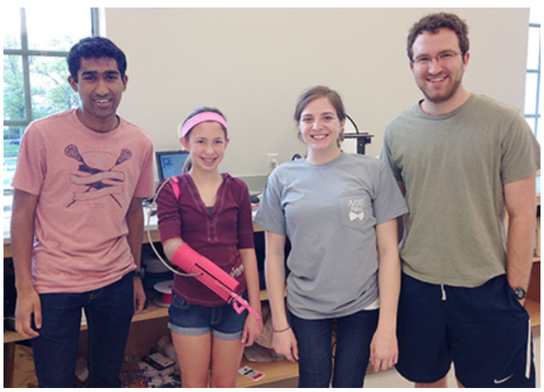
Writing Class 4

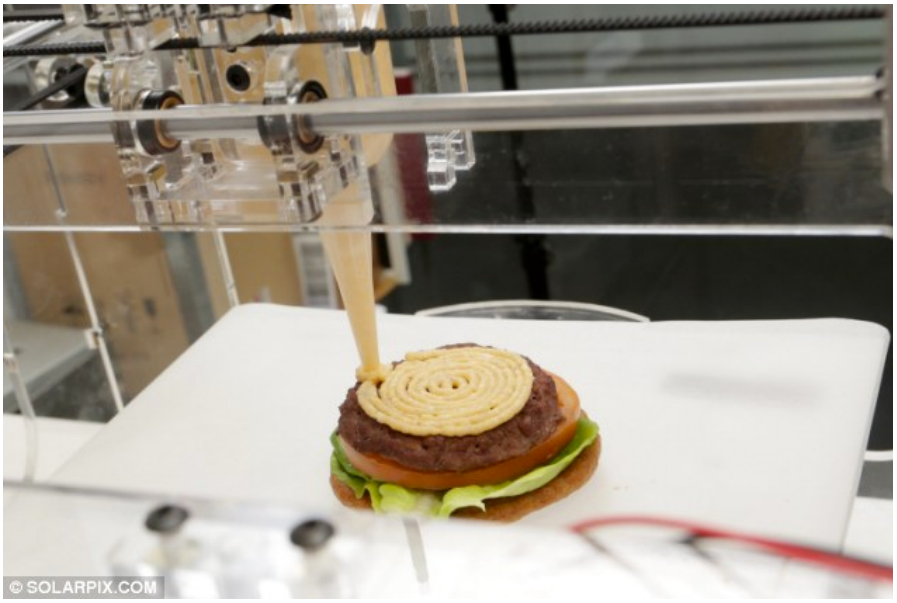
What do Cheap Houses have to do with Kidneys?

Opening Discussion



Write down important information said during the video and discussion
http://www.youtube.com/watch?v=Llgko_GpXbI

What is 3D Printing and how does it work?



Forbes Magazine
Teresa Meek

Will A 3D Food Printer Be Your Next Cool Kitchen Tool?

You may have heard of 3D-printed shoes and furniture or even the most recent headline grabber, an entire 3D-printed house.

Now, 3D printing is coming to your kitchen — if you are willing to shell out anywhere from $99 to $5,000 for a machine that ups the cool factor of a cappuccino maker by several orders of magnitude.

But can you really "print" food? How does that work?

Perhaps the easiest way to understand it is to know what a food printer is not.

"It's not the 'replicator' from 'Star Trek,'" says Lynette Kucsma, the CMO and co-founder of Barcelona-based Natural Machines, which makes a printer called the Foodini. "You don't say, 'I want salad,' and it materializes in front of you."

Instead, you combine the ingredients for each phase of a dish and place them in capsules, then the machine squirts them out in shapes and layers to form the pattern you have chosen. To make ravioli, for example, the Foodini prints out a thin layer of pastry from one capsule, then a layer of filling from another, then another layer of pastry. Each ravioli is made separately in under a minute, so a plate of 10 would take only 10 minutes to make. Foodini even has a video showing a pair of Spanish chefs trying out the machine to print rice pudding shaped like honeycombs.

The "printer" is essentially an assembly device that can make time consuming tasks like rolling dough or creating complex pastry shapes much faster and easier. It does the tedious work of putting the ingredients in order, but you still have to add the ingredients to the capsules and cook the assembled food after the printer is done, though Natural Machines is working on models that do the cooking, too.

And you often need to use another machine — a food processor — to achieve the right texture for the ingredients. Too watery, and the food mixture will drip through the food capsule; too chunky, and it will clog up the nozzle, Kucsma says.

Scientists at Cornell Creative Machines Lab, who are also developing a food printer, say 3D printing could have a big impact on both fine dining and home cooking. According to the USDA, the average American spends 33 minutes a day on food preparation. If food printing can evolve to the "set-and-forget" stage, the Cornell site says, the average person could save over 150 hours of food preparation time a year.

Some of the elaborate sugary concoctions the printers produce are clearly aimed at restaurant chefs, but the machine is also meant to be a time-saver for households that would otherwise throw a frozen pizza in the oven or a frozen dinner in the microwave.
In fact, Kucsma expects that someday, the food printer will be as ubiquitous as the microwave, and it will take less time to catch on than microwaves did since "nowadays, we're a much more tech-savvy and adaptable society."

"The point is to get people away from eating processed foods and start cooking again," she says. "We're a time-pressed society. Convenience food was invented in the '50s and is pre-packaged with preservative ingredients. A 3D printer is a mini-manufacturing plant in your house."

The Foodini is scheduled for release in October and is expected to sell for around $1,300. Mass production is set to begin in January 2015.

Natural Machines and Cornell University aren't the only ones developing food printers. 3D Systems' Chef Jet presented its model at January's Consumer Electronics Show (CES) in Las Vegas. It makes sugar sculptures in a rainbow of colors with flavors ranging from plain vanilla to mint, sour apple and watermelon. The company expects to put its machine on the market later this year at a price somewhere below $5,000.

3D Systems is also looking beyond consumers to sell to big business. It recently announced a joint venture with Hershey to "explore and develop innovative opportunities for using 3D printing technology in creating edible foods, including confectionery treats."

An Australian company appropriately named Chocabyte has also developed a printer that makes custom chocolates. It, too, debuted at CES and 500 printers were quickly sold for $99 each. The company plans to offer more in the last quarter of 2014 but hasn't specified the price.

For pastry chefs, who spend hours creating complicated sugary cake toppings and designs, the new printers could be a godsend.

"I feel like it's going to be a game changer," says Melissa Trimmer, lead pastry chef instructor at Le Cordon Bleu College of Culinary Arts in Chicago. Elaborate sugar and chocolate designs require such a high level of skill and time that many restaurants are backing away from them, she says.

"We could see that artistry come back, but rather than a chef, we'll see these machines creating it. Maybe now we'll have time to make that beautiful sugar showpiece for our client's wedding and the intricate garniture for plated desserts and still go to management meetings."

For home cooks, the picture is less clear. On the one hand, the machines offer the ability to quickly recreate dishes from a time when people could spend hours in the kitchen rolling out a lattice crust for an apple pie. On the other hand, a growing number of people miss the homespun quality of the old days and are turning off their TVs, computers and cell phones to don old-fashioned aprons and make everything from scratch.

They're not the "replicator," and whether they will become the next microwave remains to be seen, but the new 3D food printers boldly go where no kitchen machine has gone before, offering new levels of convenience, speed and intricacy to those willing to give them a try.

Comprehension Questions

1. Summarize how a 3D printer makes food.

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2. What are two benefits of individuals using 3D printers to make food?

