CellAgri

An Introduction to Cellular Agriculture

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About The Author

Ahmed Khan is a cellular agriculture consultant and the founder and editor of CellAgri. A news and market insights startup focusing on the future of food with cellular agriculture.

CellAgri provides the latest updates and insights on a range of topics and trends relating to the cellular agriculture field. CellAgri's platform also tracks all the major and upcoming players in the field. Providing them the ability to post and share their latest news and job openings.

Ahmed is a co-founder and member of the board of directors of Cellular Agriculture Canada, a non-profit organization advancing and promoting the cellular agriculture industry in Canada.

Ahmed has previously spoken about cellular agriculture in leading food tech conferences around the world, including in Canada, England, Singapore, and the United States. Ahmed first learned about cellular agriculture while studying at McGill University in Montreal, Canada.

Author's Note

In 2013, food critic and writer Hanni Ruetzler took a taste out of a dish costing more than $300,000. She remarked how it was "*close*" to tasting like real beef. The dish in question was not a plant-based meat alternative; it was in fact real beef - beef that was made in a lab!

This taste test was the first lab-grown beef burger. It was created by Dr. Mark Post and his cellular agriculture research team in the Netherlands.

Without any animals.

Since the first taste test, cellular agriculture has been explored as an alternative to the present livestock agricultural system. Many inspired researchers and entrepreneurs have entered the field looking to change the *future of food*.

I first learned about cellular agriculture through the best accident ever. I was promised a meal if I sat through a random presentation. It wasn't the best dinner, but that presentation changed everything.

I learned about how cellular agriculture is a field of growing animal products from *just cells*. And that blew my mind.

Dr. Mark Post and the first cell-cultured meat beef burger

I had to join the field and become part of the movement changing food forever. But how?

For any movement to gain traction, there has to be a news and insights source. A source of the latest updates from all the players. A one-stop platform for anyone who wants to learn and keep up with the field.

I founded CellAgri in 2017 to serve as the news and insights platform for the field. CellAgri tracks all the players and companies in the field to provide the latest updates in cellular agriculture, from research to the companies bringing products to market.

And the field is *ever-changing* and growing rapidly. This book was first published in May 2019. As its fourth edition, this book has been updated in March 2022 to be as up-to-date as possible.

Through the book, I hope you will get a complete introduction and overview to the field. The book is a collection of modified and updated articles that will help you learn about *what* this field is, *who* is in it, *how* it works, and *why* the field matters.

For the future of food.

Biology 101

Biology is the study of life. From the emergence of life to the intricate details of our DNA, biology covers a wide range of topics. And it is the source of all emerging and innovative biotechnologies.

Thanks to advancements in cutting-edge technology, scientists and researchers can bring science fiction to life: cell-grown foods.

But what is the science behind this, and how is it even possible? Here's a basic overview of cell biology to follow along!

The Cell

The cell is a basic unit of life, and we are made up of trillions of cells!

Typically, cells specialize into different types of cells to help carry out a function. Brain cells, muscle cells, skin cells. These are all different cell types that make up the body. And each different type has *differentiated* characteristics that help it carry out a different function.

Yet, how do all these different cell types emerge?

Cell Division

A new cell comes from the cell division of an existing cell. A cell will divide into more cells through a process called self-replication (also known as mitosis). A cell will only divide under the right conditions. This is when the cell has enough nutrients, energy, and growth factors to start dividing.

In the laboratory, scientists use cell culture media to grow cells. The cell culture media, which includes the cell culture *serum*, provides all the nutrients and growth factors that the cells may need to replicate. In this way, the cell culture media makes the cells believe they are still in its body and will grow accordingly, if all the right conditions are in place.

But not all cells can divide. Most cells in the body lose their ability to divide as they get older. Most cells can only divide a certain number of times in their lifespans.

The Stem Cell

A stem cell is a unique type of cell that has the ability to divide to produce more of itself via self-replication. These new stem cells can also self-replicate to produce more stem cells. A stem cell also has the unique ability to become a different cell type (like a muscle cell or a brain cell) through a process called differentiation.

Yet, once again, not all stem cells are the same. Early on in development, stem cells have the ability to self-replicate indefinitely and to differentiate into many different cell types. Typically, stem cells found in most adult tissues (like satellite cells in muscle) have a limited number of self-replications in their lifespan and can only differentiate into specific cell types.

We cover other scientific terms as we go along (including a list of 6 terms that will help you understand cellular agriculture).

Chapter 1

Cellular Agriculture: An Introduction

What exactly is cellular agriculture?

Cellular Agriculture: An Introduction

WHAT EXACTLY IS CELLULAR AGRICULTURE?

Cellular agriculture is the field of growing agricultural products directly from cell cultures instead of using livestock. At the moment, the primary research has revolved around growing meats (beef, pork, poultry, and seafood) as well as animal products (such as milk and egg white protein) in cell cultures. Instead of raising, for example, a cow from birth for milk and meat, cellular agriculture presents an alternative way to get the same product without all of the problems associated with raising livestock.

HOW DOES IT WORK?

Cellular agriculture can be broken up into two categories: cellular and acellular agriculture. In this context, cellular agriculture refers to growing agriculture products that are based on living or once-living cells, such as meat. To put it simply, growing meat is the process of taking the cells that make meat from the animal of interest and growing them in a cell culture media to become meat. The cell culture media and how the cells are grown are important aspects in this process, because they help the cells become the *same* meat that comes directly from animals.

Acellular agriculture involves growing and harvesting a product that the cell cultures make. This is used to make products such as milk and egg white. Just like egg white, milk is a mixture of different proteins and fats. These different components can be grown without using animals and, instead, by using microbes, like yeast. For example, to grow casein, which is a key protein in milk, a copy of the casein gene from a cow is inserted into yeast. The yeast will then make many copies of the specific animal's protein (casein from a cow) that can be used to formulate dairy milk that is identical to the milk made from a cow. Without requiring a cow.

The process of using yeast to grow a protein of interest is not novel to cellular agriculture; this process has been used since 1978 to make insulin for diabetes treatment. It is also used to make rennet and vanillin.

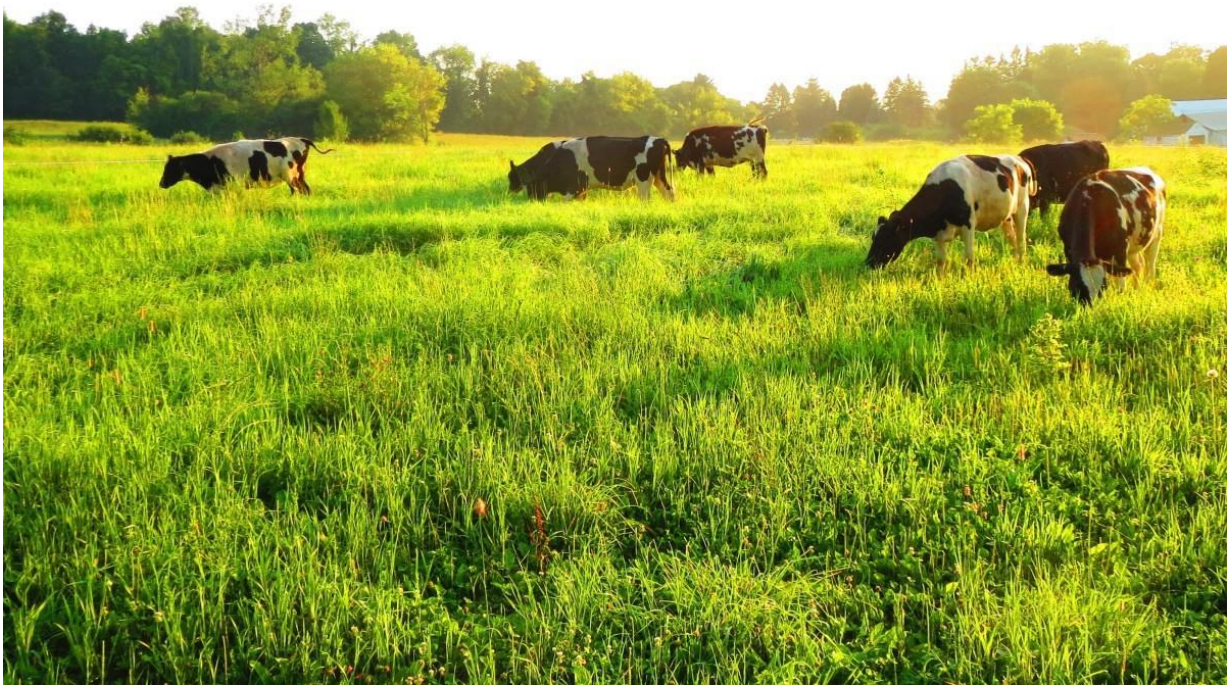
WHY IS IT IMPORTANT?

Besides the incredible fact that it *is* possible to make animal meat and milk without requiring an animal, cellular agriculture is critical in developing a sustainable livestock agricultural system. The present system has produced enough to meet current demands. But it will not be able to keep up with future demands. Especially with a growing population.

It is predicted that the global population will be between 9 and 11 billion people by 2050. The global demand for animal-based foods will skyrocket by at least 70%. Almost doubling from current levels.

How can a system that already requires so many resources sustainably produce that much more meat and animal products?

The growing global demand for meat and animal products illustrates that people are not ready to change their eating habits from meat to plant-based alternatives. Instead of urging people to eat more plant-based diets, the next best option is to find a better way to produce meat. That is exactly what cellular agriculture offers.



ENVIRONMENTAL REASONS

It is shocking how many resources, like land, water, and electricity, are consumed in livestock agriculture. To produce one 8-ounce (0.23kg) steak, not only is 1.6 kg of feed required, the production process requires 3,515 liters of water. It also requires enough energy to fully charge one laptop *sixty* times.

These numbers reflect the resources required to produce one 8-ounce steak. Not an entire cow.

The large amount of resources required by livestock agriculture reflects its significant environmental footprint. Approximately 25% of the earth's surface is taken up for livestock farming. This is approximately 70% of all land used for agriculture. The production of animal products constitutes about 30% of all fresh water usage.

After cattle farming, sheep and pig farming consume the next most resources, respectively, followed by poultry farming.

Most alarmingly, livestock agriculture generates 14.5% of all greenhouse gas emissions. Considering all that has been done in the automobile industry to reduce carbon emissions, it is shocking how livestock farming contributes such a significant proportion of all greenhouse gas emissions with little done to reduce it. Until now.

Cellular agriculture has the potential of reducing global greenhouse gas emissions as well as promote more responsible uses of natural resources.

Compared to livestock agriculture, cellular agriculture provides an alternative that is more environmentally friendly and more sustainable. Meat produced via cellular agriculture would use approximately *less than a tenth of the land and water*. This meat would also produce significantly less greenhouse gas emissions.

