

TECHNOLOGY

Why This Cardiologist Is Betting That His Lab-Grown Meat Startup Can Solve the Global Food Crisis

The future of your entrée is quietly growing in Memphis Meats' lab.

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CREDIT: Ramona Rosales

Uma Valeti remembers the first time he really thought about [where meat comes from](#). A cardiologist turned founder, Valeti grew up in Vijayawada, India, where his father was a veterinarian and his mother taught physics. When he was 12, he attended a neighbor's birthday party. In the front yard, people danced and feasted on chicken tandoori and curried goat. Valeti wandered around to the back of the house, where cooks were hard at work decapitating and gutting animal after animal to keep the loaded platters coming. "It was like, birthday, death day," he says. "It didn't make sense."

Valeti remained a carnivore for more than a decade, until after he had moved to the U.S. for his medical residency. But in time, he found himself increasingly disturbed by food-borne illness. He was especially grossed out by the contamination that happens in slaughterhouses when animal feces get mixed in with meat. "I loved eating meat, but I didn't like the way it was being produced," he says. "I thought, there has to be a better way."

In a tiny R&D suite in a nondescript office building in the unglamorous Silicon Valley exurb of San Leandro, a lanky, red-haired molecular biologist named

Eric Schulze is fiddling with a microscope, and I'm about to get a look at that better way. Like the specimen he'll show me, Schulze is something of a hybrid. Formerly a Food and Drug Administration regulator, he's now an educator, TV host, and senior scientist at [Memphis Meats](#), the company that Valeti founded in 2016 and whose laboratory he is showing me. Lining one wall is a HEPA-filtered tissue cabinet, to which someone has affixed a "Chicken Crossing" sign, and a meat freezer labeled "Angus." Along the opposite wall is an incubator dialed to 106 degrees Fahrenheit, the body temperature of *Anas platyrhynchos domesticus*--the domestic duck.

Beefing Up

Food trends come and go. But meat is a mainstay, as evidenced by global data on its production from 2001 through 2014:

**15%
increase**

in production of beef

**34%
increase**

in production of pork

**71%
increase**

in production of chicken

Sources: Food and Agriculture Organization of the United Nations

Schulze plucks a petri dish from the incubator, positions it under the microscope, and then invites me to look into the twin eyepieces. "Do you see those long, skinny things? Those are muscle-forming cells," he says. "These are from a duck that's off living its life somewhere." The cells look like strands of translucent spaghetti, with bright dots--nuclei, Schulze says--sprinkled here and there.

He removes that petri dish and inserts another. In it, scattered among the spaghetti strands, are shorter, fatter tubes, like gummy worms. Those, he explains, are mature muscle cells. Over the next few days, they'll join together in long chains, end to end, and become multicellular myotubes. These chains will form swirls and whorls until they look like the sky in Van Gogh's *Starry Night*. Also, Schulze casually notes, "they'll start spontaneously contracting."

Wait. Contracting? As in ... flexing?

"This is all living tissue. So, yes," Schulze says.

The idea of a dish full of duck mince suddenly beginning to twitch and squirm makes me shake my head. What's making duck bits move if not a brain and nerves? Schulze is used to this reaction. "For the past 12,000 years, we've assumed that when I say the word 'meat,' you think 'animal,'" he says. "Those two ideas are concatenated. We've had to decouple them."

Meat without animals. It's not a new notion. In a 1932 essay predicting sundry future trends, Winston Churchill wrote, "We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium." The basic science to grow meat in a lab has existed for more than 20 years, but no one has come close to making cultured meat anywhere near as delicious or as affordable as the real thing. But sometime in the next few years, someone will succeed in doing just that, tapping into a global market that's already worth trillions of dollars and expected to double in size in the next three decades. Despite a bevy of well-funded competitors, no one is better positioned than Memphis Meats to get

there first.