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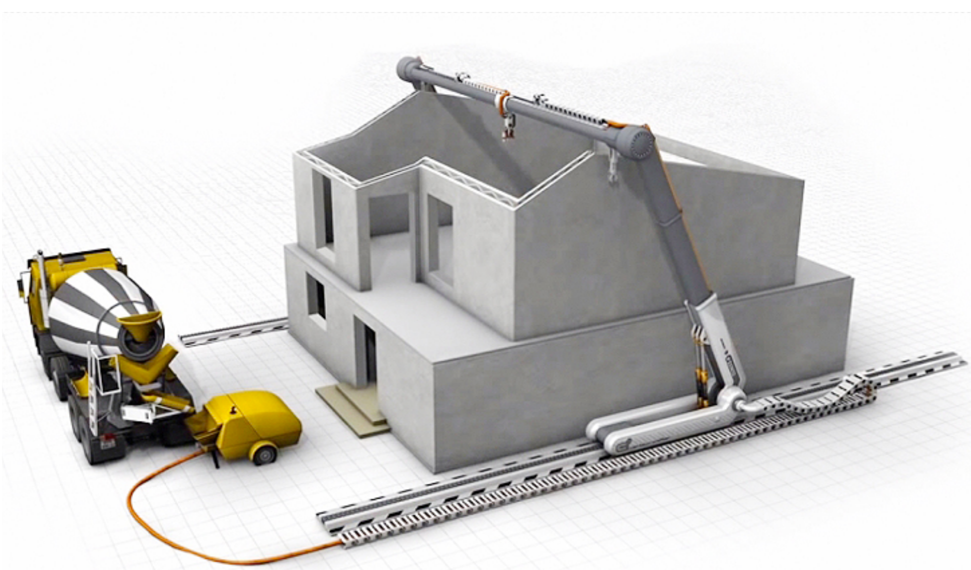
3. What are companies using 3D printers for?

Note Taking
http://youtu.be/x6WzyUgbT5A?t=43s

3D Printing: Now Printing Food too



http://www.businessinsider.com/3d-printed-houses-are-here-2014-9

The First 3D Printed House Is Coming,
And The Construction Industry Will Never Be The Same

Comprehension Questions

1. How will this benefit people with different values?

2. Why is it essential to have a new manufacturing process like this?

3. Why is sustainability so important?

The Guardian

3D Printing Could Offer Developing World Savings on Replica Lab Kit

Working replicas of expensive scientific equipment could be made for a fraction of conventional costs using cheap 3D printers, possibly saving developing world labs thousands of pounds each time, says a researcher whose has written a book on the subject.

This and similar advances mean the age of appropriate technology – affordable, sustainable solutions designed and built to meet local needs – may be here, argues Joshua Pearce, a materials science and engineering professor at Michigan Technological University in the US, in an article in last month's Physics World magazine.

"For example, my lab developed an open-source 3D printable colourimeter for water testing, which costs $50 (£30) instead of $2,000," says Pearce, whose book is called Open-Source Lab: How to Build Your Own Hardware and Reduce Research Costs. The cheaper version worked as well as the $2,000 one, he adds.

"Let us say it cost us $3,000 to develop [the instructions for a cheaper device] the first time, primarily for the labour costs, and Brazil does something similar for another water-testing tool that they currently buy 10,000 units a year from Germany," he says. "They pay $3,050 for the first one – that's an investment – but only $50 for each additional one, saving themselves over $19m in the first year."

Pearce says with the advent of 3D printers, companies relying on extracting monopoly prices on products for which there is already an equivalent open-source alternative must either reduce their margins or continue to innovate to remain economically viable.

"If you print out – instead of buying – a single magnetic tube rack and buy the magnets yourself, you can easily justify the cost of a RepRap [self-replicating] 3D printer to do it," says Pearce. RepRaps cost about $1,000 assembled, and can be put together from parts costing under $500.

The idea of appropriate technology to deal with poverty was used as early as the 1970s by the World Health Organisation (WHO), when villagers were encouraged to make water pumps and farming tools. But 3D printing has given the concept a boost, Pearce says.

The WHO's efforts worked well, he says, but took in only one village at a time. "There was incredibly wasteful duplication of effort to solve nearly identical problems all throughout the world."

Now, with affordable 3D printers on sale, widespread internet access and the open-source movement gaining followers, more people can use, study, copy and change a design for free – and share the improvements online, Pearce says.

He cites a range of initiatives that are making appropriate technology a more-realistic prospect. The Wikipedia-like website Appropedia lets users develop collaborative solutions in sustainability and international development.

There are other initiatives that develop or make use of free online instructions to build research equipment, for example the Tekla Labs online community or an inexpensive microscope created as part of the OpenLabTools initiative. Sites such as Thingiverse host 3D printable designs for everyone to use. And open-source programmes such as OpenScad allow users to modify existing designs of 3D-printable lab equipment to meet their needs.

Talented scientists in many developing countries lack the research instruments they need, says Carlo Iorio, deputy chairman of the European Physical Society's Physics for Development group. Many poorer nations may be "full of good theoreticians, but because of the lack of instruments, applied sciences that are the core of the wealth in the [developed world] are greatly neglected there", he adds.

The Physics for Development movement is trying to change that by getting people to develop high-quality technology from local or recycled materials. Pearce says the movement may encourage developing nations to introduce policies to support the funding of open-source scientific equipment and further bring down its cost.

Practical Answers, a knowledge-sharing service run by the charity Practical Action, has a large open-source database of appropriate technologies. Rob Cartridge, who oversees the service, says the open-source concept is crucial for delivering technology justice, as it gives people a right to decide, choose and use technologies that assist them in leading the kind of life they value in a sustainable way.

"Whether you are talking about a water pump in Zimbabwe or a gyroscope designed to monitor earthquakes and landslides in Peru, it is critical that technologies are not hidden behind intellectual property rights or subscriptions that make them inaccessible to the poorest communities," he says.

Discussion/Comprehension Questions

1. How do 3D printers help to save organizations money?

2. How is the internet further helping developing nations?

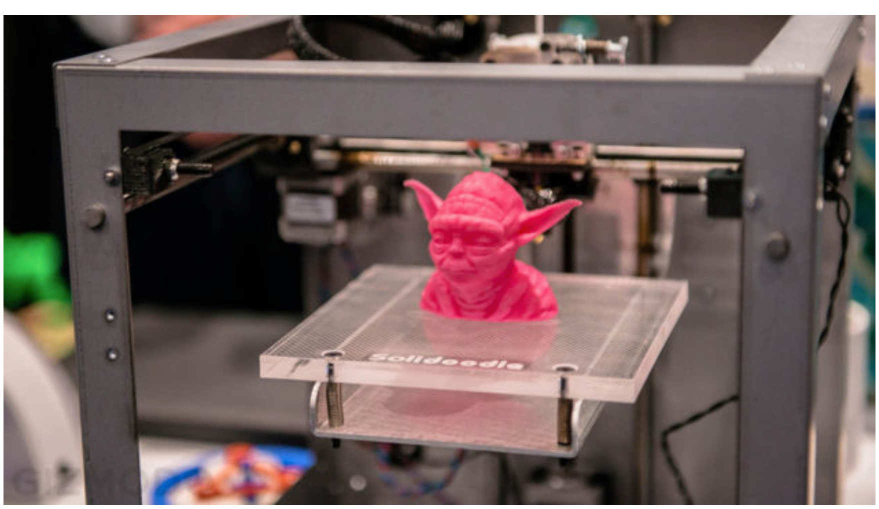
3. How is the open-source concept important?

http://www.youtube.com/watch?v=SDYFMgrjeLg

Project Daniel - Not Impossible's 3D Printing Arms for Children of War-Torn Sudan

http://www.businessinsider.com/the-next-industrial-revolution-is-here-3d-printing-2014-8

How 3D Printing Will Revolutionize Our World



Comprehension Questions

1. What are the three revolutions?

2. How does 3D printing improve products?

Small Group Project: What should some new uses of 3D printers be?

Business Insider
Rob Wile

This Technology Could Have The Biggest Impact On American Jobs Since Offshoring

Manufacturing in the U.S. will never be what it was. Employment in the sector is down nearly 50% from its May 1979 peak, and fell more than 10% during the Great Recession.

But 3D printing, which last fall Credit Suisse forecast could grow up to 30%, has the potential to reshape how America makes stuff, creating new high tech jobs in the U.S. and bringing old ones back from abroad.

“I see manufacturing taking a profound turn with additive technologies in the next five years," S. Kent Rockwell, CEO of 3D printing firm ExOne, said in a recent PriceWaterhouseCoopers report. "We’ll see elite job shops grow, and new start-ups grow. We’ll also see blue-collar employees learn the technology and adapt and start wearing white shirts."

3D printing, which is also known as additive manufacturing, is the process of creating products and parts on site.

