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selected essays from introductory writing subjects at MIT

The New Food Revolution: Lab-Made Meat

You are at a restaurant and are served a basket of golden-brown chicken tenders. You cannot wait to bite into that crispy fried coating and taste the salty juiciness of chewy white chicken meat. Now, wait one second… you bite into the nugget and the texture resembles that of tofu. Caught off guard, you immediately spit it out in your napkin. This is not the chicken tender you expected.

This is what the food tech industry coins the "Uncanny Valley of Food." Inspired by the famous "Uncanny Valley Hypothesis" created by Masahiro Mori, this phenomenon describes the immediate reaction of disgust a consumer has towards food that tastes or looks slightly off[6]. In a world where we have long figured out which foods won't kill us, these innate preferences serve as an anachronistic survival mechanism[3]. However, in today's world, these food choices seem to be a hindrance to emerging industries focused on creating food alternatives. One of these is the lab-made meat industry.

Figure 1. Lab-made hamburger meat presented by Mosa Meat at the University of Maastricht's International Symposium on Cultured Meat.[8]

Why Lab-Made Meat?

In 2001, the first patent was filed to produce cultured meat for consumption[21]. Since then, the industry of lab-made meat – also called cultured, cell-based, or clean meat – has emerged with one goal: reinvent how mainstream meat is produced to reduce environmental impact. As suggested by a 2011 Oxford University study, if all beef production was lab-made, there would be a drastic decrease in environmental pollutants[30] (Figure 2). Why is this such an urgent matter? To put this in perspective, a third of the world's land and 16% of the world's fresh water is currently devoted to livestock farming[2]. The raising of animals also contributes to about 15% of greenhouse gas emissions, 75% of Amazon rainforest deforestation and huge amounts of water pollution[18,21]. Today, more than 320 million tons of meat is produced to sustain market demand[22]. Taking into account our exponentially growing population and world economy, animal agriculture is projected to increase about 70% by 2050[22].

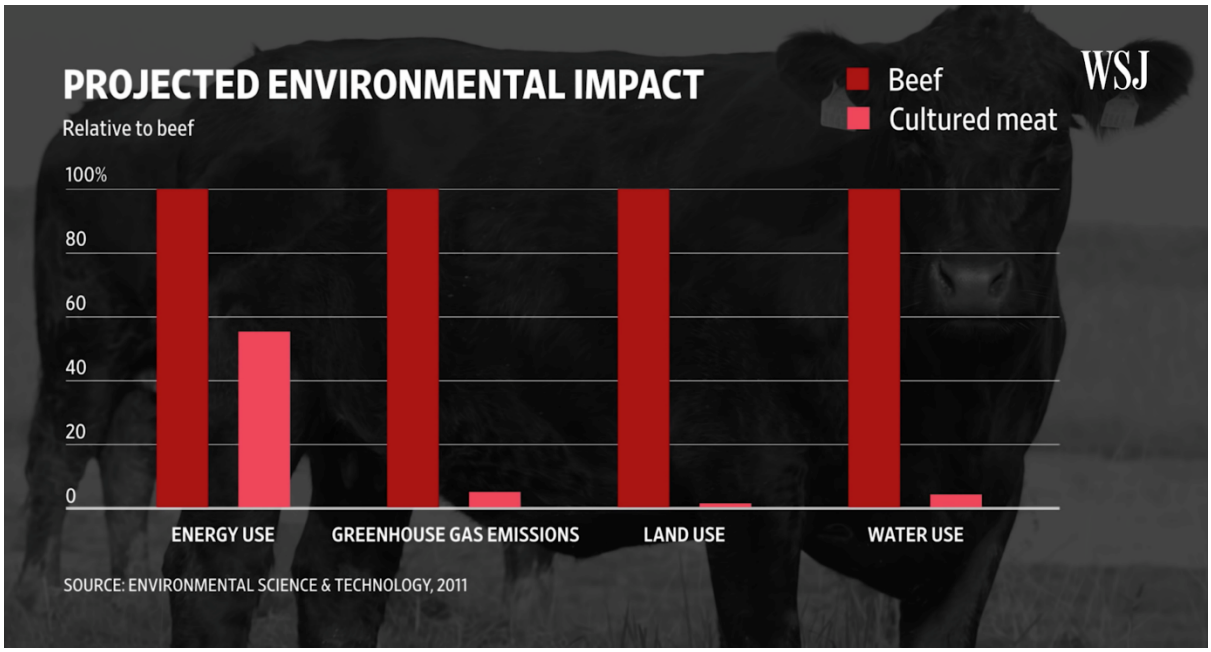

Figure 2. Chart comparing difference in resources required between beef farm raised and lab-made from Oxford University[30]

