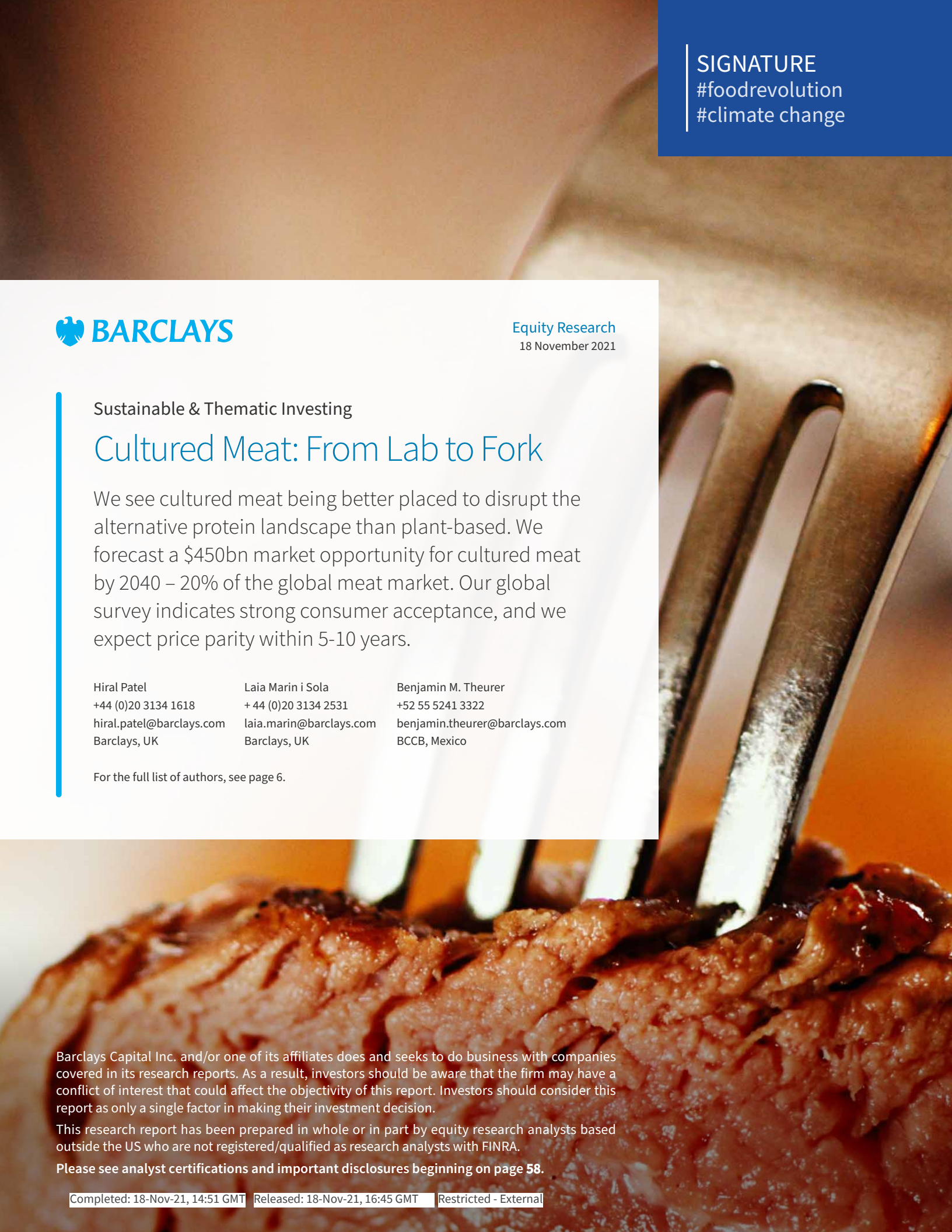

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Equity Research
18 November 2021

Sustainable & Thematic Investing

Cultured Meat: From Lab to Fork

We see cultured meat being better placed to disrupt the alternative protein landscape than plant-based. We forecast a $450bn market opportunity for cultured meat by 2040 – 20% of the global meat market. Our global survey indicates strong consumer acceptance, and we expect price parity within 5-10 years.

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The growing recognition of the importance of protein diversification within climate-mitigation strategies has led to several avenues of opportunity within the alternative protein landscape. We now see the underlying technology behind cultured meat better placed to address consumer concerns relating to taste and sustainability, relative to existing plant-based products driven by recent regulatory approvals and company investment. Our discussions with industry participants suggest cellular technology is highly scalable, with our Americas Agribusiness team forecasting a $450bn market opportunity by 2040 – 20% of the global meat market. In our view, it will likely take another 5-10 years before we see cultured products reach price parity with mainstream availability in food outlets. Our analysis is based on three key factors: 1) regulatory approvals, 2) pricing & manufacturing efficiency and 3) consumer adoption. Our consumer survey of 5,000 adults (China, India, Brazil, the US, the UK) suggests that two-thirds of adults would consider purchasing cultured meat – with higher acceptance among the younger demographic, emerging markets and surprisingly vegetarians/vegans – Figure 1. Following Singapore's approval of cultured chicken in Dec-20, we have been encouraged by the level of investment activity as cultured meat companies continue to launch product prototypes and invest in production facilities. Public companies have been keen to gain exposure to the cultured meat value chain, a trend we anticipate will gather momentum given the broad range of B2B/B2C private companies and recent pure-play IPOs (refer to our Cultured Meat Company Landscape – Figure 25). We anticipate additional regulatory approvals in 2022, with the growing potential for cellular technology to also be applied to areas beyond meats (beef, chicken, pork), including cultured seafood, dairy and fats.

- **Cultured – meat the future:** Using technology that replicates tissue regeneration, cultured meat is also referred to as lab-grown, in-vitro, cell-based and cultivated meat. The manufacturing process involves growing animal cells in bioreactors at high densities, using a nutrient-rich growth medium. The animal cells are sourced from a tissue biopsy, without having to slaughter or harm the animal. Compared to traditional meat, cultured meat is positioned to be healthier and more sustainable in respect to land use and animal welfare. It also eliminates the need for antibiotics and increases supply chain resilience by reducing the production timeline to a matter of weeks, while also helping to meet global protein demand driven by ongoing population growth – Figure 4. One current drawback is the high energy usage required to run the bioreactors.

