

Cultivated meat

Engineering the growth of alternative meats

Alternative meat demand is booming, with products increasingly available around the globe, at local grocery stores, department stores and even the neighbourhood Starbucks. Demand for cultivated meat, part of the larger alternative meat market, is forecast to grow at a 41% CAGR, faster than both plant-based and conventional meats, reaching c US\$600bn in size by 2040, according to Kearney. Investors have taken notice of this significant potential and the industry raised US\$366m in investments in 2020 and US\$1,570m since then. The number of entrants has grown rapidly from small pureplay companies such as MeaTech 3D, distributors and servers such as Burger King and large multinationals such as Nestlé. Cultivated meat has the potential to significantly disrupt both meat and non-meat markets over several decades.

Several key trends driving growing demand

Over the past decade, the demand for protein has grown across the globe, driven by increasing population and wealth accumulation, and Kearney forecasts global meat-market revenues to nearly double through 2040. This increase in demand has boosted the growth of the alternative meat market, with a long list of products now available in multiple venues and consumers increasingly turning to alternative meat sources rather than conventional meat. Several key trends are driving this shift to alternative meats (ie cellular agriculture and plant-based meats), including concerns over animal welfare, the improved health benefit of some types of alternative meats and environmental issues.

Biologically and sensorily equivalent

Cellular agriculture is the process of creating meat that is biologically equivalent to the tissues of meat from animals. It starts with gathering stem cells from an animal, then growing them in bioreactors so they become muscle tissue and fat, and eventually harvesting them in centrifuges where the cells, growth media and other ingredients are separated. Much of the development work has focused on improving the quality of the products and optimising the cell lines, scaling up the process from laboratory to pilot size, and moving towards replicating the sensory experience of conventional meat as closely as possible. For instance, MeaTech 3D is developing a 3D bioprinting process for creating a product nearly identical to a conventional cut of meat. Moreover, Singapore was the first country to approve cultured meat in H220 and it has been available at one restaurant since then.

Potential US\$600bn+ market size

According to Kearney, the market for cultivated meat is expected to grow at a 41% CAGR from 2025–40, outpacing conventional and plant-based meats and reaching c US\$600bn to make up 35% of the global meat market. In addition, cellular agriculture is developing non-meat products too and has the potential to disrupt markets such as leather, cotton and seafood. Enthusiasm is building among investors, who have several options for accessing the alternative meat market, including pureplay producers, distributors and servers, large multi-nationals, investment funds such as Agronomics and Cult Foods, an investment platform.

Edison themes



7 January 2022

From the street

'The cultured meat market potential is enormous, backed by global and systemic trends supporting sustainability, food safety and food security. New production technologies and products ranging from hybrid plant-based through to fully 3D printed steaks, like those being developed by MeaTech, have the potential to transform the future of food.'

Guy Hefer, CFO, MeaTech 3D

Edison themes

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Companies mentioned in this report

Agronomics*
Aleph Farms
Bell Food Group
Beyond Meat
BRF
Burger King
Cargill
Eat Just
Future Meat Technologies
Impossible Foods
JBS
McDonalds
MeaTech 3D*
Merit Functional Foods
Modern Meat
Mosa Meat
Multus Media
Nestlé
Starbucks
Tesco
Tyson
UPSIDE Foods
Very Good Food Company
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Yum! Brands

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Companies mentioned above do not translate into buys or sells as other themes (and valuation parameters) may conflict with this one.

Cultivated meat

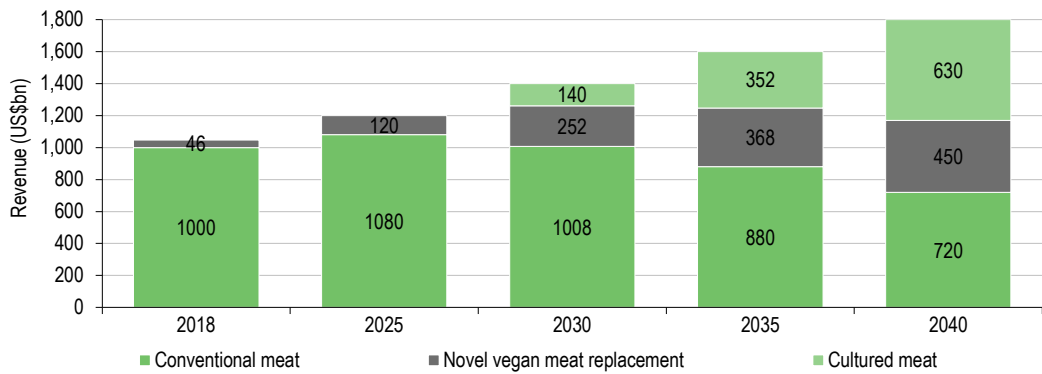
Over the past decade, demand for protein has been growing across the globe, driven by increasing population and wealth accumulation. Meat protein itself has witnessed a steep increase in demand, though the global supply has been disrupted by outbreaks such as the Asian swine flu and the current COVID-19 pandemic. The global population has reached 7.9 billion people and the United Nations projects that it could reach nearly 10 billion by 2050. To feed that many people will require an immense amount of food, including meat. Kearney forecasts that global meat market revenues will almost double over the next 20 years and grow from c US\$1tn in 2018 to c US\$1.8tn by 2040 (Exhibit 1). However, much of that growth will likely come from meat alternatives, as consumers have become increasingly aware of other options besides conventional meat from animal and, according to Kearney, the cultivated meat market could be worth US\$ 630bn by 2040 from relatively nothing in 2021.

As can be seen by anyone who shops at grocery stores, department stores, supermarkets and fast-food restaurants, meat-alternatives have proliferated throughout the shelves, with multiple offerings from suppliers such as Beyond Meat and Impossible Foods. Many of these products can mimic the taste, smell, look, texture and nutrition of conventional meat, giving a meat-like experience. For instance, UK-based Greggs recently announced a shortage of vegan sausage rolls, one of its most popular bakery items.

While plant-based meat is currently the most affordable and commercially available alternative, we believe cultivated based meat has the potential to become a desirable alternative to conventional meat due to improved animal welfare with cultivated meat, greater health benefits (eg lower/no use of antibiotics) and less environmental impact (eg much lower CO₂/water footprint). Over the next decade, plant-based meat growth could overtake conventional meat, though cultivated meat should surpass both by 2040. For instance, Cargill opted for cell-based meat over plant-based with its decision to invest in Aleph Farms, a cultivated meat company focused on developing complex meats, with some of its products expected to be released to market in approximately the next three to five years.