"I loved eating meat, but I didn't like the way it was being produced." --Uma Valeti, the vegetarian co-founder of the lab-meat startup Memphis Meats. CREDIT: Maurizio Di Iorio

Operating with a team of just 10 (though it's expected to grow to 40 in a matter of months), the startup has already cultivated and harvested edible beef, chicken, and duck in its bioreactors, a feat no one else has achieved. Even allowing for the vagaries of regulation--it's not clear which federal agency will oversee a foodstuff that's real meat but not from animals--the company expects to have a product in stores by 2021. "They're the leader in clean meat. There's no one else that far along," says venture capitalist Steve Jurvetson, whose firm led Memphis Meats' recent \$17 million Series A. Before he met Valeti in 2016, Jurvetson spent almost five years researching lab-grown meat and meat alternatives, believing the market was set to explode. "They're the only one that convinced me they can get to a price point and a scale that would make a difference in the industry," he says.

Going in with Jurvetson was a lineup of household-name investors that includes Bill Gates, Richard Branson, and Jack Welch; their money will be used to build up Memphis Meats' already formidable trove of intellectual property and to fine-tune the process of combining cells to produce the tastiest steaks and patties, and drive down the cost. The infusion of prestige

also boosts competitors. Memphis Meats' lineup of backers "is enormous, especially for a small company like mine," says Mike Selden, CEO of lab-grown fish-filet startup Finless Foods. "When investors tell me, 'Great idea, but we can't really vet the technology,' I can say, 'Richard Branson and Bill Gates think it's great.' "

The business case for clean meat, as the fledgling industry's progenitors prefer to call it, could hardly be plainer. As emerging middle classes in places like China and India adopt Western-style diets, global consumption of animal protein skyrockets. (Memphis Meats is working on duck because it's so popular in China, which consumes more of it than the rest of the world combined.) But the U.N.'s Food and Agriculture Organization estimates 90 percent of the world's fish stocks are now fully exploited or dangerously overfished. More than 25 percent of Earth's available landmass and fresh water is used for raising livestock. Only one of every 25 calories a cow ingests becomes edible beef. And meat processors often must pay disposal companies to haul away their inedible tonnage--hooves, beaks, fur, cartilage.



If lab-meat startup Memphis Meats has its way, this chicken and its brethren will lead vastly different lives. *CREDIT: Maurizio Di Iorio*

But it's not just the financial opportunity that has the likes of Gates and Branson so excited: Meat is an ongoing environmental and public-health catastrophe. Livestock account for 14.5 percent of greenhouse gas production--more than all transportation combined. As meat demand soars, virgin rainforest gets razed to grow feed, and freshwater sources are diverted from drought-prone regions. Overcrowded pig and poultry farms are reservoirs for global pandemics; animals raised in them are pumped full of antibiotics, spurring the rise of drug-resistant superbugs.

A subset of affluent consumers is willing to pay higher prices for free-range beef, cage-free eggs, and other animal products marketed as sustainably produced and cruelty-free, but that's a tiny slice of the market. With the FAO expecting meat consumption to nearly double by 2050, only a radical break with the past will prevent doubling down on practices such as high-density feedlots and vertical chicken farms.

The idea of such a radical break attracted Branson, who stopped eating beef in 2014 out of concern over deforestation and slaughterhouse practices. "I believe that in 30 years or so," he wrote in a blog post, "we will no longer need to kill any animals and that all meat will either be clean or plant-based."

Big as it would be if Branson's prediction comes true, those behind Memphis Meats believe they're part of something even larger. Already, so-called cellular agriculture produces everything from leather and vaccines to perfume and building materials. Within a few years, proponents say, it could eliminate

organ donation, oil drilling, and logging. The possibilities are as broad as life itself. "Human civilization was largely enabled by the domestication of livestock," says Nicholas Genovese, Valeti's co-founder. "If we can master producing meat without livestock, it's really going to be the second domestication."