- **450bn by 2040E – 20% of the global meat market:** Our Americas Agribusiness research team estimates a $450bn market size for cultured meat by 2040, based on the overall growth of the meat market at a 3% CAGR from the 2019 Barclays estimate of $1.4tn. Within our base case scenario, we model a market share of 10% by 2035, 20% by 2040 and 40% by 2050. Our **Bull vs. Bear scenario analysis** indicates we are more bullish on cultured meat vs. plant-based diets in the mid to long term, with the potential for government taxes on animal meat to further catalyse market penetration.

- **Road to price parity by 2030E – three key factors:** The cultured meat industry has already presented many successful prototypes, but the ability to scale commercially and increase yields relies on three key factors: i) regulatory approval, ii) pricing & manufacturing efficiency and iii) consumer acceptance. Many cultured meat companies are hoping to begin commercialising within the next 12-24 months, and our expectation is that we remain 5-10 years away from cultured meats being widely available at price parity. In the interim, we will likely see many 'hybrid' products emerge that incorporate both plant-based and cultured meat – an option we anticipate companies will

increasingly utilise to help accelerate their go-to-market strategies. Key areas of R&D focus include the use of 3D bioprinting, the potential use of GMO techniques and the growth in serum-free media.

- **Barclays Consumer Survey indicates strong consumer acceptance:** Our global survey of 5,000 adults (China, India, Brazil, the US, the UK), indicates two-thirds of adults would consider purchasing cultured meat if it became commonly available. This is driven largely by the younger demographic, with consumer acceptance higher in China and India than in the US and the UK. Encouragingly, 81% of vegetarians & vegans would consider purchasing cultured meats. The environment, animal welfare and sustainability were the top 3 appeals for consumers, with the survey highlighting a further need to raise consumer awareness, particularly in the West. Pricing remains a key barrier, with only 50% indicating they would be willing to pay more for cultured meat.

- **Investor Guidebook – Gaining exposure via strategic M&A and IPOs:** We highlight three ways to gain exposure:

    - **1) Public companies investing in private cultured meat companies:** Within Americas Agribusiness, investments in cultured meat companies have been made by **BRF** (Aleph Farms - 2021) and **Tyson** (UPSIDE Foods, Future Meat – 2018). Within EU Consumer, **Nestlé** also announced a partnership with Future Meat (2021) to explore technologies linked to cultured meats and ingredients. To create lower-cost growth media, **Merck** within EU Pharma has been a key R&D partner when exploring serum-free culture media, and within EU Chemicals **DSM** entered into a joint agreement with Meatable (2021). To gain exposure to cultured seafood, **Nomad Foods** within US Foods has agreed to explore products in Europe in collaboration with BlueNalu (2021). Refer to the Sector Implications chapter for further information.

    - **2) Pure-play cultured IPOs are emerging:** The IPOs of **BioMilk** (cultured milk) and **MeaTech** (3D bioprinting & cultured fats) this year, alongside UK-listed **Agronomics** (alternative protein investment vehicle), suggest that investor appetite for this nascent investment theme is growing.

    - **3) Private companies attracting significant levels of VC funding:** A wide range of private companies across the value chain have attracted significant amounts of VC funding – including both B2C and B2B business models aiming to develop cultured meat inputs, services or end-products. The recent momentum in Series B funding has been particularly encouraging, with additional M&A anticipated as the market begins to consolidate ahead of commercial production and price parity. We summarise recent **VC activity** (**Figure 28**), with our **Cultured Meat Landscape (Figure 25)** providing a full list of companies (public/private) linked to theme. We provide company profiles for key players including: **Mosa Meats, UPSIDE Foods, Shiok Meats, Good Meat and Aleph Farms**.

To aid company engagement, we provide questions for management, the Barclays SDG wheel and key ESG considerations.

FIGURE 1. **Cultured Meat: From Lab to Fork**

Cultured Meat: From Lab to Fork

What is cultured meat?

- Meat produced in bioreactors without the slaughter of an animal, using a tissue biopsy
- Identical to animal meat at the cellular level
- Often referred to as clean meat, cell-based meat or cultivated meat

Alternative protein landscape — appetite for disruption

We believe cultured meat has the potential to be a credible option within the alternative protein landscape

Now

- Plant-based

Future

- Insect protein
- Fermentation
- Cultured

Scaling commercial production — how is it made?

Cell source & cell lining
An adult stem cell is extracted from an animal through a biopsy

→

Cell culture medium
Cells are added to a bioreactor with cell culture media to proliferate

→

Bioreactors
Cells differentiate into muscle, fat and connective tissue

→

Scaffolding
Cells are structured via scaffolding materials

Cultured meat has the potential to be more sustainable than traditional farming…

- Lower carbon footprint
- Animal welfare
- Biodiversity protection
- Reduced risk of diseases & antibiotic-resistance
- Potential healthier alternative

2030 cultured meat roadmap — the road to price parity

2021
Pilot facilities & initial product launches

2023
Scaling of the manufacturing & production process

2030
Price parity & emerging applications of cellular agriculture

Three factors influencing the scaling of cultured meat

1 Regulatory approvals
Singapore's approval of cultured chicken (Dec-20) suggests the regulatory landscape remains favourable, with upcoming catalysts to consider in the US and the EU

2 Manufacturing challenges
Pricing has dropped significantly, with the cost of cell culture media being a key variable to consider, alongside other technical challenges

3 Consumer acceptance
Need to raise consumer awareness and address consumer preferences towards alternative protein and product transparency

Barclays Consumer Survey — 5,000 adults in UK, US, China, India and Brazil

2/3 of adults
would consider purchasing cultured meat

Driven mainly by the younger demographic, with support from the vegans & vegetarians

