

Cellular Meat, Perspectives on a Growing Industry

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Cellular Meat is the Future: Making the Case

With a greater knowledge of what are called hormones . . . 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. Synthetic food will, of course, also be used in the future. Nor need the pleasures of the table be banished . . . The new foods will from the outset be practically indistinguishable from the natural products, and any changes will be so gradual as to escape observation.

-Winston Churchill, Fifty Years Hence (1931)

It's no great surprise that we have been hoping to change how we get our meat for quite some time. It sounds like science fiction, but by Winston Churchill's account, we are actually several decades late. Meat produced without a live animal is poised to become a huge industry and ultimately supplant traditional meat production. What are the advantages over traditional meat production? How does one "grow" meat without a live animal? And finally, a question which is now at the fore of the discussion, how do we regulate an entirely novel food product to ensure safety, fairness, sustainability, and consumer satisfaction? As meatless meat will soon become a part of all of our lives, it bears upon all of us to think about these questions and others.

What's wrong with meat as it is?

The meat industry has serious issues in several areas of sustainability and beyond. Some of the most severe social issues include the overuse of antibiotics and subsequent proliferation of antibiotic resistant bacteria, disease spread through mishandling or lack of food safety protocol, poor working conditions for slaughterhouse

workers, and the quite sizable ethical issue of animal welfare. Meat also has detrimental effects on our environment, including direct greenhouse gas (GHG) emissions due to methane released by livestock, indirect GHG emissions related to the food grown and fed to livestock, land use change, which is accelerating climate change through the loss of important carbon sinks, as well as other indirect environmental problems such as water and air quality issues associated with confined animal feeding operations (CAFOs).

Of course, (common reasoning goes) most people need to eat meat on a regular basis to thrive, and the current system we have devised is the only possible way to produce meat at the scale necessary for modern society, and so we tolerate or perhaps try to mitigate some of the most pernicious and damaging aspects of our current industrial meat regime. This line of thinking has given us some good advances, cage-free raising of chickens for example, is relatively better for animal welfare. Grass-fed beef (though not possible at a sufficient scale) can help reduce some of the environmental effects of traditional meat production. But these solutions are most often paired with the advice “eat less meat,” or even “go vegan,” as part and parcel of a strategy to reduce the environmental impacts of our food system. As global population continues to climb, the demand for meat is expected to rise. For some, eating less meat that is more expensive and more ethically produced is fine, however the great bulk of consumers in the US and around the world in the growing middle class cannot and will not “go vegan” for the planet, and so a more scalable solution is needed.

Social and Environmental Concerns

A report released by the World Health Organization in 2017 recommended meat producers cease the use of antibiotics in healthy animals to prevent the spread of antibiotic resistance among dangerous bacteria (WHO 2017). The meat industry has regularly used antibiotics across livestock populations both as a prophylactic but also as a growth agent (UN FAO 2017). The irresponsible overuse of antibiotics allows bacteria to build resistance to the drugs, which can surface as human and animal infections which are increasingly difficult to treat. Some countries have banned this type of antibiotic use in animal livestock raising (the drugs can still be used to treat illness in specific animals) but these regulations are weaker in the US. Antibiotic resistance is one of the largest threats to global health, development, and food security today, according to the World Health Organization (2017). Cellular meat would not require the use of *any* antibiotics and would have a significantly reduced risk of foodborne illness since the production systems could be much cleaner than the conventional model. Using pharmaceutical or biomedical manufacturing as a model, cellular meat could be produced in an entirely sterile environment, with purpose-built packaging that would ensure a food-safe consumer product.

Beyond the rising threat of antibiotic-resistant superbugs, the meat industry is a huge burden on our global carbon budget, and a key driver in global GHG emissions. Three main factors contribute to meat-related GHG emissions: methane from cattle, emissions associated with the huge amount of feed grown for cattle, and finally, deforestation to expand grazing areas. All of these impacts comprise a majority of the GHG impact related to food production, but meat only makes up around 18% of global

food calories (Mottet et al. 2017). This outsized impact on the stability of our climate is a huge issue tied to our food system, and represents a huge opportunity for climate change mitigation. Beyond carbon, our industrial meat system produces a huge amount of water and air pollution, primarily through toxic waste byproducts (quite often a slurry of animal waste) which enters our waterways, causing eutrophication downstream. Localized air quality problems are a huge issue near CAFOs, similarly due to the concentration of animal waste (NALBOH, 2010).

