

## THE SECOND DOMESTICATION

On a muggy August day in 2014, I found myself wandering through the Brooklyn Army Terminal, a former World War II-era train station in New York's hippest borough which is now home to several dozen start-ups. Train cars from two generations ago stood motionless on their tracks, surrounded by brand-new, and mostly empty, office spaces. Could this place, frozen in time, really be the headquarters of a biotech company that, along with several other start-ups, is currently pioneering a technology that promises to upend our current food system?

As someone who's devoted my career to making our agricultural system more sustainable, especially through my work at the Humane Society of the United States, I've visited many food start-ups that claim their products will save the planet and prevent many of the illnesses that plague us—all while providing enough food to feed the world's growing population. Yet almost invariably they're located in the Bay Area, close to the Silicon Valley wealth that created them and continues to drive them toward the better future they're seeking

to create. To me, Brooklyn seems far more bearded hipster than biotech haven, but this is where Andras Forgacs invited me to visit his new company, Modern Meadow.

Neither “modern” nor “meadow” came to mind as I surveyed the surroundings. The former military supply station was bought by New York City in the early 1980s and has since been converted to office space. Now home to several dozen tenants, the station contains mostly start-ups. One of them, Modern Meadow, is generating headlines around the world.

After fifteen minutes of searching the terminal and passing several other biotech start-ups, I finally found the lab’s entrance. Forgacs, in his late thirties, welcomed me into the humble-yet-pristine space with a warm smile. Just about a dozen employees worked for him at the time. I wondered if I was really about to see history in the making.

After I entered, Forgacs and I chatted about the Modern Meadow process: culturing cow cells to grow beef and leather outside of the bovine. In other words, producing genuine leather without having to slaughter the cow from whom it came. The company was founded in 2011 as the first commercial venture to grow meat and leather in a lab, and I’d read that Forgacs could (theoretically) grow the entire world’s beef supply from just one microscopic cell. The implications of this technology, if it can be perfected and scaled, are of course tremendous, potentially allowing us to continue to eat and wear animal products without causing the suffering, waste, and environmental damage wreaked by our current agricultural system.

Although Modern Meadow was the first company founded to commercialize these products, Forgacs isn’t alone in his efforts. Several other companies—including all those that will be profiled in this book—have since been founded with the goal of bringing cultured-animal products into the mainstream.

We toured the quietly humming reactors where the culturing happens, and then Forgacs shocked me with a simple question.



“Want to try a sample?”

I came expecting to see, not to eat, and after more than two decades of happily enjoying a vegan diet, the thought of consuming beef wasn't exactly appealing.

I was also aware that, at that time, far more humans had gone into space than had eaten meat grown in a lab. Until Modern Meadow's existence, only a few academics had ever actually cultured meat in vitro, and perhaps less than a couple dozen people the world over had consumed it—ever.

“I've not eaten meat in a very, very long time, so I'm not sure my review would be that valid,” I managed to mutter, half joking and fully hoping I'd successfully talked myself out of the situation.

I also contemplated the cost of the food, knowing from news reports that any amount of this beef would have to be worth a fortune.

“Didn't the burger they just served up in Europe cost \$330,000, from cell to bun?” I was referring to the now-famous first-ever lab-grown hamburger—funded by Google cofounder Sergey Brin—that had been cooked and eaten at a press conference in London just a year earlier.

“Don't worry,” Forgacs assured me. “You're our guest. And it's only a small sample—a steak chip, if you will. Really, it only cost about one hundred dollars to produce. And that'll come way down soon.”

I'd certainly eaten a lot of steak fries in my life, but a steak chip was another beast altogether. Forgacs didn't simply want to create cultured versions of foods we already enjoy, like burgers; he also wanted to invent entirely new culinary experiences. The idea for the steak chip—think of them as potato chips made of meat—came from the realization of how much cheaper it would be to make thin sheets of meat than it would be to grow more complex pieces. Just as someone might grab a stick of beef jerky at a gas station for a quick snack, might they also try a bag of steak chips? “High in protein, low in fat, and superconvenient. I'd want that,” Forgacs offered with a grin.

Initially on the fence, I quickly recognized the opportunity to be one of the first people ever to try a food that was generating so much buzz—and controversy—that I decided to accept my host's generous offering.

Forgacs pulled the steak chip from its container. I smiled and held it, wondering how my body would react to its first bite of meat in more than twenty years. I had little ethical concern about eating the meat, but it still felt bizarre to be on the precipice of ingesting animal flesh, especially flesh as novel as this.