Would pay more		Would not pay more	
India	80%	UK	58%
China	74%	Brazil	51%
		US	41%

Pricing is not the predominant reason to buy cultured meat

Top 3 appeals		Top 3 concerns	
Environment	38%	Pricing	36%
Animal welfare	37%	Claimed benefits	33%
Sustainability profile	34%	New/novel food	30%

With the need to raise consumer awareness in the West

Cultured meat — $450bn market opportunity by 2040E

$450bn by 2040E

(20% of global meat market share)

Based on overall growth of the meat market at a **3% CAGR** from the Barclays 2019 estimate of **$1.4tn**

Barclays scenario analysis: bull vs. bear

Our scenario analysis for cultured meat market

2035		
	Bull	15% penetration
	Base	10% penetration
	Bear	5% penetration
2040		
	Bull	30% penetration
	Base	20% penetration
	Bear	10% penetration
2050		
	Bull	50% penetration
	Base	40% penetration
	Bear	20% penetration

Source: Barclays Research

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CULTURED MEAT – THE NEXT PROTEIN ALTERNATIVE

Global protein consumption continues to rise, with the growing demand for livestock placing significant environmental pressure on available land and the broader agricultural industry. Using animals to convert plants to meat remains extremely inefficient; livestock provides just 18% of calories consumed by humans, but takes up to 77% of global farmland, according to the Good Food Institute (GFI).

Unsurprisingly alternative protein has attracted significant investor interest in recent years, with plant-based products a mainstream reality within supermarkets and restaurants today. However, another revolution is also taking place behind the scenes and is considered to be one of the biggest upcoming trends in food technology – cellular agriculture and more specifically cultured meat (Figure 2).

In this section, we define cultured meat and consider how the production process has the potential to circumvent many of the ethical and environmental issues surrounding conventional animal husbandry. Our analysis of the manufacturing process indicates the underlying technology is at a pivotal point in its journey to commercial viability, with the need to further consider some of the practical realities influencing cost and scale.

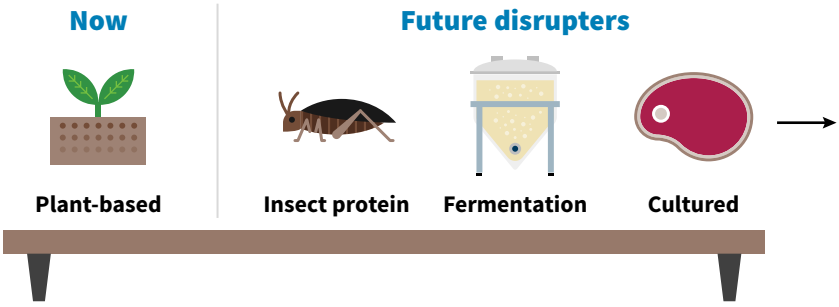
Defining cultured meat

We believe cultured meat has the potential to be a credible option within the Alternative Protein Landscape (Figure 2), alongside plant-based and insect protein.

While there is no global definition per se, cultured meat is produced using animal cell culture technology. This is where meat is made from animal cells using a combination of tissue engineering, molecular biology and synthetic processes, with cultured meat being identical to conventional meat at the cellular level. It can sometimes be referred to as lab-grown meat, in-vitro meat, cell-based meat, cultivated meat and clean meat.

The technology differs from plant-based as cultured is made from animal cells in a bioreactor, though no animals are killed in the process. Breeding, fattening, slaughtering and processing thus have the potential to be replaced by protein factories with large-scale bioreactors in which the animal stem cells are grown. It takes anywhere between 3-6 weeks to produce, with the potential to produce red meat, poultry, fish and dairy. However, there are a number of hurdles to overcome before cultured meat can become a mainstream reality, including manufacturing costs, regulatory approval and customer acceptance.

FIGURE 2. **Alternative Protein Landscape – Cultured meat deserves a place on the table…**



Cultured meat

Produced in bioreactors without the slaughter of an animal, using a tissue biopsy

Often referred to as clean meat, cell-based meat or cultivated meat

Identical to animal meat at the cellular level

Source: Barclays Research

How is cultured meat made? 4 key components

The manufacturing process begins with acquiring and banking stem cells from an animal. These cells are then grown in bioreactors at high densities and volumes. Similar to what happens inside an animal's body, the cells are fed an oxygen-rich cell culture medium made up of basic nutrients (e.g. amino acids, glucose, vitamins and inorganic salts) which are supplemented with proteins and other growth factors – Figure 3.

Key components to the manufacturing process

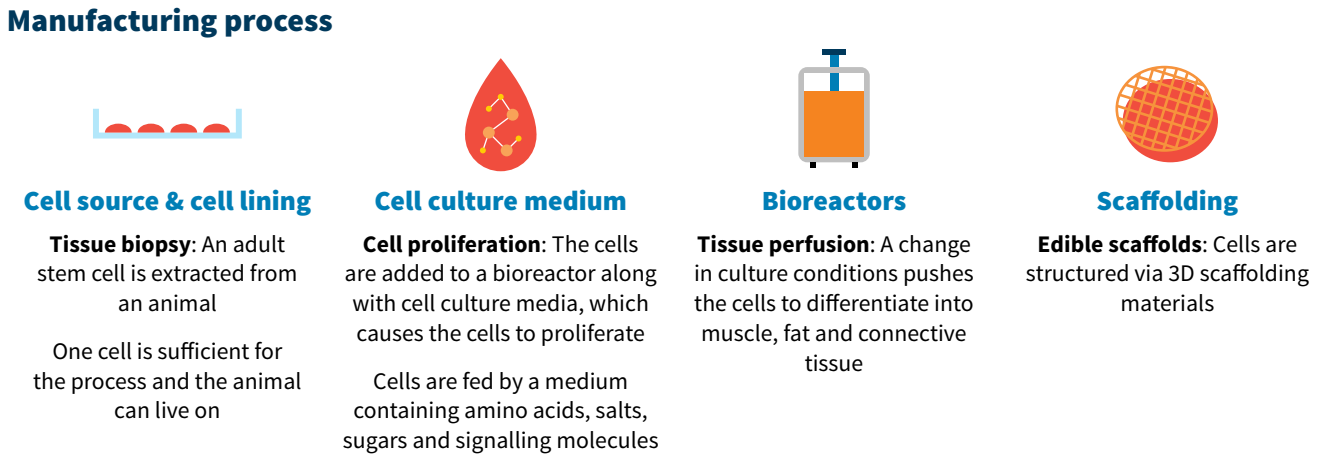
1. **Cell source & cell lining:** A variety of sources and techniques have been deployed by companies to obtain stem cells. Cells are typically sourced from a tissue biopsy or in select cases may be sourced from a feather or hair follicle. The types of stem cell matters for process scale and cost because some can grow more rapidly or have more flexibility in the type of cell they can eventually become. Cell lines (population of cells) are then formed to propagate repeatedly. To support long-term replication (sometimes even indefinitely), a number of cultured companies have started to explore cell line engineering techniques and have also supported the scaling of cell banking.

