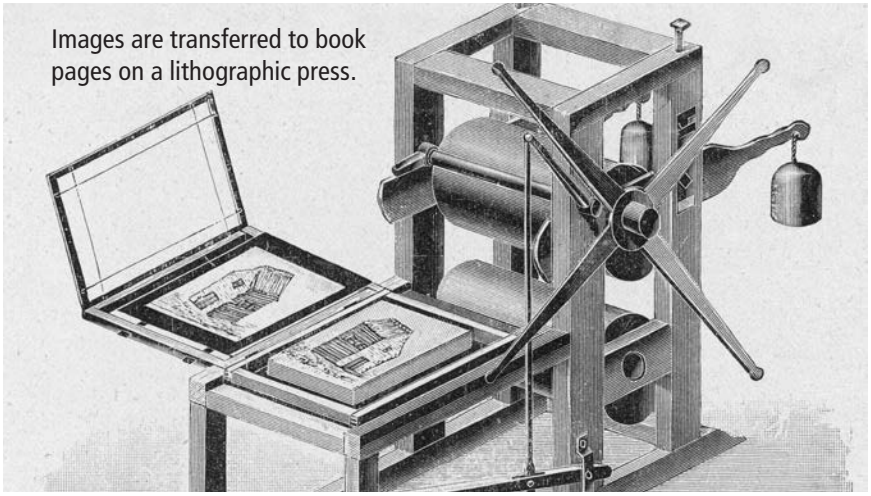
Working from an X-ray of Beauty's head, the engineer was able to design a plastic replica of Beauty's original beak on his computer. He then used a 3D printer to create the replica beak. Beauty had surgery to permanently attach the new beak, and she can now drink, eat, and clean herself like a normal eagle.

From Stamps to Lasers

When most people think of printing, they imagine seeing text or images on smooth surfaces such as paper or cloth. The markings are made by applying a layer of ink onto the surface, either by hand or machine. Throughout history, a variety of printing techniques have been used to apply the ink.

About two thousand years ago, people in Eastern Asia used a process known as *xylography*, or woodblock printing. First, they drew an image on a block of wood. Next, they carved out the areas around the image. Then they coated the raised image that remained with ink and pressed it onto a flat surface. When they lifted the block, a thin layer of ink in the shape of the raised image appeared.

If you've ever used an ink stamp and stamp pad, you've used xylography. And you probably know that it would take a long time to fill just one page with multiple stamped images. This problem was solved with the invention of the printing press in 1450. Johannes Gutenberg, a German blacksmith, invented the printing press, a machine that allowed the first mass production of printed books.



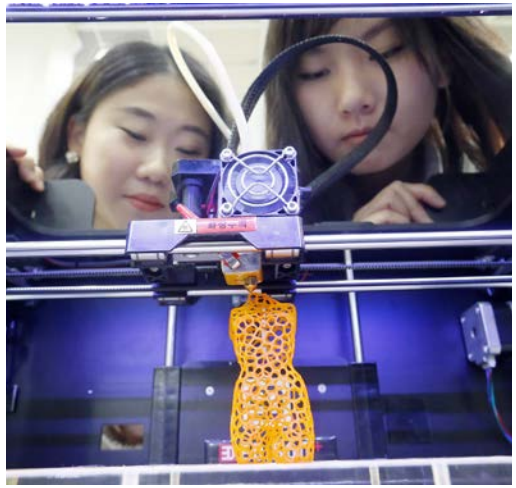
Images are transferred to book pages on a lithographic press.

Instead of using one stamp at a time, many stamps, or pieces of type, were arranged in a tray. Then a piece of paper was pressed against the tray. In just one motion, a layer of inked type was pressed onto the entire page! This process made it much easier to produce multiple copies of the same page.

Over hundreds of years, printing processes evolved. One technique, called *lithography*, uses water and oil. Images are transferred to book pages on a lithographic press. The printed surface contains both the image and background areas on one level printing plate. The printing area is treated so that the image to be printed attracts oil-based inks. Since oil and water don't mix, the non-printed areas repel the inks. The lithographic process was devised in 1796 and is still used today to print many magazines and books.

A New Technology Takes Off

By early in the twenty-first century, stereolithography became the preferred method for creating prototype parts used in industry and manufacturing. A prototype could be designed, produced, and tested in a matter of hours or days rather than weeks or months. Most early 3D prototypes were made of plastic. As the technology improved, other kinds of materials, such as ceramics and metals, were also used to make objects.



A 3D printer produces a sculpted form at a design show in Seoul, South Korea.

Being able to use a variety of materials expanded the possibilities for 3D printing. People from different fields saw this technology as a way to create **customized** items in a much shorter time. Designers could craft one-of-a-kind pieces of jewelry. Artists could create unique three-dimensional sculptures. And they could do it affordably, since 3D printing uses only as much material as is needed.