To be sure, cellular meat would not reduce the environmental impacts to zero, but depending on the realized economies of scale, researchers estimate huge reductions in environmental impacts. Consider the resources used to grow a live animal, and the necessary byproducts which cannot be used or consumed. According to a series of life cycle analysis comparisons and projections of cellular meat production, cellular chicken would reduce waterway pollution by 70% over conventional methods and cellular beef could reduce the amount of land used by 95%+ (Tuomisto et al. 2014). Pair these benefits with the reduced risks of foodborne diseases and antibiotic resistance, and the relative advantages of cellular meat with respect to global climate and public health are stark.

In addition to the benefits to humans, it is hard to overstate the amount of base animal suffering that would be avoided if we were able to transition the majority of meat production to cellular meat. As it stands, the US food system alone uses billions of chickens for eggs and meat, and slaughters enough cows to produce millions of pounds of beef. The sad truth is that the vast majority of these animals live miserable lives. As an abnegation of needless suffering alone, the case for cellular meat is strong. It is one

thing to show how our current system of meat production is deeply flawed, but quite another to build a new system from the ground up. Fortunately, there are already plenty of nonprofit organizations and companies large and small working to make large scale cellular meat a reality.

Major Players in Cellular Meat

One of the best resources on cellular meat technology, economics, and regulatory approaches is The Good Food Institute (GFI). Founded in 2016, this nonprofit organization was created to offer reliable resources and support both plant-based and cultured meat alternatives. GFI employs a staff of scientific researchers, public and governmental relations experts, entrepreneurs, and lawyers focused on “using markets and food technology to transform our food system away from factory farmed animal products and toward cellular meat and plant-based alternatives.” By providing a platform to share data across companies innovating in the cellular meat space and taking the lead on key issues like regulation and finding the right name for this new product category, GFI is making headway for cellular meat. Their approach also aligns with the effective altruism movement, effectively directing philanthropy dollars towards foundational aspects of cellular meat and plant-based meat which can be statistically validated.

In addition to GFI leading in the non-profit space, there are a handful of leading startups blazing the trail. One of the leading startups receiving lots of media attention and outside funding is Memphis Meats. After producing both the first “cell-based” meatball and poultry products, receiving funding from the likes of Cargill, Bill Gates, and

investment from Tyson Foods, Memphis is primed to be one of the first companies to hit the market with a cellular meat product. Other cell-based meat leaders from around the world include Silicon Valley-based Just Inc. (formerly Hampton Creek Foods, responsible for the plant-based, “Just Mayo”), Mosa Meat, Israel-based Aleph Farms, and Japan-based Integriculture. With Memphis Meats already leading the way in the cell-based beef meatball and cell-based poultry areas, these other startups are staking out cell-based markets in steaks, burgers, salmon and other seafood, foie gras, and even pet food (Brodwin 2018).

The potential market for cell-based meat is not only game-changing, but potentially huge. This is part of the reason some big players in the conventional agriculture and meat industry are investing in cell-based meat. Cargill and Tyson foods both have stakes in some of the startups mentioned above and would be positioned well to help the cellular meat industry take off rapidly. At this point it is clear that a critical mass of financing, entrepreneurship, and demand are present for cellular meat to begin making an impact. But two key pillars are yet to be entirely figured out: the technical side of scaling cellular meat—a straightforward enough engineering and organizational challenge—and the more wily issue, that of policy and regulation.

Process & Industry Development

The landscape of cellular meat development is rapidly expanding across the world. As entrepreneurs and food scientists inch closer to creating market ready products, we can begin to break down the production process, nascent aspects of the industry, and explore opportunities for investment and development.

The technical process of creating cellular meat is a multi-step process which begins with cells extracted harmlessly from a real animal, which are then induced to divide and reproduce themselves indefinitely (Specht 2017). Finding the right cells which are able to “immortalize” or reproduce themselves indefinitely without human interference, is the first step. These cells are referred to as “cell lines” (Specht 2017). Once a cell line for a given animal species is found, it can be used to propagate a limitless quantity of clean meat.

Once a suitable cell line is isolated, the next step is “feeding” the cells. The environmental conditions under which the cell line reproduces is called the cell culture media (Specht 2017). The media consists of the things a cell would normally need to grow within a body: salts, proteins, and fats. The media also includes specialized signaling molecules called “growth factors” which direct the cells in differentiation into particular meat or fat cells.