Cultivated meat does face some challenges that could impede its growth. Consumer acceptance of these products will be key, especially in light of the strong ties consumers have with conventionally created meat. Regulatory concerns could also be a headwind, as cultivated meat is approved only in one restaurant in one country (Singapore) since H220, and the industry's growth will likely attract more regulatory attention. Costs are another challenge that could affect cellular agriculture's growth, as production costs for cultivated meat are significantly higher than conventional meat. Finally, cellular agriculture still operates on a laboratory scale. To reduce costs towards parity with conventional meat and produce commercial size quantities, companies must evolve to pilot and then industrial-sized scale, including providing enough raw materials to support a large, commercial sized operation. For instance, MeaTech 3D is examining 3D printing of cultivated meat, and how to best scale that technology initially to pilot sized operations in a cost-efficient manner.

Exhibit 1: Global meat market revenues



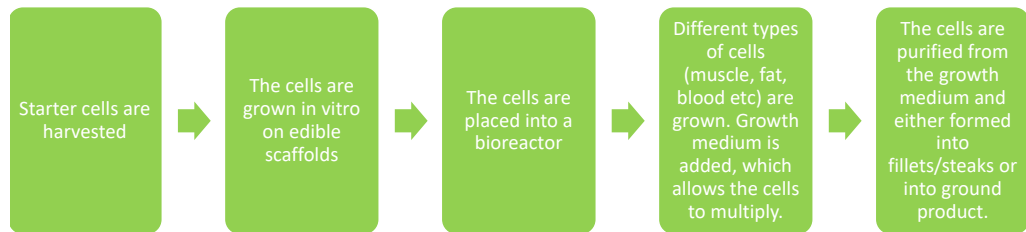
Source: Kearney, Edison Investment Research

What is cultivated meat?

This meat alternative has been called by many names, including cellular meat, cultivated meat, lab grown, in vitro, clean, cell-based, and slaughter-free. For purposes of this report, we will use cultivated meat. Of course, each of these names is best used in its own specific context, whether it be regulators, research or consumers, as 'in vitro' or 'lab grown' may be appropriate for scientists or regulators. Using the right name will be critical going forward as using the wrong one could drive consumers away. For instance, it is hard to imagine many consumers wanting to buy a T-bone or filet labelled 'in vitro' or 'lab grown' but labelling it 'cultivated' or 'slaughter-free' would likely make the product more palatable.

As displayed in Exhibit 2, the process for creating cultivated meat starts with painlessly harvesting stem cells from an animal, typically cattle, though many companies are using cells from poultry and seafood, and also for non-meat products like leather, cotton and cocoa. These cells are kept in storage and then thawed when ready to use. Next, scientists feed the cells growth proteins, carbohydrates, vitamins and minerals in a bioreactor, so that they multiply to create the desired cell type, including muscle and fat tissue, which are the main components we consume. The cells are equivalent to the tissue itself, though without vascularization. Also, because the process begins with stem cells, these are grown in quantity and then differentiated into fat and muscle tissues. Whether printing or mixing, the proportion of fat and muscle can be readily adjusted to the desired cut of meat and health profile (eg avoiding saturated fats), etc.

The typical time spent in the bioreactor depends on the species, but it is much shorter than conventional livestock farming; beef cells can take about 30 days to mature, considerably less than the 24 months in conventional farming. Chicken cells can mature in about one to two weeks versus about four months in a typical chicken coop. The key difference from plant-based proteins, which is likely to make cultivated meat much more attractive to consumers, is that cultivated meat is equivalent to the tissues of normal meat, thus providing the same taste and nutritional profile as traditional meat. Once the cells reach the desired density, they are sent to centrifuges for harvesting, where the cells, vector and used growth medium are separated. Finally, the cultivated meat cells are formed depending on the ultimate end product, such as mince or steak, and then can be matured further or packaged and distributed.

Exhibit 2: Production process for cultivated meat

Source: Edison Investment Research

3D bioprinting

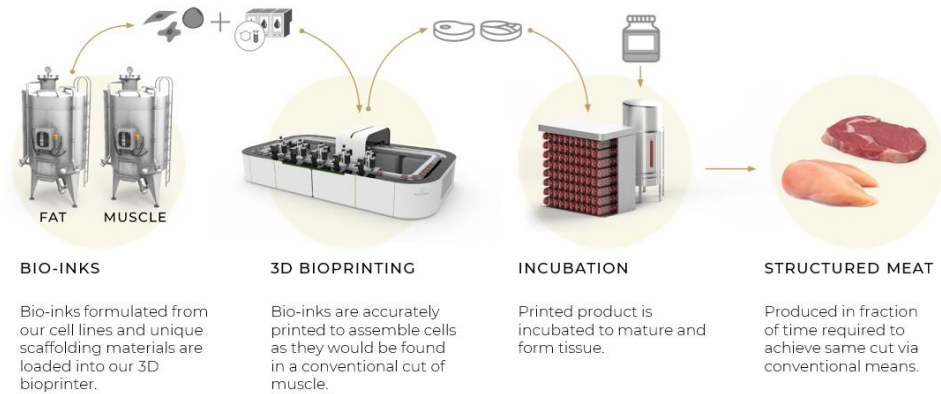
An intriguing new development is in 3D printed tissue by MeaTech 3D, an Israel-based firm. Recent research has focused on 3D bioprinting, a novel technology that creates tissues such as meat, vessels, etc, via the additive technology of 3D printing. As described in a [scientific study by Matai, et al](#), 3D bioprinting is designed to position biologics (including living cells) into a specific 3D structure to create tissues and organs. This technology plays a key role in tissue engineering applications where the need is to generate scaffolds to support the printed products. For instance, it can be used to repair and regenerate human organs by printing biological materials onto a substrate structure and ensuring that the individual cells and cell types are held together. The bio-inks can be printed into the desired shapes and sizes, and so create 3D tissues from the original source of cells.

One issue facing the alternative meat market has been that the fibrous structure and visual appearance of 'structured meats' such as steak and chicken have been difficult to reproduce. As a result, 3D printing is being used by several firms to position the cells in the desired location, and so build the desired structure. As displayed below in Exhibit 3, bio-inks are formulated from the meat cell lines and then loaded with unique edible scaffolding materials into a 3D bioprinter, including the actual live stem cells. These bio-inks are printed to create structures more similar to what would be found in a conventional cut of meat. The printed product is then sent to an incubator to mature and form meat tissue that has the same structure and appearance as one would find with conventional meat.