The labor input savings 3D printing can yield for employers are substantial — and at the same time, the technology appears poised to create markets for new, higher-skilled jobs. Scott Paul, president of the Alliance for American Manufacturing, gave PwC the example of a small tool-and-die casting company whose costs start falling as their upfront investment in a 3D printing pays off, allowing them to take on larger-scale jobs that require more complexity.

"As we see the possibilities of new materials expand and the cost of industrial printers go down, and the print speeds rise, you'll see adoption not only by larger companies, but also by the smaller companies," he said.

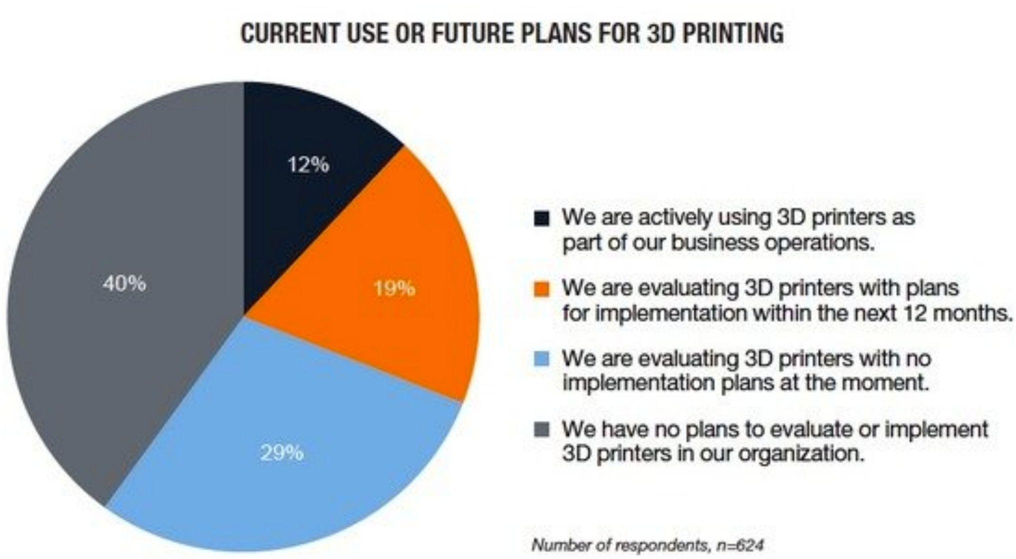
Paul said that viability could become an issue for those who aren't willing to make the leap.

3D printing is already reshaping job requirements at industrial conglomerates. GE Aviation, for example, is developing 3D printed (or additively manufactured) fuel nozzles to be used in its LEAP engine for commercial planes.

"I actually see additive as producing situations where you're going to have higher-skilled positions that companies are going to need to fill, both on the technician level, and the engineering and design level," Greg Morris, who leads the GE team, told Business Insider. "And I frankly think you'll see a different type of machining that will challenge the current state of machining, meaning you'll get complex parts that a machinist will have to work with versus starting with a block of material. So you're not replacing machinists, you're just asking them to learn a little different skill set of what they start with and work with."

The growth of 3D manufacturing may end up reverberating through global labor markets. Brian Krassenstein, founder of 3D Printing news site 3DPrint.com, says that as manufacturing costs rise in China and fall in the U.S., jobs at megafactories like Foxconn could begin to disappear.

"In fact, we have already seen this beginning to happen with Apple and Google," he writes. "Sure, many of these jobs will be suited best for machines, but someone has to maintain these machines, manage the supply chains, and oversee production."



Large firms' search for more efficient labor that first gave rise to offshoring. If they can once again find it at home, they will act decisively.

"3-D printing ... appears poised to bring about a global trade rebalancing, as the new economics of manufacturing rewards high-skill workforces like that of the U.S. and make supplies of cheap labor in countries like China less relevant," National Journal's Ben Schreckinger wrote recently.

"Upstream" manufacturing, the point at which goods are produced, is likely to feel the most effects from the growth of 3D printing. But the jobs impact could also flow downstream to retail. Angel investor Esther Dyson has written that furniture sellers and other household goods peddlers could start disappearing, replaced by individuals who manufacture and sell furniture at the same location.

"Over time, these print shops will replace thousands of stores carrying millions of items, some of which sit around for months waiting to be bought," she says. "They will print goods using designs from online services that offer designs for both open-source, free-design goods and branded goods that may not seem very distinct except for a logo."

The impact 3D printing could have on manufacturing has already been acknowledged by President Obama, who launched the National Additive Manufacturing Innovation Institute. In his 2013 State of the Union address, Obama talked up the institute, which is run out of a manufacturing facility in Youngstown, Ohio.

"A once-shuttered warehouse is now a state-of-the art lab where new workers are mastering the 3D printing that has the potential to revolutionize the way we make almost everything," Obama said.

Not everyone agrees the technology's impact on labor will be so enormous. Right now, 95% of 3D printing is used to make small industrial parts like GE's nozzle. Writing on Gizmodo, Nick Allen, the founder of 3D printing company 3D Print UK, believes limitations on output quality will prevent 3D printers becoming a mass-market item. Thus, there will still be a need for people to hawk non-3D printed food and personal supplies.

"3D printing will continue to grow in areas like the prototyping market, low-volume production runs (on very high-end machines), medical, aerospace — the list goes on," he writes. "But as an everyday household object? I'm not convinced."

Despite their growth, the biggest 3D printing firms, like 3D Systems and Stratsys, only employ a few thousand people. PwC found that 45.3% of manufacturers attributed their "lack of current expertise in our company to fully exploit the technology" as a barrier to implementing 3D printing into their business.

But these are only the firms that are directly in the industry. Retail, product development, and manufacturing firms all potentially stand in 3D printing's firing line— and as International Labour Organization's David Seligson points out, 3D printing is likely to blur the line between jobs in these industries.
"Take, for example, the car company that wants to move from printing prototypes of components to printing those components at scale," he said. "That would effectively mean that its model-makers would be doing the work of assembly-line workers, which could lead to contractual disputes and complaints over deskilling, intellectual property and so on."

It may simply be too early to say what the technology's lasting impact will be. Even 3DPrint.com's Krassenstein acknowledges as much.

"You could ask a hundred economists what they think will eventually happen once the 3D printing and robotics markets mature, and you will likely get a hundred different answers," he writes. "We have seen what technology has done in the past, destroying millions of jobs, but in the process creating tens of millions of new jobs. There is little reason to believe that this wave of progress will be any different."

Comprehension Questions

1. How will 3D printers change manufacturing in America?

2. What jobs will be in greater demand? Why only these?

3. What is limiting 3D printers from being widely used today?

Skill Building

Comparison

There are three ways to write a comparative essay:
1. Mixed Paragraph Method
2. Alternating Paragraph Method
3. One Subject at a Time Method

Imagine that we are writing an essay about which country is the best. Let's choose Korea, Canada and Finland. Then we must choose measures to compare the countries, such as quality of education, wealth of citizens, and happiness. In our body paragraphs, we can organize our thoughts using one of the three methods.

1. Mixed paragraph method:
   Paragraph 1: Quality of Education in Korea + Quality of Education in Canada + Quality of Education in Finland
   Paragraph 2: Wealth of Citizens in Korea + Wealth of Citizens in Canada + Wealth of Citizens in Finland
   Paragraph 3: Happiness of Koreans + Happiness of Canadians + Happiness of Fins

Strengths:

Weaknesses:

2. Alternating paragraph method:
   Paragraph 1: Quality of Education in Korea
   Paragraph 2: Quality of Education in Canada
   Paragraph 3: Quality of Education in Finland

Paragraph 4: Wealth of Citizens in Korea
Paragraph 5: Wealth of Citizens in Canada
Paragraph 6: Wealth of Citizens in Finland
Paragraph 7: Happiness of Koreans
Paragraph 8: Happiness of Canadians
Paragraph 9: Happiness of Fins

Strengths:

Weaknesses:

3. One subject at a time method:
    Paragraph 1: Quality of Education in Korea
    Paragraph 2: Wealth of Citizens in Korea
    Paragraph 3: Happiness of Koreans
    Paragraph 4: Quality of Education in Canada
    Paragraph 5: Wealth of Citizens in Canada
    Paragraph 6: Happiness of Canadians
    Paragraph 7: Quality of Education in Finland
    Paragraph 8: Wealth of Citizens in Finland
    Paragraph 9: Happiness of Fins

Strengths:

Weaknesses:

This method is only recommended for <u>short</u> essays with simplistic subjects that the reader can easily remember as (s)he goes along.