2. **Cell culture medium:** Cells are given a nutrient-rich cell culture medium, which enables cells to grow and form into meat. The culture medium contains critical components including amino acids, vitamins, glucose, inorganic salts and growth factors. The growth factors are by far the most complex and expensive component to cell culture media. The exact composition of the cell culture medium is dependent on a given cell line and cell species, meaning there is no one-size-fits-all approach for the most efficient medium solution. Research on optimised formulations, food-grade and animal-free components and recycling technologies is needed to help make media significantly more affordable.

3. **Bioreactors:** Cells are then harvested in a large-scale bioreactor until they grow enough to form a suitable amount of meat. Cells have two main jobs once they make it to the bioreactor: **1. Proliferation** (division to generate a large number of cells) and **2. Differentiation** (cells become the desired and final cell type suitable for consumption, i.e. muscle cells or fat cells). How the cells accomplish these tasks is dependent upon the cell culture medium, bioreactor design and in some scenarios **a scaffold.**

4. **Scaffolding:** The scaffold can be considered materials (hydrogel, collagen, mycelium) and tissue construction techniques (such as 3D printing, electro-spinning, or electrical stimulation) that are used to turn 'unstructured' cells into different types of realistic cuts of meat. A challenge is creating scaffolds that mimic collagen and other internal structures that are naturally present in meat, and that are 3D and edible.

FIGURE 3. **Cultured meat – 4 key components to the manufacturing process**



Source: Barclays Research, Good Food institute

Attractive sustainability credentials (environmental & social)

Food production is responsible for approximately 26% of global emissions, with the vast majority relating to livestock & fish farms, land use for livestock and crops for animal feed. Cattle farming in particular is estimated to be responsible for c.9% of all human-induced GHG emissions, with industrial livestock production presenting a growing problem in terms of animal welfare, environmental sustainability and human health. However, like plant-based meat, cultured meat is positioned to be healthier and more sustainable, while also helping meet global protein demand amid ongoing population growth (Figure 4).

- **Lower carbon footprint**: The majority of the carbon footprint of cultured meat relates to the use of electricity in the production process. If renewable energy were used to power the bioreactors, cultured meat would outperform all sorts of traditional meat in terms of carbon footprint, assuming production at scale. According to a life-cycle assessment (*LCA*) and techno-economic assessment (*TEA*) performed by the GFI, cultured meat would potentially reduce global warming by up to 92% when compared to traditional beef, 52% when compared to traditional pork and 17% when compared to chicken.

- **Biodiversity protection:** Cultured meat could also reduce land use by up to 95% when compared to beef, 72% when compared to pork and 63% when compared to chicken, according to the GFI. With demand for soy expected to rise as it is a vital protein source for meat-eaters and vegetarians alike, cultured meat also presents an opportunity to reduce continued deforestation (*Biodiversity: Investing In Nature*, 23.09.2020).

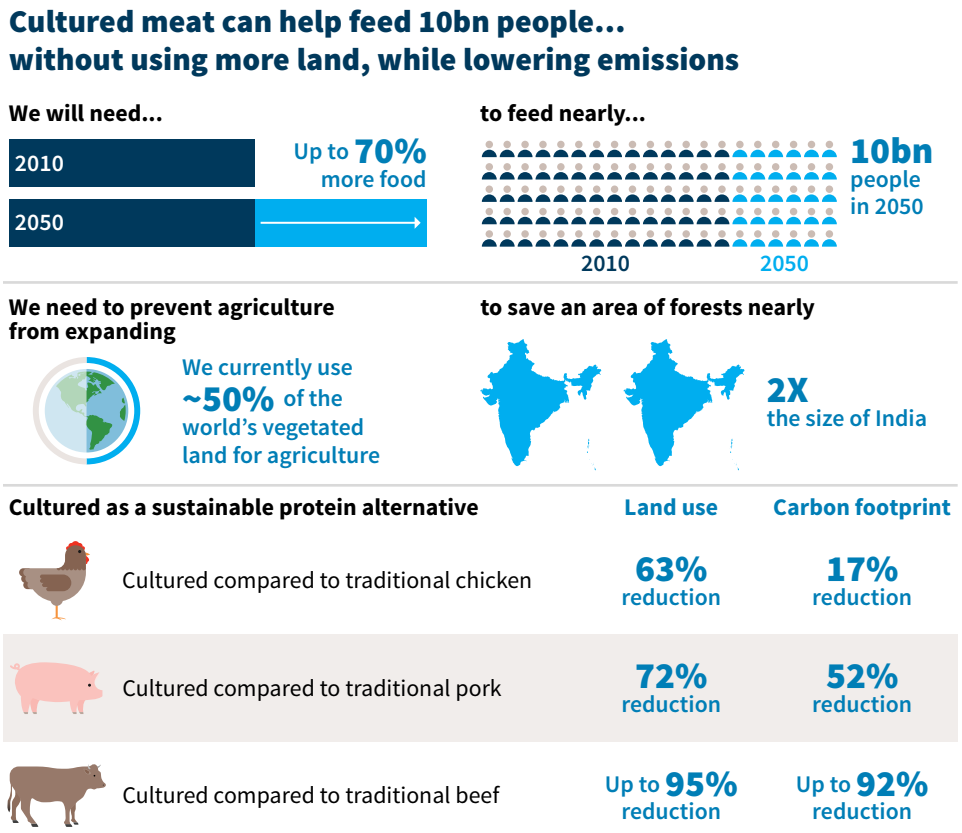
- **Reduced risk of zoonotic diseases & antibiotic-resistance:** In the current meat production process, animals are given high doses of antibiotics to prevent infectious diseases. This widespread use of antibiotics is associated with a rise in pathogenic and antibiotic-resistant bacteria. In theory, cultured meat carries fewer health risks as it is produced in a controlled environment without the use of antibiotics or pesticides. It also reduces the likelihood of zoonotic diseases (salmonella, ebola).