Exhibit 3: 3D cultured meat printing

MEATECH'S CULTURED STEAK VISION

A FLEXIBLE MANUFACTURING PROCESS FOR 3D PRINTED TISSUE



Source: MeaTech 3D

As of 2020, MeaTech, a firm we believe is at the forefront of development in 3D cultured meat printing, is using lab-scale bioreactors to produce these muscle and fat tissues and working towards pilot-scale production in the near future. Last month, it announced several tasting events for its hybrid chicken products at European Food Trade shows, with hybrid products that offer ‘an enhanced, ‘meatier’ experience than with wholly plant-based meat products. In December 2021, [MeaTech 3D reported a breakthrough with the printing of a 3.67oz cultivated steak](#) consisting of real, living muscle and fat tissues, without utilising any soy or pea protein. Management believes this is the largest cultivated steak produced to date.

MeaTech also announced plans to establish a pilot plant for cultured chicken fat production by the end of 2022 for use in potential industry collaborations. Much of the technology comes from the recently acquired Belgian firm Peace of Meat, and management explains, ‘As observed in laboratory work and public taste tests, cultured chicken fat has the potential to significantly enhance the flavor, mouthfeel and texture of plant-based alternative meat products.’ The resulting hybrid products can ‘offer a meatier product to consumers as compared to purely plant-based meat alternatives.’ Ultimately, MeaTech would leverage those chicken fat technologies to accelerate its commercialisation and development of a process for cultivating and producing real meat cuts with 3D bioprinting such as steak or chicken breast.

Cultivated meat versus plant-based meats

In contrast to conventional and cultivated meat products, plant-based meats are created exclusively from plants. The production process (see Exhibit 4) begins with extracting and hydrolysing proteins from plants, and then adds binders, fats, flavours and nutrients to improve its texture, taste, appearance and nutritional profile. Finally, the mixture is processed into the final shape and product via one of several methods, such as stretching, kneading, press forming, extrusion, etc. As mentioned earlier, plant-based products can be found in grocery stores, restaurants and supermarkets in many countries, and are currently the only meat alternatives that are widely commercially available.

However, a key difference between cultivated meat and plant-based proteins is that cultivated meat is equivalent to conventional meat, providing the same nutritional profile and taste, while plant-based are different in composition. Furthermore, cultivated meat could be viewed as more natural or less processed, as it does not require many of the fats, binders, adhesives and other additives that are used in plant-based products. It is also more environmentally friendly than either conventional or plant-based proteins, as cellular agriculture generates lower carbon emissions, is

less resource intensive than conventional livestock farming, will not accumulate pollution or contaminants (eg mercury in tuna) and requires little to no antibiotics. According to Kearney's [When consumers go vegan, how much meat will be left on the table for agribusiness?](#), cultivated meat has a longer shelf life and needs less refrigeration during shipping than conventional meat. Overall, these characteristics could make cultivated meat more desirable to consumers than plant-based meats.

Exhibit 4: Plant-based process

Process to create novel vegan meat replacement

1. Isolation and functionalization	2. Formulation	3. Processing
<ul style="list-style-type: none"> Plant-protein concentrates are extracted from plants. Proteins are hydrolyzed (broken down) to improve their functional traits. 	<ul style="list-style-type: none"> Binders, fats, and flavors are added to improve the sensory profile. Nutrients are added to at least meet the amount of nutrients in meat. 	<ul style="list-style-type: none"> The mixture is shaped into final product via stretching, kneading, shear-cell processing, press forming, folding, layering, or extrusion.

Source: Kearney – 'When consumers go vegan, how much meat will be left on the table for agribusiness?'

What is driving the demand for meat alternatives?

Choosing a meat-free diet is by no means a new idea, though the popularity of plant-based foods has been accelerating recently with approaches such as flexitarianism (primarily a plant-based diet, elimination of processed foods, occasional meat consumption), vegan and vegetarian. According to the Vegan Society, nearly half of the UK is flexitarian, vegan or vegetarian, which by itself provides a significant demand for meat alternatives. Moreover, Good Food Institute estimated a 29% sales growth for the US plant-based meat market between 2017 and 2019, which outperformed the overall United States retail food market growth of 4%. Recent surveys have also indicated that most consumers chose high protein, low carbohydrate diets over a vegan diet, and many high-protein meat alternatives are now available to meet that consumer preference. The number of food companies offering meat alternatives is also expanding, made up of both small, venture backed firms and large, multinational companies with significant R&D budgets like Nestlé, Tyson and Tesco. Finally, a Barclays survey of 5,000 adults from the United States, UK, China, India and Brazil suggested that two-thirds would consider purchasing cultured meat, with higher acceptance rates among younger consumers, emerging markets and vegans/vegetarians.

Animal welfare, health benefits and climate change

Several key drivers are behind this trend of eating less meat or switching to alternatives such as plant-based meats. The first involves animal welfare, as there are many graphical videos, images and information on slaughterhouses, animal processing and intensive farming readily available across the internet. In fact, a study published the Vegan Trade Journal indicated that 51% of polled UK vegan consumers stated they were vegan for ethical reasons. No animals are harmed with meat alternatives like cellular agriculture, making the idea of 'slaughter-free' meat popular with many consumers.

The health benefits of alternative meats are also a key driver of consumer demand. A number of studies have shown that illnesses such as cardiovascular and hypertension have been reduced through a decline in eating conventional meat, and others indicated that those who mostly ate plant-based foods were less likely to die from heart disease. Alternative meat diets also have the potential to aid in weight loss and reduce body fat. The idea that a plant-based or alternative meat diet is healthier than one high in red meat consumption has been widely publicised. Of course, the healthiness of an alternative diet is primarily based on the saturated fat content of the cultivated cuts themselves. If the cultivated meat cut has similar saturated fat levels to conventional meat, it would not be expected to have any health benefits versus conventional meat.