I didn't decide to take a permanent vacation from meat because I didn't like eating it; I always enjoyed it as a kid and still enjoy the plant-based meats that are increasingly popular among omnivores today. Rather, I became vegan in 1993 having learned as a young teenager about the consequences of a meat-centric diet. Humans don't need to eat animals in order to be healthy, and the meat industry causes a lot of problems for animal welfare and the planet. So I figured why not do what I can to reduce this harm by leaving animals off my plate? Eating lower on the food chain also allows more food to be produced, since so many resources—like grains and water—are needed to feed livestock. Such efficiency has become even more important as the global population continues to boom.

Eventually, my love of animals led me to a career in animal protection, helping to spearhead legislative and corporate campaigns both to gain protections for farm animals and reduce the number of them being raised and slaughtered for food in the first place by helping people enjoy more plant-based meals. I'd been reading and talking about the concept of growing meat in a lab for years and always thought it was a promising solution to a vexing problem but never thought of the theoretical food as a product for myself as much as it was for those who were wedded to meat.

Yet here I was about to add real animal meat—albeit a slaughter-free version of it—back into my diet, at least for the day. The chip

looked like a thin piece of jerky. As I stared at it, I contemplated just how remarkable—technologically and symbolically—this little piece of dried beef was. Perhaps I was holding in my hand the answer to so many of the problems animal agribusiness poses for humanity and the planet that hosts us. I raised the meat to my mouth, took a breath, and placed it on my tongue.

I've read accounts of other longtime vegetarians who've experienced all types of sensations after tasting meat for the first time in years: everything from a rush of endorphins and euphoria to nausea, stomach pains, and vomiting. But nothing like that happened to me. I chewed the steak chip, it tasted good, and it reminded me of barbecue.

My mind raced with questions: Was I about to get sick? Was I still a vegetarian? Did that even matter?

In actuality, it doesn't really matter if vegetarians or vegans will eat meat that was grown rather than slaughtered. They're not the intended audience. The real question—the one running through my mind in the Modern Meadow office and the one that's a subject of this book—is whether meat-eaters will accept this new method of producing the beef, chicken, pork—and a whole host of other animal products—that have come to form such a substantial part of our diets. Would we, as a society, at least consider easing ourselves into lab-grown animal products by first wearing some of Modern Meadow's in vitro leather? (The company is now focused exclusively on growing leather while others tackle meat.) And even if we'll accept such foods and clothing, can Modern Meadow and other culturing companies bring their products to market in time to correct the damage currently being inflicted by animal agriculture? In short, was that modest, albeit pricey, steak chip a preview of the future of food?

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Our species is facing a crisis: as the global population swells, just how are we going to feed billions more people on a planet already suffer-

ing from a shortage of natural resources? Humanity's population has doubled since 1960, but our consumption of animal products has risen fivefold, and it's projected by the United Nations to keep rising. Complicating matters further, as poorer nations like China and India (which are also the most populous in the world) become richer, many of their citizens who'd previously subsisted on a largely plant-based diet will start to demand a more conventionally American regimen, heavy in meat, eggs, and dairy—products previously reserved for the wealthy but which they can now afford. As many sustainability experts observe, given how inefficient it is to raise animals rather than plants for our food, the earth just can't accommodate such an increase in animal-product demand. The change in climate will be too great, the deforestation too severe, the water use too massive, and the animal cruelty too unbearable.

Projections show that by 2050 there'll be nine to ten billion humans walking the earth. If most of them have the means to eat as lavishly as Westerners—particularly Americans—do today, it's hard to see how we can support the massive amount of land and other resources that will be needed to satisfy this demand. For the American palate alone, more than nine *billion* animals are raised and slaughtered for food annually, not counting aquatic animals like fish, who are counted in pounds, not as individual animals. In other words, more animals are used for food in America in just one year than there are people on the planet. And nearly all of those animals are confined for life inside factories that more closely resemble gulags than farms.

The green revolution—in which agricultural research led to huge increases in crop yields—dramatically expanded humanity's ability to produce more food with fewer resources, but the time we bought ourselves when we increased our agricultural productivity is running short, and we need to innovate our way out of the new agricultural crisis of our own making.

To put the problem in perspective, imagine walking through the



poultry aisle of your local supermarket. For each chicken you see, envision more than one thousand single-gallon jugs of water sitting next to it. Then imagine systematically, one by one, twisting the cap off each jug and pouring them all down the drain. That's about how much water it takes to bring a single chicken from shell to shelf. In other words, you'd save more water skipping one family chicken dinner than by skipping six months of showers.

California and other drought-stricken areas may be content for now to impose restrictions on lawn care or suggest shortening shower times, but as the demand for water grows increasingly intense, no amount of individual restraint can make up for the amount of water required to sustain—not to mention grow—our animal-agriculture system.

