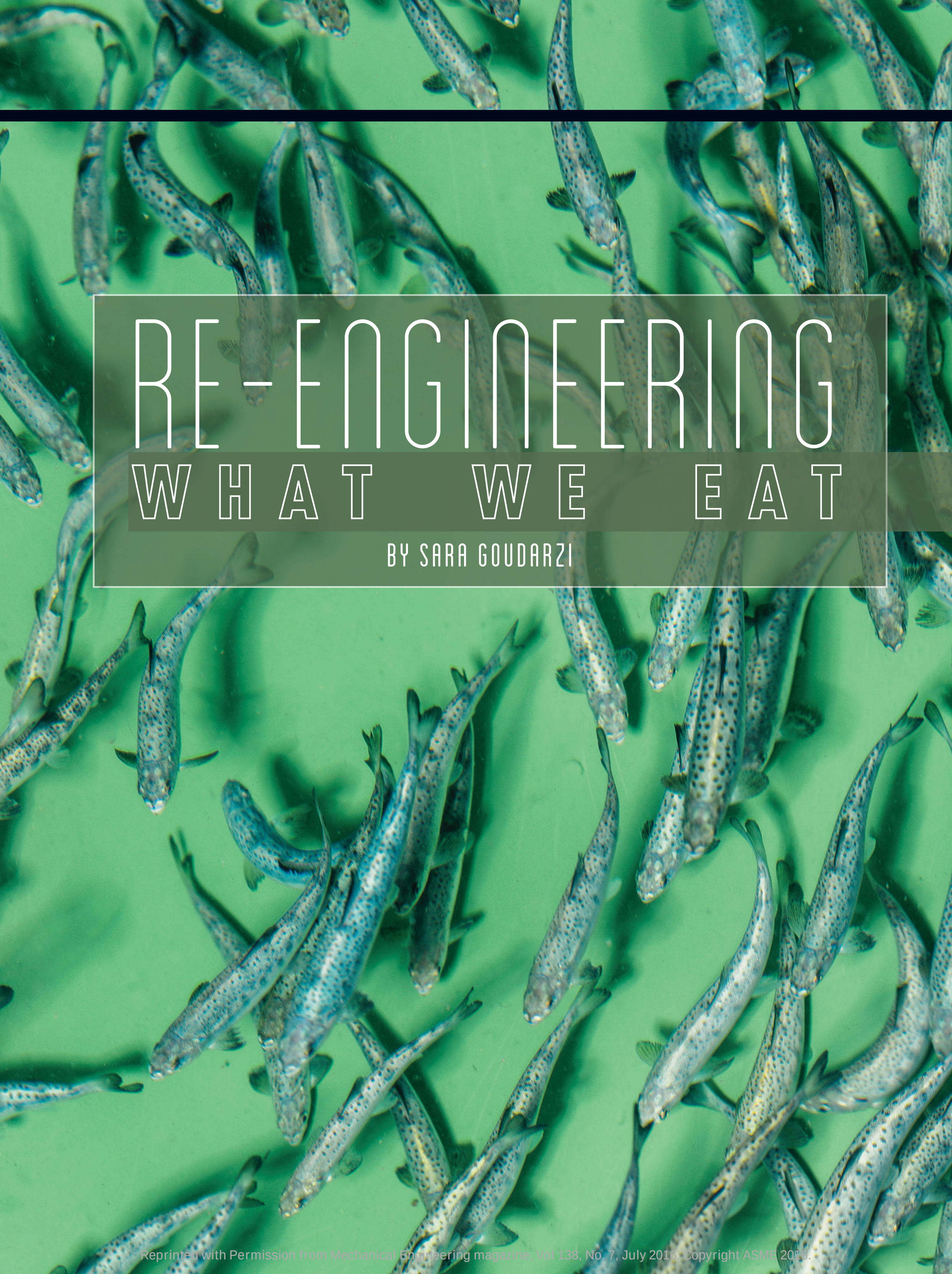


RE-ENGINEERING WHAT WE EAT

BY SARA GOUDARZI

AN EVER-CHANGING BALANCE OF SUPPLY, DEMAND, AND RESOURCES WILL REQUIRE US TO ALTER THE WAY WE CONCOCT WHAT WE CONSUME.

A curious group of a few dozen culinary students and a handful of chefs gathered in the amphitheater of the International Culinary Center in Manhattan last February to hear about a new way to make food. Drim Stokhuijzen, a visiting research scholar at Columbia University, told them about his work designing a machine that can print food and why such a technology is needed.