It should, however, be noted that there are conflicting studies about the impact of switching to meat alternatives. For instance, in August 2020 the Cochrane Institute stated that there was no link between saturated fat and the risk of dying from heart disease, but this contradicted their earlier 2015 report that indicated a mortality risk from saturated fat. Nutrition standards are constantly changing, especially in regard to government recommendations on how much red meat one should include in a diet. In spite of these issues, the point that meat alternatives are healthier for you is relatively easy for consumers to understand, which will likely drive demand going forward.

Climate change and sustainability issues are the third driver behind consumers eating less conventional meat. Concerns over global warming and climate change have been growing across many nations, and according to Bloomberg, investments in renewable power, electrical vehicles and other technologies focused on reducing our dependence on fossil fuels grew at a 19% CAGR through 2020 to US\$501bn. Thirty-two percent of respondents to a 2020 UK government poll said that limiting the effects of climate change was the reason they were avoiding or eating less meat, up from 20% in 2019. Conventional meat requires substantial amounts of land and water for both the animal feed and meat production, and according to Our World in Data, meat and dairy currently occupy 77% of the world's agriculture landmass but only contribute 17% of the world's calorie supply. Exhibit 6 compares the nutrition versus environmental cost in terms of water use between beef and other products. Also, cultivated meat production can be more local and hence shipping itself would be over shorter distances, thus a generating a lower carbon footprint. Could also make the point that production can be more local and hence shipping itself will be over shorter distances hence lower carbon footprint. But that wouldn't be according to Kearney so may be best mentioned elsewhere. However, energy consumption for heating and cooling is relatively high for meat alternatives, though this should fall dramatically as cultivated meat operations move from pilot scale to commercial sizes with larger bioreactors. Notably, plant-based meat also can have a negative environmental impact. Soy is a key protein plant-based alternatives, and its production is considered one of the leading causes of deforestation. In fact, 65% of the world's soy comes from countries with the highest deforestation rates, according to the BBC. Nevertheless, environmental concerns will likely continue contributing to the demand for meat alternatives, especially cultivated meat products.

The COVID-19 pandemic has also benefited non-meat alternatives, with US plant-based sales growing 264% in the nine weeks ending 2 May 2021, according to Nielsen. The ongoing shipping delays have caused supply shortages and could lead to significant price increases for conventional meat, while a Mintel report stated that 25% of UK millennials found veganism more appealing as a result of COVID-19.

While these factors will significantly drive demand, consumer acceptance will be crucial to cellular agriculture's growth. Eating meat is a part of our human culture, and consumers have strong historical, culture and psychological ties to the idea of eating beef, chicken, pork, etc. But on the other hand, as McKinsey aptly describes it, 'consumers know exactly how their salmon steaks and chicken tenders should taste and feel. These subtleties make replicating the meat experience tricky'. This is why cultivated meat companies are focusing on how to reproduce the sensory experience (taste, look, smell, texture, etc) that consumers enjoy when consuming meat, whether it be blending cultivated cells with or adding cultivated created fat to plant-based proteins.

Food safety is improved with the cultivated meat process, which reduces the likelihood of health hazards from bacteria such as E. coli, drug-resistant pathogens like some strains of salmonella and viruses like avian influenza, given the absence of mass slaughtering. The production processes are much cleaner, the potential for diseases is drastically less and far fewer growth hormones are used in the process as compared to conventional meat. Because the process is cleaner, the food safety benefits carry over into the finished product and the shelf life itself is lengthened. This alone has significant cost implications for distribution costs, maintaining shelves, etc. as there are fewer bacteria in the process that would otherwise cause spoilage.

Food security is also becoming more prevalent, as governments strive to become less reliant upon imports and move towards self-sufficiency. Local production is key, as supply disruptions and shortages are more prevalent now with COVID-19's determinantal impact on shipping and distribution. For instance, [Singapore's '30 by 30' programme](#) is targeted on building up their agri-food industry capability and generating 30% of their needs locally and sustainably by 2030, and the government has funded many different technologies and initiatives focused on this objective. Cellular agriculture can help meet this need for local food generation, as producers do not need large areas of land to raise cattle and slaughterhouses for processing (as with traditional meat production) while cultivated meat can be created in local facilities and shipped same day to consumers, reducing the need to import meat.

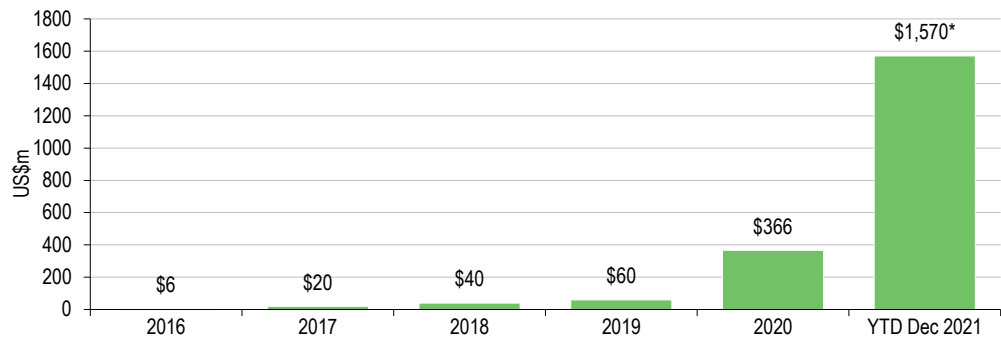
Other markets for cellular agriculture

Protein and meat supply are not the only potential markets for cellular agriculture. Cell-based products are being evaluated for non-red meat alternatives such as fish, seafood, chicken, dairy, gelatine and even for non-foods like leather, cotton and silk. While there is a wide variety of prospective markets for cellular agriculture, consumer acceptance will likely vary accordingly based on the product. Surveys on consumer attitudes to cultivated food have shown that younger consumers are more accepting of these alternative products and, as discussed earlier in this report, the labelling and naming of the products will be key to desirability. As described by McKinsey, exotic meats such as ostrich, kangaroo and alpaca could be made cheaper and more widely available than through current conventional means. Moreover, leather created through cellular products may be more desirable to consumers, as it would avoid many ethical issues associated with animal-based leather and reduce the environmental impact of using the harsh, toxic chemicals often utilised in making traditional leather. In the near term, we believe that the consumer goods space will be the primary market that sees expansion, especially for more expensive products such as prime cuts of meat, leather and expensive cheeses.