And it's not just chicken.

It'll be increasingly hard to ignore the fifty gallons of water behind every single egg, easily enough to fill your bathtub to the brim. Or the nine hundred gallons of water needed for every gallon of cow's milk (now you're talking about a few hot tubs' worth of water). By comparison, you save eight hundred and fifty gallons of water when you buy a gallon of soy milk instead of cow's milk.

These stark inefficiencies remain regardless of whether we're talking about local, organic, non-GMO, or other buzzwords often labeled on animal-product packaging. Such facts make it clearer than ever that, as our population grows, if we're going to continue consuming meat, milk, and eggs at anywhere near the quantity we do today, we'll need to get more efficient—*much* more efficient.

Today, a group of scientists and entrepreneurs is trying to accomplish just that. Their goal: to grow *real* meat so that omnivores can continue enjoying beef, chicken, fish, and pork without having to raise and slaughter animals. If these start-ups succeed, they may do more to upend our dysfunctional food system than perhaps any other innovation, while addressing many of the biggest problems we face—

from environmental destruction and animal suffering to food-borne illness and perhaps even heart disease. These young companies are racing to make real a world in which we can have our meat and eat it, too: where we can enjoy abundant amounts of meat and other animal products without all the environmental, animal welfare, and public health costs.

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Forgacs and his team at Modern Meadow are hardly the first people to think about growing animal products without raising entire animals. In addition to the imaginations of many sci-fi writers (perhaps most prominently Margaret Atwood in her novel *Oryx and Crake*, and even earlier in *Star Trek*), plenty of forward thinkers—including several outside of science or science fiction—have predicted that such a shift is inevitable. One of them would even become one of the most important figures in Western history.

“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,” proclaimed Winston Churchill in a 1931 essay entitled “Fifty Years Hence.” His predicted time frame was admittedly a few decades off, but his foresight was remarkable, essentially foreshadowing the technology that would make Modern Meadow and its steak chips possible. “The new foods will from the outset be practically indistinguishable from the natural products,” the future prime minister continued, “and any changes will be so gradual as to escape observation.”

Churchill was predicting a major disruption in the way humans, for millennia, have obtained our protein. Not unlike the way cars largely relegated horse-powered travel to the history books, he was anticipating a technological advancement, he believed, would completely transform our relationship with a whole category of animals. Nor was Churchill the first to make such a prediction. As early as 1894,

then-famed French chemistry professor Pierre-Eugène-Marcellin Berthelot claimed that by the year 2000, humans would dine on meat grown in a lab rather than from slaughtered animals. When pressed by a reporter about the feasibility of such meat production, Berthelot replied, "Why not, if it proves cheaper and better to make the same materials than to grow them?" Like Churchill, Berthelot's timing was off, but perhaps not by much.

Humans have always sought ways to improve what we eat. For most of our existence, *Homo sapiens* subsisted by foraging and hunting. Then, ten thousand years ago, some of us began shifting from the spear to the seed, domesticating plants and later animals in a veritable agricultural revolution. We soon began culturing, starting with products like beer and yogurt—perhaps the first biotech foods. And within the last century, the industrialization of our food supply revolutionized our options yet again, enabling immensely greater yields that can support—and encourage—an ever-increasing population explosion.

Today we may be witnessing the start of the next food revolution: cellular agriculture, the process of growing foods—such as real animal meat and other animal products—in a lab while leaving the animals alone and perhaps returning huge swaths of cropland back to their more natural habitats. Using technology first developed by academics and the medical field and now being commercialized by several start-ups, innovators are taking tiny biopsies of animals' muscle and then culturing those cells to grow more muscle outside the animals' bodies. Some entrepreneurs are even ditching the initial animal starter cells altogether and are growing—from the molecule up—real milk, eggs, leather, and gelatin that are all essentially identical to the animal products we know—even though they never involved a living animal at all.

With this new application of the technology, the start-ups you'll meet in this book are working hard to make Churchill's vision come

to life. Right now, as I write this, these companies are producing real animal products from microscopic animal cells—or even from yeast, bacteria, or algae—that have the potential to revolutionize the food and fashion industries as we know them. At the same time, they offer the promise of solving enormous environmental and economic challenges posed by our growing global population—that is, assuming they can get the funding, regulatory approval, and consumer acceptance necessary to market their products on a global scale.