Remember to keep the same order of measures and subjects when writing

Practice:
Create a simple outline for an essay about the greatest Disney movie. Choose the most appropriate method of comparison.

Space for Brainstorming

Movie (Across) / Comparison (down)			

A Vision of Crimes in the Future

Essay Question
After hearing about the dangers that arrive with the increased used of 3D printers, do you believe that their benefits outweigh the drawbacks? Should 3D printers be continued to be made, or should production of them stop?

Brainstorm

Thesis: ____

Ideas

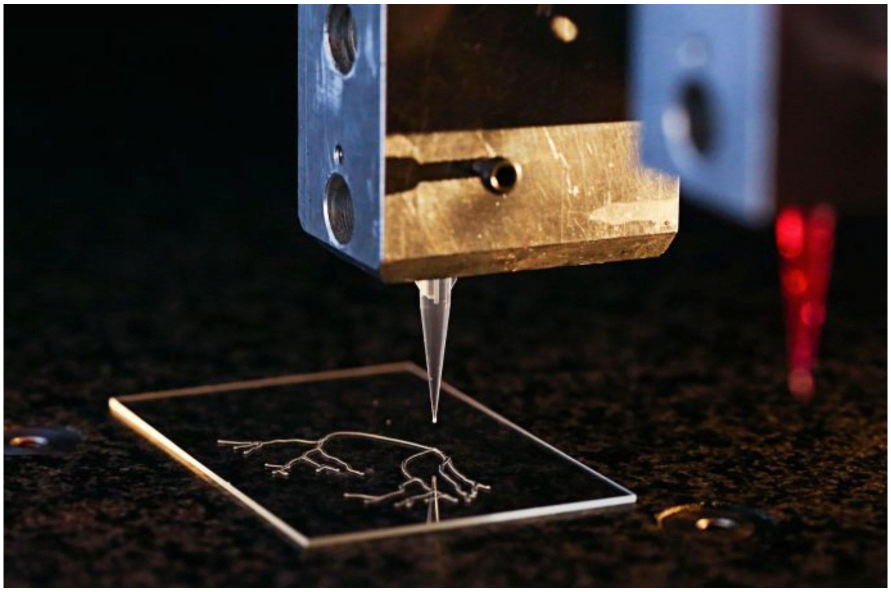
Organize

Main Ideas

________________ ________________ ________________

Essay

Homework



There are many scientific words in this article that you do not need to fully understand. When reading, do your best to try to understand the main themes and concepts rather than all of the specific details

The New Yorker
Jerome Groopman

Print Thyself

In February of 2012, a medical team at the University of Michigan's C. S. Mott Children's Hospital, in Ann Arbor, carried out an unusual operation on a three-month-old boy. The baby had been born with a rare condition called tracheobronchomalacia: the tissue of one portion of his airway was so weak that it persistently collapsed. This made breathing very difficult, and it regularly blocked vital blood vessels nearby, including the aorta, triggering cardiac and pulmonary arrest. The infant was placed on a ventilator, while the medical team set about figuring out what to do. The area of weak tissue would somehow need to be repaired or replaced—a major and dangerous operation in so small a patient. The team consulted with the baby's doctors at Akron Children's Hospital, in Ohio, and they soon agreed that they had just the right tool for this delicate, lifesaving task: a 3-D printer.

As its name suggests, a 3-D printer prints ink not on a flat substrate, such as paper, but in three dimensions, in successive layers; the ink is substrate and substance in one. The first 3-D printers were developed in the nineteen-eighties, by an American engineer named Charles Hull. The "ink" was an acrylic liquid that turned solid when exposed to ultraviolet light, typically from a laser beam. Makers of cars and airplanes could design complicated parts on a computer and then print out prototypes for manufacture; now they often print the part, too. Three-dimensional printers have become inexpensive and ubiquitous. Staples and Amazon now offer 3-D printing services, and the list of 3-D-printed products generally available includes nuts, bolts, earbuds, eyeglasses, athletic cleats, jewelry, cremation urns, “Star Wars” figurines, architectural models, and even entire houses. In the United States, debates have erupted over whether citizens should be allowed to 3-D-print handguns at home, which the technology makes possible. Today’s printers print in plastics, and also in silver, gold, and other metals, along with ceramics, wax, and even food. (NASA is working on a zero-gravity 3-D printer that can make pizza for orbiting astronauts.) For a small fee, you can upload a photograph of your face and receive back your likeness in the form of a 3-D-printed bobblehead doll.

The medical procedure at the University of Michigan worked on a similar principle. The researchers began by taking a CT scan of the baby’s chest, which they converted into a highly detailed, three-dimensional virtual map of his altered airways. From this model, they designed and printed a splint—a small tube, made of the same biocompatible material that goes into sutures—that would fit snugly over the weakened section of airway and hold it open. It was strong but flexible, and would expand as the boy grew—the researchers likened it to “the hose of a vacuum cleaner.” The splint would last for three years or so, long enough for the boy’s cells to grow over it, and then would dissolve harmlessly. Three weeks after the splint was implanted, the baby was disconnected from the ventilator and sent home. In May of 2013, in The New England Journal of Medicine, the researchers reported that the boy was thriving and that “no unforeseen problems related to the splint have arisen.”

This sort of procedure is becoming more and more common among doctors and medical researchers. Almost every day, I receive an e-mail from my hospital’s press office describing how yet another colleague is using a 3-D printer to create an intricately realistic surgical model—of a particular patient’s mitral valve, or finger, or optic nerve—to practice on before the actual operation. Surgeons are implanting 3-D-printed stents, prosthetics, and replacement segments of human skull. The exponents of 3-D printing contend that the technology is making manufacturing more democratic; the things we are choosing to print are becoming ever more personal and intimate. This appears to be even more true in medicine: increasingly, what we are printing is ourselves.

This past June, I attended the Aspen Ideas Festival, in Colorado, which opened with a focus on innovations in health. The first speaker was Scott Summit, a tall, bearded industrial designer for a company called 3D Systems. The company was started by Charles Hull, and has since grown into one of the world’s leading purveyors of 3-D printers and services. The company contributed to the design of a popular product called Invisalign, an alternative to the metal braces used in orthodontics. Treatment begins with a scan of the patient’s bite, to determine how it might be fixed over time. Then an individualized “aligner,” which looks like a clear plastic mouth guard, is printed for the patient to wear. Periodically, the design is adjusted and a new aligner is printed, until the problem is corrected.

3D Systems has made steady inroads into the medical market. A few months ago, the company, together with researchers at Children’s Hospital Oakland, completed an early test of a new kind of spinal brace for young adults with scoliosis. To correct the disorder, the typical brace must be worn during virtually every waking hour, but most kids can’t stand to do so. “If you look at the braces now, they press against the body,” Summit told me over the phone. “They come with Velcro straps; they’re hot in the summer. Most teen-agers don’t want to walk around looking like that.” I could sympathize. Several years ago, after a spinal-fusion operation, I had to wear a similar brace for months, and the experience was torture—the brace was highly uncomfortable and impossible to disguise. Summit’s new brace looked, instead, like a formfitting lace tank top. It was made from finely ground nylon powder that had been precisely melted, then left to solidify into a filigree pattern. The end result was light, breathable, and customized to the wearer’s body and medical needs, and could be easily worn under clothing. The company tested the brace with twenty-two girls, and is working toward making it more widely available.

At Aspen, Summit appeared onstage with a forty-six-year-old wheelchair-bound woman named Amanda Boxtel. In 1992, a skiing accident left Boxtel unable to use her legs; she is now the director of Bridging Bionics, a foundation that tries to restore mobility to people who are paralyzed. In 2013, researchers at 3D Systems scanned the contours of Boxtel’s lower body and then printed snug sleeves, made of flexible nylon fibres, for her torso, thighs, and shins. They then connected these to an existing set of motorized leg braces and hand controls made by a company called Ekso Bionics. The result, in effect, is a customized exoskeleton; when Boxtel wears it—as she later did at the conference—she can slowly walk. Other motorized mobility aids exist, Summit said, but because they aren’t personally sculpted, the wearer risks getting abrasions and infections when the device puts pressure on the hips and legs. “I love my robot,” Boxtel told me later. “It was made from me and for me. But I want more. I want to think of it as my sleek and sexy sports car.”