Industry dynamics

While the cultivated meat market is still in the early stages, it is becoming a noteworthy alternative to plant-based and conventional meats. McKinsey estimates that the cultivated meat market could reach US\$25bn by 2030 while Barclays' America's Agribusiness research team projects that it could reach a US\$450bn size by 2040. Cultivated meat has the potential to significantly disrupt the market due to its ability to produce biologically equivalent products without the animal welfare, health and environmental issues associated with conventionally farmed meats. Global investment in the cultivated meat industry totalled US\$50m in 2018, about 6% of the funds invested in plant-based meat. According to a Good Food Institute report, that amount grew to US\$366m in 2020 and a recent FAIRR report estimates that US\$506m has been invested in H121, and investors include large firms like Tyson, Nutreco and SoftBank. Exhibit 5 displays the rising trend of investments into cultivated meats, having grown from US\$6m in 2016 to c US\$1,570m YTD through December 2021.

Exhibit 5: Investments into cultivated meats, 2016 – December 2021



Source: Good Food Institute, Edison Investment Research. Note: *Estimated by Edison Investment Research.

Most cellular agriculture companies are only five to six years old, so they are still in the early stages of investment, although they have received significant support from celebrities, financial firms and even conventional meat producers. In fact, cellular agriculture could be produced on an industrial scale as early as 2025 and at a price similar to conventional meat. In Q220, KFC, part of YUM! Brands, signed an agreement with Mosa Meat to purchase its lab-grown chicken once it is commercially available. In late 2020, the 1880 club in Singapore, the only country where cultivated meat is currently approved for consumption, was the first to offer chicken grown from cells in three sample dishes.

Cellular agriculture is on course to be a worldwide phenomenon, although it will be at different stages depending on the location and cultural affinities for meat consumption. A Kearney study forecast that through 2025, most cultivated meat growth will be in the United States, EU and Asia Pacific, while growth will be initially slower in areas with low meat consumption, such as India and Africa. Meat alternatives could provide about one-third of global meat supply within the next 10 years, while demand for conventional meat should decrease by 3% per year.

Regulatory concerns

One headwind for cultivated meat would be regulatory restrictions. As noted earlier, Singapore is the only country where cultivated meat is approved for consumption, and that is only at one restaurant. For cultivated meat to expand globally, its products must ultimately be approved by regulators, although it is not yet clear which government agencies would regulate its products in different countries, some firms do expect it to be the standard food regulators in most locations. As cellular agriculture grows and becomes closer to commercialisation, it is likely to attract more regulatory attention. In the United States, for example, approval for cultivated meats is required by both the US Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA), while seafood only requires approval by the FDA and products such as cultivated leather would not require approval as they are not foods. Moreover, regulation would be at both the jurisdictional and product level, and changing components or ingredients would potentially require a new safety assessment each time, increasing the regulatory burden on cellular agricultural firms. For instance, in the EU, regulatory approval would be required by both the European Food Safety Authority via the novel food regulation and each individual state. Moreover, the farm, dairy and ranching industries will likely lobby strongly against these new products, as well as funding campaigns to encourage consumers to reject alternative meats.

Plant-based meat can provide insights on how regulations may affect cellular agriculture. For instance, restrictions on the use of genetically modified organisms in products have limited plant-based meat expansion into the EU. Brexit has also caused uncertainties on how the EU and UK regulations will affect industry growth. Restrictions on labelling, marketing or branding alternative meat products as 'meat' are an issue, for example in France, where plant-based food companies face a US\$370k fine for using 'meat' or any related terms as it has been deemed misleading to

consumers. Furthermore, a YouGov study indicated that in the UK, only 47% of consumers agreed that it would be acceptable to label plant-based products as meat.

Cost parity

Cost has always been an issue for alternative meat sources, and production costs for cellular agriculture are still substantially higher than for conventional meat. For instance, the first cultured burger in 2013, made by Dutch scientist Mark Post, cost c US\$300k to produce. Furthermore, the conventional meat industry is often heavily subsidised too, helping traditional meat products maintain lower prices than their alternative counterparts. In the EU, the animal farming sector receives payments of ~€28–32bn per year or ~18–20% of its total budget. The industry’s capacity to sell its products at lower prices could potentially boost the long-term growth of conventional meat industries and impede that of alternative meat products. Exhibit 6 compares meat-based and plant-based products, showing the relative disparity in prices of the majority of the products.

Exhibit 6: Price comparison between conventional meat and alternatives		
Company	Meat-based product	Plant-based alternative
Burger King	Whopper: US\$5.89	Impossible Whopper: US\$6.89
Ikea	Meat balls 500g: US\$5.00	Plant balls 500g: US\$5.99
Tesco	Cocktail sausages: £6.80/kg	Vegan sausage roll: £8.89/kg
	Steak bake: £1.10	Vegan steak bake: £2.50
Hotel Chocolat	Milk chocolate batons: £7.00	Nutmilk chocolate batons: £7.00
Walmart	Tyson chicken strips: US\$4.27/lb	Gardein chicken strips: US\$6.05/lb
	Great value cheese pizza: US\$2.24	Great Value cauliflower crust margherita pizza: US\$4.98

Source: Company websites, Edison Investment Research. Note: Prices are as of 16 November 2021.

As noted above, cultivated meats have much higher production costs than conventional meat. Cellular agriculture’s expense is primarily related to the growth medium, which needs to be optimised for each cell line. Barclays estimates that the cell culture medium makes up 99% of the baseline production cost. Furthermore, most growth media are only available in small quantities, suitable for a lab but cost-prohibitive for larger-scale operations. In 2019, the Good Food Institute estimated that the current cost of standard growth medium was US\$377 or US\$8,600 per kilogram of final meat product. Kearney compares the prices of meat and its alternatives as of 2018, with ground beef at US\$0.80/100g, compared to a vegan burger at US\$2.50 or cultivated meat at US\$80, considerably less than the cost of growth medium.

Several options exist for potentially reducing this cost, such as cheaper alternatives, better sourcing and improving the fermentation process. McKinsey projects that cultivated meats may be able to reach cost parity by 2030, with ~75% of savings from greater scale and improved manufacturing and the remaining 25% from more efficient R&D, eventually reaching less than US\$5 per pound of meat. Cost reductions could come from bulk purchasing of inputs, improved plant design and optimising production efficiency. Note that suppliers of products along the value chain (eg Thermo Fisher Scientific, Merck) have entered the market to provide inputs, products and solutions to lower costs, assist in reaching industrial scale and speed up commercialisation.