- **Improved ethical profile & animal welfare:** Cultured meat is considered an ethical alternative to industrial livestock production as it involves only taking cells from animals through a biopsy, without needing to farm or slaughter the animal. The use of Foetal Bovine Serum (FBS) in the culture medium continues to attract significant concern, though the

industry is actively attempting to eliminate its use by considering serum-free alternatives (refer to Figure 8 for further detail on the technical challenges within the manufacturing process).

- **Healthy alternative:** The cell extraction process only involves cells from muscle tissue which contain no fat. Fat is always added at a later stage of the production process, posing an opportunity for cultured meat companies to produce healthier products with a more tailored nutritional profile depending on the end-market. For example, companies could avoid adding saturated fats but instead substitute them for healthier ones such as Omega 3, or add more vitamins and nutrients. Relative to some plant-based products, which may contain multiple ingredients that are highly processed or contain artificial fillers and additives, cultured meat has the potential to be viewed as a healthier alternative.

FIGURE 4. **Cultured meat to help create a sustainable food future by 2050**



Source: World Resources Institute, Good Food Institute, Barclays Research

SIZING THE CULTURED MEAT MARKET OPPORTUNITY

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We estimate a market size for cultured meat of c.$450bn by 2040 —20% of the global meat market. This is based on overall growth of the meat market at a 3% CAGR from Barclays 2019 estimate of $1.4tn. Although cultured meat currently holds no relevant market share, we believe adoption will be faster than for other food alternatives, given the similarity of cultured and traditional meat and cultured meat's ability to address several challenges faced by the animal-based meat industry. Comparison points include plant-based dairy (13% market share after an increase in demand in the 2010s), craft beer (12% market share) and plant-based proteins (projected by Barclays, I Can't Believe It's Not Meat, 22 May 2019, for 10% market share in 2030). In our view, the greatest barriers to achievement of this market share are regulatory hurdles, pricing and a lack of supply.

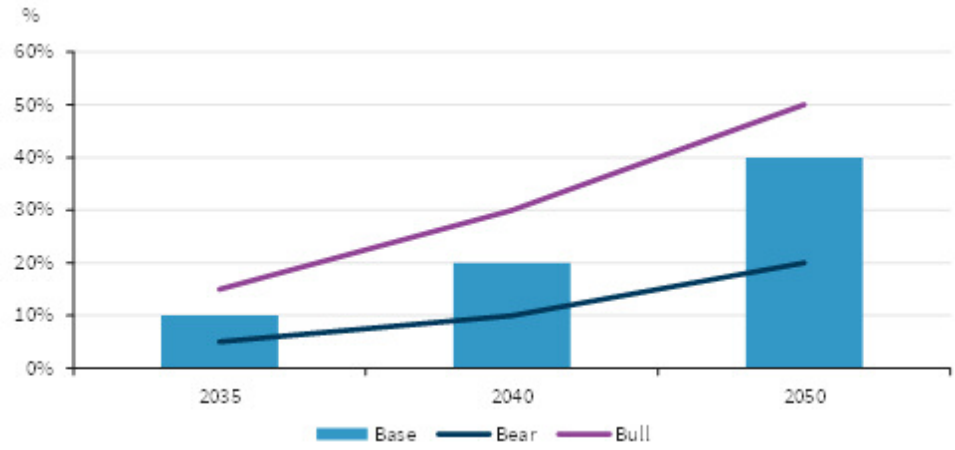
$450bn by 2040E – 20% of the global meat market

Through the next decade, global meat consumption is set to continue rising for two reasons: 1) rising global populations and 2) the 'Westernisation' of Asian diets. On the former, world population is set to grow at roughly 1% per year for the decade, leading to a total population of 8.5bn (based on UN population forecasts). This increase should drive a spike in food demand that will need to be met via higher production and sales. Regarding the 'Westernisation' of Asian diets, rapid economic development and globalisation over the last decade have pushed diets in the region more towards Western products such as beef and dairy. Together with rapid population growth, Asia should contribute the most towards rising meat sales. Interestingly enough, consumers surveyed in India and China were among the most willing to pay a premium for cultured meat, which, in our view, bodes well for the sector's growth potential – Figure 10.

Cultured meat can look to capitalise on this rising demand for meat and the growing concerns both for animal welfare and sustainability. Companies in the overall alternative meat space have marketed products as the non-compromising solution – consumers can still enjoy meat as they always have, but make a sustainable and ethical choice at the same time. Additionally, several large food suppliers have made sizeable investments into cultured meat, such as Tyson Foods and Cargill. If these major companies pivot some production into cultured offerings, making them broadly available across the different channels, with a wide presence and affordability, we see scope for cultured meat's market share to increase sharply.