"Food printing allows for personal nutrition, convenience, sustainability and new food experiences," Stokhuijzen said. The technology, he explained, could be used for those with medical conditions, such as patients with diabetes and dysphagia, and professionals like soldiers and astronauts. Food printing provides "the possibility to create personalized food on demand, which tastes and looks better."

Rather than struggle with following incomprehensible recipes, a person who wanted a custom-made meal could download a file, plug in the right cartridges, and have their food printer lay down a dinner line by delicious line.

Much of how we live and work has been transformed by high technology over the past few decades, but food is one of the few areas that has remained largely the same. We still cook using very old techniques—over a flame—and for the most part use ingredients from sources that have been around for many years. The writer Michael Pollan has advised, "Don't eat anything your great-grandmother wouldn't recognize as food," and that can still be done, with effort.

However, with a growing population, warming climate, and limited resources, researchers are thinking of alternative ways of producing edibles. Three-D food printing is just one of the technologies that's shaping the future of food. To provide a growing population with enough to eat, we may have to reengineer the very plants and animals we consume.

IT'S WHAT'S FOR DINNER

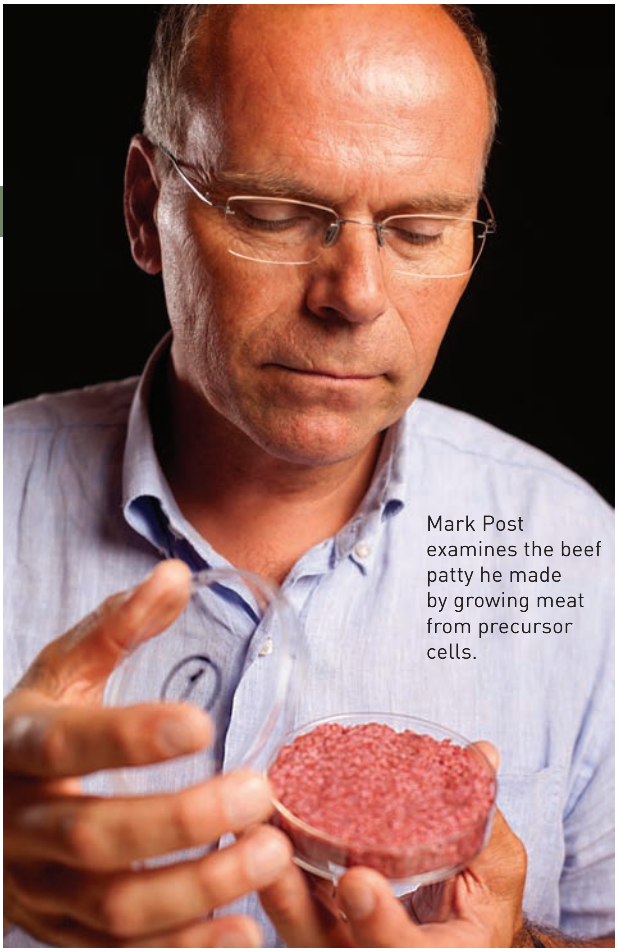
Sustainability is one major challenge for our present agricultural system—the way we produce food today demands too many resources. That pressure is only going to increase: According to the United Nations Food and Agriculture Organization, food production will need to double in the next 35 years to feed the expected global population.

The problem will be especially acute if the new mouths to feed expect a Western, meat-rich diet. Livestock production already uses more land than any other human activity and is said to contribute up to 20 percent of total greenhouse gas emissions. And beef is the biggest problem. In a 2014 study published in the *Proceedings of the National Academy of Sciences*, researchers estimated that beef requires 28 times more land and 11 times more water to produce than what is needed for other livestock.

To mitigate that, some researchers have taken beef production inside the walls of a laboratory. "The process is simple: Take a small muscle biopsy from a cow, harvest its stem cells, let the stem cells proliferate until you have trillions, and then let the muscle-specific stem cells produce muscle tissue," said Mark J. Post, professor and chair of physiology at Maastricht University in the Netherlands.

Post made headlines when he created the first morsel

THE FIVE-OUNCE PATTY COST A WHOPPING $325,000 TO PRODUCE. BUT WITH LARGE-SCALE PRODUCTION, THE PRICE WILL BE COMPARABLE TO CONVENTIONALLY PRODUCED BEEF.