At this point, the growing mass of cells are indistinguishable from cells growing within an animal’s body on the cellular level. However, muscle and fat cells don’t exist as masses, but within structural forms provided by other cells. Consider the particular texture of a steak, with chewier or tender sections, as opposed to ground beef for

instance. Meat is not simply fat and protein grown together, but a complex structural formation with other cells. These interconnective cells help constitute the higher structural form, i.e. tissues. In cellular meat, other materials are used in place of these interconnective cells, with various materials being considered and researched by the many startups and labs working simultaneously. This part of the process is called “scaffolding” or “structuring.” As scaffolding in cellular meat becomes more sophisticated, one can see the progression from simpler products like meatballs, shredded chicken, or ground beef, to a flaky fish filet or a well-marbled steak (Specht, 2017).

Once the bundle of cells has the nutrients and environment it needs through the cell culture media and a structure to support and form it, there needs to be a larger apparatus in which the growth occurs. This is what is referred to as a bioreactor (Specht, 2017). Here again there are many different approaches from different organizations, and we expect to see highly specialized and proprietary versions of this apparatus. Ideally, an effective bioreactor should allow for cells to proliferate continuously while allowing collection of finished product to be moved along the production line. An effective bioreactor would have a sophisticated array of sensors and environmental control systems to ensure the ideal conditions are maintained. Additionally, the ability to recycle outputs of the process back into a new batch are essential to meeting the high expectations of efficiency and cost control in cellular meat production (Specht, 2017).

The area of cellular culture media is where we can see the resource advantages of cellular meat come into light. In comparing the “food” sources of cellular meat to

traditional meat production, there is vastly more flexibility and efficiency in cellular meat “food”. A very bright prospect for cultured media is in using currently existing byproducts of our food system to feed the culture. Imagine if instead of feeding cows thousands of pounds of corn and soy, we were able to use waste materials from other food system processes to feed our cellular meat. Similarly, finding novel scaffolding materials could create usable materials from what we had previously been considering waste. Each particular aspect of this process is ripe for innovation and investment.

The foundations of the cellular meat industry lie in these four production processes (cell lines, culture media, scaffolding, bioreactors) as well as the development of a supply chain and distribution system. Each one of these areas will no doubt evolve through innovation, investment, competition, and regulation. One would expect a potential synergy in existing meat supply chain and distribution systems, a trend evidenced by investment from Big Food. Beyond that final step of the process, an entirely new industrial cluster will need to emerge around clean meat. In order to grow the market effectively, all of these areas will need to coordinate their production methods, along with the need for stable regulation and consumer demand.

The Good Food Institute has positioned itself to help coordinate across the private production and public consumer/regulation spheres, and provides resources to interested laypeople as well as industry insiders. Other non-profit organizations like New Harvest are working to support and coordinate scientific research related to cellular meat and provide rigorous academic backing for policy and cultural goals (Kim, 2017).