ANIMAL WELFARE

Beyond the environmental impact, cellular agriculture would impact animal welfare. Without requiring livestock, cellular agriculture (obviously) reduces the number of animals used in the food production process.

Furthermore, as the global demand for meat increases, large factory farms would be put under more pressure to produce even more animal products. It's likely that animal welfare conditions would worsen from their current state, including increased confinement and imperfect slaughter conditions, to meet the demand. By providing another method to meet the global demand without worsening livestock conditions, cellular agriculture provides an opportunity to improve livestock welfare.

HUMAN HEALTH

Regarding human health, meat produced via cellular agriculture would not be fed the large amounts of antibiotics given to animals. In the US, nearly 80% of all antibiotics sold go to animal agriculture. Antibiotic usage in animal agriculture has led to various health issues, such as the rise of antibiotic resistant bacteria.

In addition, most bacterial contaminations that cause food-borne illnesses, such as E. coli and salmonella, often occur through interaction with infected animal feces. By cutting out livestock in cellular agriculture, there will be no E. coli or salmonella from livestock that could contaminate the meat or other products.

In light of the devastating impact of the Covid-19 pandemic around the world, companies and non-profits have written about the connection between zoonotic diseases like Covid-19 and harvesting animals. With cellular agriculture, nobody would need to harvest animals anymore for those products. Ultimately, cellular agriculture can end that connection.

FOOD SECURITY

As the pandemic's impact is felt globally, the importance of food security is starting to be discussed in places like North America and Europe. Covid-19 has highlighted the need for resilience in food supply chains to ensure people do not lack access or availability to their food needs. Cellular agriculture can address that by being a way to produce food *locally* anywhere and everywhere on the planet *and* in outer space.

Food security is a major reason why there is an explosion of interest for cellular agriculture in Asia, particularly in Singapore, Japan, and across the Middle East. Without requiring as many sources like land for farming, countries that rely heavily on food imports can now produce enough food for their populations locally through cellular agriculture.

CONCLUSION

Prior to cellular agriculture, there had not been an environmentally friendly and sustainable alternative to the livestock agriculture system for meat and other animal products. While research estimates the energy required to produce meat via cell cultures may be greater than conventional livestock farming, cellular agriculture may be more sustainable when comparing land and water use and greenhouse emissions. Ultimately, more research needs to be conducted to understand the environmental impact of cellular agriculture at scale.

There are still many obstacles to overcome before cellular agriculture products become commercial. One of the most difficult ones to overcome will be challenging any negative *public perceptions* of food that come from cell cultures instead of from animals.

To overcome this, it will be important to inform the public on what cellular agriculture is and how this field provides a solution to an unsustainable livestock agricultural system. It will also be very important for all actors in the field to be transparent and clear about all of their scientific findings and all aspects of the manufacturing processes.

Chapter 2

6 Terms You Need to Know to Understand Cellular Agriculture

Here are a few more terms that will help make cellular agriculture easy to understand!

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Here are a few more terms that will help make cellular agriculture easy to understand!

Cellular Agriculture

It makes sense to start off with this definition!

Cellular agriculture (commonly abbreviated as cell ag) is the field of growing animal products directly from cell cultures instead of using livestock. Eliminating the need to use animals. The main research has revolved around growing animal meats (such as beef, poultry, and seafood) as well as animal products (like milk, leather, and egg whites) in cell cultures. So instead of raising a cow from birth for milk, meat, and leather, cell ag presents an alternative way to get the same animal products without all of the problems associated with conventional livestock agriculture.

Cellular agriculture can be broken down into two categories, based on how the cell cultures are used: cellular agriculture (where the actual cells are harvested, like for meats) and acellular agriculture (where a product that the cell cultures make and *not* the actual cells are harvested).

Cultured Meat

Cultured meat refers to the meat grown in vitro from cell cultures via cellular agriculture. Cultured meat is also referred to as cell-based meat, cultivated meat, clean meat, lab-grown meat, and in vitro meat. To grow cell ag meat, muscle cells are taken from the animal of interest and these cells are grown in a cell culture media. The cell culture media and how the cells are grown help the cells develop into the *same* meat that directly comes from animals.

The first taste test for cultured meat occurred in 2013 when Dr. Mark Post and his team created the first lab-grown beef burgers. Since then, the cost of producing a burger has dropped significantly. In 2016, Upside Foods (formerly Memphis Meats) became the first company to make the cell-based meatball. In March 2017, Upside Foods also became the first company to produce cell-based poultry meat (chicken and duck). Later in 2017, Finless Foods became the first company to produce fish meat.

In September 2018, New Age Meats introduced the world to the first cell-based pork sausage. And in December 2018, Israeli startup Aleph Farms surprised many to produce the world's first cell-grown beef steak. In 2019, many cell-based seafood companies showcased prototypes of their first cell-grown fish products. Similarly, in 2020 and 2021, companies around the world regularly showcased their innovative cell-based food products.

Cell Cultures

Cell cultures refer to growing cells in a controlled environment (like a laboratory) outside of where the cells would normally be found. In order to survive and replicate, these cells are placed in a cell culture media formulation (including the serum) that contains all the nutrients that will help the cells grow.

One of the key obstacles ahead in cell ag is *scaling* production of cell cultures to get from lab to market. For example, cell ag researchers are looking for the best cell lines to grow in cell cultures and eliminate their dependence on animal-derived cell culture serums.

Conventional Livestock Agriculture

Conventional livestock agriculture refers to traditional animal agriculture and using animals to produce animal products. While this is the norm, one of the driving forces for the field is the need to develop a sustainable system for animal products. The global population will grow to be between 9 and 11 billion by 2050. The demand for animal products will nearly double. With an increased need for meats and other animal products, conventional livestock agriculture is not sustainable to meet the growing demand due to its resource demand and environmental impact.

Biofabrication

Biofabrication is the field of using cells to produce biomaterials for various functions. Through cellular agriculture, biofabrication offers an efficient and sustainable way to produce animal-derived materials, such as leather, spider silk, and fur, for clothing and other purposes.

Unlike conventional leather, cell-cultured leather can be molded into different shapes and sizes. By overcoming the need for cattle and the chemically intensive steps in leather tanning, cell-cultured leather avoids and reduces the majority of carbon emissions associated with leather production and can be more environmentally friendly.

The first company to use cellular agriculture to grow leather was Modern Meadow growing the protein collagen, the main component of leather. In recent years, more companies have entered the field to produce cell-cultured leather, including VitroLabs and Provenance Bio.

Cell-cultured spider silk can be used to make a range of products, from clothing and shoes to wristwatches and cosmetics. Since 2011, several spider silk companies have explored different applications of cell-cultured spider silk, including AMSilk, Spiber, and Bolt Threads.

Plant-based Meat Alternatives

Plant-based meats alternatives are products that use plant-based ingredients to mimic and replicate the flavor of meat. In the past, many of these veggie burger attempts have not been successful in attracting the conventional meat consumer. They just didn't have the same taste or texture as conventional meat. In recent years, companies like Impossible Foods and Beyond Meat have created unique plant-based meat products that have the same taste and texture as conventional meat.

While plant-based meat alternatives also aim to reduce the environmental impact of conventionally produced meat, these are products are not the same as cell ag meat products. Cell-based meat consists of actual animal muscle tissue, grown without requiring animals in the process. Plant-based meats are entirely plant-based and do not contain any animal components. Ultimately, however, both cell ag and plant-based meats are working towards the same goal: a healthy and sustainable source of animal products

Chapter 3

From Lab to Market

There are four key areas that need to be further developed to scale production, and this section will highlight these different parts of production

From Lab to Market

In 2013, when Dr. Mark Post's team developed the first cultured meat burger, it took three lab technicians *three months* to grow and put together 20,000 cow muscle fibers. To make the first $330,000 lab-grown burger. In the coming years, more cellular agriculture companies are preparing to release their first commercial product. Scaling the production process will be important to ensure that cell ag is a commercially viable option.

There are four key areas that need to be further developed to scale production, and this section will highlight these different parts of production.

Cell Lines

Researchers are looking for stem cell lines from different animals that will (*ideally*) divide indefinitely into more cells. These cell lines would then become the stable source of all other stem cells and differentiated cells that produce cell-cultured meat.

Stem cells are unique because they have the ability to produce more of itself via self-replication or to produce cells that become different cell types via differentiation. At the moment, to produce cell-based meat, some researchers are using cells found in muscle called satellite cells (Yes, these cells are also in us!). When activated, the satellite cells will either self-replicate to produce more satellite cells or differentiate into muscle fiber cells that can become the meat product. The problem with these cells, however, is that satellite cells have a limited number of self-replications in their lifespans.

Once a stable cell line is found and becomes widely available for animals of interest (like cows, pigs and chickens), the sourcing of stem cells to make cell-cultured meat will no longer be an obstacle.

Cell Culture Media

The cell culture media, is the nutritious mixture that cells grow in, which includes the cell culture serum. The cell culture media provides all of the nutrients and growth factors that cells may need to replicate or differentiate into another cell type. There are two main obstacles in scaling cell culture serum: its sourcing and price.

In many scientific labs, a common cell culture serum used to grow cells is fetal bovine serum. Not only would this still involve animal sourcing in the production process, fetal bovine serum is inconsistent from batch to batch as well as very costly. Animal-free serums have been developed for medical purposes, but the problem of costliness remains for scaling production.

The development of an inexpensive and animal-free growth serum for cell lines has once been described as the *Holy Grail* for cellular agriculture companies, as it is one of the main obstacles to scale production. Further innovation and research are required to find a cost-effective solution that would make scaling cell ag production feasible and affordable.

Many cellular agriculture companies have stated that they have developed their own cell culture media formulation.

Bioreactor

A bioreactor is a chamber that houses the cell culture serum and scaffolding to promote the growth and differentiation of cell lines to cell-based meat. Essentially, bioreactors are the chambers where all the parts of scaling cellular agriculture production come together to form the finished product. Bioreactors will likely be large tanks that would be like large brewery tanks.

While companies are exploring how to build them, there are currently no large-scale bioreactors that would accommodate commercial scaling for cultured meat. Research is investigating how to scale contemporary bioreactors and modify them for growing meat.

Scaffolding

When a building is under construction, it is surrounded by scaffolding for structural support. In this way, the scaffolding outlines how the building will look like while providing it support.

Similarly, in cellular agriculture, scaffolding provides structural support to cells by outlining the composition and shape of cell-cultured meat. This is important to make sure that the cells grow into muscle fibers that have the same taste, texture, and shape as conventional meat. Scaffolding also promotes the growth of larger muscle fibers needed to scale production.

Further innovation is required to create scaffolding to grow complex meat tissues like steaks. Steaks consist of different amounts of muscle, fat, and connective tissue, and a complex scaffolding will have to be able to replicate their appearance and composition.