Unlike the also-promising plant-based protein revolution already well under way—the one that’s given us brands like Tofurky, Silk soy milk, and Beyond Meat—these lab-grown products are not alternatives to meat, milk, and eggs; they are real animal products. Such technology may seem entirely novel, but in fact, nearly every bite of hard cheese you eat today contains rennet—an enzyme complex that causes milk to curdle and that, traditionally, had to be extracted from a calf’s intestines—that was synthetically produced via nearly identical processes to those used by many companies in this book. And if you’re a diabetic, you’re almost certainly regularly injecting yourself with human insulin that was produced via the very same biotech process, too.

Meanwhile labs have, for years, been using similar processes to create real human tissues for experimentation and transplantation purposes. For example, a lab can take a patient’s skin cells, culture them to grow new skin, and create real human skin that’s identical to the skin the patient was born with. The body doesn’t seem to know the difference because there is no difference—other than the fact that it was grown outside the body.

By applying what have largely been medical technologies to growing animal-agricultural products, scientists are developing what Dr. Uma Valeti, CEO of the cellular-ag start-up Memphis Meats, calls the “second domestication.”

In the first domestication, thousands of years ago, humans began



selectively breeding livestock and planting seeds and were therefore able to exert more control over where, how, and in what quantities we produced food. Today, we're taking that control down to the cellular level. "It's a clean-meat process," Valeti says, "that will let us produce meats directly from high-quality animal cells, thus using only the best quality muscle cells to produce the best meats." One of Valeti's investors in Memphis Meats, Seth Bannon, likes the analogy. His venture capital fund—named Fifty Years, in a tip of the hat to Churchill's essay—exists to help founders like Valeti. "Traditionally, we've domesticated animals to harvest their cells for food or drink," Bannon says of the work Memphis Meats is doing. "Now we're starting to domesticate cells themselves."

The scientists and entrepreneurs in this book are seeking to correct the course of an animal-agricultural system that's at the center of so many global ills. They've started in different places and have different values, but their goal is the same: racing to make real their vision of a world in which we produce our meat and other animal products not through raising and slaughtering chickens, turkeys, pigs, fish, and cows, but rather through culturing processes that essentially remove living, feeling animals from the process altogether.

"I see beer being brewed or yogurt—the yeast and lactobacillus do not cry out because it's in a tank," Forgacs quipped to a journalist a year after our meeting at the Modern Meadow headquarters. "That's our goal, to apply those principles to an animal product. We don't have to industrialize sentient beings."

If these companies succeed, the potential benefits to the planet, animals, and our health are obvious. And of course, what's also obvious to the investors pouring tens of millions of dollars into these start-ups is that where there's a major disruption to be had, there are also riches to be made. In a December 2016 interview on CNBC, Bill Gates talked about the promise of these start-ups in a discussion about the new Breakthrough Energy Ventures fund that he and fel-

low billionaires, like Jeff Bezos and Richard Branson, created. “We’ll have several dozen companies that we’re going after,” the Microsoft founder commented. “Even in areas like agriculture we’ll have artificial meat, where there’s already some people doing things there. That’s a big source of emissions there. . . . And if you can make meat another way, you avoid a lot of the issues like cruelty, and you should be able to make a product that costs less money.”

While Gates had been funding plant-based meat alternatives for years, in August 2017 he, along with fellow business titans like Branson and former General Electric CEO Jack Welch, began pumping investment into the clean-meat space. Branson enthusiastically celebrated the funding he and his colleagues provided one start-up, prophesizing that “I believe that in 30 years or so we will no longer need to kill any animals and that all meat will either be clean or plant-based, taste the same, and also be much healthier for everyone. One day we will look back and think how archaic our grandparents were in killing animals for food.”

Just in terms of food safety alone, these products could be game-changing. In slaughter plants, there’s great risk of fecal contamination, whether it’s from feces on the animals—they often defecate when introduced to the novel and daunting environment of a slaughter facility—or from feces in the gut that can contaminate the meat during the slaughter and butchering process. Many of the most dangerous food-borne pathogens are intestinal bugs like *E. coli* and *Salmonella* that result from such contamination. Of course, with meat cultured outside the animal, there’s no fecal matter to worry about; it’s produced in a completely sterile environment. As we’ll see later, this is a primary reason the Good Food Institute (GFI), which promotes cellular agriculture products, popularized the term “clean meat.”

That’s why at least some food safety advocates are cheering the advent of such clean meat. Michael Jacobson, PhD, the founder of the Center for Science in the Public Interest, is one of them. The man

who's crusaded against the dangers of food additives like trans fats and olestra is optimistic about cellular agriculture. "It's a good way to have animal products that would be a lot safer to consume and more sustainable to produce," he tells me. "I'd be happy to eat it."