Mark Post examines the beef patty he made by growing meat from precursor cells.

of lab grown meat in 2013. His five-ounce patty cost a whopping $325,000 to produce. With the right technology and larger scale production, he believes, the price ought to go down significantly and be comparable to conventionally produced beef.

Nutritionally the burger will also be similar to traditionally grown beef, “but some nutrients, such as vitamin B12, will have to be added to the feed of the cells,” Post said.

One area that researchers are still working on with lab grown meat is the taste—a complex combination of proteins, glycosylated proteins, and other compounds in the fat. Up to now, while the tissue the research team has created closely resembles meat, it is lacking the fat contained in traditional beef. Post said they currently are working on fixing that.

Another area that needs improvement is texture. Animals are continually “exercised” as they move, and their meat has connective tissue giving it the chewy texture that carnivores are familiar with. However, critics contend lab grown meat lacks that type of texture and is, instead, mushy. Some researchers have proposed mechanical means of exercising the meat—such as using electrical stimulation.

Post, however, believes electrical stimulation is undesirable from an energy standpoint and that the meat exercises itself by spontaneously contracting. “The tasters actually mentioned that the texture was already pretty good,” he said. “But can be further improved to make the fibers longer, for instance.”

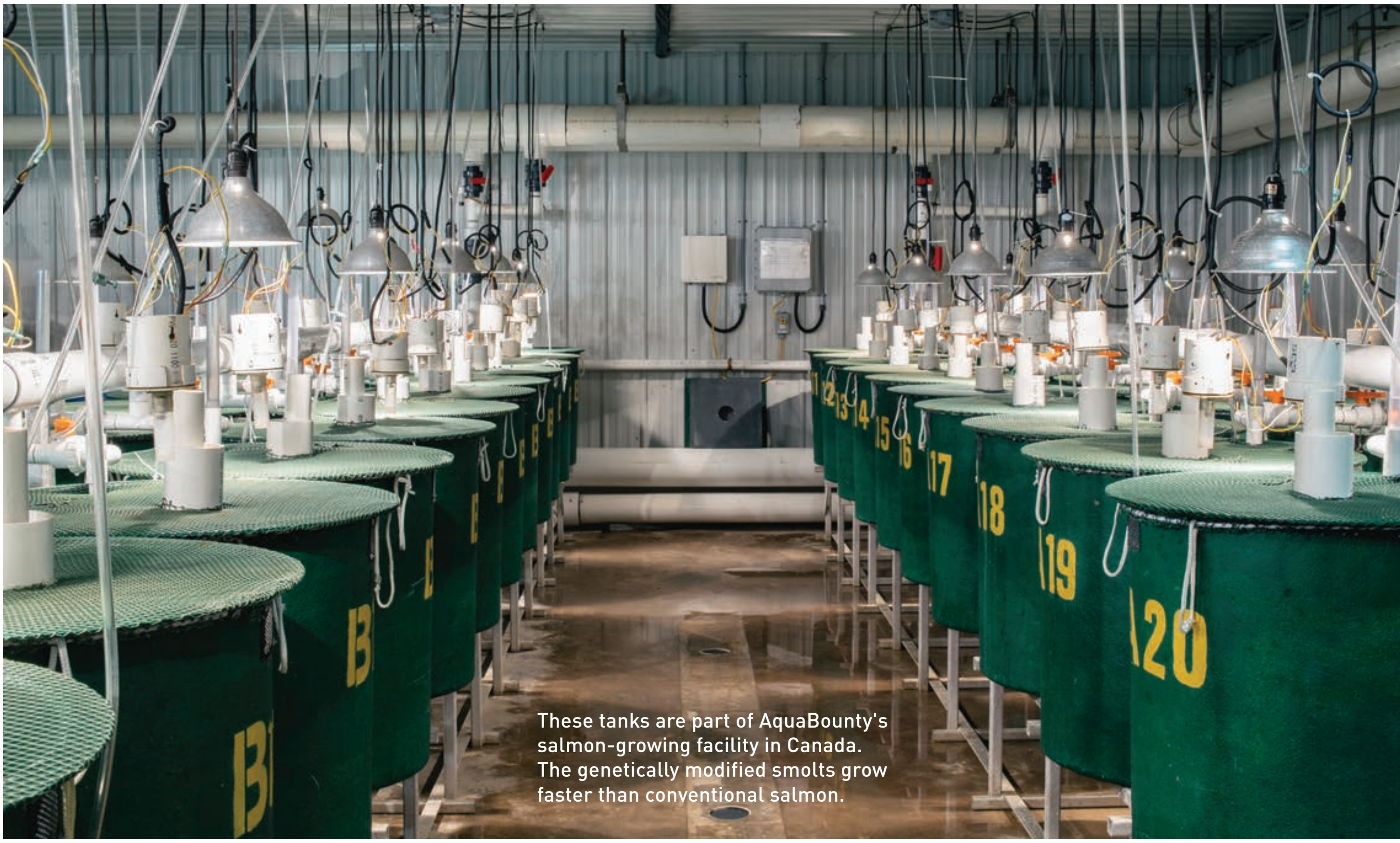
Accomplishing that is relatively easy, he said, and could be achieved by increasing the diameter of the central column (or distance between anchor points) around which the muscle fibers are placed when growing in a gel medium.