Conclusion

In the future, a stable and immortal stem cell line will be produced by obtaining relevant cells from the animal of interest. This cell line is stable and a constant source of stem cells, so animals are no longer required in the production process. These stem cells are grown in an inexpensive, animal-free cell culture media in a bioreactor. As the stem cells self-replicate and differentiate to muscle fibers and other cell types, the cells mature into cell-based meat.

There is a long way before this idealistic situation can become a reality at scale. Having said that, not all of these topics need to be solved before the first products come to market. Starting with cell-cultured ground beef or poultry avoids many of the issues relating to scaffolding.

Chapter 4

The Products Leading a Revolution

Cellular agriculture will soon be available at a store near you!

The Products Leading the Revolution

While some players and companies believed that cell-cultured meat first come to market at the earliest by 2021, other companies are working to get to their cell-cultured products to market faster. We highlight some of the upcoming products in each sector and when to expect them!

BOLT THREADS' SILK TIES, LEATHER BAGS, AND SKINCARE

Bolt Threads is a cell-cultured materials startup that uses animal-free spider silk to make clothes. By using microbes to produce spider silk. Bolt Threads has already released a few products in limited amounts, such as a silk necktie and a toque.

In 2018, Bolt Threads announced its latest product line: *Mylo*. Unlike their other products, Mylo is not made from spider silk. It's a leather alternative, made from mushrooms. Licensing the technology from Ecovative Design, Mylo is a leather material produced from mycelium, the root structure of mushrooms. In September 2018, Bolt Threads announced the first commercial product from the Mylo line: The Driver Bag.

Since then, Bolt Threads has announced a range of partnerships to commercialize its Mylo product line, including with Stella McCarthy and Lululemon, through the Mylo Consortium.

In March 2019, Bolt Threads announced entering the cosmetic industry to produce *skincare products with silk*. Calling its subsidiary Eighteen B, the project launched with two products with its trademarked '*b-silk*': a silk protein moisturizer and cream.


EIGHTEEN·B
SCIENTIFICALLY
DESIGNED SKINCARE

GELTOR'S COLLAGEN

Geltor uses cellular agriculture to create animal-free gelatin by using microbes to produce the protein collagen. Collagen is the main component of gelatin, and it is used in a range of other products, such as cosmetics. In May 2018, Geltor won the CEW's Award for Innovation for 2018 for their first cosmetic product: *Collume* (formerly N-Collage), a collagen skincare product.

In March 2019, Geltor launched *HumaColl21*, the first ever human collagen created for cosmetic formulations. In April 2020, Geltor announced the launch of their product: *Elastapure*, the first human elastin protein designed for skincare use.

During the summer of 2021, Geltor announced the launch of its cell-cultured collagen product for the food and nutrition markets. Branding the product *PrimaColl*, Geltor partnered with Arxada to manufacture and scale the production of its first food product.

The Sustainable Future of Pet Food

Pet food startup Wild Earth first launched its koji-based dog treat in October 2018 before launching its koji-based dog food in July 2019. Koji is a type of fungi that is found in miso soup and soy sauce, and Wild Earth plans to use it as the source of their clean protein. Similarly, in May 2020, pet food startup Bond Pets announced the launch of its Protein-Packed Dog Treat Bar.

In August 2021, pet food startup Because Animals began taking pre-orders on its website for the first cell-based meat pet treat: a cell-cultured mouse meat cat snack called “Harmless Hunt Cultured Mouse Cat Treats. In September 2021, Wild Earth announced plans to start developing cell-based meats for its pet foods.

PERFECT DAY'S ANIMAL-FREE DAIRY

Perfect Day uses acellular agriculture to make animal-free dairy proteins. In July 2019, Perfect Day made history by launching the first-ever animal-free dairy ice cream. With the limited release of the ice cream, Perfect Day became the *first* cellular agriculture company to launch a food product. One year later, in July 2020, Perfect Day launched its own ice cream brand, Brave Robot, through its subsidiary the Urgent Company.

Since then, Perfect Day has partnered with numerous companies to develop a range of animal-free dairy products. From Graeter's Ice Cream to Igloo Dessert Bar in Hong Kong, Perfect Day recently partnered with General Mills and Natreve to produce animal-free cream cheese and whey protein powder, respectively, at the end of 2021.

In November 2021, Perfect Day also announced a range of its own new products with its cell-cultured dairy proteins. Through its Modern Kitchen product line, Perfect Day launched its own animal-free dairy cream cheese. At the same time, Perfect Day also launched its own whey protein powder brand called California Performance Co.

EAT JUST LAUNCHES GOOD MEAT

Soon after announcing its entry into the cell-based meat sector in 2017, Eat Just ambitiously planned to release its first cell-based meat product at the end of 2018. And again by the end of 2019.

On December 2nd, 2020, Singapore made history by becoming the first country in the world to give regulatory approval for the sale of the first cell-based meat product by Eat Just. After working with the Singapore Food Agency for the previous two years, it is promising to see Eat Just become the first company to launch a commercial cell-based meat product. In December 2021, the company received additional regulatory approval to sell new types of its cell-cultured chicken products in Singapore.

Branding its cell-based chicken subsidiary as GOOD Meat, the sale and purchase of the first cultured meat chicken bites took place on December 19th, 2020, at the 1880 Restaurant in Singapore for $23 each. GOOD Meat's cell-cultured chicken is also served at the Madame Fan restaurant in the JW Marriott Singapore South Beach.

At the start of March 2022, Loo's Hainanese Curry Rice became the first hawker in Singapore to sell GOOD Meat's cell-cultured chicken. Hawker centers are an integral part of the Singaporean food culture, and this was the first time that GOOD Meat sold its cell-cultured chicken at a hawker restaurant for a limited launch.

CHICKEN-FREE EGG WHITE

Formerly known as Clara Foods, The EVERY Company uses acellular agriculture to produce a range of animal-free proteins, specifically cell-cultured egg white proteins. In March 2021, The EVERY Company launched its first product: a pepsin protein. Traditionally sourced from animals like pigs, pepsin is a digestive enzyme commonly used as a processing aid for a range of products, including food, beverages, and dietary supplements.

In November 2021, The EVERY Company announced the launch of its cell-culutred egg white protein product, ClearEgg. According to the company, ClearEgg is a highly soluble and nearly tasteless protein that can be used to increase the protein content of various foods and beverages. At the time, The EVERY Company partnered with plant-based snack company Pressed to launch ClearEgg in a Pressed smoothie.

In March 2022, The EVERY Company announced a partnership with specialty macaron company Chantal Guillon to launch its latest egg white product, EVERY EggWhite, in a new animal-free macaron product. According to the company, EVERY EggWhite is the world's first cell-cultured egg white product that delivers the functional aspects of egg white that formulators are looking for to make animal-free baked goods.

CELL-BASED SEAFOOD IS COMING

The year 2019 was a big milestone for cell-based seafood. For the first time, many cell-based seafood companies showcased prototypes of what their products could be one day. Following Shiok Meats' showcase of the first cell-based shrimp dumpling in Singapore in March 2019, California-based Wildtype presented the first cell-based salmon dinner in June.

In October 2019, Hong Kong-based Avant Meats showed how cellular agriculture could be used to develop a diverse range of products by producing the first cell-based fish maw product, a popular dish in China and South Asian cuisine. To end the year 2019, BlueNalu presented the first cell-based yellowtail amberjack in San Diego, California.

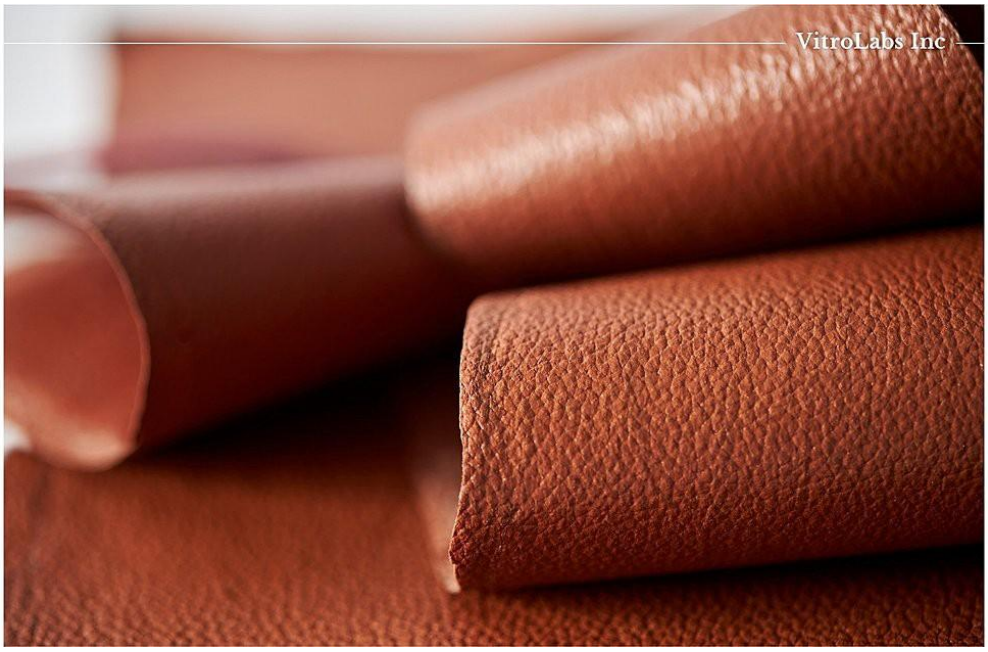
The wide range of products highlight how cell-based seafood can be as versatile as conventional seafood. Since then, both Avant Meats and Shiok Meats have showcased a new cell-based fish fillet and cell-based lobster and crab, respectively. While there are no cell-cultured seafood products on the market, Shiok Meats aims to launch its shrimp product by 2023.