Valeti's meat-without-animals epiphany came soon after his cardiology fellowship at the Mayo Clinic in 2005. In a cutting-edge clinical trial, he used stem cells to repair damage caused by cardiac arrest. Stem cells are undifferentiated cells that can become different types of tissue as they mature; injected into a heart that's been ravaged by a coronary, they can form healthy new muscle to replace what has been lost. If stem cells could be cultivated into heart muscle, he thought, why couldn't they be manipulated into making a drumstick or a porterhouse? Why not grow just the porterhouse and skip the rest of the cow? And while you're at it, why not grow a steak with a healthier nutritional profile?

A bit of research showed Valeti that he was far from the first to have the idea—but also convinced him that what hadn't been feasible was quickly becoming so. Rapid DNA sequencing was making it radically faster and cheaper to, say, program yeast cells to manufacture proteins. Advances in data science made it possible to tease out relationships in huge volumes of experimental data. Meanwhile, the growing high-end market for sustainable and humanely raised foods pointed to a path for a product that was bound to be expensive in its earliest incarnations.

The Post-Meat Ecosystem

Cattle ranchers' and chicken farmers' lives will radically change once meat comes from a lab. But getting animal protein onto plates drives more than \$1 trillion in U.S. business—so a world of clean meat would reinvent much more.

Feed

Feeding cells is easier than feeding animals. Clean meat producers expect the nutrient broth in which cells are grown to be their biggest cost. Existing animal feed producers will retool; expect new entrants, too.

Meatpacking

Slaughterhouse work employs half a million in

"If I continued as a cardiologist, maybe I would save 2,000 or 3,000 lives over the next 30 years," Valeti says. "But if I focus on this, I have the potential to save billions of human lives and trillions of animal lives." His ambitions got a major boost in 2014, when a friend from New Harvest, a nonprofit institute that supports work in cellular agriculture, offered to introduce him to Genovese, a stem cell biologist. Like Valeti, Genovese had become vegetarian. As a high school student, Genovese was a member of his local 4-H Poultry Club, competing to raise the largest chickens. "Everyone would get their baby chicks on the same day. A few months later, there's a weigh-in, and they give out trophies," he recalls. "As a teenager, it's very exciting." It was also sobering. Those chickens, he says, "looked up to you for their feed, and looked up to you to protect them. You lock them up at night so the foxes don't get them. But at the end, you send them to their demise."

He earned degrees in cell biology and tissue engineering and eventually got a job in a lab run by Vladimir Mironov, who was investigating the use of

dangerous and low-paying jobs, in settings where most food-borne illnesses start. The harvesting and packaging of cultivated meat will likely be heavily automated.

Refrigerated trucking

Meats are a huge category for this sector. Clean meat still needs transporting, but not as far, since it can be cultivated anywhere. And it's largely bacteria-free, so there's no need to keep it as cold.

Rendering

Up to half of an animal's weight is inedible. Bones, skin, and other leftovers are rendered into pet food, glue, and other products. In a post-farm world, a smaller industry will handle expired meat and restaurant grease.

Leather

Most leather produced today is a slaughterhouse byproduct. As fewer cows are killed for meat, leather will become another arena for cellular agriculture. Startups like Modern Meadow are already heading there.

bioprinting—3-D printing using living cells—to generate replacement organs. In 2010, Genovese accepted a three-year fellowship from People for the Ethical Treatment of Animals, the controversy-courting animal welfare nonprofit, to conduct research into cultured meat. The PETA connection also made him a target for protest from local hog farmers, who objected to his presence after he moved to the University of Missouri. After learning about Valeti's work, Genovese quickly nabbed a position in his new lab at the University of Minnesota.

By 2015, with Genovese on board, Valeti realized it was time to ditch academia. Another New Harvest contact suggested he reach out to IndieBio, the life-sciences-oriented tech accelerator. He did, and within an hour he was on the phone with its director, Ryan Bethencourt.