To make “test-tube steaks” available to the general population, producers would need large-scale cell fabrication, efficient production of feed for the cells, biomaterials that allow tissue formation, and bioreactors that create the right conditions to allow tissue growth on a scale that could be used in a mass market. While all that entails a lot of up-front capital costs, the payoff is faster meat production. The growth process should take around nine weeks to produce a salable slab of meat, compared to about 15 months to bring a calf to market.

Once the method takes off, researchers anticipate they could use it to produce chicken and even fish meat in the laboratory.

ENGINEERING GENES

Other researchers suggest the best way to produce animals and plants faster while using fewer resources is to embrace genetically modified and genetically edited foods. Unlike in vitro meat, GM meats are already closer to showing up at the butcher. Last year, for the first time, the U.S. Food and Drug Administration approved the meat of a genetically modified animal for consumption in the United States. The FDA-approved salmon, named AquAdvantage, grows



These tanks are part of AquaBounty's salmon-growing facility in Canada. The genetically modified smolts grow faster than conventional salmon.

to maturity in about 20 months, 16 months faster than conventionally farmed fish.

"The founder fish, from which the AquAdvantage salmon line was developed, was created by microinjecting the transgene (a Chinook salmon growth hormone gene coupled to a promoter sequence from ocean pout) into fertilized Atlantic salmon eggs," said Dave Conley, director of corporate communications at AquaBounty Technologies, Inc., in Maynard, Mass., the company who developed the fish. Chinook is the largest Pacific Ocean salmon, while an ocean pout is a fish capable of withstanding and growing during freezing temperatures. Conventional salmon don't typically grow during the colder months.

Although it's not clear when AquAdvantage salmon will hit the market, it's safe to assume that it will be at least two years for the first batch to mature and be ready for sale. Those involved with the fish believe that if well received, the technology could have a huge impact.

"Given the unpredictable nature of climate change, our ability to rapidly develop plants and animals for food production in the future is even more pressing [now] than it was in the 1980s when we first began our journey," Conley said.

Professor Wendy Harwood of the John Innes Centre at Norwich Research Park agrees that getting the gene just right in a food supply could have a whole slew of possible benefits. Her approach, however, is not by modifying the gene as in the AquAdvantage salmon but through editing genes via a tool known as CRISPR, short for clustered regularly interspaced short palindromic repeats. That tool could be used on any living organism and is causing excitement in both the medical and agricultural research fields due to its potential benefits.

"It could certainly have an impact on making plants more disease resistant," she said. "It could also have an impact in cases where there's a compound in the plant that you really rather wished wasn't there—maybe something you're allergic to or is toxic. It gives you a way of removing that type of compound from the plant."

Gene editing is a technique that allows researchers to have the ability to home in on one specific gene and make a very small change that disrupts the function of that gene so it doesn't work anymore. If that particular gene causes a disease, for example, then the ability to either stop that gene from functioning or make a correction to it is extremely powerful.

In plants, gene editing requires two components: A guiding system to direct all the bits necessary to the right location and an enzyme that makes a break in the DNA strand in that targeted gene. The guiding system—which can be a small guide ribonucleic acid (RNA)

molecule or a protein complex—takes the enzyme along with it, and makes a break in a very precise place in the gene. Then, the machinery in the cell tries to correct that break and in the process makes a mistake, introducing a mutation. In many cases that mutation disrupts the function of that gene so it doesn't work anymore.

So far, gene editing has successfully been used in a whole range of crops, such as barley, brassica, wheat, potato, and tomato. Although most of the work on crops is still at the research stage, an herbicide-resistant oil seed rape crop developed by the San Diego–based company Cibus is currently being grown in the fields in the U.S., opening the door to more genetically edited crops to hit the market in the near future.