(Left to Right): A selection of cell-based seafood prototypes. Shiok Meats' lobster and shrimp products; Wild Type's salmon; Avant Meats' fish maw; BlueNalu's yellow amberjack

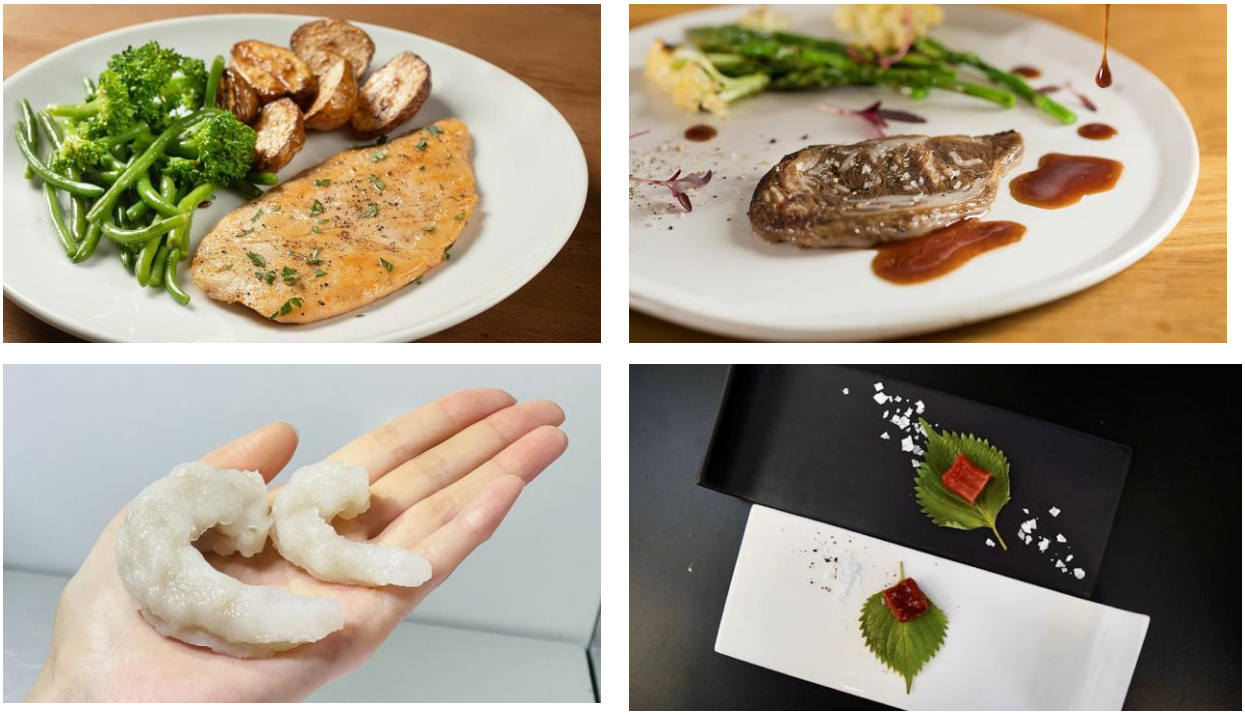
BIOLEATHER

Compared to conventional leather, cell-cultured leather can be designed and customized into different shapes and sizes for designers to produce *exactly* what they require without wasting materials. Previously, the company Modern Meadow created a prototype t-shirt known as Zoa and displayed it at the Museum of Modern Art in New York City in 2017.

More recently, biomaterial company VitroLabs announced a partnership with global luxury group Kering to support its cell-cultured leather production process. While VitroLabs did not share a timeline on when the company plans to come to market, VitroLabs shared that it has spent the last few years optimizing its platform to improve the look, feel, and performance of its leather at scale.



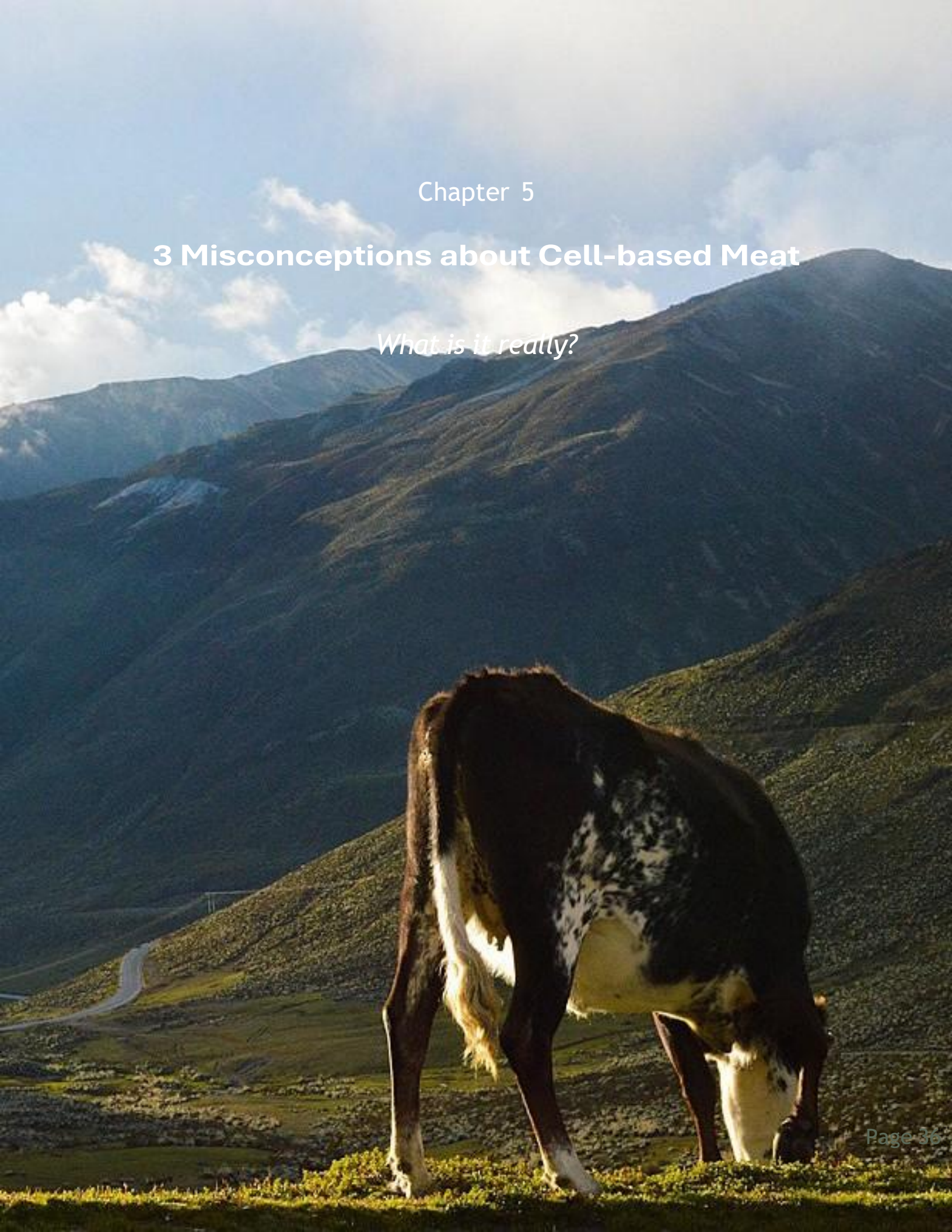
LOOKING TO THE FUTURE



(Left to Right): *Coming to Market One Day* - Select Product Showcases of 2021. Future Meat's chicken breast; Aleph Farms' ribeye steak; CellMeat's Dokdo shrimp; CellX's pork prototype.

Compared to when the field just began, there are nearly new product reveals every few months. The accelerating speed of the new product showcases highlight the major advancements companies are achieving in the field.

Beyond the companies and products in this section, there are many other companies that plan to release their own cellular agriculture products later on. Beyond any regulatory issues and other obstacles, one of the main hurdles ahead for cellular agriculture is scaling production to be commercially viable. Once that is developed, we are likely to see more cellular agriculture products in the near future!



Chapter 5

3 Misconceptions about Cell-based Meat

What is it really?

3 Misconceptions about Cell-based Meat

Cell-based meat.

The USCA doesn't want it to be considered meat. The NCBA says it should count as meat, but should be as strictly regulated as slaughterhouses.

Some call it cultivated meat, others cultured meat. But what is it really?

Beyond Singapore, there may still be some time before cell-based meat comes to market in other parts of the world, like the US. But there are already quite a few misconceptions about it.

This section will address three of the main misconceptions surrounding cell-based meat.

MISCONCEPTION #1: IS IT MEAT?

According to the Oxford Dictionary, meat is defined as "the flesh of an animal, typically a mammal or bird, as food". The US Cattlemen's Association (USCA) support this definition and have petitioned the US Department of Agriculture (USDA) to redefine meat as the flesh of an animal that has been raised, slaughtered, and harvested in the 'traditional' manner.

This raises the question: if animal 'flesh' can be raised *without* requiring the animal, can it still be meat?

People in the cellular agriculture field believe it can.

Cell-based meat is derived from the same source of cells (stem cells) that become meat in animals. This means that the same cells that make up conventional meat from a raised animal will make up cell-cultured meat: animal muscle cells, fat, and connective tissue that adds to the flavour. If conventional and cell-cultured meats appear similar under a microscope (because they're compositionally the same), can cell-based meat really be excluded from the definition of meat? Should there be any difference in its labelling?

While the USCA doesn't believe cell-based meat qualifies as meat, others in the meat industry think otherwise. The larger National Cattlemen's Beef Association (NCBA) believes cell-based meat meets (no pun intended) the definition of a meat product and, therefore, the United States Department of Agriculture (USDA) should be in charge of regulating it as *strictly* as they regulate beef slaughterhouses.

In addition, Tyson Foods and Cargill, the largest meat and poultry producers in the United States, have invested in cell-based meat company Upside Foods (formerly Memphis Meats). Upside Foods is the first cellular agriculture company to produce cell-grown poultry as well as the first meatball. Tyson and Cargill have since invested in other cell-based meat companies outside of the United States.

While the meat industry will continue to debate what qualifies as meat, the support of large meat corporations investing in cell-based meat shows that it can be a way to produce meat in the future. Ultimately, legal definitions may need to modernize to reflect the advancements in technology.

MISCONCEPTION #2: WHO'S REGULATING CELL-BASED MEAT? IS IT EVEN SAFE?

One of the first questions many people have about cellular agriculture and cell-based meat is who is in charge of marking sure it's safe? In Europe, new regulation has put the European Commission in charge of approving and regulating novel foods, including cell-based meat. In Singapore, the Singapore Food Agency announced that it will oversee developing a comprehensive regulatory framework to govern novel food production in the country, including cell-based meat.

In the United States, where many cell ag companies would like to launch, the question was only recently solved. As the NCBA and USCA have noted, the USDA regulates and oversees animal products like meat, milk and eggs. But what if those animal products are coming from cell cultures, a field that the Food and Drug Administration (FDA) would have oversight over?

In October 2018, the USDA and FDA held a joint public meeting over the regulation of cell-based meats. During the two-day event, the two agencies stated that they intend to *jointly* regulate these products. This will be the *first* instance where both agencies are in charge of regulating a field of products. In March 2019, the USDA and FDA established a basic framework to regulate cell-based meat, putting into writing what was agreed upon in October.

In regard to safety, one of the names that cell-based meat has been previously branded as is *clean meat*, and that name is meant to reflect the health and environmental benefits of it. In addition to the environmental benefits (animal agriculture emits 14% of all greenhouse gas emissions), cell-cultured meat will likely be produced in sterile environments where they will be free from microbial contamination. In the future, more studies and research will be conducted to ensure the safety of cell-grown food products as well as its environmental impact.