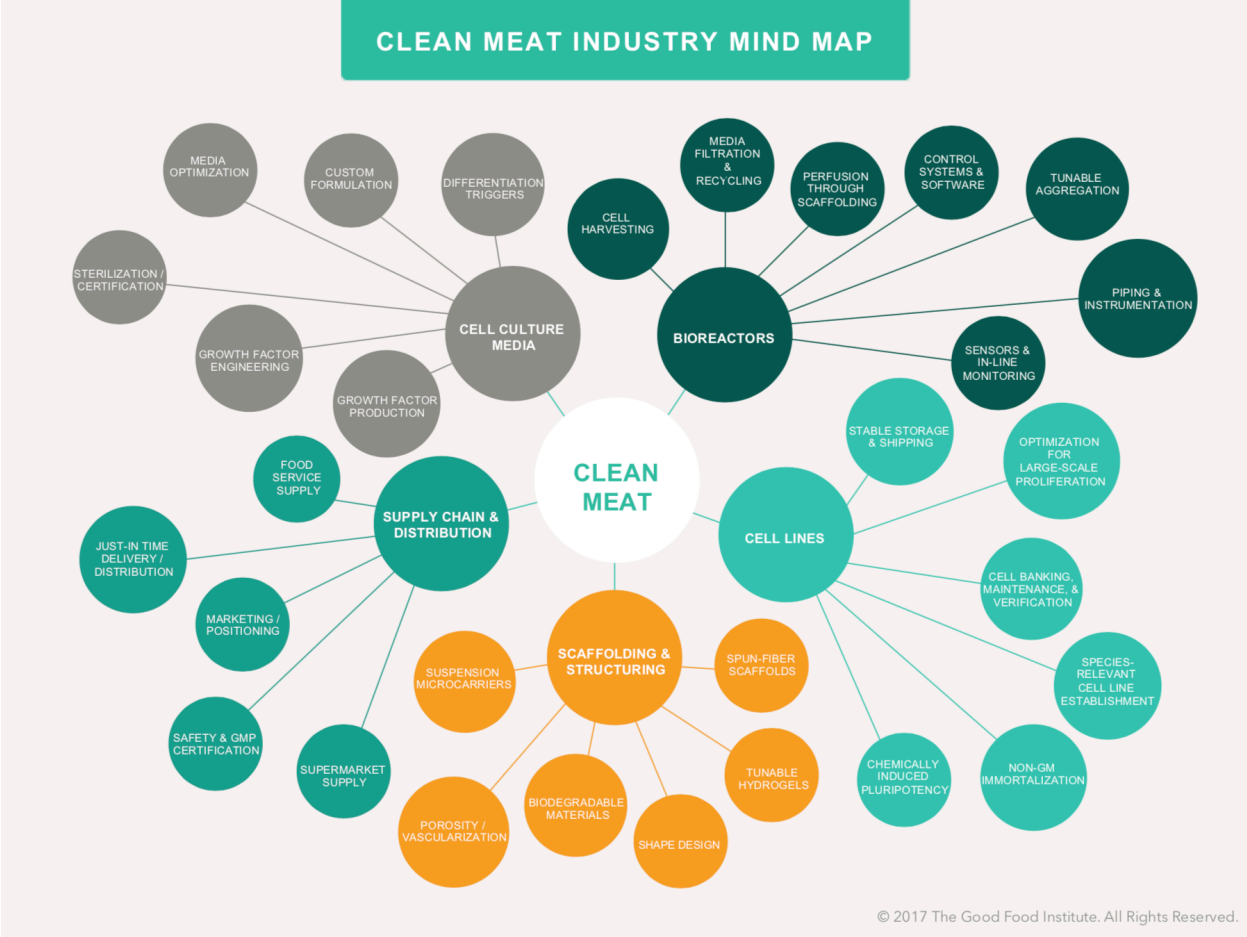


Figure 1 - A conceptual mind map. Good Food Institute (Specht, 2017).

<i>Cellular Meat – Industry Development</i>	
Supply Chain/ Distribution	Huge food companies like Tyson and Cargill can operationalize and scale up proven processes as well as provide needed funding, logistics support, & strategy
Startups	Risk-taking and innovation are needed. Entrepreneurs, engineers, and biochemists working together can rapidly generate solutions
Non-Profits	Coordination beyond partnerships and across continents will accelerate the adoption of cellular meat processes and set the stage for consumer acceptance
Consumers	Global demand for meat is very high, but consumer acceptance remains an unanswered question. Price, labeling, and safety will play into the speed of adoption of cellular meat on a mass scale.

Cellular Meat: The Regulatory Round-up

Alternative products such as those described above should thus not be permitted to be labeled as “beef,” which is widely understood by consumers to be the flesh of a bovine animal, such as cattle, harvested for use as food or as “meat,” which is understood to be derived from animal tissue or flesh for use as food.

-U.S. Cattleman’s Association, Petition to US Department of Agriculture, Food Safety and Inspection Service for the Imposition of Beef and Meat Labeling requirements, 2018

Cell culture technology will enable the production of high-quality protein foods without posing risks that cannot be managed effectively by responsible producers. FDA can regulate this industry by using science- and risk-based regulatory approaches under its existing authorities as well as its extensive experience to help ensure the safe production of cellular meat.

-Good Food Institute public comment submitted to the Food and Drug Administration, 2018

Given the huge potential for the cellular meat industry to displace the current traditional meat industry and revolutionize our food system, it is no surprise that the regulation of cellular meat is a contentious issue. Legacy meat producers stand to go out of business if they do not adapt, and the potential upside for those buying in early to cellular meat is enormous. Furthermore, the introduction of a food source which mimics a natural food source down to the molecule but is synthesized in a controlled environment is unprecedented. There are battles to be fought over which part of the federal government should regulate cellular meat, whether we should call it cellular

meat, clean meat, or something else, and whether we should be able to call it “meat” at all.

Is It Meat?