Bethencourt, a vegan, was well versed in the challenges and promise of cultured meat. He had previously tried to persuade Mark Post, a Dutch researcher who'd produced the first full hamburger patty out of lab-grown beef, to bring his work to IndieBio. (Post demurred but subsequently launched MosaMeat, backed by Google co-founder Sergey Brin.) "I said to Uma, this is an opportunity to become a leader in this space and transform food as we know it," Bethencourt recalls. IndieBio became the first outside investor in Valeti and Genovese's startup, initially dubbed Crevi Foods, after the Latin word for "origin." (The founders quickly realized that it was a bit too clever. "Nobody understood it," Valeti says.)

In September 2015, the two men moved to the Bay Area and started culturing cow muscle and connective tissue cells. (We think of meat as synonymous with muscle, but much of meat's flavor and mouthfeel comes from the breakdown of collagen, a component of skin, ligaments, and fascia. It's necessary to blend different types of cells to make lab meat that tastes like the real thing.) By January, they had enough to make their first tiny meatball. "I'll never forget when we first tasted what we had harvested," says Valeti. "It just immediately brought back all the memories you get when you eat meat." It had been 20 years since Valeti had, but it nonetheless confirmed that, as far as they still had to go, they'd produced, on the most fundamental level, meat.

That helped validate the idea of trying to grow meat in the first place. All the aims of Memphis Meats and its ilk—making food healthier, more humane, and more ecofriendly—could arguably be better served by leading consumers to

plant-based alternatives. Such options are getting more sophisticated: Another Silicon Valley startup, Impossible Foods, has raised almost \$300 million for a veggie burger that browns like ground beef and even "bleeds" when served rare, thanks to the presence of heme, a component of the blood molecule hemoglobin, which is also found in plants. The Impossible burger mimics the taste of a haute fast-food patty, though its consistency is not quite there—the outside caramelizes, but the interior is a tad puddingy. (Gates has put money into Impossible, as well as in its competitor, Beyond Meat.)

But the lab-grown-meat crowd believes plants will never be the whole answer. Meat is simply too complex and culturally ingrained. "Humans evolved over thousands of years eating meat," says Valeti. A high-tech veggie burger might be able to replace ground chuck, but that's one narrow application. Lab meat, he says, "because it's meat, can be cooked any way meat is cooked. People can buy it off the shelf, take it home, and cook it in the ways they've known for centuries."

Those arguments led Hampton Creek, one of the best-known and best-funded plant-based food startups, to expand into clean meat. For its first four years, Hampton Creek focused on using plant proteins to replace eggs in products like mayonnaise and cookie dough. But CEO Josh Tetrick came to appreciate consumers' attachment to what they know. "A big limiting step to plant-based meat is culture. My family wouldn't go to Walmart and buy something that says 'plant-based hamburger,'" says Tetrick, who grew up in Alabama.

Tetrick's pivot toward clean meat happened amid a conflict with the company's board of directors, which led to all five outside directors resigning. That followed a long series of company stumbles, including an attempted coup by top executives who tried to go behind Tetrick's back to the board and were promptly shown the door; accusations of a large-scale buyback program to boost sales, which drew scrutiny from the Justice Department; and the loss of one of its biggest distributors—Target. Skeptics wonder if the company's surprise June announcement that it will have one or more cultivated-poultry products in stores by the end of 2018 was a diversionary tactic. The timeline seems optimistic. Even if the kinks can be worked out that quickly, there's no guarantee regulators will sign off in time. Still, Hampton Creek has raised more than \$200 million in venture capital and has a team of 60 working on R&D, including top cell biologists from academia and industry. In September, to punctuate an announcement that it had secured patents around its clean-meat processes, Tetrick tweeted a video of what looks like a burger sizzling in a skillet; a spokesman declined to say whether the video shows the company's first clean beef. A knowledgeable industry insider says Hampton Creek's progress and dysfunctions are real. "I think the only thing that will prevent Hampton Creek from being first to market with this is the company exploding," says the source. (Asked for a response to this statement, Hampton Creek declined to comment.)