Until fairly recently, most 3-D-printed medical devices were aimed at shoring up the human body from the outside, but, increasingly, they are being slipped into us as well. 3D Systems supplies its printing technology to a company called Conformis, which prints more than a thousand customized knee implants a year. (Although the market for customized knee implants is surging, the jury is still out on whether they provide a better outcome than generic implants do.) Earlier this year, surgeons in Wales used a 3-D printer to reconstruct the facial bones of a twenty-nine-year-old man named Stephen Power, who fractured his left cheekbone, eye sockets, upper jaw, and skull in a motorcycle accident. The medical team scanned Power's skull and, based on the unbroken bones, determined what his full facial structure should be. They then printed a replica in titanium and successfully implanted it.

Recently, I spoke with Dr. Oren Tepper, the director of craniofacial surgery at Montefiore Medical Center, in the Bronx, who has found an innovative use for 3-D printing in his practice. In 2012, he was presented with an infant girl named Jayla, who had been born with only a rudimentary jaw. The condition made it difficult for her to breathe; the next step would have been to give her a tracheostomy. The usual solution, a full jaw reconstruction, would have required numerous, risky bone-graft surgeries and can't be performed until a child is older.

Instead, Tepper made a full CT scan of Jayla's head, and from that information arranged to have 3-D-printed a detailed plastic model of her ideal jaw. The model wouldn't replace her existing jaw; rather, Tepper would transform her existing jaw into one very similar in shape to the model. Tepper then had printed something akin to a three-dimensional stencil that fit exactly around the lower part of her face; it had slits and holes in it to indicate where he could drill without damaging her facial nerves. Finally, he attached a ratchet to her jaw; each day, he tugged her jaw forward by a millimetre, allowing her bone cells to grow and fill in the stretched region. When the whole process was complete, many weeks later, Jayla had a normal-sized jaw. Tepper now treats two or three children with similar malformations each year.

"I'm from the younger generation, comfortable with new technology," he told me. "You could try to do such a complex surgery without virtual modelling, and without 3-D printing. But it would be much more challenging, much more risky, with much more opportunity to fail."

The biggest leap for medical 3-D printing lies ahead. For years, researchers have dreamed of engineering kidneys, livers, and other organs and tissues in the lab, so that a patient who needs a transplant doesn't have to search for a donor. But growing usable tissue in the lab is notoriously difficult; the advent of 3-D printers that can print ink made of cells has offered a ray of hope. In the early nineteen-nineties, Anthony Atala, the director of the Wake Forest Institute for Regenerative Medicine, began growing human bladder cells on biodegradable scaffolds in his lab. The cells formed a kind of pouch, which he successfully implanted around the bladders of seven children with poor bladder function, relieving their condition. That achievement was soon followed by a cascade of announcements declaring victory in the race to create a true human organ. Most of these projects involved growing tracheal cells or cardiac cells or kidney cells on polymer scaffolds, often produced with 3-D printers, but none have succeeded in growing into full-fledged organs. As scientists make more concerted efforts to grow organs in the lab, the question is no longer whether they will succeed but how.

The first microscopes were invented in the sixteenth century, around the time of the invention of the telescope. Two realms were soon revealed: the macrocosmic world of celestial bodies and the vast distances between them, and the intimate, interior world of microscopic organisms and cells. But, whereas astronomers readily grasped that the mechanics of the universe proceed in three dimensions, cell biologists often still seem stuck in a two dimensions. Partly that's a function of how most microscopes work: a specimen must be placed on a thin glass slide so that it can be illuminated from above or below. As a result, even with modern computers and mapping software, biologists struggle to understand how our cells interact with one another to form three-dimensional tissues and organs, and they've had an even harder time re-creating those geometries.

In my lab, for example, I study endothelial cells, which line the insides of our veins, arteries, and capillaries. When these cells are removed from the body, they quickly die; growing and sustaining them in a lab requires special procedures and equipment. First, the cells are placed on a plastic dish coated with a gelatinous mix of collagen and other proteins. Then the dish is placed in an incubator, which is set at a certain temperature and infused with just the right amounts of oxygen, nitrogen, carbon dioxide, and water vapor, in an effort to approximate the ambient conditions within a living body. The cells survive for a few weeks, but I can't control how they organize themselves in the collagen matrix. I have yet to place a dish of endothelial cells in the incubator and return several days later to find a working blood vessel.

It's hard to overstate the importance of structure to the proper functioning of a biological system. Sickle-cell anemia is caused by a single, shape-altering gene mutation. The normal gene codes for a protein called globin, which helps red blood cells carry oxygen to the body's tissues. When the gene mutates, however, the resulting protein collapses on itself and can clog the blood vessels. Until recently, Alzheimer's researchers did not have reliable ways of studying how brain cells spontaneously make the abnormal amyloid proteins that are thought to be at play in the disease. Neurons raised in petri dishes simply don't behave the way they do in the brain. But in October, in an article in Nature, a team of scientists at Massachusetts General Hospital reported that when they grew the neurons in a gel matrix, so that the cells could interact with one another in three dimensions, they saw a far more realistic representation of the disease—a potential boon for future lab research on Alzheimer's.

Efforts to engineer tissues and organs have been similarly hampered by two-dimensional constraints. Jordan Miller, a bioengineer at Rice University, has noted that a viable replacement organ will need to be made of at least a billion working cells, of many different types. "Scaling up tissue constructs is first and foremost a numbers game," Miller wrote recently in the journal PLOS Biology, in a paper titled “The Billion Cell Construct: Will Three-Dimensional Printing Get Us There?” A flat petri dish, or several of them, won’t suffice; the cells need to be organized in such a way that they can exchange nutrients, growth factors, and other information.

But the expertise for wrangling such numbers, Miller wrote, “is still off by several orders of magnitude.” Scientists have typically tried to address the challenge by growing different cell types atop plastic or epoxy scaffolds. These masses soon become tombs; as the cells on the outside proliferate, those on the inside, starved of nutrients and deprived of oxygen, die. One could conceivably grow billions of kidney cells, and even make them look like a kidney, but, without a growing vasculature to nourish the whole mass, the behavior of that mass will bear little resemblance to that of an actual kidney.

“This is an area that has a lot of hype,” Jennifer Lewis, a materials scientist at Harvard, told me recently. “I remember the first time I saw a TED talk: I started watching the video, and the guy announced, ‘We’re printing a kidney!’ Then he showed some material in the shape of a kidney. I thought it was misleading, printing the shape but presenting it as if it were a kidney. We don’t want to give people false expectations, and it gives the field a bad name.”

Lewis is fifty, with short brown hair, rimless glasses, and a friendly, focussed manner. Although she likes to dampen any expectations about the 3-D printing of organs and tissues, her work is becoming central to the emerging field. In February, Lewis and a graduate student, David Kolesky, and other members of their research group published a paper in Advanced Materials describing a potential way to keep large masses of cells thriving. With a customized 3-D printer, they were able to print a protein matrix and living cell types in a pattern similar to what is found in the body. Critically, they managed to create within these blocks of tissues a network of vascular channels that, much like blood vessels, can deliver nutrients to the cells and keep them alive. It isn’t 3-D-printed organs, but it is a vital advance toward that goal. “We call it 3-D bioprinting,” Lewis told me, with an emphasis on “bio.”

Lewis grew up in Palatine, Illinois, and went to college at the University of Illinois at Urbana-Champaign. As a freshman, she was recruited into the ceramic-engineering program; she stayed with it and eventually, at M.I.T., got her doctorate in ceramics science. Lewis said that she likes ceramics for their unusual properties. They can form glass, porcelain, and clay, but they also readily conduct electricity and are a key material in many high-tech electronics.

“Ceramics processing has always been part science, part art,” she told me. “What I found most fascinating was that a given material’s properties can vary widely depending on how it is assembled." She added, "I fell in love with the idea of creating matter that matters."