For these reasons, well-known names such as Bill Gates, Tyson Foods, and Google are investing heavily in the research and market development of lab-made meat products[24,27]. As Bill Gates writes in his personal blog, "Put simply, there's no way to produce enough meat for 9 billion people. Yet we can't ask everyone to become vegetarians. That's why we need more options for producing meat without depleting our resources[24]." Others driven by animal cruelty concerns have also joined the movement to advocate for alternative methods of meat production. PETA (People for Ethical Treatment of Animals), for example, has invested in this research as its members claim their mission to eliminate animal suffering aligns with the lab-made meat industry.[13] . The diversity of those who support this food revolution – from powerful capitalists to humanitarian organizations – illustrates the sheer scale at which lab-made meat can have beneficial impact.

Where is food technology today?

In 2013, Dr. Mark Post from Maastricht University in the Netherlands created the first lab-made hamburger. This hamburger was cooked and taste-tested publicly at a press event in London and served as the first proof of concept that lab-made meats could be available for human consumption. Since 2013, there has been a booming lineup of other proof-of-concept food samples around the world: salmon filet (Wild Type from San Francisco, California), chicken nuggets (JUST Inc. from San Francisco, California), foie gras (IntegriCulture from Tokyo, Japan), and even steak (Aleph Farms from Rehovot, Israel)[1,14,15,31] (Figure 3).

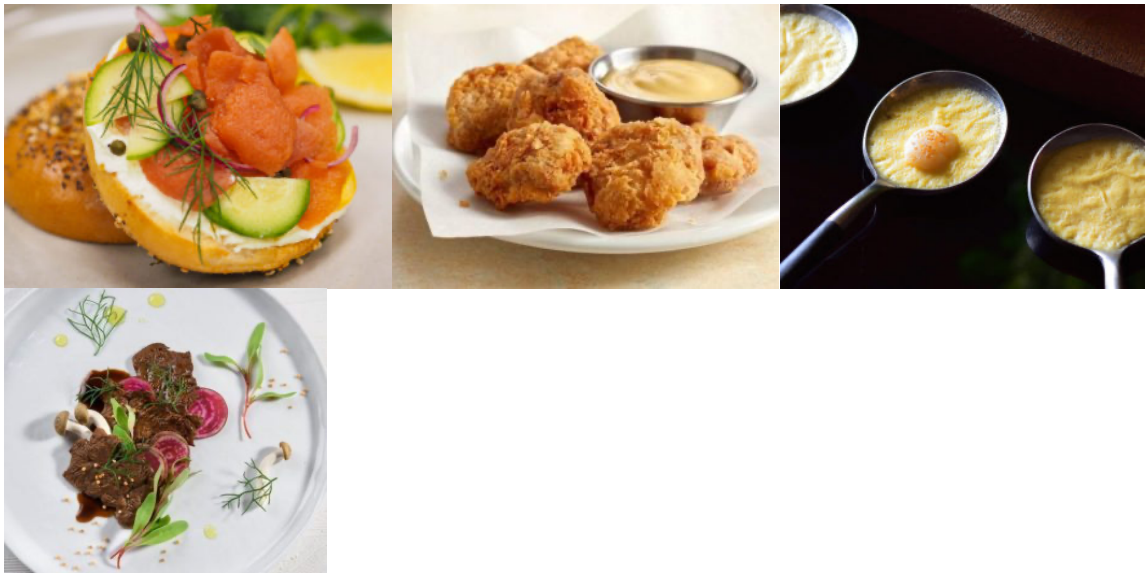

Figure 3. Lab-made meats: salmon lox from Wild Type, chicken nuggets from JUST Inc, foie gras from IntegriCulture, steak filets from Aleph Farms[1,14,15,31]

As mentioned before, people are the toughest critics when it comes to food. Above all else, lab-made meat companies must create products good enough to overcome the Uncanny Valley of Food phenomenon. As founding CEO of Mosa Meat, Peter Verstrate emphasizes, "When they [the consumers] taste the product, they have to have the experience of meat, not the experience of a product that looks like meat and comes close to meat or has the distinct hints of something that looks like meat[24]." This sentiment spoken by Verstrate is a prime representation of the industry's mentality; from taste to texture to smell, there is no question that cell-based meat companies are aware of consumer expectations.

So, how is this even done? Making meat from a hunk of cells is essentially a four-step process: 1) Biopsy/Isolation 2) Expansion 3) Differentiation 4) Assembly[5,25].