MISCONCEPTION #3: IS CELL-BASED MEAT A GMO?

GMO stands for genetically modified organisms. It involves the science of inserting the DNA of a gene of interest into the DNA sequence of another organism to produce a specific outcome.

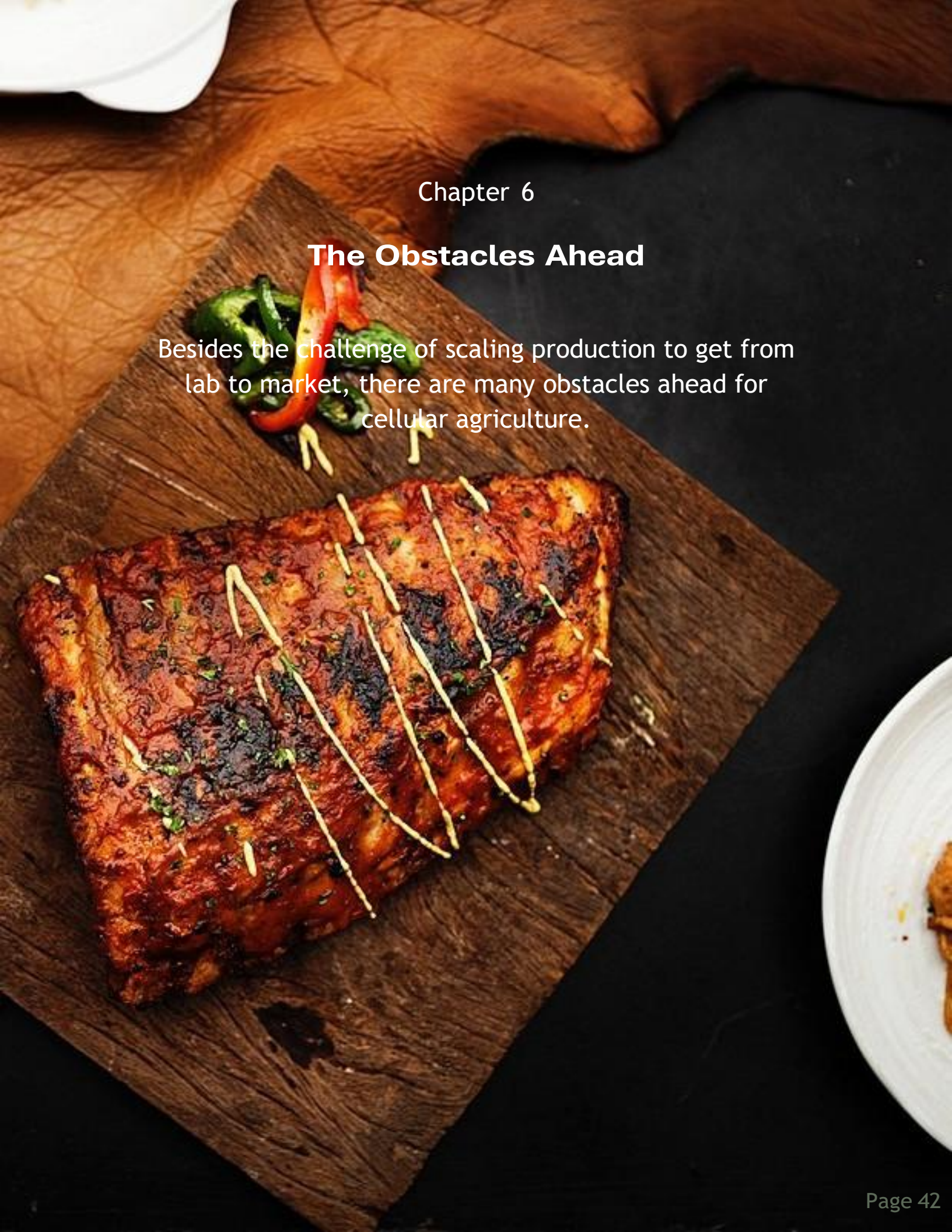
Since cell-based meat comes from unmodified animal cells, it is not considered a genetically modified food. Therefore, cell-based meat will not contain genetically modified organisms.

Having said that, there are some valuable lessons that cell-based meat companies and the wider cellular agriculture field can learn from the launch of GMOs. And avoid making the same mistakes.

There is still a lot of public mistrust over GMOs. When genetically modified foods first came onto the market, there was little public education or information about the new technology. *Are GM foods safe and healthy to eat? And what will happen if I eat them?*

With little public information about the new technology (and associated food), other actors filled the gaps in information – and *not* to promote a new technology that they didn't know much about. What emerged was a public that mistrusted and feared a new technology in their food.

The cellular agriculture space is learning from those lessons. All the major players in cellular agriculture are trying to be transparent by presenting their technology and the processes involved in making animal products, including cell-based meat. With this so-called "radical transparency", cell ag may not be vulnerable to the same downfalls as GMOs.



Chapter 6

The Obstacles Ahead

Besides the challenge of scaling production to get from lab to market, there are many obstacles ahead for cellular agriculture.

The Obstacles Ahead

From the first $300,000 burger in 2013, a lot has changed in cellular agriculture. Since that taste test, cellular agriculture companies have gotten traction and have gone beyond their own taste tests to launch the *first* cellular agriculture products.

Beyond the first regulatory approval for cell-based meat, cellular agriculture has gained momentum elsewhere too. Both Perfect Day and The EVERY Company have brought their animal-free dairy and egg white proteins, respectively, to market through partnerships.

Clearly, the cellular agriculture field has made progress.

Besides the challenge of scaling production to get from lab to market, there are many obstacles ahead for cellular agriculture.

REGULATORY ASPECTS: WHO'S IN CONTROL?

One of the first questions many people have about cellular agriculture is who is in charge of making sure it's safe? In Europe, new regulation has put the European Commission in charge of approving and regulating novel foods, including cell-based meat. In Singapore, the Singapore Food Agency announced that it will govern novel food production in the country, including cell-based meat.

In the United States, where most cellular agriculture companies are based, the answer was only recently settled. Since the start of 2018, there has been a regulatory turf war between the US Department of Agriculture (USDA) and Food and Drug Administration (FDA) over who will regulate cell-cultured meat. In May 2018, a congressional subcommittee nearly gave the USDA regulatory control over cultured meat, but the bill did not pass. The following month, the FDA unilaterally announced that they plan to be in charge of regulating *all* cell-based meats.

In August 2018, Upside Foods and the North American Meat Institute proposed a joint regulatory pathway forward in which both the USDA and FDA regulate cell-based meats. The FDA would be responsible for ensuring cell-based meats undergo pre-market safety tests while the USDA would be in charge of monitoring the meat facilities. This is the first time a cellular agriculture company and a meat industry player have come together to support a regulatory pathway that could appeal to both fields. And it seemed to work.

In October 2018, the USDA and FDA announced that they will *jointly* regulate cell-based meats. Using their expertise in their special fields, this may be a way forward to bring cell-based meats to markets. In March 2019, the USDA and FDA published a basic framework on how they will regulate cell-based meat, putting into writing what was agreed upon in October.

Having said that, there are still many questions about what cell-cultured products would look like at scale. Will *antibiotics* be required to keep the cell culture serum sterile? How will the products be *labelled*? And, most of all, what will the product even be called?

In August 2019, to advocate for a clear regulatory pathway to market for the field, several US cell-based meat companies announced that they formed a regulatory coalition called the Alliance for Meat, Poultry and Seafood Innovation to educate consumers stakeholders about the emerging industry.

Cell-based chicken nuggets by JUST and Upside Foods' cell-based chicken burger

Cellular agriculture companies with acellular products, like Perfect Day's cow-free dairy proteins and The EVERY Company's chicken-free egg white proteins, could skip FDA's regulatory safety assessment altogether. This can be done by showing their products use procedures and ingredients that have already been Generally Recognized As Safe (GRAS). Since egg white proteins and milk proteins like casein and whey are already deemed GRAS, these two companies may be able to skip FDA safety approval by using pre-approved GRAS yeast strains.

Yet this begs the question: should these acellular agriculture companies *still* voluntarily go through FDA's safety regulation? More so, how could these companies address consumer safety concerns if they bypassed the FDA? Nearly all cell ag startups pride themselves in being transparent with the public, so it would be surprising if they choose not to voluntarily show that their products are safe.

That is exactly how acellular foods first came to market.

In April 2020, Perfect Day shared a letter from FDA stating that the FDA has no objections or questions about the company's GRAS determination for its flora-based whey protein. Described as 'coveted' the FDA letter was an important regulatory step forward for Perfect Day to bring its dairy proteins to market. At the time of Perfect Day's limited release in July 2019, Perfect Day had secured self-determined GRAS status for its cell-cultured whey protein and had submitted its determination to the FDA for a no objections letter.

Similarly, The EVERY Company announced the launch of its first product in March 2021: an animal-free pepsin protein. Pepsin is a digestive enzyme used as a food processing aid as well as in a range of items, including food, beverages, and cosmetics. In the process of launching, The EVERY Company received self-determined GRAS status for the first animal-free pepsin protein and submitted its filing to the FDA to receive a no objections certification.

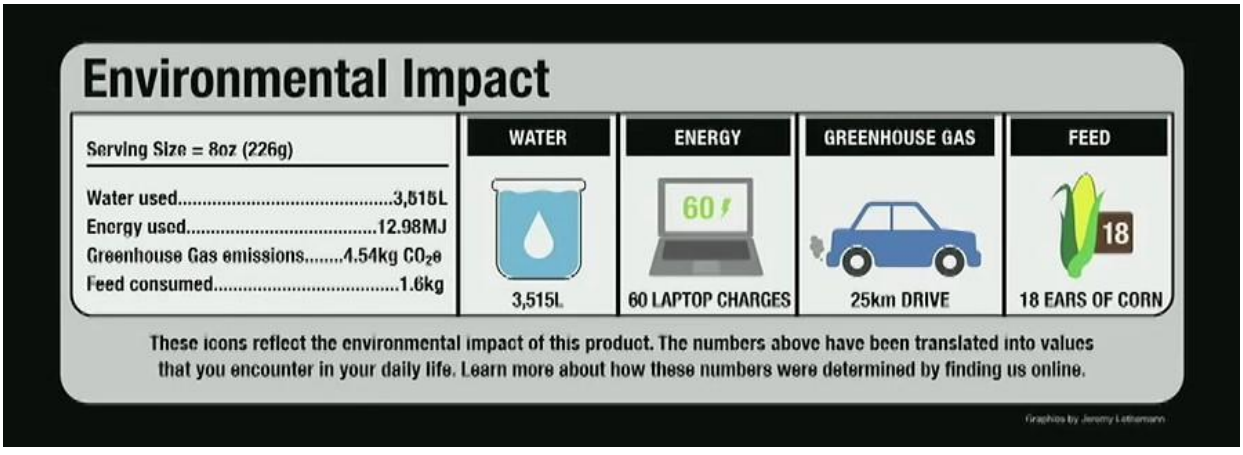
PUBLIC PERCEPTION

No matter how safe or sustainable cellular agriculture may make animal products, or how many regulations are put to ensure the product's safety, it ultimately comes down to consumers and the public to accept cellular agriculture. As with most novel technologies, time will tell to see how the public perceives and accepts this new category of sustainable goods.