Moreover, the cost advantage of conventional meat has been decaying as COVID-19 has driven up prices, and government initiatives and subsidies for alternative meats have also helped reduce the gap. The UK announced that it is reducing some EU farm subsidies and instead applying the funds towards public or climate issues. Canada announced in June 2020 that it would be providing financing for Merit Functional Foods, a firm that produces plant-based proteins. Further government support and rising conventional meat prices should boost the growth of the alternative meat industry.

Simply put, for cellular agriculture to become a profitable competitor, it would need to reach some level of cost parity with conventional meat, which McKinsey estimates would take about a decade. Nick Halla, senior VP for International at Impossible Foods, explained, ‘You’ll buy the product once based on novelty, you’ll come back if the taste is good and if there are benefits such as nutrition and sustainability, and you’ll buy it in the long run if the price is right.’ Encouragingly, Future Meat

Technologies announced earlier in 2021 that it had reduced production costs by nearly 50% and can now produce 110g of cultured chicken breast for under US\$4, and predicts that its cost will drop below US\$2 within 12–18 months from mid-2021.

However, exact price parity is not necessarily required for cultivated meats to compete with conventional meat. In fact, based on US pricing data collected by McKinsey, consumers pay a premium for alternative products that are important to them, such as 51% more for cage-free eggs, 149% for organic eggs, 83% for organic milk, 226% for grass-fed whole cuts of beef and 311% for grass-fed ground beef. Whether it is organic eggs or milk, or grass-fed beef, the point here is that many consumers will pay up to 300% more for a premium product.

Expanding from laboratory to pilot to industrial scale

While some meat alternatives are mass-produced and readily available to consumers, cellular agriculture still operates on a laboratory scale. To reduce its costs and eventually produce commercial-size quantities, cellular agriculture must scale up from lab scale (<1,000 litres) to pilot scale (~5,000 litres) and then to industrial scale (>20,000 litres). For instance, recent announcements from [Upside Foods](#) shows them opening a small-scale production facility targeting 50,000 pounds per year.

However, scaling up from laboratory to pilot to industrial scale is easier said than done, as there are many challenges associated with this evolution in size. For instance, the technology for mass production must be developed, and larger bioreactors and associated equipment must be created, as much of what is required for industrial-sized operations does not currently exist. The greater pressure in larger bioreactors is also an issue, especially at the bottom, since if the vessel is too large, the pressure could damage the cell structure and cause the process to break down. This alone could limit the maximum size of bioreactors and hence have a significant impact on the final cost. Transferring technology from one type of product to another can also be an issue, as different cells require different growth media and process conditions.

Providing enough raw materials to support an industrial-scale operation will also be challenging. For instance, McKinsey estimates that reaching a US\$25bn cultivated meat market would require the production of about 1.5m tons of cultivated meat. To reach this level of mass meat production requires 220–240m litres of fermentation space. Mosa Meat provides a helpful comparison between the scaling needs for cultivated meat and the production capacity of the wine industry. If one assumed a 50% market share of global meat consumption, it would require about 15bn litres of bioreactor volume. The wine industry consumes about the same volume (about 15bn litres), so its existing capacity requirements compare well with the scaling needs for cultivated meat and suggests that the scaling needs could be achievable.

Ultimately, it is essential that solutions to these types of challenges are found if cultivated meat can successfully scale to industrial size and become a profitable business model.

Going to market

So how do companies typically go to market in this nascent space? As with many privately owned, early-stage companies in other sectors, cellular agriculture firms must raise private equity funds via successive investment rounds to support development and make progress towards commercial scale and viability. As the appetite for alternative meat products has increased, so has funding, as many firms have entered the market and received either private or public funding. Exhibit 7 displays the latest private funding rounds for several alternative meat firms.

Exhibit 7: Select funding for alternative meat companies

Name	Last funding amount	Date	Funding round	Total funding to date	Enterprise value*	Sector
Aleph Farms	US\$105m	July 2021	Series B	US\$118m	N/A	Cultured meat
Beyond Meat	US\$1bn	Mar 2021	Post IPO	N/A	US\$5.1bn	Plant-based meat
Eat Just	US\$97m	Sep 2021	N/A	Higher	c US\$1–1.2bn	Cultured meat, plant-based eggs
Higher Steaks	N/A	Aug 2020	Seed	N/A	N/A	Cultured meat
Impossible Foods	c US\$500m	Nov 2021	TBD	c US\$2b	c US\$4bn	Plant-based meat
MeaTech	US\$25m	Mar 2021	IPO	N/A	US\$52m	Cultured meat
Modern Plant-Based Foods	C\$2.5m	July 2021	IPO	N/A	US\$37m	Plant-based meat
Mosa Meat	US\$85m	Mar 2021	Series B	c US\$95m	N/A	Cultured meat
Multus Media	US\$2.2m	July 2021	N/A	c US\$2.3m	N/A	Growth media
UPSIDE Foods	US\$161m	Jan 2020	Series B	c US\$206m	N/A	Cultured meat
Very Good Food Company	US\$30m	Oct 2021	Direct offering	N/A	C\$144m	Plant-based foods
Future Meat	US\$320m	Dec 2021 (ongoing)	TBD	N/A	C US\$600m	Cultured meat

Source: Edison Investment Research, company data, Refinitiv, Bloomberg historical data. Note: *Estimated if not public. As of 29 November 2021.

Public funding of meat alternatives has been substantial too, as Beyond Meat, listed on Nasdaq in 2019, was the first public investment opportunity in plant-based meats, raising US\$240m in funding and a substantial US\$1bn follow-on offering in March 2021. The Very Good Food Company listed in June 2020 and raised C\$4m in its IPO, and in October 2021 completed a US\$30m direct offering, while Modern Meat listed the next month and raised C\$2.5m. MeaTech 3D was the first cultivated meat company to go public, launching a US\$25m IPO in March 2021, and has also raised over US\$12.7m in private funding. Finally, Israeli cultured meat firm Future Meat is currently raising US\$320m at a \$US600m valuation, which would make it the highest valued Israeli company in its sector.

Private companies UPSIDE Foods raised US\$161m in its Series B funding round and Future Meat Technologies raised US\$14m in Series A funding. Eat Just had a US\$200m financing round earlier in 2021, and Impossible Foods just announced a funding round worth c US\$500m.