In addition to the food-safety benefits, growing our meat rather than raising farm animals would also dramatically reduce our risk of the kind of global pandemic that keeps public health professionals up at night. Bird flu outbreaks, especially in Asia, tend to kill millions of animals annually. But the big concern is that avian influenza could jump species into humans, which is exactly what caused the massive Spanish flu outbreak of 1918, infecting nearly a third of humanity and killing upward of fifty million people. And this was a time when the world's population totaled only 1.2 billion people, a fraction of the 7.5 billion who call Earth home only a century later. And as the population has risen, so has our mobility, with millions of people traveling around the world each day. If an outbreak on the scale of the 1918 pandemic occurred today, it could prove even more devastating.

In 2007, the journal of the American Public Health Association editorialized on the pandemic threats posed by chicken factory farms, observing:

*It is curious, therefore, that changing the way humans treat animals—most basically, ceasing to eat them or, at the very least, radically limiting the quantity of them that are eaten—is largely off the radar as a significant preventive measure. Such a change, if sufficiently adopted or imposed, could still reduce the chances of the much-feared influenza epidemic. It would be even more likely to prevent unknown future diseases that, in the absence of this change, may result from farming animals intensively and from killing them for food. Yet humanity does not consider this option.*

A decade later, so far, humanity still doesn't seem to have considered the option the American Public Health Association suggested: drastically slashing animal agribusiness to cut down on the risk of a pandemic catastrophe. But even if the chance of such an event is low at any given time, there are even more compelling reasons in the near term to think about raising fewer animals for food.

A major pandemic could be catastrophic to our civilization, but the likelihood of it happening in any given year is minimal. Yet some of the threats that factory farming of animals pose are already manifesting themselves today. Perhaps most notably, we're now facing a crisis of antibiotic resistance in human medicine, a problem that many medical and public health professionals say is due to animal agriculture. About 80 percent of all antibiotics in America are fed to farm animals, not to treat illness but subtherapeutically as a means of promoting growth and preventing sickness in such overcrowded conditions. Concerned about the ability to continue using literally life-saving antibiotics in human medicine, the American Medical Association now calls for a federal ban on using antibiotics to promote growth in farm animals, but due to the ag and pharma lobby interests, the doctors' call so far has fallen on deaf federal ears.

On a planet where demand for meat is only increasing as more developing countries rise out of poverty, we know that the earth's finite resources simply won't allow other nations to gorge themselves on the meat-heavy diet that Americans and Europeans have come to expect. Historically, richer nations have been able to afford high levels of meat consumption while the poor have subsisted largely on grains, beans, and vegetables, with meat being regarded more as a less frequent treat.

Even though Americans have begun consuming somewhat less meat in recent years, as household income rises in countries like India and China, so is the demand for meat. Alarmingly, just as one ex-



ample, China's per capita meat consumption has skyrocketed fivefold in the past three decades. Where once beef was referred to as the "millionaire's meat" in the nation, it's now a daily part of the diet for hundreds of millions of Chinese citizens.

At least since the publication of Frances Moore Lappé's *Diet for a Small Planet* in 1971, it's been clear that Earth isn't big enough to sustain a global population of American-style meat-eaters. "Imagine sitting down to an eight-ounce steak, and then, imagine the room filled with 45 to 50 people with empty bowls," Lappé wrote. "For the feed cost of your steak, each of their bowls could be filled with a cup of cooked cereal grains."

While externalized costs of production in the United States help make animal products artificially inexpensive at the cash register, producing meat is an exceedingly pricey way to feed ourselves. Even long before Lappé's seminal work, President Harry Truman urged Americans to cut back on meat (including poultry) and egg consumption by cutting out animal protein on Tuesdays and Thursdays to save resources for the postwar European-rebuilding effort.

Fast-forward to today, and the message is still clear. "The reality is that it takes massive amounts of land, water, fertilizer, oil, and other resources to produce meat," says global relief charity Oxfam, "significantly more than it requires to grow other nutritious and delicious kinds of food."

The biggest cost associated with raising animals for food is the feed they're given, and they need a lot. When you think of soy, you might think about tofu or soy milk, but the lion's share of soy grown in the world is used as animal feed, and those soybeans take up a huge amount of land. Sadly, animal feed is the leading cause of rainforest deforestation, essentially killing the lungs of our planet. The World Wildlife Fund points out this fact, observing that "the expansion of soy to feed the world's growing demand for meat often contributes

to deforestation and the loss of other valuable ecosystems in Latin America.” In other words, slogans like “Save the Rainforest” might be more instructive if they concluded with “Eat Less Meat.”