The issue of whether or not cellular meat can indeed be called meat is a contentious issue with significant ramifications on both sides. Given the fact that cellular meat starts with actual living animal cells and is identical at a cellular level to traditional meat, a strong case for continuing to use the word meat can be made. The U.S. Cattleman’s Association (USCA), whose partisan interest is clear, petitioned the U.S. Department of Agriculture in February of this year to exclude cellular meat from their definitions of “meat” and “beef” (USCA 2018). The crux of the USCA’s argument rests on the USDA’s “Standard of Identity” for meat and beef and the fact that a food which is meant to imitate another food must prominently display “imitation” on its label, or else it is mislabeled. As it stands, the USDA’s Food Standards and Labeling Policy Book does not explicitly define “Meat” or “Beef,” although it has myriad definitions for things like meatballs, meatloaf, beef Bourgogne, and Beef tripe stew. In asking for specific guidelines for these terms the USCA is trying to short-circuit a profound and ultimately philosophical question at the heart of the cellular meat issue: *Is this stuff meat? And if it’s not meat. . .what is it?*

The notion that meat must come from something “born, raised, and harvested in the traditional manner” is not prima facie obvious. We eat wild game and call it meat, as well as seafood like crab which is caught wild. Should the USDA require hunters to stop calling their venison jerky a type of “meat”? Beyond that, the “traditional manner” is just vague enough to allow for the sophisticated and new methods of cattle insemination,

feeding, confinement, slaughter, etc. employed by big beef producers, but excludes lab synthesized meat. Calling for animals to be raised in the “traditional manner” could imply pre-industrial farming techniques, which would disqualify most all of the parties represented by the USCA.

On the other hand, the National Cattlemen’s Beef Association did not support the USCA’s petition and in particular would support cellular meat being defined as a “meat product,” though they reserve the term “beef” for product derived from cattle (Congressional Research Service, 2018). Overall, this petition from the USCA seems like a desperate attempt to head off the coming market share war between conventional beef and cellular meat replacements. As of now the USDA has not responded directly to the USCA petition, but has begun its decision making process regarding cellular meat. A lot has happened on this front in 2018, and with the recent passage of the Farm Bill, the picture of cellular meat regulation for 2019 is beginning to become more clear, though there are still huge questions left unanswered.

USDA vs. FDA: Who Gets to Regulate it?

According to the US Secretary of Agriculture, Sonny Purdue, who was asked about cell-cultured meat in a US House Appropriations Committee, “meat and poultry are under the sole provision of the USDA and that any product labeled as meat would be under USDA purview” (Congressional Research Service, 2018). Not two months later the commissioner of the FDA announced that under the Federal Food, and Drug, and Cosmetics Act, the FDA has oversight for cellular meat (Congressional Research Service, 2018). Finally in October of this year the USDA and FDA held a joint public

meeting to discuss the potential regulatory structure and accept public comments regarding the regulation and inspection of the production, processing, and labelling of cellular meat. The tentative agreement between the two agencies was for the FDA to oversee cell collection, and growth and differentiation, while the USDA would regulate food production and labelling (Shaffer, 2018). However, the recently passed Farm Bill gave the USDA express jurisdiction over lab-grown meat products (Owens, 2018).

Thinking back to the examination of industry development, it seems the cell line process as well as the bulk of research and development would be regulated by the FDA, while the culture media, scaffolding, bioreactor, and subsequent processing, packaging, and distribution would fall under USDA regulation. This is speculation however, since no exacting rules have been made yet. Assuming this division of regulation is correct however, one can imagine the process for manufacturers which integrate all aspects of production to enter the market would be burdensome and labyrinthine. It is important not to stifle a potentially revolutionary industry in order to protect legacy competitors, particularly if the upstart industry has a better chance at mitigating long term environmental and human health issues.

No announcement has yet been made regarding how this new category of products will be regulated, but it appears either way, the USDA will be in charge of production and labeling of cellular meat. This means that like conventional meat products, cellular meat production facilities will need to be inspected on a frequent basis, and all labelling claims will require prior USDA approval. Contrast this with the FDA's relatively more hands off approach to labelling and inspections, and one can see why the burgeoning industry was angling for FDA supervision. There is a sort of double-

bind with this preferred outcome. Consider the fact that all cellular meat companies would prefer to be able to use the term “meat” in their product labels and be regulated by the FDA, but if something is indeed “meat” then it is technically under the jurisdiction of the USDA. Currently, plant-based meat alternatives are regulated by the FDA, and the battle over what types of terms they can apply to their products is still unresolved.