In 1990, Lewis returned to Urbana-Champaign to teach, and began to work on 3-D printing, which she considered the perfect tool for constructing materials "voxel by voxel"—volume element by volume element. "If you think about 3-D printing thirty years ago, it was focussed on ultraviolet-curable resins, or thermoplastics, and it was largely a prototyping tool to make shapes or forms," she said. "I wanted to create functional materials and devices, rather than simply making prototypes."

In 2001, she began collaborating with Scott White, an accomplished materials engineer who for years had been working to create plastics and other building materials that would mend themselves when damaged. White told me that the kinds of cracks that can compromise the plastic or metal components in a car or an airplane typically occur within the material and aren't easily detected from the outside. White and his colleague Nancy Sottos had found a multi-step solution to the problem. First, with a 3-D printer, they created materials populated with microcapsules that, in turn, were filled with special healing agents; as the material suffered wear and tear, the microcapsules would break open and release their contents. The contents were monomers, simple plastic molecules that, when they encountered a certain other chemical that was embedded in the material, would react to fill a potential crack.

Second, once Lewis joined the team, the researchers realized that the material should have microchannels in it, so that the healing agents could more easily reach the cracks, just as clotting proteins and platelets in the body travel through capillaries to reach and heal open wounds. At first, they used a wax-based ink that would melt when heated. In 2011, Lewis went about developing Pluronic ink—a material that is gelatinous at room temperature but, counterintuitively, turns to a liquid when it is cooled to just above freezing. With their 3-D printer, Lewis and White could then make plastic objects that were embedded with intricate networks of the Pluronic-ink gel. Afterward, the object could be cooled down and the liquified ink could be sucked out, leaving a nexus of channels. For this reason, Lewis often refers to the material as "fugitive ink."

"It's a bio-inspired approach to creating materials that can heal themselves," Lewis said. "My big role in the project was to find ways to use 3-D printing to embed this microvascular network. Once we did that, it was pretty easy for me to see the broader implications."

In 2013, Lewis left Urbana-Champaign and took up a faculty post at Harvard, doing research at the Wyss Institute for Biologically Inspired Engineering. Her laboratory has several dozen undergraduates and graduate students working in it and occupies the better part of a new concrete-and-glass building on a quiet street just north of the main campus. Central to the lab's work are three customized 3-D printers, each worth a quarter of a million dollars. When I visited Lewis in September, I told her I was eager to see one.

Lewis led me through a warren of corridors and offices to a room where one of the printers sat on supports. It was immense. The base of the printer was a granite block five feet long, four feet deep, and a foot high, weighing a ton and a half. The printer does such fine-scale work that a stable base is essential, Lewis said. Resting on the block was a flat stage or platform, above which, in a vertical row, stood four rectangular steel containers, each a foot or so tall—the ink dispensers. They resembled the tubes of nuts in the bulk-foods section of the grocery store, although each of these dispensers ended at the bottom in a small, conical plastic tip, like that of a pipette. A tangle of colored wires connected the dispensers to some machinery behind them, and each dispenser was controlled at the top by a robotic arm. To the side sat a large monitor and a computer, which controlled the printer.

Each dispenser contained a different biological material, Lewis explained. One held an aqueous suspension of chemically treated collagen, which serves as the matrix on which many of the body's tissues take shape. Two others held suspensions of fibroblasts, the gristly cells that form the body's connective tissue. (The fibroblasts were harvested from discarded neonatal foreskins, which many hospitals save for use in research.) The last dispenser contained the fugitive ink that Lewis had developed to create channels within materials. David Kolesky, the graduate student who was working with Lewis, then demonstrated how it all worked.

First, he placed a clean glass slide on the platform, under one of the dispensers. On the computer, he called up a software program and found an image representing the block of tissue that he would be printing. It looked like a rectangle of semi-clear gelatin, within which was a vascular network: a channel entered at one end and branched into smaller vessels, which looped around and ultimately joined back into a single vessel that exited at the other end. It was a simple network, approximating the way that an artery divides into smaller capillaries that eventually recombine into a vein. "You can design whatever vascular pattern you want," Kolesky said. He showed me another slide, with a more complex branching pattern; it looked like a leafless tree branch. I recognized it: it was modelled on the pattern of blood vessels that supply oxygen and nutrients to the surface of the heart.

Then Kolesky hit "Run." The dispenser with the fugitive ink moved quickly and almost imperceptibly, releasing an exceptionally thin stream of what looked like agar onto the glass slide. The printer clacked and clattered like a busy riveting machine. In a minute or so, the job was done; the printer had left a trail of gelatinous ink that exactly matched the pattern on the computer. The stream of ink was about a tenth of a millimetre in diameter, and the entire pattern covered an area a little larger than a matchbook.

The printer wasn't rigged to finish the job, but Kolesky explained what would typically happen next. The other ink dispensers would take their turn, laying down a lattice of collagen and fibroblasts that would solidify around the network of fugitive ink, encasing it in tan-colored living tissue. To drain the fugitive ink, Kolesky would place the tissue on a chilled stone cube; this would cause the ink to change from a gel to a liquid, after which he could then extract it with a small suction device. The end result would be a block of living tissue suffused with intricate vessels capable of carrying nutrients to the cells within.

The last step was to me the most remarkable. Once the vessels were empty, Kolesky would take a suspension of endothelial cells—the cells that line the insides of blood vessels—and inject it into the vessel network. The cells would settle in and multiply to line the insides of the channels, effectively turning the channels into blood vessels. And then the cells would spread—they would begin to branch off the existing vessels and form new ones. In effect, Lewis and her team have created an environment that the cells consider home—it is far more natural to them than a petri dish or the inorganic scaffolds that had previously played host to cultured tissues.

"I like to say that we design the highway and then get out of the way and let the endothelial cells create their own driveways," Lewis said. "It's better to rely on the intelligence of the cells themselves in terms of how they like to sprout."

Lewis's approach is only one of many in the wider effort to create complex tissues. A team of researchers from Brigham and Women's Hospital and Carnegie Mellon University are working toward building a magnetically controlled "micro-robot" that can arrange cells in pre-specified structures. Other groups, at Boston University, Rice University, and at M.I.T., are pursuing ways of 3-D-printing vascular channels using a sugar-based ink. "I think it's wonderful," Jordan Miller, of Rice, said of Lewis's work. "She is a world leader."

For her part, Lewis is passionate about the changes that 3-D printing could bring to the pharmaceutical industry. Billions of dollars each year are spent on drug development that fails. If bioprinted tissues were readily available, experimental drugs could be tested on them to see how the drugs are metabolized and what side effects result. "We want to provide a fail-fast model," Lewis said, "so that drugs can be assessed in 3-D human tissue and their toxic properties identified before spending money and effort in animal and human testing."

But Lewis admits that she does think about the prospect of printing whole, functioning organs. “The grand challenge is to make a whole kidney—that is our moon shot,” she said. The first step would be to make a nephron, the fundamental filtering unit of a kidney. She noted that her team has already demonstrated the ability to print any pattern of vascular channels that it wants; the blood-vessel patterns of a nephron are just one more option. And recently the team found a way to line channels with epithelial cells taken from human kidneys. “We see this as a ladder, one step following the next,” she said. “Creating just a single nephron would be a great achievement. But there are a million in each kidney.”

Before I left the lab, Kolesky showed me the incubator, a white box near the printer that was about the size of a dorm-room refrigerator. He opened the door. On a shelf, on a glass slide, was a finished block of printed tissue. A fine plastic tube, the size of a strand of spaghetti, entered it at one end, delivering glucose, amino acids, and other critical nutrients. Another spaghetti-like tube emerged from the other end, carrying off carbon dioxide, broken-down proteins, and other cellular waste. The tissue had been alive for the past two weeks, Kolesky said. There wasn’t much to see, but the tissue was thriving, and it looked to me like the start of something very big.