"The outcome is actually very similar to mutation breeding and it can even be similar to a natural mutation because the DNA is changing and mutating all the time. It's possible that you could have a natural mutation which could be identical to one we have created using gene editing," said Harwood.

PRINT AND SERVE

When it comes to final preparation, however, the amount of control in gene editing pales in comparison to food printing.

During his February talk at the International Culinary Center, Stokhuijzen explained that the idea of food printing is very similar to 3-D printing—the layer-by-layer formation of an object from a computer-aided design file. There are different methods that could achieve that type of printing, or deposit of material. A machine might set down edibles—such as chocolate or dough—through syringe nozzles onto a plate, or it could work with powdered food that is selectively bound together with a fluid.

According to Kjeld Van Bommel, a research scientist at TNO, the Netherlands Organization for Applied Scientific Research in The Hague, the technology uses a printer head to deposit droplets into a layer of powder, such as sugar. "As a result the sugar will start to bind together," Van Bommel said. "If this is done in a controlled manner and layer by layer, this process will result in a 3-D agglomerated sugar object that can be taken out of the non-agglomerated sugar."

Confectionary chefs may soon have access to high-end machines like this. The manufacturer 3D Systems, Inc., has an event space in Los Angeles featuring sculptural deserts made of printed sugar. But main courses one could conceivably print at home will also have to start with highly processed ingredients, such as powders and gels, that can fit in a cartridge.

"You're not going to print a tomato or a steak," said Hod Lipson, a mechanical engineering professor at Columbia University and the author of *Fabricated: The New World of 3D Printing*. "But I have to say that more than half of what we eat is processed foods, so this is quite a large portion of foods."

Although devising the cartridges and their fillings will take some ingenuity, many home-cooked meals already start with ingredients that are powders, gels, liquids or pastes. For instance, the basic ingredients in everyday meals such as a pizza could be squeezed from tubes. In fact, in 2013, NASA awarded a $125,000 grant to a start-

up to develop a pizza printer for the space agency.

Researchers also are currently working on incorporating infrared cookers that cook the food as it prints, which would give users very precise control over the process. For example, one could get the edges of a pizza crust well done, while cooking rest of the pizza normally. "It's not a uniform oven that cooks everything in the same way but can cook different parts [of a dish] to different extents and different temperatures," Lipson said.

So how would a food printer work for the average household? One possibility is that the printer would have an interface on an app that runs on a tablet computer such as an iPad; consumers could flip through recipes, load the necessary ingredient cartridges into the printer, and watch the device produce the dish.

In the end, scientists envision a food printer to be a kitchen appliance that would not replace the idea of conventional cooking but supplement it when necessary.

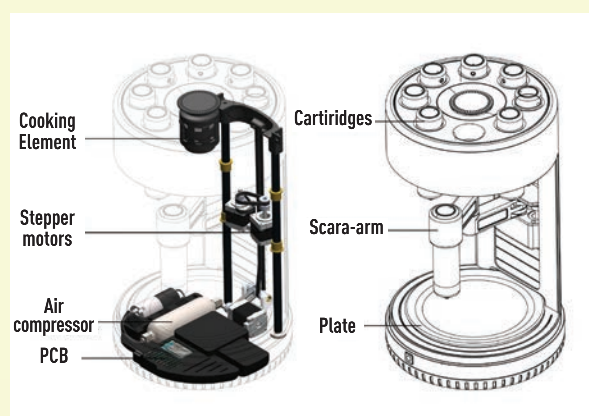
"A good analogy would be a Nespresso machine," Lipson said. "You pay $100 for the machine and then you pay a dollar or so per cartridge or per cubic inch of food or whatever the unit is going to be. I'm sure if it's a cartridge of caviar or a cartridge of cookie dough it's going be different."

While countertop food printers may make take the home cook one step further from the farm, it could also have some unexpected environmental benefits. "I'd like to say that because it's a print on demand it would use less material because you would print what you need instead of buying in bulk, though nobody has really done an in depth analysis." Lipson said.

Whether through tinkering with genes, growing foods in laboratories, or preparing them through printers or robots, technologies revolving around food are undergoing rapid research and development.

"The implications for human health, food production, and environmental remediation are very exciting," AquaBounty's Conley said. **ME**

SARA GOUDARZI is a technology writer based in Brooklyn, N.Y.



Jerson Mezquita (top left) and Drim Stokhuijzen work with a prototype food printer at their lab at Columbia University. The machine would print powdered ingedients sold in cartridges (mocked up at botttom).