The Center for Biological Diversity recognizes this crucial connection between what we put on our plate and whether many species will have a planet to live on. That’s why the environmental nonprofit launched a campaign called “Take Extinction Off Your Plate,” in which it urges eco-minded consumers to prevent the eradication of wildlife by taking action every time they sit down to eat. The sole recommendation of the anti-extinction campaign: “The planet and its wildlife need us to reduce our meat consumption.”

The strain that high levels of meat production put on our planet becomes even more apparent when you consider climate change. “Preventing catastrophic warming is dependent on tackling meat and dairy consumption, but the world is doing very little,” warns the Britain-based Royal Institute of International Affairs, perhaps the most prestigious think tank in Europe. The institute, also known as Chatham House, notes that animal agriculture is a leading contributor to greenhouse gas emissions and that “it is unlikely global temperature rises can be kept below two degrees Celsius without a shift in global meat and dairy consumption.”

The bottom line is that it’s grossly inefficient to use resources to grow grains in order to feed farm animals simply so we can then eat those animals. And since nearly all farm animals in our country are grain-fed, we’re essentially throwing massive amounts of food away when we opt to consume meat.

Even when you consider the most efficiently produced meat—chicken—it still pales in comparison to plant-based proteins. Chickens require so much grain that we have to feed them nine calories just to get one calorie back out, and again: that’s the *most* efficient meat. A lot of those calories are used for biological processes we don’t care that much about: growing beaks, breathing, digesting, and more.

We just want the meat, but to get it, we need to waste a lot of food. Bruce Friedrich, executive director of GFI, compares raising chickens for meat to taking nine plates of pasta and throwing them straight into the trash every time we wanted to enjoy just one dish of spaghetti. Few of us would do that, but the difference between that and buying meat may not be that substantial.

Yet despite all the evidence that producing meat is so inefficient, it's been a difficult proposition for those of us who've come to expect a high-meat diet to voluntarily opt for plants over animals. Many people simply love to eat meat. As I can attest, even at social events for vegetarians, the plant-based meats (veggie burgers, "chik'n" tenders, and more) are typically the most popular among guests, with lonely tubs of hummus and vegetables often remaining relatively untouched.

Despite decades of advocacy from vegetarian and animal protection organizations, the percentage of Americans who are vegetarians has hovered around 2 to 5 percent for the last thirty years. Yes, we've gone from around 220 pounds of beef, pork, and poultry per person in 2007 to 214 pounds in 2016, but even with this modest decrease, Americans still rank among the heaviest meat-eaters on the planet.

Plant-based protein pioneers like Pat Brown, CEO of Impossible Foods—purveyors of a very meat-like burger made from plants—are trying to help omnivores eat less meat without sacrificing taste. Even before Impossible Foods had a single product on the market, it had raised \$182 million in investments from Google Ventures, Bill Gates, and more. Brown, a Stanford biology professor, argues that if we're going to significantly reduce, let alone reverse climate change, there's no way we're going to do it without a major reduction in the consumption of animal products. "Take every car, bus, truck, train, ship, airplane, rocket ship—all together," Brown says. "They produce less greenhouse emissions than the animal-agriculture industry."

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But what if we could have our meat and eat it, too? What if we could enjoy actual animal products like meat and leather without the substantial environmental and ethical concerns associated with them today?

Andras Forgacs and his colleagues in the just-budding cultured-animal-products industry are committed to making this possibility a reality. The projected environmental benefits for their animal products are stark. For example, a 2011 study published in the journal *Environmental Science & Technology* by an Oxford University researcher, Hanna Tumisto, estimated that cultured beef could require up to 45 percent less energy, 99 percent less land, and 96 percent less water than conventional beef. Admittedly, any life cycle analysis performed so early has limitations, since it's still unclear what technologies will be invented that will actually make cellular-ag products commercially viable. But it's likely that growing animal products rather than raising animals would be tremendously more resource-efficient. That's why a 2015 study published in the *Journal of Integrative Agriculture* comparing the environmental impacts of cultured meat in China concluded that "replacing meat with cultured meat would substantially reduce greenhouse gas emissions and the demand for agricultural land."

And the Chinese government does indeed seem interested. In September 2017, the China Science and Technology Daily, a state-run newspaper, covered one American company's efforts to bring clean meat to the People's Republic, provocatively asking readers to imagine a world in which "you have two identical products; one . . . you have to slaughter the cattle to get. 'The other' is exactly the same, and cheaper, no greenhouse gas emissions, no animal slaughter, which one would you choose?"