In our base case scenario, where we consider that cultured meat will reach a market share of 10% by 2035, 20% by 2040, and 40% by 2050, we expect support from different stakeholders: companies, consumers and government, private and public entities. A series of factors should be aligned for cultured meat products to be affordable, accessible and heavily promoted by different organisations. We consider that governments imposing higher taxes on animal meat – in an effort to reduce GHG – could help reduce the gap in prices vs. cultured meat; the measures to promote cutting GHG via electric vehicles are a clear example of how governments can foster innovation and more private initiatives to drive the growth of new technologies. Further investment by private entities is also needed to achieve lower costs, which could later be supported by economies of scale. **If production costs for cultured meat fall to levels unreachable by animal-based meat, the upside potential becomes higher, as depicted in our bull case scenario.**

FIGURE 5. **Cultured meat market share scenarios**



Source: Barclays Research estimates

Bull vs. bear scenario analysis

We are more bullish on cultured meat vs. plant-based meat as we consider that the flexibility in producing the former helps achieve a better product, faster. Technology and the lack of restrictions associated with using plant-based materials could help cultured meat adapt easily and cater to consumers' tastes, in our view. **While plant-based meat could reach a 10% market share sooner than cultured meat, we consider that it could be harder for plant-based meat products to reach the penetration that we forecast for cultured meat.**

On the other hand, we reflect in our bear case scenario the risks ahead; there are, in our view, 3 main roadblocks that could stop cultured meat from achieving our estimated market share. The first is regulatory blocks – Singapore is the only location in the world that allows the sale of cultured meat, with other countries either reviewing submitted products or developing regulatory standards. With the process taking at least 18-24 months, any bumps in the clearing process could cut out significant market time.

Second, higher prices could turn consumers away. If consumers are not willing to pay a higher price for cultured meat, the product will have a rough start until costs can compete with traditional methods. Finally, a lack of supply could hurt prices and market share. Production capabilities are relatively low, contributing to higher prices, and potentially limiting availability outside of upscale restaurants. Without a relevant presence in grocers, cultured meat could face an uphill battle to find a significant stake in the market.

CLOSER TO REALITY – HEADING TO SHOPS SOON

The industry has already delivered many successful prototypes for cultured products, but the ability to scale commercially and bring cultured to mainstream reality relies on three key factors: i) regulatory approval, ii) pricing & manufacturing efficiency and iii) consumer acceptance.

Many of the cultured meat companies have indicated they are hoping to launch further product prototypes in the next 12-24 months (pending regulatory approval), and our expectation is that we remain 5-10 years away from it being widely available in grocery stores. Based on our discussions with industry experts, we think it will likely take until 2030 for cultured meat to achieve price parity relative to conventional meat at commercial scale. In the interim, we envisage ongoing investments in production capacity, with the launch of 'hybrid' products being the fastest route to market to begin with (e.g. both cultured- and plant-based ingredients).

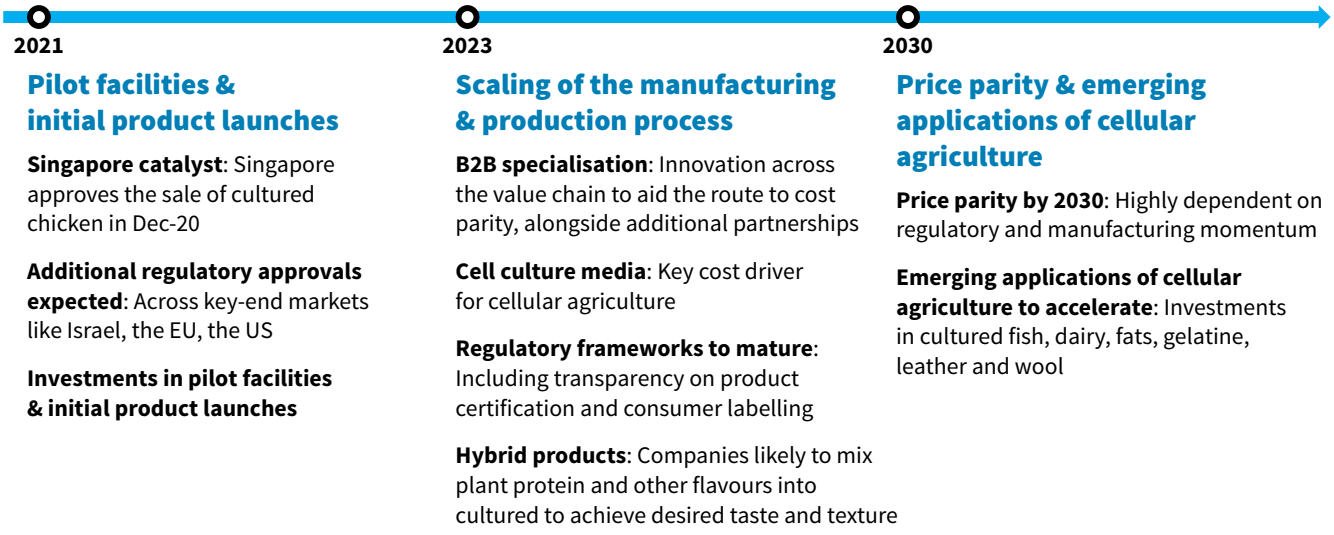
In this section, we outline how we see the timing and availability of cellular agriculture technology developing over the next 5-15 years (Figure 6).

- **Regulatory approval:** Following Singapore's approval of Eat Just's cultured chicken in December 2020, the regulatory landscape remains favourable, with upcoming catalysts to consider across key end-markets such as the US and EU. While our primary focus in this report is to consider the potential for cultured meat (beef, chicken, pork), we think the extended use of cellular agriculture to additional end-markets such as dairy and seafood is also relevant within the 2030 time-frame.
- **Pricing & manufacturing efficiency:** While the manufacturing process has advanced significantly in recent years, technical challenges remain as manufacturers launch pilot facilities ahead of commercial scale – Figure 8. Pricing has dropped significantly, with the cost of cell culture media being a key variable to consider. A range of B2B companies have emerged across the cultured meat technology stack, hoping to provide critical inputs and services to help commercialise end-products.
- **Consumer acceptance:** To better assess consumer attitudes and preferences towards cultured meat, we conducted a consumer survey (5,000 respondents in China, India, Brazil, the US, the UK) – Figure 10. Encouragingly, the results suggest that two-thirds of adults would consider purchasing cultured meat if it becomes commonly available. The environment, animal welfare and sustainability were the top 3 appeals for consumers, with the survey also highlighting the need to further raise consumer awareness.