Comprehension Questions

1. Which example of 3D printed health products do you find the most significant? Why?

2. How is 3D printing helping individuals to become more comfortable with their prosthesis?

3. How will 3D printing help the pharmaceutical industry?

4. What do Lewis want to make before kidney? Do you think it is a good idea to do that first?

Printing a Human Kidney

Watch online at:
http://www.ted.com/talks/anthony_atala_printing_a_human_kidney
0:00 - 13:21

There's actually a major health crisis today in terms of the shortage of organs. The fact is that we're living longer. Medicine has done a much better job of making us live longer, and the problem is, as we age, our organs tend to fail more, and so currently there are not enough organs to go around. In fact, in the last 10 years, the number of patients requiring an organ has doubled, while in the same time, the actual number of transplants has barely gone up. So this is now a public health crisis.
0:43
So that's where this field comes in that we call the field of regenerative medicine. It really involves many different areas. You can use, actually, scaffolds, biomaterials -- they're like the piece of your blouse or your shirt -- but specific materials you can actually implant in patients and they will do well and help you regenerate. Or we can use cells alone, either your very own cells or different stem cell populations. Or we can use both. We can use, actually, biomaterials and the cells together. And that's where the field is today.
1:17
But it's actually not a new field. Interestingly, this is a book that was published back in 1938. It's titled "The Culture of Organs." The first author, Alexis Carrel, a Nobel Prize winner. He actually devised some of the same technologies used today for suturing blood vessels, and some of the blood vessel grafts we use today were actually designed by Alexis. But I want you to note his co-author: Charles Lindbergh. That's the same Charles Lindbergh who actually spent the rest of his life working with Alexis at the Rockefeller Institute in New York in the area of the culture of organs.
1:55
So if the field's been around for so long, why so few clinical advances? And that really has to do to many different challenges. But if I were to point to three challenges, the first one is actually the design of materials that could go in your body and do well over time. And many advances now, we can do that fairly readily. The second challenge was cells. We could not get enough of your cells to grow outside of your body. Over the last 20 years, we've basically tackled that. Many scientists can now grow many different types of cells. Plus we have stem cells. But even now, 2011, there's still certain cells that we just can't grow from the patient. Liver cells, nerve cells, pancreatic cells -- we still can't grow them even today. And the third challenge is vascularity, the actual supply of blood to allow those organs or tissues to survive once we regenerate them.
2:49
So we can actually use biomaterials now. This is actually a biomaterial. We can weave them, knit them, or we can make them like you see here. This is actually like a cotton candy machine. You saw the spray going in. That was like the fibers of the cotton candy creating this structure, this tubularized structure, which is a biomaterial that we can then use to help your body regenerate using your very own cells to do so. And that's exactly what we did here.
3:16

This is actually a patient who [was] presented with a deceased organ, and we then created one of these smart biomaterials, and then we then used that smart biomaterial to replace and repair that patient's structure. What we did was we actually used the biomaterial as a bridge so that the cells in the organ could walk on that bridge, if you will, and help to bridge the gap to regenerate that tissue. And you see that patient now six months after with an X-ray showing you the regenerated tissue, which is fully regenerated when you analyze it under the microscope. We can also use cells alone. These are actually cells that we obtained. These are stem cells that we create from specific sources, and we can drive them to become heart cells, and they start beating in culture. So they know what to do. The cells genetically know what to do, and they start beating together. Now today, many clinical trials are using different kinds of stem cells for heart disease. So that's actually now in patients.

4:19

Or if we're going to use larger structures to replace larger structures, we can then use the patient's own cells, or some cell population, and the biomaterials, the scaffolds, together. So the concept here: so if you do have a deceased or injured organ, we take a very small piece of that tissue, less than half the size of a postage stamp. We then tease the cells apart, we grow the cells outside the body. We then take a scaffold, a biomaterial -- again, looks very much like a piece of your blouse or your shirt -- we then shape that material, and we then use those cells to coat that material one layer at a time -- very much like baking a layer cake, if you will. We then place it in an oven-like device, and we're able to create that structure and bring it out. This is actually a heart valve that we've engineered, and you can see here, we have the structure of the heart valve and we've seeded that with cells, and then we exercise it. So you see the leaflets opening and closing -- of this heart valve that's currently being used experimentally to try to get it to further studies.

5:31

Another technology that we have used in patients actually involves bladders. We actually take a very small piece of the bladder from the patient -- less than half the size of a postage stamp. We then grow the cells outside the body, take the scaffold, coat the scaffold with the cells -- the patient's own cells, two different cell types. We then put it in this oven-like device. It has the same conditions as the human body -- 37 degrees centigrade, 95 percent oxygen. A few weeks later, you have your engineered organ that we're able to implant back into the patient. For these specific patients, we actually just suture these materials. We use three-dimensional imagining analysis, but we actually created these biomaterials by hand.

6:14

But we now have better ways to create these structures with the cells. We use now some type of technologies, where for solid organs, for example, like the liver, what we do is we take discard livers. As you know, a lot of organs are actually discarded, not used. So we can take these liver structures, which are not going to be used, and we then put them in a washing machine-like structure that will allow the cells to be washed away. Two weeks later, you have something that looks like a liver. You can hold it like a liver, but it has no cells; it's just a skeleton of the liver. And we then can re-perfuse the liver with cells, preserving the blood vessel tree. So we actually perfuse first the blood vessel tree with the patient's own blood vessel cells, and we then infiltrate the parenchyma with the liver cells. And we now have been able just to show the creation of human liver tissue just this past month using this technology.

7:15

Another technology that we've used is actually that of printing. This is actually a desktop inkjet printer, but instead of using ink, we're using cells. And you can actually see here the printhead going through and printing this structure, and it takes about 40 minutes to print this structure. And there's a 3D elevator that then actually goes down one layer at a time each time the printhead goes through. And then finally you're able to get that structure out. You can pop that structure out of the printer and implant it. And this is actually a piece of bone that I'm going to show you in this slide that was actually created with this desktop printer and implanted as you see here. That was all new bone that was implanted using these techniques.

8:00

Another more advanced technology we're looking at right now, our next generation of technologies, are more sophisticated printers. This particular printer we're designing now is actually one where we print right on the patient. So what you see here -- I know it sounds funny, but that's the way it works. Because in reality, what you want to do is you actually want to have the patient on the bed with the wound, and you have a scanner, basically like a flatbed scanner. That's what you see here on the right side. You see a scanner technology that first scans the wound on the patient and then it comes back with the printheads actually printing the layers that you require on the patients themselves.

8:45

This is how it actually works. Here's the scanner going through, scanning the wound. Once it's scanned, it sends information in the correct layers of cells where they need to be. And now you're going to see here a demo of this actually being done in a representative wound. And we actually do this with a gel so that you can lift the gel material. So once those cells are on the patient they will stick where they need to be. And this is actually new technology still under development.

9:16

We're also working on more sophisticated printers. Because in reality, our biggest challenge are the solid organs. I don't know if you realize this, but 90 percent of the patients on the transplant list are actually waiting for a kidney. Patients are dying every day because we don't have enough of those organs to go around. So this is more challenging -- large organ, vascular, a lot of blood vessel supply, a lot of cells present. So the strategy here is -- this is actually a CT scan, an X-ray -- and we go layer by layer, using computerized morphometric imaging analysis and 3D reconstruction to get right down to those patient's own kidneys. We then are able to actually image those, do 360 degree rotation to analyze the kidney in its full volumetric characteristics, and we then are able to actually take this information and then scan this in a printing computerized form. So we go layer by layer through the organ, analyzing each layer as we go through the organ, and we then are able to send that information, as you see here, through the computer and actually design the organ for the patient. This actually shows the actual printer. And this actually shows that printing.

10:38

In fact, we actually have the printer right here. So while we've been talking today, you can actually see the printer back here in the back stage. That's actually the actual printer right now, and that's been printing this kidney structure that you see here. It takes about seven hours to print a kidney, so this is about three hours into it now. And Dr. Kang's going to walk onstage right now, and we're actually going to show you one of these kidneys that we printed a little bit earlier today. Put a pair of gloves here. Thank you. Go backwards. So, these gloves are a little bit small on me, but here it is. You can actually see that kidney as it was printed earlier today.

11:39

(Applause)

11:55

Has a little bit of consistency to it. This is Dr. Kang who's been working with us on this project, and part of our team. Thank you, Dr. Kang. I appreciate it.

12:07

(Applause)

12:12

So this is actually a new generation. This is actually the printer that you see here onstage. And this is actually a new technology we're working on now. In reality, we now have a long history of doing this. I'm going to share with you a clip in terms of technology we have had in patients now for a while.

12:29

And this is actually a very brief clip -- only about 30 seconds -- of a patient who actually received an organ.