A lot of actors in the field are trying to promote cellular agriculture by being as transparent as possible about the science, the manufacturing process, and the positive environmental implications. Research has shown that when taught about the sustainability aspects of cell ag in comparison to conventional animal products, people view it more positively and are more interested in trying it.

Regarding labeling, using *quantitative* labels on animal products could help show the environmental impact of conventional animal products when compared to their cellular agriculture counterparts. This would be more effective than *qualitative* labels, like a Rainforest Alliance Certified sticker, that would require prior knowledge to understand what they mean.

Beyond public understanding, there are questions about cultural acceptance that still need to be addressed. For the world's Jewish and Muslim populations, it is yet to be determined whether cell-based meat can be labelled as kosher or halal, respectively. It will be important for all actors in the field to fully address this and any other questions or concerns that emerge as cell ag products enter the market.



Quantitative Labelling. Photo taken from TedX presentation by Isha Datar: Rethinking Meat at TedxToronto, 2013

SOCIO-POLITICS AND MARKET COMPETITION

A key challenge that cellular agriculture (and all innovative technologies) has to face is the socioeconomic impact of what their technology may cause. In the United States, over 1.6 million people are employed by the livestock industry, which makes up about 22% ($31.8 billion) of all income from agricultural exports. If cellular agriculture successfully enters the market and one day becomes large enough to disrupt the livestock industry, what would happen to all the people involved in the livestock industry? While this isn't a question that cellular agriculture companies would necessarily be asking, it is an important political question that may have severe implications and ramifications for the field.

In order for cellular agriculture to be successful and widespread, there will need to be political support—either in the form of positive policies or a lack of negative targeting policies. Will politicians and governments embrace the new technology, or will they feel threatened by it? It is important to balance the needs of one's constituents and citizens with the needs for a sustainable food system that provides enough to feed the world by 2050.

Only time will ultimately tell what happens.

One group that may feel threatened by a rise in cellular agriculture would be the incumbent meat and dairy players. There have been investments by large meat producers like Tyson Foods, Cargill, and European poultry giant PHW that suggest some companies may be interested in cell-based meat technology.

In November 2021, Brazilian meat giant JBS acquired Spanish cell-based meat startup BioTech Foods as part of its $100 million plan to enter the cell-based meat field.

This doesn't mean that the whole industry is ready to accept cellular agriculture. Particularly when it threatens their market shares.

In February 2018, the United States Cattlemen's Association petitioned the USDA to narrow the definition of meat to exclude anything that does not come from a slaughtered animal. Following that, the National Cattlemen's Beef Association called for the USDA to exclusively regulate the field in hope that they would be more favorable to meat incumbents.

Will other companies and groups use their means and power to prevent a successful cellular agriculture launch in the United States? Or will cellular agriculture likely be too small for many corporations to even be concerned about initially?

CONCLUSION

In May 2018, the state of Missouri passed a law that banned plant-based and cellular agriculture companies from using the word *meat* or any meat-derived terms to describe their products. The law came into effect on August 28, 2018. And so did the fight for the word meat.

The Good Food Institute, the non-profit supporting the commercialization of both plant-based and cell-based meats, sued the state of Missouri to stop the law. The case may impact whether other states could follow Missouri's lead and pass regulations restricting the definition of meat. Since then, other states in the US have passed similar laws.

There are clearly many obstacles for cellular agriculture to overcome. It is important to note that not all of them have to be addressed before cellular agriculture food products hit the market. Some challenges are more long-term obstacles that the cellular agriculture field will eventually have to face.

As the first company to launch a cell-based meat product in Singapore, Eat Just will play a *pivotal* role in how the public views the cell-based meat sector. It will be important for Eat Just and all companies to communicate with and inform the public on not just *how* cell-based meat is produced, but *why* scientists and companies around the world are working to produce animal products in this sustainable manner.

Closing Thoughts

The first lab-grown beef burger cost $330,000 to produce in 2013; by the end of 2020, the first cell-cultured chicken nugget sold for $23 each in Singapore. The field is *clearly* moving forward.

The rise of new startups in the field as well as constant investments pouring into the field are a great sign of what is to come.

Yet the field is still in its early stages. Besides a few cellular agriculture products, most products are still in development. It will likely stay this way until the companies learn to overcome some of the obstacles ahead, particularly scaling production.

Until then, we can only wait to see what happens next in the field!

In a short few years, cellular agriculture has grown from a theory to the lab and, now, to the market.

Cellular agriculture is no longer an idea. It *can* be done. It *can* become the future of food.

Thank you for taking the time to read an Introduction to Cellular Agriculture!

We would love to hear back from you on the book – comments, thoughts, suggestions, everything!

You can leave your comments on the CellAgri website, or you can tag CellAgri in your feedback on Twitter (@cellagritech), Linkedin, or Instagram (@cellagri).

If you have any questions or comments, please feel free to contact us on our website.

You can keep up-to-date with the future of food by subscribing to CellAgri's weekly newsletter. We keep you posted with the latest news and insights coming out of the field changing food forever.

Over $2 billion has been invested into cellular agriculture companies

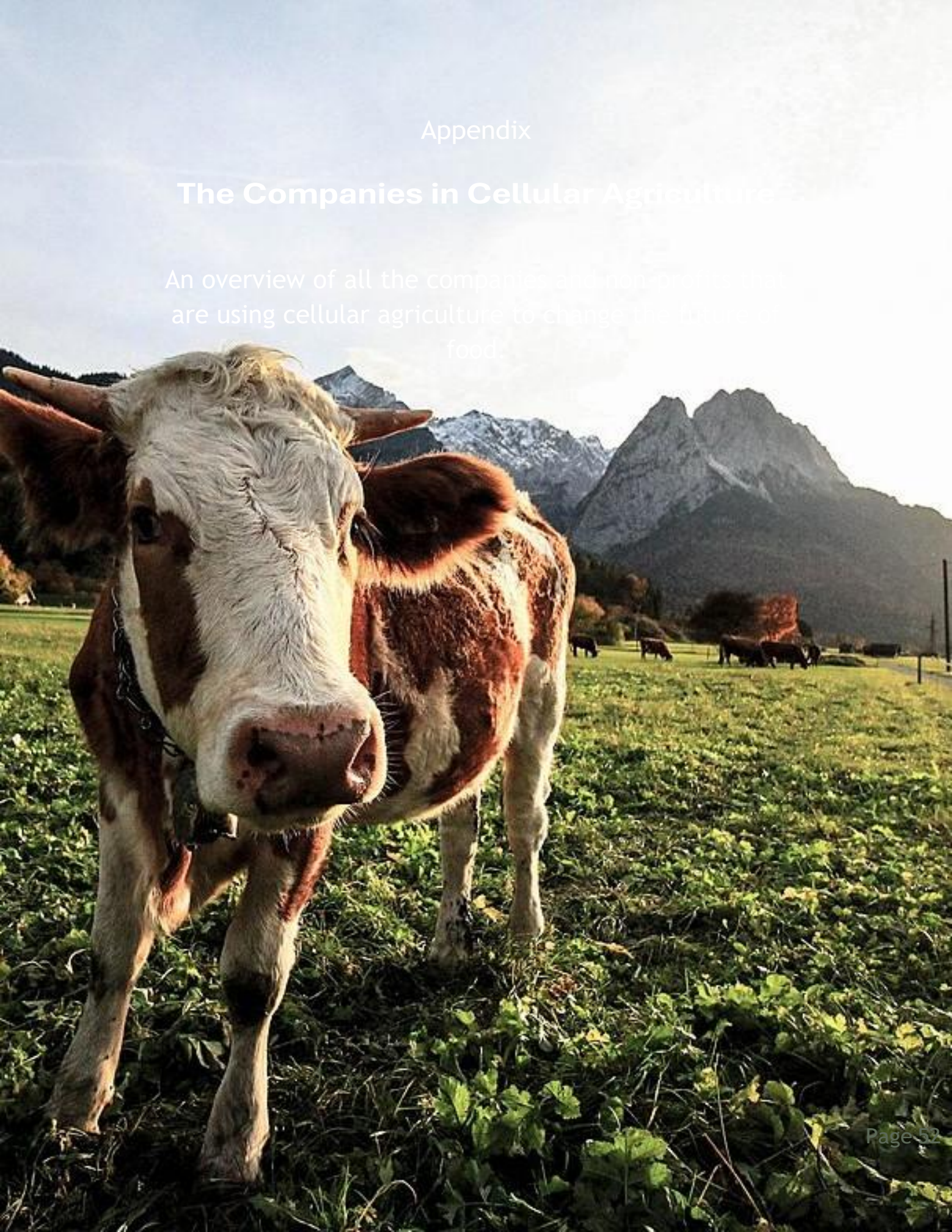
The CellAgri Investment Report series, through its investment breakdown and supply chain pain points, highlights how everyone can get involved in the future of food.

ACCESS NOW

Appendix

The Companies in Cellular Agriculture

An overview of all the companies and non-profits that are using cellular agriculture to change the future of food.