Cultured meat roadmap: the road to price parity

Our roadmap considers both the availability and timing of cultured meat (Figure 6), with the latter being influenced primarily by regulatory approval. Many cultured manufacturers have indicated they are hoping to launch further product prototypes within the next 12-24 months, with mainstream availability to be influenced by whether manufacturing challenges can be addressed and whether consumer demand is sufficient to disrupt conventional meat consumption. The latter is key when considering how quickly cultured meat can move from being available only at high-end premium restaurants to begin with, to then becoming widely available at grocery stores at price parity.

FIGURE 6. **2030 cultured meat roadmap**



Source: Barclays Research

Variable 1: Regulatory approvals

As cultured products move closer to commercialisation globally, we have started to see many countries actively establishing regulatory pathways, with Singapore being the first country to approve the sale of cultured chicken in Dec-2020. We see this as a good sign for potential regulatory green lights in other countries over the years to come. Various regional hot-spots have emerged within the cultured meat landscape, including Japan, the US, the UK, Israel and Europe. The majority have used existing novel food regulation to assess cultured products, but some are establishing new frameworks tailored to cultured meat to ensure the adoption of a rigorous food-safety process. China has yet to formally announce its regulatory stance on cultured meat.

Asia

- **Singapore:** Assessing applications on a case-by-case basis, the Singapore Food Agency (SFA) has published guidance on its requirements for the safety assessment of novel foods. This includes specific requirements on cultured meat products. In Dec-2020, Singapore approved the sale of Eat Just cultured chicken nuggets, becoming the first country to approve a cultured meat product. In 2H21, Singapore also approved the first industrial manufacturing platform for Singapore-based Esco Aster. This means other companies will be able to use the facility to manufacture cultured product for commercial market launch as well.

- **Japan:** Certain production methods of cultured meat already fall within existing regulation; however, the country is working on developing a specific regulatory framework to ensure food safety and consumer acceptance. There are two main bodies collaborating to create better industry standards: the Food Tech Research Group (launched in April 2020 by the Ministry of Agriculture, Forestry and Fisheries) with more than 100 companies, and the Japan Association for Cellular Agriculture (JACA) to create rules for cultured meat, egg and dairy products.

- **China:** There is no current regulatory framework for cultured meat. However, the issue has been raised in the National People's Congress. CPPCC National Committee Member Sun Baoguo raised the issue in June 2020, proposing to follow the EU's precedent and classify cultured meat as a 'novel food'. This designation would place it under the country's current novel food legislation. Sun also discussed using the US's food monitoring framework to ensure consistent safety.

- **Qatar:** In March 2021, Eat Just received $200 million funding led by Qatar's sovereign wealth fund (Qatar Investment Authority) as part of a partnership with Doha Venture Capital and Qatar Free Zone Authority (QFZA) to finance the construction of the first cultured meat facility in the Middle East. According to Eat Just, pending regulatory approval (expected soon), the facility in Qatar will initially produce cultured chicken.

North America

- **United States:** The US regulators have been keen to develop a predictable regulatory framework for cultured meat since announcing their intention to implement a joint regulatory framework in 2019. The US Food and Drugs Administration (FDA) will oversee the earlier stages of production (cell collection, cell banks, cell proliferation and differentiation, including inspections of cell banks and culturing facilities), and the USDA will oversee the later stages (harvesting/post-harvesting facilities and product labelling). Various working groups have been launched to refine the technical details. Labelling has proven to be a contentious issue at the state level, following the US Cattlemen's Association submitting a petition in 2018 to the USDA regarding beef labelling requirements and the use of the term 'meat'.

- **Canada:** Cultured meat and seafood are characterised as 'novel foods', requiring evidence that the product is safe for consumption including nutritional composition, molecular characterisation, toxicology and allergenicity. For cultured meat using genetic engineering techniques, additional information will be required. In general, a cultured product will be marketed if it passes the novel food assessment process, a premarket assessment for animal feed and an environmental assessment based on the New Substances Notification regulation.

Europe

- **European Union:** The Novel Foods Regulation is responsible for authorisations of cultured meat products; however, as in Canada, if genetic engineering is used in the production process, regulation on genetically modified food will apply instead. The novel food regulation requires the European Food Safety Authority (EFSA) to conduct a risk assessment on the safety and nutritional profile of a product. If a positive review is issued, a final agreement from all EU member states is needed for market approval. The GFI estimates that the length of the entire novel food approval process for cultured meat in the EU could be from 18 months up to three years.

- **United Kingdom:** Cultured companies will need to receive authorisation from the UK Food Standards Agency (FSA). After Brexit, the UK maintains the same threshold for risk assessment of novel food and genetically modified food as the EU; however, the approval

process in the UK might be expected to be faster than that in the EU, given that final approval will be granted by government ministers as opposed to representatives from individual member states. With regard to timing, a recent study by Oxford Economics suggested the cultured meat industry could support up to £2.1bn of the country's GDP when considering its entire associated value chain. However, this would require the FSA to give approval to the commercial sale of cultured proteins by the end of 2022 to keep up with developments elsewhere internationally.