12:36

(Video) Luke Massella: I was really sick. I could barely get out of bed. I was missing school. It was pretty much miserable. I couldn't go out and play basketball at recess without feeling like I was going to pass out when I got back inside. I felt so sick. I was facing basically a lifetime of dialysis, and I don't even like to think about what my life would be like if I was on that. So after the surgery, life got a lot better for me. I was able to do more things. I was able to wrestle in high school. I became the captain of the team, and that was great. I was able to be a normal kid with my friends. And because they used my own cells to build this bladder, it's going to be with me. I've got it for life, so I'm all set.

Comprehension Questions

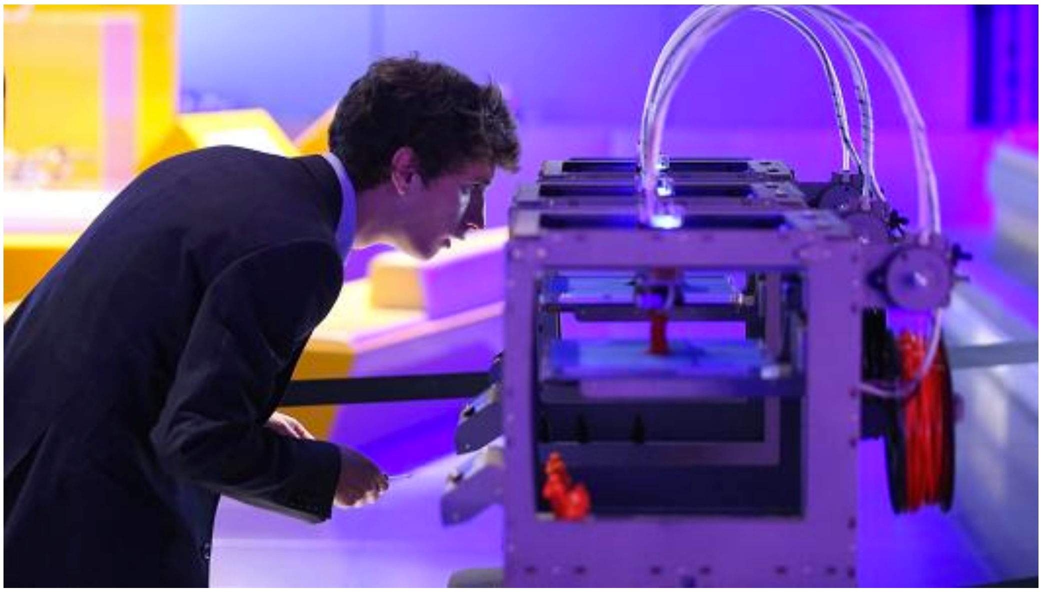
1. What is the current public health crisis?

2. What three challenges have scientists overcome to produce biomaterials?

3. Summarize the process of repairing deceased or injured organs?

4. How could a 3D printer heal someone who has a cut?

5. How did Luke's life change because of his operation?



This article is to help you think of creative ideas and write a better essay

CNBC
Linda Federico-O'Murchu

How 3-D printing will radically change the world

If you're not excited by 3-D printing it's because you're not thinking big enough, say some technology visionaries who predict that life on Earth will soon radically change because of it.

According to these futurists, 3-D printing will make life as we know it today barely recognizable in 50 to 75 years.

"Realistically, we're going to be living to 100 ...110. With bio-printed organs, living to 110 won't be anything like living to that age today," contends Jack Uldrich, a technology trend expert. "We're already printing skin, kidneys, a replica of a beating human heart. If a person loses a limb, we'll be able to print, layer by layer, a replacement. It's theoretically possible."

Uldrich says companies will soon be able to manufacture goods domestically, with virtually no wasted materials and no need for international outsourcing.

"If we can print a shoe here, we don't have to go to China or Indonesia," he says. Uldrich also predicts the demise of the construction and agriculture industries, which he says will make many traditional methods of building and food production obsolete.

"Right now, you have to feed a cow 20,000 gallons of water and 10,000 pounds of grain in its lifetime. Then there's the cost of slaughtering, shipping and packaging. Our grandkids will say, 'that was insane.' "

In fact, 3-D printing technology is advancing at a staggering rate. American designers are now working on 3-D printed cars, while in China and Holland, 3-D printers are building entire houses. The first 3-D printed hamburger was recently created in England, heralding the possibility of a man-made food supply.

Boeing, GE and other industry leaders are manufacturing state-of-the-art aerospace equipment with the new technology, while NASA, using Zero-G technology, is demonstrating how 3-D printers will one day be used in space.

Perhaps most dramatic are the advances being made in the medical field. Research and development of 3-D printing-based medical techniques have already saved countless lives and opened the doors to previously unimaginable possibilities in medicine.

"It's opening up a whole new world," agrees Sarah Boisvert, chief 3-D printing officer at Potomac Photonics and a technology consultant at MIT. However, she cautions that, despite its increasingly dominant presence in highly specialized industries, 3-D printing technology will not meaningfully change the lives of the average person in the foreseeable future.

"I'm so sick of reading the hype," she admits. "Like, 'we can press a button and make anything.' Yes, that is the future and it's coming, but right now it's complicated. Not every 3-D printer can generate every material. Some guy in his garage is not going to be able to print Titanium."

"I don't want to be a naysayer, but these are grandiose notions we should keep at bay," warns Tim Shinbara, technology director at the Association of Manufacturing Technology in McLean, Virginia. Shinbara, who is currently helping create the first crowd-source designed, 3-D printed car (to be unveiled at the International Manufacturing Technology Show in October), says people's excitement should not override their common sense.

"3-D printing is not that new; we've heard all this before," Shinbara says. "Inventions like the computer changed things, yes, the world progressed, but still, we're not living in a Jetsons world. We're not flying around in cars."

One area that particularly concerns him is 3-D printed food.

"Even if it technically works, should we be doing it? If we start creating food instead of growing or harvesting it—that gets a little scary. At a molecular level, does your body accept something that's been artificially and genetically manufactured? Even if it looks the same under a microscope, what will it do to you over 10, 20 years?"

The hype over 3-D printing, say technology experts, ignores the potential problems it will create. One significant problem is the legality and ethical ramifications of widespread public use. Right now, additive manufacturing (the technical term for 3-D printing) is in its "Wild West" phase, meaning, the laws have not yet caught up with the technology.

An example of this is 3-D printed guns. Last year, blueprints for a 3-D-printable gun, The Liberator, were posted online and downloaded some 100,000 times before the State Department ordered them taken down.

"If gun control advocates hoped to prevent blueprints for the world's first fully 3-D-printable gun from spreading online, that horse has now left the barn about a hundred thousand times," Forbes magazine wrote.

A few months after The Liberator incident, President Obama extended the 1988 Undetectable Firearms Act, which prohibits the manufacture, sale or possession of guns that are undetectable by X-ray machines or metal detectors. Critics protested that 3-D printed guns could easily be modified to circumvent airport surveillance machines.

And there are other ethical issues to be considered with 3-D printing. Though Daniel Castro, Senior Policy Analyst at the Information Technology and Innovation Foundation in Washington, DC, believes 3-D printing's capacity for innovation will ultimately benefit society, he wonders how intellectual property rights will be protected and enforced.

"I don't think we're going to be too worried about consumers printing out Mickey Mouse and Disney being mad about that," says Castro. "We're more likely to be concerned about India or China or another country stealing digital designs using corporate espionage, and then being able to perfectly replicate what's been produced in the US or elsewhere. Governments will have to hold companies accountable for what could be massive intellectual corporate property theft."

Technology gurus like Jack Uldrich, however, say there's no stopping a speeding a train. The choices are get on board, get passed by or get run over, he says.

"If you can print out food, components of homes, body parts as we age, it points to a really interesting future," he speculates. "We'll be treating animals in a humane way, rewriting the rules of society. What if we really don't need to work? In the hands of 7 billion creative people—we can't even begin to imagine how people will use this technology."

Essay

How will 3D printing have its greatest impact? Talk about 3 industries:

- Food
- Housing
- The Developing World
- Manufacturing
- Crime
- Health Care.

Compare these industries in three different ways.

Brainstorm

Thesis: ______________________________

Ideas

Organize

Main Ideas

Essay