108Labs

Location: Davis, California

Focus: Dairy (breast milk)

Founder: Shayne Guiliano

Website: https://108labs.net/

Aleph Farms

Location: Tel Aviv, Israel

Focus: Meat

Founders: Didier Toubia and Shulamit Levenberg

Website:www.aleph-farms.com

All G Foods

Location: Sydney, Australia

Focus: Dairy; plant-based

meat Founder: Jan Pacas

Website: https://allgfoods.com/

AMSilk

Location: Munich, Germany

Focus: Spider silk

Founders:Thomas Scheibel and Lin Romer

Website:www.amsilk.com

Animal Alternative Technologies

Location: Cambridge, United Kingdom

Focus: Bioreactor Bioprocessing

Founders: Clarisse Beurrier and Yash Mishra

Website:https://www.animalalternativetechnologies.com/

Ants Innovate

Location: Singapore

Focus: Scaffolding

Founders: Hanry Yu and Shujian Ong

Website: https://www.antsinnovate.com/

Ark Biotech

Location: Boston, Massachusetts

Focus: Bioreactor

Founder: Yossi Quint

Website: https://www.ark-biotech.com/

Avant Meats

Location: Hong Kong, China

Focus: Seafood

Founders: Carrie Chan and Mario Chin

Website:www.avantmeats.com

Balletic Foods

Location: Davis, California

Focus: Meat proteins

Founder: Anita Broellochs

Website: https://balleticfoods.com/

Because Animals

Location: Toronto, Canada

Focus: Pet food

Founders: Joshua Errett and Shannon Falconer

Website:www.becauseanimals.com

Better Dairy

Location: London, United Kingdom

Focus: Dairy

Founders: Jevan Nagarajah and Christopher Reynolds

Website:www.betterdairy.co.uk

Biftek

Location: Ankara, Turkey

Focus: Cell culture media

Founders:Can Akcali, Erdem Erikci, and Kerem Erikci

Website:www.biftek.co/

BioBQ

Location: Austin, Texas

Focus: Brisket (beef)

Founders: Katie Kam and Janet Zoldan

Website: www.biobqing.com/

Biofect Innovations

Location: Toronto, Canada

Focus: Meat proteins

Founders: Ralph Christian Delos Santos, John Abousawan, Teshager Kefale, and Louis Lo

Website:www.biofectinnovations.com/

Biomilq

Location: Durham, North Carolina

Focus: Dairy (breast milk)

Founders: Michelle Egger and Leila Strickland

Website: www.biomilq.com

Biotech Foods

Location: San Sebastian, Spain

Focus: Meat

Founders:Mercedes Vila Juárez and Iñigo Charola

Website:www.biotech-foods.com

BlueNalu

Location: San Diego, California

Focus: Seafood

Founders: Lou Cooperhouse, Chris Dammann, and Chris Somogyi

Website:www.bluenalu.com

Bluu Seafood (Prev. Bluu Biosciences)

Location: Berlin, Germany

Focus: Seafood

Founders: Sebastian Rakers and Simon Fabich

Website: www.bluu.bio

Bolt Threads

Location: San Francisco, California

Focus: Clothing (Spider silk, leather)

Founders: Dan Widmaier, David Breslauer, and Ethan Mirsk

Website:www.boltthreads.com

Bond Pets

Location: Boulder, Colorado

Focus: Pet food

Founders: Rich Kelleman and Pernilla Audibertt

Website:www.bondpets.com

California Cultured

Location: Davis, California

Focus: Chocolate

Founders: Alan Perlstein, Harrison Yoon, and Debbie Neumann

Website: www.cacultured.com/

Cell Ag Tech

Location: Toronto, Canada

Focus: Seafood

Founders: Joshua Pollack and Valentin Fulga

Website: www.cellagtech.com

CellAgri

Location: Remote

Focus: News & market insights Founder: Ahmed Khan Website: www.cell.ag

Cellivate Technologies

Location: Singapore

Focus: Bioprocessing (microcarriers)

Founder: Viknish Krishnan-Kutty

Website: www.cellivate.xyz/

CellMeat

Location: Gwangju and Seoul, South Korea

Focus: Seafood

Founder: Giljun Park

Website: www.thecellmeat.com

CellRev (Prev. CellulaREvolution)

Location: Newcastle, United Kingdom

Focus: Bioreactor

Founders: Leo Groenewegen, Martina Miotto, and Che Connon

Website: www.cellrev.co.uk/

Cellular Agriculture Australia

Location: Sydney, Australia

Focus: Non-profit

Founder: Bianca Le

Website: cellularagricultureaustralia.org

Cellular Agriculture Canada

Location: Toronto, Canada

Focus: Non-profit

Founders: Yadira Tejeda Saldana, Ahmed Khan, Lejjy Gafour, Netta Fulga

Website:www.cellag.ca/

Cellular Agriculture France

Location: Paris, France

Focus: Non-profit

Founders: Nathalie Rolland, Tristan Roth, and Nicolas Bureau

Website: https://agriculturecellulaire.fr

Cellular Agriculture Japan

Location: Suginami City, Japan

Focus: Non-profit

Website: www.crs-japan.org/programs/cellular-agriculture/

Cellular Agriculture Ltd

Location:Bath, United Kingdom

Focus: Bioreactor

Founders:Illtud Llyr Dunsford and Marianne Ellis

Website:www.cellularagriculture.co.uk/

Cellular Agriculture Society

Location: San Francisco, California

Focus: Non-profit

Founder: Kristopher Gasteratos

Website: www.cellag.org

Cellular Agriculture UK

Location: London, United Kingdom

Focus: Non-profit

Website: www.cellag.uk

CellX

Location: Shanghai, China

Focus: Meat

Founders:Ziliang Yang and Ran Liu

Website:www.cellx.tech

Change Foods

Location: Melbourne, Australia and San Francisco, California

Focus: Dairy

Founders: David Bucca and Junior Te'o

Website:https://www.changefoods.com/

Clear Meat

Location: Delhi, India

Focus: Meat

Founders: Siddharth Manvati and Pawan Dhar

Website:www.clearmeat.com

Core Biogenesis

Location: Paris, France

Focus: Growth Factors

Founders: Alexandre Reeber, Chouaib Meziadi, and Maurice Maloney

Website: www.corebiogenesis.com

Cubiq Foods

Location: Barcelona, Spain

Focus: Animal fat

Founders: Raquel Revilla and Andrés Montefeltro

Website: www.cubiqfoods.com

Cultimate Foods

Location: Paris, France

Focus: Animal fat

Founders: George Zheleznyi, Oskar Latyshev, and Eugenia Sagué

Website: www.cultimatefoods.com

Cultivate UK

Location: Birmingham, United Kingdom

Focus: Non-profit

Founders: Illtud Dunsford, Marianne Ellis, Abigail Glencross, Alexandra Sexton, and Neil Stephens

Website: www.cultivate-uk.org

Cultured Decadence

Location: Madison, Wisconsin

Focus: Seafood

Founders: Ian Johnson and John Pattison

Website:www.cultureddecadence.com

Daisy Lab

Location: Auckland, New Zealand

Focus: Dairy

Founders: Irina Miller, Nikki Freed, and Emily McIsaac

Website: www.daisylab.co.nz

DaNAgreen

Location: Seoul, South Korea

Focus: Scaffolding

Founders: Kiwoo Kim, Jenna Ju, and Jay Jee

Website: www.danagreen.kr

De Novo Dairy

Location: Cape Town, South Africa

Focus: Dairy

Founders: Jean Louwrens, Joni Symon, Richard Grieves, and Leah Bessa

Website: www.denovodairy.com

Eden Brew

Location: Canberra, Australia

Focus: Dairy

Founders: Jim Fader, CSIRO, Norco

Website: www.edenbrew.com.au/

E-FISHient Protein

Location: Tel Aviv, Israel

Focus: Seafood

Founders: BioMeat and Volcani Institute

Every Company (Prev. Clara Foods)

Location: San Francisco, California

Focus: Egg white proteins

Founders: Arturo Elizondo, David Anchel, and Isha Datar

Website: www.theeverycompany.com/

Evolved Meats (Prev. Caro Meats)

Location: Kitchener, Canada

Focus: Meat

Founders: Alireza Shahin, John Cappuccitti, and Ravi Selvaganapathy

Website: www.caromeats.com/

Fermify

Location: Vienna, Austria

Focus: Dairy

Founder: Eva Sommer

Website: https://fermify.org

Finless Foods

Location: San Francisco, California

Focus: Fish

Founders: Mike Selden and Brian Wyrwas

Website:www.finlessfoods.com

Fisheroo

Location: Singapore

Focus: Seafood

Founders: Aaron Chua Yu Xiang, Nicholas Chia, and Jian Bin Tan

Website: www.fisheroo.co

Fork & Goode

Location: New York, New York

Focus: Meat

Founders: Niyati Gupta, Gabor Forgacs, and Andras Forgacs

Website:www.forkandgoode.com/

Formo (Prev. Legendairy Foods)

Location: Berlin, Germany

Focus: Dairy (cheese)

Founders: Raffael Wohlgensinger and Britta Winterberg

Website: www.formo.bio

Furoid

Location: Amsterdam, Netherlands

Focus: Fur (wools)

Founders: Maria Zakurnaeva and Henri Kunz

Website: www.furoid.com

Future Fields

Location: Edmonton, Canada

Focus: Cell culture media

Founders: Matthew Anderson-Baron, Lejjy Gafour, and Jalene Anderson-Baron

Website: www.futurefields.io

Future Meat Technologies

Location: Jerusalem, Israel

Focus: Meat

Founders: Yaakov Nahmias and Rom Kshu

Website:www.future-meat.com/

Gaia Foods

Location: Singapore

Focus: Meat

Founders:Vinayaka Srinivas and Thanh Hung Nguye

Website:www.gaiafoods.xyz

Galy

Location: Sao Paulo, Brazil; and Boston, Massachusetts

Focus: Cotton

Founders: Luciano Bueno and Paula Elbl

Website: www.galy.co

Gelatex

Location: Tallinn, Estonia

Focus: Scaffolding

Founders: Märt-Erik Martens and Mari-Ann Meigo Fonseca

Website: www.gelatex.com

Geltor

Location: San Francisco, California

Focus: Collagen (gelatin, cosmetics)

Founders: Alex Lorestani and Nick Ouzounov

Website: www.geltor.com

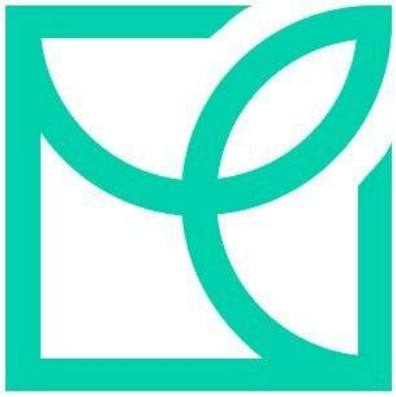
Good Dog Food

Location: London, United Kingdom

Focus: Pet Food

Founders: Owen Ensor, Agronomics, and Roslin Technologies

Website: www.gooddogfood.com



Good Food Institute

Location: Washington, D.C.