Hoping to provide those kinds of choices is a whole cadre of start-ups seeking to make that happen. Those companies—like Modern Meadow, Hampton Creek, Memphis Meats, Mosa Meat, Finless Foods,



SuperMeat, Future Meat Technologies, Perfect Day, Clara Foods, Bolt Threads, VitroLabs, Spiber, Geltor, and others—are seeking to disrupt and ultimately revolutionize our food and fashion industries, something their wealthy venture capital backers are banking on. As former Morgan Stanley senior vice president and *Forbes* writer Michael Rowland told me, “Cultured-meat technology, once perfected, will totally reshape our global meat supply. Our meat will be made with science, not animals.”

That’s exactly why so many environmental and animal welfare advocates are championing these companies. They see cellular agriculture as being akin to the clean energy movement. “Factory farming is kind of like coal mining,” explains Isha Datar, CEO of New Harvest, a nonprofit devoted to advancing cultured-animal-product technologies. “It pollutes and it’s damaging our planet, but it gets the job done. And cellular agriculture is like renewable energy when it was still in its nascence. It has the promise of getting the same job done, but without so many terrible side effects.”

Knowing the potential size of the impact they could have, the women and men in the cellular-ag community are almost boundlessly optimistic about what they may be able to do with this new application of technology. And, interestingly, for the most part they don’t consider one another rivals as much as they do friendly competitors, all working toward the same goal of producing meat and other animal products through culturing processes that may one day render humanity less reliant on the exploitation of chickens, turkeys, pigs, fish, and cows.

In attempting to commercialize a technology that most consumers have, at this point, barely even heard of, each of these companies has different ideas about how best to introduce it to the market. In the meat space, should we start with growing beef, considering that current beef production wreaks more havoc on the environment than

any other meat? Or should we start with chicken, since more chickens are slaughtered than any other animal (save perhaps fish)? Or should we begin with milk, which is simpler to produce? Or should we set food aside altogether and focus instead on producing lab-grown leather, since leather produced in the lab will probably be easier for the public to “digest” than cultured meat?

There’s a ways to go before these companies’ dreams are realized. At this point, it’s likely that clean animal products will be on the market in a limited way in the very near-term future, but producing commodity clean meats that can compete on price is still years away. As Jason Matheny, one of the pioneers of the early cultured-meat movement, joked to me several years ago, no matter what year someone asks him how long it’ll be until cultured meat is available for sale in supermarkets, his answer is always the same: “Perhaps five years.” But because of the work described in this book, that window appears to be closing rapidly.

There are several significant barriers facing the entrepreneurs featured in this book, each of which they must overcome to have any impact at all. The first is simply bringing the cost down—way down. All of them believe they can do this (or else they wouldn’t even be doing their work), but that belief is based on their faith that they’ll make technological breakthroughs that have yet to be made.

They also want people to understand the barriers they’re trying to overcome. Before they can persuade consumers to try one of their burgers, they still need to figure out just how to actually produce their meats at scale. Since much of the technology they’re using was invented for medical, not food, purposes, the size and cost of what they can do are both quite limiting. For example, they’ll need to find better scaffolds—the “bones” on which the muscle grows—since the scaffolds cultured meat is currently grown on are expensive and incapable of producing anything other than ground meat. (So meatballs and hamburgers but not chicken breasts or steaks.) They also need

to invent industrial scale bioreactors (aka fermenters) in which the muscle could actually grow at commercial scale—something that doesn't yet exist, since, at present, such reactors are typically only used for medical purposes.

Another barrier that could hinder their success, even if they could scale up and compete on cost, will be potential government regulations and other bureaucratic obstacles that could stall pathways to the market. We've been applying modern biotechnology to food for decades, but regulating agencies might still be skeptical of this particular technology, given how novel it intuitively seems, which could slow down the approval process.

And finally, there's the ever-important question of whether consumers will even want to eat these foods—no matter how high-quality or inexpensive they become. With a growing number of consumers demanding “natural” and minimally processed foods, will there be a backlash against cultured-animal products as so-called Frankenfoods, a name that some have used to describe genetically modified organisms (GMOs)?

But unlike ag giants such as Monsanto and Dow AgroSciences, which have been quietly introducing GMOs into the marketplace in recent decades, the relatively tiny start-ups creating cellular-ag products want the public to know exactly how they're making their meat. “Radical transparency” is the buzzword these companies regularly tout, constantly seeking to tell the story of exactly what they're doing and how they're doing it. They're convinced that if consumers understand that what they're doing isn't that different from some of the foods or medical interventions we already routinely use, the acceptance and even eagerness will be there.