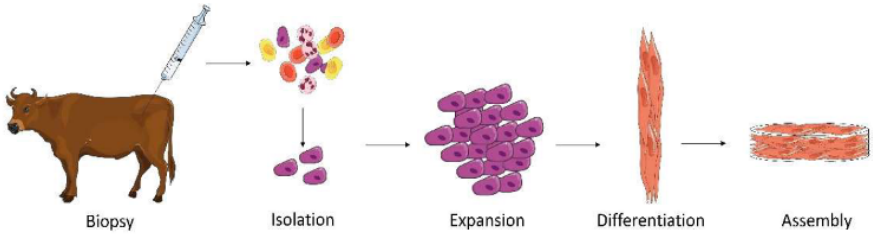

Figure 4. Simple schematic of lab-made meat published in the Journal of Integrative Agriculture[4]

First, muscle stem cells – cells derived from skeletal muscle that can mature into multiple muscle fiber types– are non-invasively isolated from a tissue sample of an animal. The cells are fed with essential nutrients and grown in plastic dishes. Once the cell colonies expand into 2D cell sheets, they are then relocated and fed a modified nutrient solution. This change in environment causes the stem cells to differentiate into mature muscle fibers. Lastly, scientists assemble these thin layers of muscle fibers into multiple layers and add other cell types such as fat cells to create the final product[25] (Figure 4).

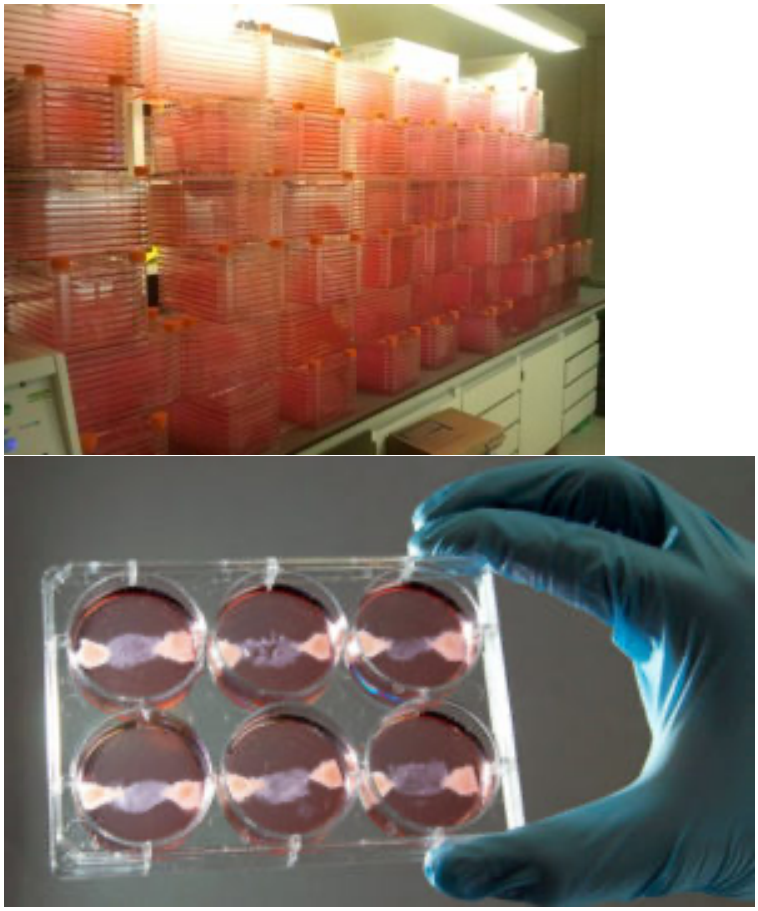

Figure 5. Left: Tissue culture flasks used for making the first lab-made hamburger in 2013 (during the expansion step)[9]*. Right: In vitro meat samples (during the differentiation step)*[20]

Making lab-made meat sounds easy. What's the catch?

The simplified pipeline of lab-made meat production seems straightforward. You might be wondering: why aren't lab-made meats found in supermarkets yet? As you might guess, mimicry of nature is hard for scientists to perfect in a laboratory, let alone on a global market scale. Scientists have yet to fully understand the numerous molecular factors and tissue interactions that result in the various meat textures and tastes. Further, the enormous scale at which lab-made meat would need to be produced for world-wide consumption creates a large manufacturing obstacle; how can we convert a laboratory protocol into a business model? These issues of scalability and texture perfection are driving the lab-made meat industry's research today.

In Figure 4, the steps of muscle stem-cell expansion in 2D layers is shown. Unfortunately, this method severely limits the number of cells that can be grown per square unit. It has been shown that muscle stem cells are surface-dependent; they must be attached to a solid surface to survive[23]. This 2D culture also affects fiber formation of the muscle cells, resulting in a disappointingly soft texture[29]. As a result of this constraint on replicating natural meat textures, a large focus of research investigates new technologies to enable 3D cell expansion while also maintaining the structural integrity of muscle.