Unfortunately, most plant-based firms are operating at a net loss, due to low-margin sales and high R&D expenses. For instance, Beyond Meat has operated at a loss since 2016 despite record revenues in 2019 and 2020. As a result, these companies could be acquisition targets for larger, multinational firms such as Unilever and Danone, which have the scale, presence and finances to grow these products, speed up the time to market and eventually generate a profit. On the other hand, these larger firms could decide to grow through in-house R&D or buy smaller firms that are earlier in the process.

Cultivated meat is not just the province of small start-ups though. As shown in Exhibit 8, the industry dynamics are changing as several large, multinational firms have entered into strategic collaborations with cultivated meat firms, made significant investments in early-stage firms or added their own brands of alternative meat to their product mix. As can be seen, the cultivated meat industry is entering into a stage of commercialising its products.

Exhibit 8: Selected Strategic collaborations and investments by multi-nationals

Firms	Date	Description
Cargill and UPSIDE Foods	2017, 2020	Minority investment
Tyson Foods and UPSIDE Foods (formerly Memphis Meats)	Jan 2018	Minority investment
Tyson Foods and Future Meat Technologies	May 2018	Seed investment
Merck, Bell Food Group and Mosa Meat	Jul 2018	€8.8m Series A investment
Cargill and Aleph Farms	May 2019	Series A investment
KFC-3D Bioprinting Solutions	Jul 2020	KFC partnering with Moscow based 3D Bioprinting Solutions to develop laboratory 3D produced chicken nuggets to mimic the taste and texture of KFC's conventional nuggets for the Russian market.
Qatar Investment Authority and Eat Just	Mar 2021	\$200m funding as part of larger partnership to finance construction of first cultivated meat facility in the Middle East. Will initially produce cultured chicken.
BRF and Aleph Farms	Mar 2021 and Jul 2021	March partnership to co-develop and produce cultivated meat, followed by July US\$2.5m investment
Nestlé and Future Meat Technologies	Jul 2021	Evaluating technologies to produce cultured meat and develop blended products of plant-based and cell-based meats
Tiv Ta'am Group and MeaTech 3D	Jul 2021	Israel-based food group and marketing chain Tiv Ta'am partnering with MeaTech 3D in joint research and development, including the establishment of a production facility for cultivated meat products.
DSM and Meatable	Sep 2021	Develop growth media for cultivated meat
Nomad Foods and BlueNalu	Sep 2021	Partnership to introduce cultured seafood into Europe
JBS and BioTech Foods	Nov 2021	The Brazilian firm acquired Spanish-based BioTech Foods, will make a US\$41m investment into a new production facility in Spain and establish in Brazil JBS's first 'Centre for Research and Development in Biotechnology and Cultivated Protein'.
Merck's collaborations with universities and cultured meat firms such as Lab Farm Foods	Various	Merck's focus is on developing technology and solutions that enable others to produce cultivated meat, including optimising cell culture media, bioreactors, scalable scaffolds, etc.

Source: Edison Investment Research, company websites

Along with its investment in Beyond Meat, Tyson backed several cultivated meat firms, including UPSIDE Foods (originally named Memphis Meats) and Future Meat Technologies, and has raised seed investments in its Tyson Ventures group. Nestlé acquired plant-based food company Sweet Earth in 2017. It has launched several plant-based meat products over the last few years and is now working with Future Meat Technologies to explore the potential for cultured meat. Brazilian meat producer BRF partnered with Aleph Farms in March 2021 to develop cultivated meat for sale in Brazil, and in July 2021 invested US\$2.5m in Aleph Farms as part of a US\$105m funding round. Cargill has also backed UPSIDE Foods and is launching its own product line. European meat supplier Bell Food Group has made several investments in Mosa Meat, a cultivated meat start-up in the Netherlands. Most recently, Brazilian multinational JBS, one of the largest global animal protein producers, announced a US\$100m investment into cultured meat production, and expects to reach commercial production of cultivated protein (eg beef, chicken, pork and fish) by mid-2024.

Investing in cellular agriculture

How can one invest in alternative meat products like cultivated meat? While the majority of cultivated meat firms are private, there are some avenues to investing in the alternative space: first, pure-play producers such as MeaTech 3D and Beyond Meat; second, companies that distribute and/or serve cultivated and plant-based meats including Walmart, Starbucks, Burger King and grocery stores; and third, large multinationals with a broader portfolio that include meat alternatives as part of their product mix. Exhibit 9 presents an overview of many of these public investment opportunities.