The importance of labeling and the standard of identity of “meat” cannot be understated. Consumers are sensitive to labels and naming, and having to offer cellular meat products without being labelled as meat would likely handicap the industry. According to a consumer insights study conducted by the Good Food Institute, “Clean Meat” and “Safe Meat” were the most likely to be purchased among “Meat 2.0,” “Cultured Meat,” and “Pure Meat” (Good Food Institute, 2016). No research was available regarding any name without the term “meat,” but it seems likely that consumers would be much less willing to purchase any meat substitute that did not use the term “meat.” Despite this, one could imagine this labeling restriction as an enormous marketing opportunity. Designating your cellular meat product as a “cultured tissue agricultural product” is not a very attractive option, but if we assume this restriction applies to all such products, brand naming, advertising, and slogans would become key differentiators within cellular meat competitive markets. All of this is assuming people would willing buy a “cultured tissue agricultural product” at all.

The Question of Consumer Acceptance

Having all of the relative advantages regarding environmental and human health concerns of cellular meat laid out leaves out one big question: will people eat it? Studies

such as the Good Food Institute naming study suggest there is a willingness for some consumers to buy “clean meat,” but invariably, this is assuming an advantage in price. While it is likely that cellular meat will eventually beat the traditional methods on price, a true cost accounting of the environmental and social costs of traditional meat would likely render cellular meat cheaper by a significant amount, and sooner. In order for cellular meat to gain a solid foothold in our food system, some mechanism for including the true cost of traditionally raised meat will need to be put into place. Consider a carbon tax, for instance. If the environmental costs of the embedded carbon-intensive resources used to make a traditional steak were included, the price would jump precipitously. In order to adequately address climate change, many systems of commerce and culture, including our food systems, will need to be radically shifted. If suddenly conventionally produced meat products triple in price, and cellular meat alternatives are available at a much lower price, consumers, and importantly, food service providers, will have no choice but to move to cellular meat, even if it is labelled a “cultured tissue agricultural product.” If on the other hand we are not able to factor in the true costs of conventionally raised meat products, perhaps consumers will reject cellular meat. If however, that is the case, our food system will be faced with much more grave issues, and indeed our society writ large will be facing an existential crisis that will render labeling semantics moot.

Ethics and Predictions

Examining cellular meat, its production, the development of industry around it, and its regulation, can perhaps cause us to pass over a more fundamental question: Just because we can do it, should we? Considering the weight of environmental and animal welfare arguments alone, I believe careful but unimpeded development of cellular meat is justified. Many counterarguments rest on appeals to nature or God. “It’s just not natural” or “we shouldn’t play God” are faulty points. Consider the same processes being used to mass produce insulin. Surely no one thinks producing a life-saving chemical in a more efficient and reliable way should be done away with because its “not natural.” The same goes for any number of chemical or medical breakthroughs. Even so, there is a science fiction-derived uneasiness I share with many when we think about cellular meat. What are the long term consequences of eating cellular meat? It is conceivable there are side effects which take decades, or even generations to reveal themselves. The same is true however, for GMOs and experimental medical treatments. Given these far-off and nebulous risks weighed against the obvious and immediate material advantages, I think the continued progression of research and eventual markets for cellular meat are justified.

As far as the near-future of the industry goes, I expect the current trajectory to continue. Pop-up samples and pricey restaurants will offer the public the first tastes of cellular meat, as early as 2019. Once plant-based meat products such as the Impossible burger are commonplace, I think we will begin to see cellular meat begin to be accepted and offered more widely. Once prices drop sufficiently, or conventional meat prices begin to accurately reflect their impacts, we will begin to see cellular meat

offered in food service locations like cafeterias and chain-restaurants, no later than 2022. Structurally simple foods like meatballs, taco meat, chicken nuggets, and burgers will appear first with things like steak and fish filets needing several more years of development and refinement, I predict commercially available cellular steaks by 2025. In the regulation space, look for cellular meat groups to push back against a complicated FDA/USDA split regulation scheme, perhaps with muscular support of key Big Food investors. This is currently the main hurdle for cellular meat, and I imagine some special arrangement will be sought with regulators in order to push commercialization of some products by the end of next year.

Regardless of the short-term obstacles faced by the cellular meat industry, I believe the cultural tides will eventually turn such that the normalization of cellular meat products will be inevitable. I will not be the first volunteer to try cellular meat, but soon enough most Americans as well as people around the world will get their chance to taste the future of meat. Here's hoping it can live up to its promise, for the same of the climate and the billions of slaughtered animals the world over.

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