Focus: Non-profit

Founder: Bruce Friedrich

Website:www.gfi.org

Gourmey

Location: Paris, France

Focus: Foie gras

Founders: Nicolas Morin-Forest and Antoine Davydoff

Website:www.gourmey.com

Helaina

Location: New York, New York

Focus: Dairy (breast milk)

Founder: Laura Katz

Website: www.myhelaina.com

Heuros

Location: Brisbane, Australia

Focus: Cell culture media

Founder:Nick Beaumont

Website: www.heuros.com

Higher Steaks

Location: Bristol, United Kingdom

Focus: Meat

Founders: Benjamina Bollag, Stephanie Wallis, and David Hay

Website: www.highersteaks.com

Hoxton Farms

Location: London, United Kingdom

Focus: Animal fats

Founders: Max Jamilly and Ed Steele

Website: www.hoxtonfarms.com

Imagindairy

Location: Haifa, Israel

Focus: Dairy

Founders: Eyal Afergan and Tamir Tuller

Website: www.imagindairy.com/

IntegriCulture

Location: Tokyo, Japan

Focus: Meat

Founder: Yuki Hanyu

Website:www.integriculture.jp

Ivy Farm

Location: Oxford, United Kingdom

Focus: Meat

Founders: Russ Tucker and Cathy Ye

Website: www.ivy.farm

Jellatech

Location: Raleigh, North Carolina

Focus: Collagen (gelatin)

Founders: Stephanie Michelsen and Kylie van Deinsen-Hesp

Website: www.jellatech.com

Joes Future Food

Location: Nanjing, China

Focus: Meat

Founder: Zhou Guanghong

Website: www.joesfuturefood.com

JUST / Good Meat

Location: San Francisco, California

Focus: Meat, plant-based egg

Founders: Josh Tetrick and Josh Balk

Website:www.ju.st;www.goodmeat.co/

KCell Biosciences

Location: Busan, South Korea

Focus: Cell culture media

Founders: Thousand Oaks Pharmaceuticals and WSG

Website: http://k-cell.com/

Lab Farm Foods

Location: New York, New York

Focus: Meat

Founders:Tiziano Barberi and Dave Schnettler

Website:www.labfarmfoods.com

Liven Proteins

Location: Toronto, Canada

Focus: Collagen (gelatin)

Founder: Fei Luo

Website: www.livenproteins.ca

Luyef Biotechnologies

Location: Santiago, Chile

Focus: Scaffolding; myoglobin

Founders: Kris Blanchard, Pamela Barroso, and Andrea Villanueva

Website: www.luyef.com

Magic Caviar

Location: Amsterdam, Netherlands

Focus: Caviar

Founders: Maria Zakurnaeva and Henri Kunz

Website: www.magiccaviar.com

Magic Valley

Location: Melbourne, Australia

Focus: Meat

Founder: Paul Bevan

Website:www.magicvalley.com.au

Matrix F.T.

Location: Columbus, Ohio

Focus: Scaffolding

Founders: Eric Jenkusky and Jed Johnson

Website: https://matrixfood.tech/

Me & Foodtech

Location: Melbourne, Australia

Focus: Dairy (breast milk)

Founders: Esha Saxena and Luis Malaver-Ortega

Website: www.meandfoodtech.com

Meatable

Location: Leiden, Netherlands

Focus: Meat

Founders: Krijn de Nood, Daan Luining, and Ruud Out

Website: www.meatable.com

MeaTech 3D

Location: Ness Ziona, Israel

Focus: Meat (3D printing)

Founder: Sharon Fima

Website: www.meatech3d.com

MeliBio

Location: San Francisco, California

Focus: Honey

Founders: Darko Mandich and Aaron Schaller

Website: www.melibio.com

Melt & Marble

Location: Gothenburg, Sweden

Focus: Animal fats

Founders: Anastasia Krivoruchko, Florian David, and Jens Nielsen

Website: www.meltandmarble.com/

MicroMeat

Location: Monterrey, Mexico

Focus: Scaffolding

Founders: Anne-Sophie Mertgen and Vincent Pribble

Website: www.micromeat.com

Mirai Foods

Location: Zurich, Switzerland

Focus: Meat

Founders: Christoph Mayr and Suman Das

Website: www.miraifoods.com

Mission Barns

Location: San Francisco, California

Focus: Animal Fat

Founders: Eitan Fischer and David Bowman

Website: www.missionbarns.com

Modern Meadow

Location: New York, New York

Focus: Leather

Founder: Andras Forgacs

Website: www.modernmeadow.com

Mogale Meat

Location: Pretoria, South Africa

Focus: Meat

Founders: Paul Bartels and Elize Venter

Website: www.mogalemeat.com/

Mosa Meat

Location: Maastricht, Netherlands

Focus: Meat

Founders: Peter Verstrate and Mark Post

Website: www.mosameat.com/

Motif FoodWorks

Location:Boston, Massachusetts

Focus: Animal-free proteins

Founder: Jonathan McIntyre

Website:www.madewithmotif.com/

Multus Media

Location: London, United Kingdom

Focus: Cell culture media

Founders: Kevin Pan, Reka Tron, and Cai Linton

Website: https://multus.media/

Mzansi Meat

Location: Cape Town, South Africa

Focus: Meat

Founders: Jayson Van Der Walt and Brett Thompson

Website: www.mzansimeat.co

New Age Eats (Prev. New Age Meats)

Location: San Francisco, California

Focus: Meat

Founder: Brian Spears

Website: www.newageeats.com

New Culture

Location: San Francisco, California

Focus: Dairy (cheese)

Founders: Matt Gibson and Inja Radman

Website: www.newculturefood.com

New Harvest

Location: Remote

Focus: Non-profit

Founder: Jason Matheny

Website: www.new-harvest.org

Nourish Ingredients

Location: Canberra, Australia

Focus: Animal fats

Founders: James Petrie and Benjamin Leita

Website: www.nourishing.io

Novel Farms

Location: San Francisco, California

Focus: Scaffolding

Founders: Nieves Nieves Martínez-Marshall and Michelle Lu

Website: www.novelfarms.co

Ohayo Valley

Location: Berkeley, California

Focus: Meat

Founder: Jessica Kreiger

Website: www.ohayovalley.com/

Onego Bio

Location: Helsinki, Finland

Focus: Egg white proteins

Founders: Maija Itkone, Christopher Landowski, and Jussi Joensuu

Website: www.onego.bio

Opalia

Location: Montreal, Canada

Focus: Dairy

Founders: Jennifer Côté and Lucas House

Website: www.opaliafoods.com

Orbillion Bio

Location: San Francisco, California

Focus: Meat (Cell line development)

Founders: Patricia Bubner, Gabriel Levesque-Tremblay, and Samet Yildirim

Website: www.orbillion.com

ORF Genetics

Location: Kópavogur, Iceland

Focus: Cell culture media

Founders: Björn Örvar, Júlíus Birgir Kristinsson, and Einar Mäntylä

Website: www.orfgenetics.com

Peace of Meat

Location: Flanders, Belgium

Focus: Meat

Founders: Dirk von Heinrichshorst, David Brandes, and Eva Sommer

Website: www.peace-of-meat.com

Pearlita Foods

Location: Raleigh, North Carolina

Focus: Seafood (Oysters)

Founder: Nikita Michelsen

Website: www.pearlitafoods.com

Perfect Day

Location: San Francisco, California

Focus: Dairy

Founders: Ryan Pandya, Perumal Gandhi, and Isha Datar

Website:www.perfectdayfoods.com

Planetary

Location: Geneva, Switzerland

Focus: Bioreactor

Founders: David Brandes and Ian Marison

Website: www.planetarygroup.ch

Provenance Bio

Location: San Francisco, California

Focus: Collagen

Founder: Michalyn Andrews, Christian Ewton, and Zev Gartner

Website: www.provenance.bio

Qoa

Location: Munich, Germany

Focus: Chocolate

Founder: Sara Marquart and Maximilian Marquart

Website: www.qoacompany.com/

Qorium

Location: Maastricht, Netherlands

Focus: Leather

Founders: Rutger Ploem, Stef Kranendijk, and Mark Post

Website: www.qorium.com/

Real Deal Milk

Location: Barcelona, Spain

Focus: Dairy

Founder: Zoltan Toth-Czifra

Website: www.realdealmilk.com

Remilk

Location: Tel Aviv, Israel

Focus: Dairy

Founders: Aviv Wolff and Ori Cohavi

Website: www.remilk.com

Roslin Technologies

Location: Edinburgh, Scotland

Focus: Cell line development

Founder: Glen Illing

Website: www.roslintech.com

SCiFi Foods

Location: San Francisco, California

Focus: Meat

Founders: Joshua March and Jessica Krieger

Website: www.scififoods.com

SeaWith

Location: Daegu, South Korea

Focus: Meat

Founders: Joonho Keum and Heejae Lee

Website: www.seawith.net

Shiok Meats

Location: Singapore

Focus: Seafood

Founders: Sandhya Sriram and Ka Yi Ling

Website:www.shiokmeats.com

Space F

Location: Seoul, South Korea

Focus: Meat

Website: www.spacef.biz/

Spiber

Location: Tsuruoka, Japan

Focus: Spider silk

Founders: Kazuhide Sekiyama, Hideya Mizutani, Junichi Sugahara

Website: www.spiber.jp/en/

SuperMeat

Location: Tel Aviv, Israel

Focus: Meat

Founders: Ido Savir, Koby Barak and Shir Friedman

Website: www.supermeat.com

Tiamat Sciences

Location: Brussels, Belgium and Durham, North Carolina

Focus: Cell culture media

Founders: France-Emmanuelle Adil and Clement Carlier

Website: www.tiamat-sciences.com/

TurtleTree Labs

Location: Singapore and Davis, California

Focus: Dairy (breast milk)

Founders: Fengru Lin and Max Rye

Website: www.turtletreelabs.com

Umami Meats

Location: Singapore

Focus: Seafood

Founder: Mihir Pershad

Website: www.umamimeats.com

Unicorn Biotechnologies

Location: Cambridge, United Kingdom

Focus: Bioreactor

Founders: Jack Reid and Adam Glen

Website: www.unicornbiotechnologies.com

Upside Foods (Prev. Memphis Meats)

Location: San Francisco, California

Focus: Meat

Founders: Uma Valeti, Nicholas Genovese, and Will Clem

Website: www.upsidefoods.com

Vital Meat

Location: Sèvremoine, France

Focus: Meat

Founder: Etienne Duthoit

Website: www.vital-meat.com

Vitro Labs

Location: San Francisco, California

Focus: Leather

Founders: Ingvar Helgason and Dusko Ilic

Website: www.vitrolabsinc.com

Vow

Location: Sydney, Australia

Focus: Meat

Founders: George Peppou and Tim Noakesmith

Website: www.vowfood.com

Wanda Fish

Location: Tel Aviv, Israel

Focus: Seafood

Founders: Daphna Heffetz and the Kitchen Foodtech Hub

Website: www.wandafish.com

Wild Earth

Location: San Francisco, California; Durham, North Carolina

Focus: Pet food

Founders: Ryan Bethencourt, Ron Shigeta, Kristin Wuhrman, and Abril Estrada

Website:www.wildearth.com

Wildtype

Location: San Francisco, California

Focus: Fish

Founders: Justin Kolbeck and Arye Elfenheim

Website: www.wildtypefoods.com/

Wilk

Location: Rehovot, Israel

Focus: Dairy (breast milk)

Founders: Nurit Argov-Argaman and Maggie Levy

Website: www.wilkismilk.com

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