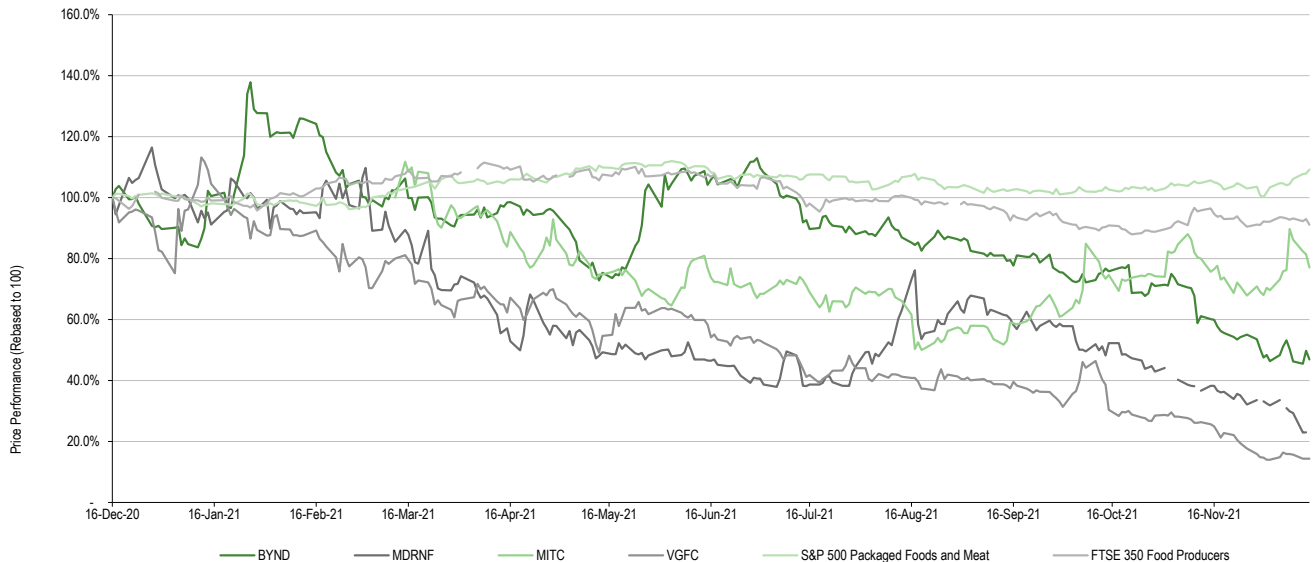
Exhibit 9: Public valuations

Ticker	Name	Description	Share price (US\$)	% perf. LTM	Market cap (free float, US\$m)	Revenue LTM (US\$m)	EV (US\$m)	P/rev FY21e (x)	P/rev FY22e (x)	EV/ EBITDA FY21e (x)	EV/ EBITDA FY22e (x)	P/E FY21e (x)	P/E FY22e (x)	Div. yield (%)
Pure-play producers														
BYND.O	Beyond Meat	A food company that offers plant-based meats	66.79	(53%)	4,230	466	4,012	9.1	6.5	N/A	N/A	N/A	N/A	-
MDRNF.PK	Modern Plant-Based Foods	Modern Plant-Based Foods, formerly Modern Meat, is a Canada-based food company that offers a portfolio of plant-based meat products	0.70	(77%)	17	2	17	N/A	N/A	N/A	N/A	N/A	N/A	-
MITC.O	MeaTech 3D****	An Israel-based biotech company developing advanced cultured meat products	7.89	(23%)	97	-	72	N/A	N/A	N/A	N/A	N/A	N/A	-
VGFC.O	Very Good Food Company	A Canada-based, plant-based food technology company	0.84	(86%)	78	12	145	N/A	N/A	N/A	N/A	N/A	N/A	-
Distributors and servers														
QSR (NYSE)	Burger King	Restaurant Brands International is a quick service restaurant (QSR) company.	58.83	(6%)	17,925	5,551	30,564	3.2	2.9	13.8	12.6	20.8	19.2	3.4
SBUX.O	Starbucks*	A roaster, marketer and retailer of speciality coffee	114.68	10%	134,266	29,061	142,271	4.1	3.8	20.2	18.1	33.3	28.7	1.6
TSCO.L	Tesco**	A retail company.	3.76	23%	28,074	79,403	42,414	0.4	0.4	7.2	7.2	13.5	13.1	4.5
WMT (NYSE)	Walmart***	Engaged in the operation of retail, wholesale and other units, as well as e-Commerce.	145.8	0%	202,832	571,962	238,220	0.7	0.7	11.9	11.5	22.7	21.7	1.5
YUM (NYSE)	YUM! Brands	Engaged in restaurant business	132.42	25%	38,748	6,437	49,000	5.9	5.5	21.0	20.0	29.1	26.7	1.7
Large multinationals														
BELL.S	Bell Food Group	A Switzerland-based company primarily engaged in the production and distribution of meat	312.28	15%	653	4,431	1,435	0.4	0.4	7.6	7.3	13.2	13.2	2.7
BRFS.K	BRF	A multinational Brazilian company that owns a diverse portfolio of products and is a producer of foods	3.61	(18%)	2,224	7,681	5,370	0.4	0.3	6.2	5.7	N/A	20.0	-
JBSS3.SA	JBS SA	JBS SA is a Brazil-based company engaged in the meat processing sector. The company's activities are divided into five business segments: Brazil, Seara, JBS USA Beef, JBS USA Pork and PPC	6.49	72%	5,301	58,003	17,735	0.3	0.3	4.6	5.2	6.7	8.2	2.5
NESN.S	Nestlé	A nutrition, health and wellness company.	138.08	26%	377,683	92,268	422,021	4.1	3.9	21.6	20.4	28.6	26.6	2.6
TSN (NYSE)	Tyson*	A food company that produces a range of frozen and refrigerated food products	85.91	33%	24,648	47,049	31,621	0.6	0.6	7.6	7.3	11.8	11.3	2.3

Source: Refinitiv, Edison Investment Research. Notes: *FY ends September. **FY ends February. ***FY ends January. ****Began trading on NASDAQ in March 2021, MeaTech 3D's Market cap and EV based on outstanding shares.

As noted earlier, the four pure-play producers (see Exhibit 9 above) have raised IPO funds over the last few years (see Exhibit 7 above) and several trade on Nasdaq either directly or via ADRs. Several enjoyed significant price increases following their IPOs. For instance, BYND was up 167% from its IPO in 2019 through to late January 2021, while VGFC rose 373% from its June IPO to late January 2021. One challenge for these producers is lack of earnings visibility as they have no consensus earnings, potential competition and regulatory headwinds, all of which could be a drag on stock prices. Unfortunately, as demonstrated in Exhibit 10, they were affected by the market turmoil resulting from COVID-19 and lack of earnings visibility, the four have underperformed the wider food industry over the last 12 months, with BYND down 53%, MDRNF losing 77%, MITC decreasing 23% and VGFC falling 86%. By comparison, the FTSE 350 Food Producer Index is down 9%, while the S&P 500 Packaged Foods & Meats Index up by 9%. We note also that BYND trades at higher multiples than the other companies in Exhibit 9, with FY21e price/revenue at 9.1x or more than twice as much as the nearest firm. The multiples for the remaining three pure-play producers are insignificant due to low revenues and are not appropriate for use with newer firms like these with negative earnings and high R&D investments.

Exhibit 10: One-year price performance for pure-play producers and related indices



Source: Edison Investment Research calculations, Bloomberg

By contrast, the share price performance of the global food companies and food service/retailers was up in the last 12 months, ranging from 10% to 15% (SBUX, BELL), 23% to 33% (TSCO, NESN, TSN) and 72% (JBS). Of course, these are typically medium to large firms with stronger financials, some of which are vertically integrated and others that have a more diversified product line like WMT, NESN, TSN and YUM. While these are less risky than the smaller pure-play producers, they offer lower return potential if companies like MITC and BYND can achieve their full growth potential.

For investors interested in alternative food funds rather than individual stocks, Agronomics (ANIC) offers an interesting option. It is a fund that invests in companies producing environmentally friendly alternatives to traditionally produced meat, dairy, seafood and materials. It is the only UK-listed vehicle focused on cellular agriculture and, as discussed in our [Edison TV interview](#), offers investors a rare opportunity to access the rapidly expanding cellular agriculture industry.

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