Harvard professor Kit Parker and his Disease Biophysics team recently published a paper in October 2019 which introduced an exciting breakthrough in this field: the creation of novel 3D edible gelatin scaffold[19]. Gelatin – a very common muscle protein derived from collagen— is spun like cotton candy creating a scaffold into which muscle stem cells can be seeded into (Figure 6). The resulting properties of the synthetic meat have been shown to have the texture and nutritional outputs of meat analogs.

Figure 6. Gelatin scaffold before cells are added, from afar and under the microscope[19]

This material could possibly replace the separate steps of expansion to assembly and could address scalability issues. For instance, a Jerusalem-based company called Future Meat uses large bioreactors (Figure 7) to scale their product production[10,17]. It may be possible to vertically layer gelatin scaffolds within the bioreactors which would allow scientists to seed and culture billions of cells at once.

Figure 7. Lab-made meat company Future Meat use pharmaceutical bioreactors to grow their chicken, beef, lamb, and pork products[17].

What should we expect for our near future?

Food science is advancing at a rapid pace; however, until specific textures and looks can be refined, companies are focused in the meantime on bringing their processed meats – hamburgers, meatballs, chicken nuggets – to market.

The first lab-made hamburger cost over $300,000 to make in 2013, but prices for production have drastically dropped over seven years[12]. In fact, Mosa Meats stated that they plan to release their first burger product to market in 2021 at a cost of about $10 each[26]. This pricing, although more than McDonald's, is within the ballpark of organic food pricing and much more affordable than ever before. Another up-and-coming company named JUST Inc. has announced partnership with local San Francisco restaurants to sell their lab-made chicken nuggets in the near future. Amongst other things, JUST Inc. has also created theoretical packaging for future cell-based hamburgers and chicken cutlets in anticipation for their commercialization (Figure 8).

Figure 8. Concept packaging for JUST Inc.[15]

Should we be afraid to eat lab-made meat?

Anticipating public skepticism, businesses are trying to rebrand "lab-made meats" to "clean meats" for good reason. Aside from getting rid of the outlandish stigma of anything labeled "lab-made," these meats are arguably more "natural" than most foods in your pantry today. Simply put, lab-made meat production would be a less worrisome process than the current production of meat from live animals.

Firstly, converting to lab-made meat would eliminate the use of antibiotics. Studies show that E. coli bacteria (a very common strain of bacteria frequently connected to antibiotic resistance) is rampant in animals that are fed grain for reasons that are beyond the scope of this article[29]. The key takeaway is that industrial farms feed enormous amounts of grain to their animals, which creates E. coli breeding grounds[7]. With lab-made meat, there is no need for grain feeding because there is no animal to raise. Instead, all we would need are sterile laboratories. Consequently, the risk of food contamination, blood borne pathogens and zoonotic diseases would be almost non-existent.

Further, the cultured meat industry is much more transparent regarding production and commercialization in comparison to industrialized farming today. Currently, there is no standard rating system for live meat production[16]. Without concrete regulation, industrialized farms are not unified in their practices and can get away with ethical and health neglect. In conjunction with the business mentality of maximizing production while minimizing cost, factory farms are one big melting pot of mixed messages, confusing labels, and claims.

Luckily, rules and regulations regarding lab-made meat production are being drafted in real-time. This enables the creation of a direct production pipeline that could be universally implemented, ethically accepted and better regulated. In other words, products that are from lab-made meat companies offer eaters the experience of responsibly sourced and regulated food.

Another consideration to take into account is the range of which lab-made meats could be bioengineered for our health benefit. Studies show that eating red meat increases risk for cardiovascular disease because of high saturated fatty acid levels[28]. The simple methodology of lab-based meat makes it possible to modify certain material components of the meat. For instance, scientists could reduce the amount of saturated fatty acids in favor of good fats such as omega3 fatty acids. Or, they could enrich the meat with more vitamins[4]. These are conversations that will most likely come to fruition in the future. So, in addition to no use of antibiotics, low risk of contamination, and manufacturing transparency, you could, in theory, gain nutritional benefits as well.

Figure 9. Lab-made meat illustration by Rejeanne de Jong[11]

Initially, it might sound scary to eat meat from a test tube. But, looking at the science, we can see that protein grown outside the body is molecularly the same as it would be grown inside the body. By making the process of lab-made meat and all its benefits transparent, the industry hopes that public acceptance will follow. While there is still a long way to go before all meats you see in grocery stores will be generated in labs, we will inevitably start to see lab-made meat products hit the market in the coming years. A new food revolution has started. Are you ready?

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