Certainly some of the same voices that oppose the marriage of biotech and our food system have serious concerns about lab-grown animal products. Their arguments are laid out in later chapters. Interestingly, though, one of the most high-profile voices in the sustain-

able foods world, Michael Pollan, author of *The Omnivore's Dilemma* and *In Defense of Food*, is supportive of these entrepreneurs' work. "In general I do think all these efforts to find substitutes for meat are worthwhile, since one way or another we're going to need to reduce our consumption—for environmental, moral, and ethical reasons," Pollan told me in response to my question about his view of cultured meat. "What the workable substitute will look like is still unclear, but research into all options seems well worthwhile, given the magnitude of the problem."

Some of the groups and individuals that have led campaigns against GMOs don't necessarily share Pollan's open-mindedness on cellular agriculture. Many of them have legitimate concerns about the way some technologies have been used to create a less sustainable food system in the past. But technology is like a knife: it can be used to lovingly prepare food for friends, or it can be used to kill—it just depends on how it's applied. One thing that's certain, though, is that the success of clean meat would do an enormous amount to reduce the number of GMOs in existence. Right now, 90 percent of the GM crops planted in America are fed to farm animals. McKay Jenkins, a sharp critic of industrial agriculture, argues in his 2017 book *Food Fight: GMOs and the Future of the American Diet*:

*The grand prize—growing meat from cell cultures rather than from actual living livestock—could mean all types of powerful changes to industrial agriculture. We wouldn't need pesticide-laden GM corn, industrial slaughterhouses, or gasoline, because we wouldn't be feeding, slaughtering, or shipping animals around the country. We also wouldn't need to deal with the mountains (or lakes) of animal waste that contaminate our water, or clouds of methane that contribute to climate change. And we wouldn't need to kill billions of animals to satisfy our bottomless desire for protein.*



Wherever the debate goes with regard to biotech and food, most of these companies want to portray their forthcoming products as natural and not dissimilar to many foods we already consume daily. Others, though, seem to embrace such characterizations of their foods as novel and foreign. One company, calling itself Real Vegan Cheese, isn't limiting itself just to making cow's milk cheese; it promises to make cheese from the (synthesized) milk of narwhal whales in order to "raise awareness of ocean health" and "show that the process will work with the genes of any sequenced mammal." Another, as you'll read in chapter 7, has already produced gummy candy using mastodon gelatin. (Yes, you read that right: lab-grown gelatin of the North American behemoth we drove to extinction millennia ago.)

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The race is on to bring the world's first cultured animal products to market. Start-ups are attracting millions of dollars from some of the biggest names in the venture capital world, all of whom are hoping to upend the way we've fed and clothed ourselves for millennia, but especially in the last half century, since factory farming expanded our access to animal products, albeit with countless externalities. And of course they aim to make a handsome profit at the same time.

Is it possible that just in the way we now have local breweries specializing in their own craft beers we'll soon have local meat breweries? Modern Meadow's Forgacs believes so. "A brewery is a bioreactor. It's where cell culture takes place. Instead of brewing beer, we could be brewing leather or meat. It's not hard to envision."

It may be that not only will we have the ability to culture meat in breweries (perhaps called carneries?), we might even have the ability to do it in our own homes. Just as it's fairly unremarkable today to have a bread-maker or ice cream-maker in our kitchens, one day we may have meat-makers, too.

Dr. Mark Post, another scientist working in this space, foreshad-

ows a time when people like him will be “selling tea bags of stem cells from tuna, tigers, cows, pigs, or whatever meat you want, and from the comfort of your own kitchen, you could grow your own meat.”

As someone who’s now eaten cultured beef, poultry, fish, dairy, and even foie gras, and held cultured leather in my hands, I wrote this book as an exploration of the promise that this emerging industry holds. My career in animal welfare has brought me to the front lines of the seemingly never-ending battles between the meat industry and animal as well as environmental advocates. Yet maybe that battle could come to an end with both sides winning: people will still eat meat, but neither the planet nor animals will be harmed nearly as much in the process. It’s possible that with the commercialization of the products described in this book, we’ll soon start seeing animal protection organizations campaigning with slogans like “Eat Meat, Not Animals.”

The world is getting more and more crowded, and hungrier for resource-intensive animal products every year. Shifting toward a more plant-based diet would help ameliorate much of this crisis, and it’s important that the plant protein sector continue to grow. But our species—and others with whom we share the planet—can’t rely on just one solution to such a large problem. Just like with renewable energy, we need many alternatives to the problem.

If cellular-ag companies succeed, it could be the biggest upheaval in how we produce food since the agricultural revolution some ten thousand years ago. And it could just be the answer to some of the most pressing problems humanity faces as we move deeper into the twenty-first century.