Who's Who in Printing Technology

- **1040 AD (approximate):** Bi Sheng, a Chinese printer, invents the world's first-known movable type technology using clay characters.
- **1450:** Johannes Gutenberg, a German blacksmith, invents the printing press, which allows the first mass production of printed books.
- **1796:** Alois Senefelder, a German author and actor, invents lithography as a cheap way to print his plays.
- **1800:** Lord Stanhope, a British scientist, builds the first cast-iron printing press.
- **1846:** Richard Hoe, an American inventor, invents the cylinder press. It can print eight thousand sheets an hour.
- **1886:** Ottmar Mergenthaler, a German-born American inventor, invents the Linotype machine. This is the first device that can make a printing press arrange complete lines of type.
- **1938:** Chester Carlson, an American physicist and attorney, invents electrophotography, also known as Xerox.
- **1953:** Remington-Rand, an American business machine manufacturer, creates the first high-speed printer for the UNIVAC computer.
- **1976:** Gary Starkweather, an American engineer, develops the first commercially used laser printer.
- **1984:** Charles Hull, an American design engineer, develops and patents stereolithography, the process known as 3D printing.

In the 1950s, the first high-speed printer was invented for use with a computer called UNIVAC, which stored **data** onto spools of magnetic tape. A modified typewriter was connected to print out the information from the tape. This computerized typewriter was able to print words and numbers much faster than any person possibly could!

When desktop computers became popular in the 1980s, inkjet printers made it possible for people to print digital images right at their desks. Data sent from the computer tells the printer which shapes it needs to print. The printer reads the data and makes those shapes by first heating a cartridge filled with ink. As the ink warms, pressure inside the cartridge rises. Then the ink shoots out of the cartridge through a nozzle, or jet, and forms layers on the paper.

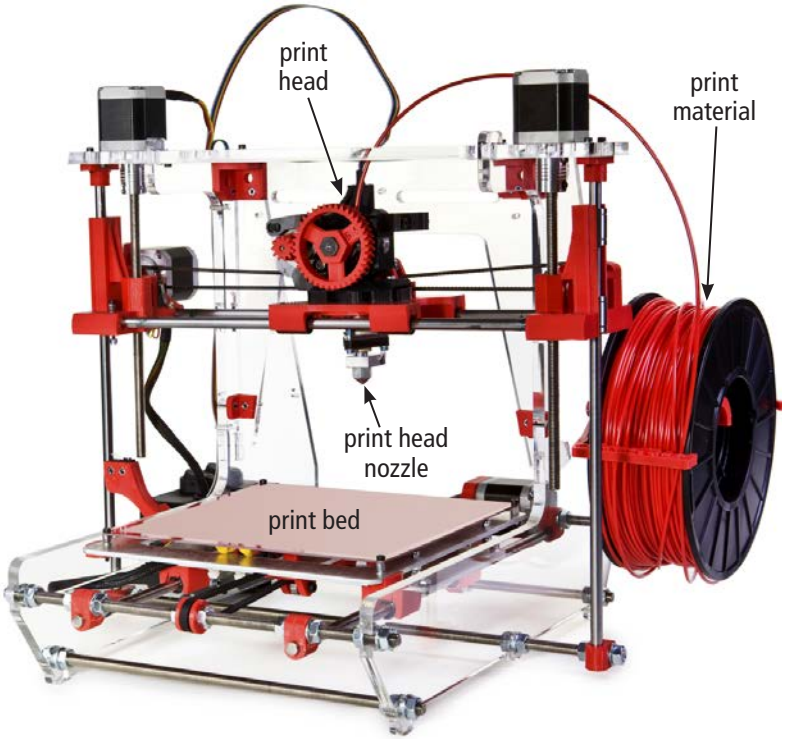
Laser printing technology was developed during the 1970s but did not become available for personal use until 1984. Laser printers use a process similar to lithography but with a twist. Instead of coating the printing surface with oil, this printing process uses lasers to zap an electrically charged image onto the paper. Dry ink **particles** pass over the paper and are attracted to the electrically charged image. A roller presses the particles to the paper, and a printed page appears.

2D to 3D

In 1984, Charles Hull invented a process called **stereolithography**, or what we now call 3D printing. Hull worked as a design **engineer**. He often grew frustrated with the weeks and months it took to develop, test, and redesign prototype plastic parts. He set out to solve this problem by finding a quicker way to make prototypes. Hull soon realized that he could use a layering process to create three-dimensional objects. 3D printing was born!


Charles Hull

Stereolithography uses inkjet and laser printer technology to create three-dimensional objects instead of flat, two-dimensional images. First, an image is created and stored as data using computer software. Then the data file is sent to a 3D printer. The printer uses the file as a kind of road map that tells the print head where to go. The print head is a tiny box with a nozzle, or jet, attached to it. It is suspended from a grid of metal bars that run along and across a print bed—the platform on which the object will be made.



This type of 3D printer uses plastic thread for printing material to create small objects.

The print head moves back and forth and side to side above the print bed. As it moves, a thin stream of material, such as plastic, is propelled out of the print head nozzle and onto the print bed. According to the information sent from the computer image file, the material is stacked in microlayers as the print bed moves up and down. As each layer is deposited, a laser heats and bonds the new layer to the one beneath it. Bit by bit, layer by layer, a three-dimensional prototype of the image on the computer monitor rises from the print bed.