For Memphis Meats, with its significant head start and singular focus, the path to success is straightforward. It needs to make its meats more appetizing and much cheaper. One morning this summer, Valeti assembled



CREDIT: Maurizio Di Iorio

his full team to talk about how far they had come and how far they still had to go. A few weeks earlier, Memphis Meats had held its first-ever tasting for outsiders, inviting more than 25 people to sample fried chicken and duck à l'orange. The event was deemed a success. "They really nailed the texture and mouthfeel," one guest, sustainable food advocate Emily Byrd, said. But it was expensive. Growing that "poultry" cost about \$9,000 per pound. At his company meeting, Valeti revealed that the most recent harvest, in May, had been considerably cheaper, with the meat costing \$3,800 per pound. "I want it to keep going down by a thousand dollars a month," said Valeti. "Our goal is to get to cost parity, and then beat commercial meat."

"It's not crazy to think you might one day be able to brew meat at \$1 per pound."

Ryan Bethencourt, a Memphis Meats investor

That remains a distant goal. But theoretically, cultivating meat should have high startup costs but low operational costs: Given the right conditions, living cells divide on their own. The major factor governing costs is the nutrient-rich medium in which those cells grow. All the companies that have successfully grown meat have relied on fetal bovine serum, which is extracted from cow fetuses, as a key medium component. But FBS is expensive, and significantly weakens claims

cultivated-meat companies can make about vegan or cruelty-free products. Hampton Creek says it has grown and harvested chicken without FBS, although it has been tightlipped about its methods. Memphis Meats acknowledges it used FBS to start its cell lines but says, "We have validated a production method that does not require the use of any serum, and we are developing additional methods as we speak."

Tetrick likens the expense of medium--it's called "feed" at Memphis Meats--to the need electric-car makers have to develop better batteries. "If we figure out how to surmount that limiting step," he says, "suddenly all the economics start looking better."

Electric cars are an apt metaphor, because whenever clean meat does hit supermarkets, it will almost certainly be pricier than conventional meat. Memphis Meats and its competitors will likely spend a few years courting consumers who buy wild-caught Atlantic salmon and grassfed sirloin at Whole Foods. "They're going to have to somehow position it as something worth paying more for," says Patty Johnson, an analyst who covers the meat industry for Mintel Group. One possibility, she says: Like Impossible Foods, Memphis Meats could persuade influential chefs to feature its wares on their menus. Another would be genetically engineering nutritional profiles so the company could tout increased health benefits--adding, say, omega-3 fatty acids to beef to make it as healthy as salmon.

Valeti is careful to avoid sounding as if he wanted to put Big Meat out of business. He argues that the big meat processors will be keen on clean technology, whether as licensees, customers, investors, or acquirers. (Agribusiness giant Cargill joined Gates and Branson in Memphis Meats' Series A; Tyson Foods has a venture fund that invests in similar technologies.) Cows and pigs aren't getting any cheaper to raise or slaughter, but if lab meat follows the course of other early-stage technologies, it can continue to get more inexpensive for years to come. "It's not crazy to think you might one day be able to brew meat at \$2 per pound, \$1 per pound," says Bethencourt. "At that point, we can replace pretty much all industrial meat. In 20 years, I think people will look at growing and killing an animal as bizarre."

And while Missouri's pig farmers may see their doom in a world of meat without animals, companies that buy meat from farmers view it very differently, explains Jurvetson. When an outbreak of avian flu or mad cow strikes, "if you're in their industry, it's a very scary world," he says.

Valeti won't mince words, either. "The status quo in animal agriculture is not OK. That status quo is going to kill a lot of people." All the more reason to bring on the second domestication.



| 20:20

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