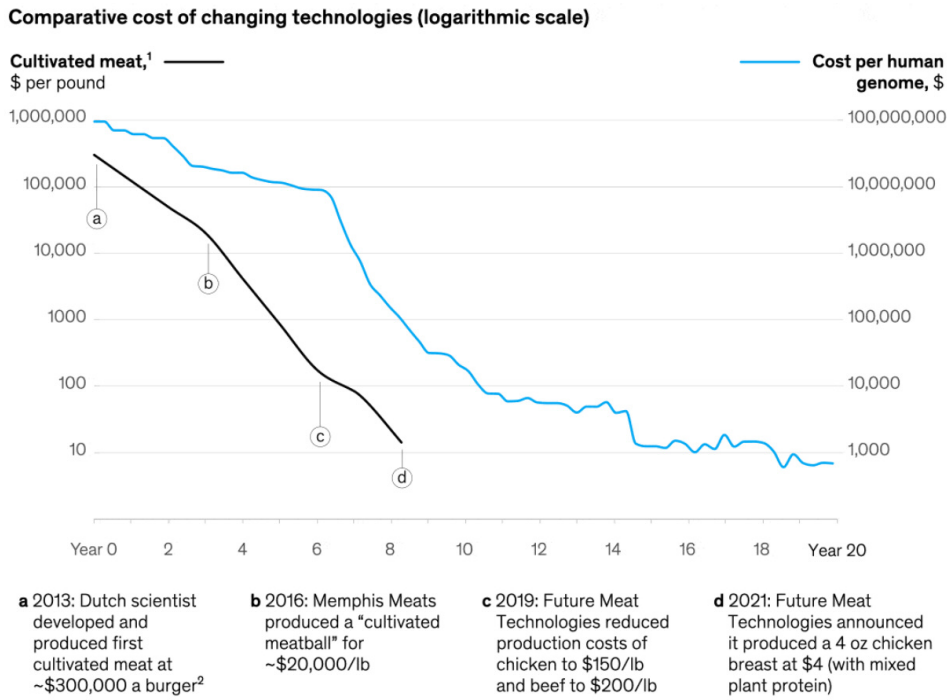
Variable 2: Pricing & manufacturing efficiency

The underlying manufacturing process has made significant strides in recent years, supporting a decline in the pricing of cultured meat – Figure 7. However, technical and economic challenges remain as the industry further invests in ramping up commercial production to achieve price parity and increase yields. While we acknowledge there are many factors influencing our expectation that cultured meat could be cost-competitive across multiple forms of slaughtered animal meat by 2030, the higher cost today is a result of pilot-scale production and remaining technical challenges relating to chemical, biological and mechanical engineering factors.

Cultured meats to reach price parity by 2030E…

The price of cultured meat has fallen significantly from the $300,000 spent in 2013 to create the world's first cultured burger by the Dutch scientist Mark Post at Maastricht University. If costs were to follow the same trajectory as that of human genome sequencing (for which costs, on average, dropped by 45% annually over 2001-21), cultured meat could achieve parity with conventional meat by 2030 according to McKinsey – Figure 7.

FIGURE 7. **Cost of cultured meat has fallen at a faster rate than genome sequencing…**



Note: Cultured meat year 0 = 2013, Human genome year = 2001. 1. Cultured meat curve smoothed out to show straight line between key data points. 2. Based on €250,000 cost.
Source: Barclays Research, McKinsey, National Human Genome Research Institute.

Encouragingly, in 2021 Future Meat Technologies (cultured chicken brand) announced that the company has been able to reduce its production costs by almost 50% and is now able to create 110g of cultured chicken for under $4. The CEO predicts the cost will drop to below $2 in the

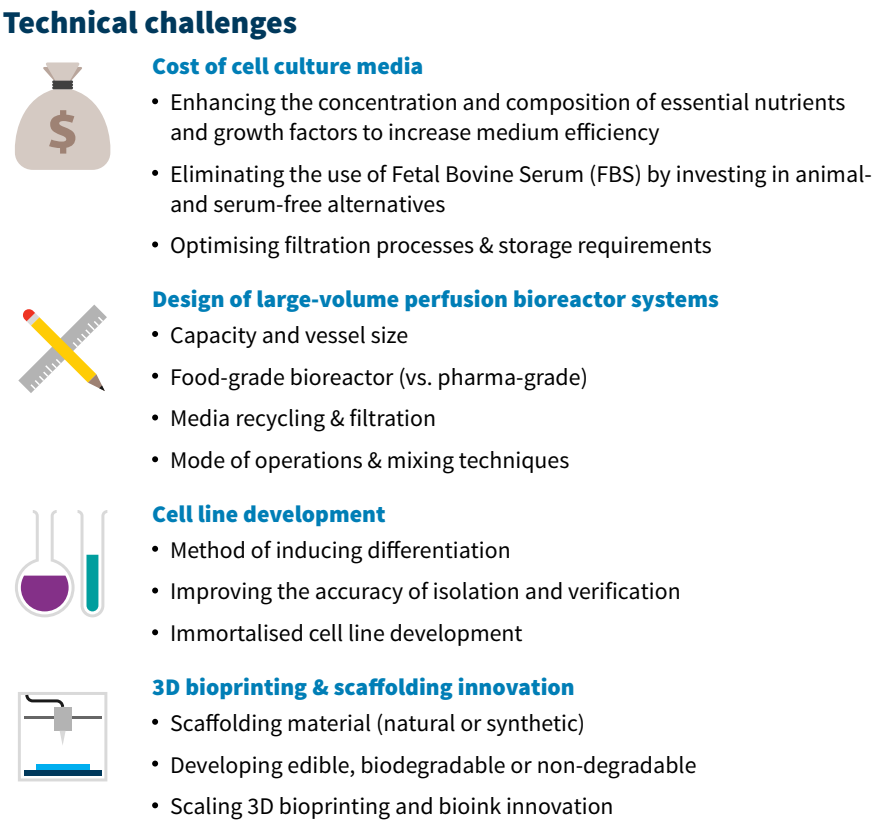
next 12-18 months, with the expectation that it will be able to launch a product in the US in the next 18 months that will have a commercially viable price, pending regulatory approval.

A recent study by CE Delft (supported by the GFI) models a theoretical large-scale cultured meat production facility and suggests that, by 2030, the cost of cultured meat at scale could drop to $5.66 per kg. The study was informed by data contributed from over 15 companies across the supply chain, including 5 cultured meat manufacturers. To realise this competitive production cost, relaxed payback periods and a menu of financing strategies and incentives would be needed to lower the cost burden on cultured meat manufacturers and enable them to install new infrastructure at high rates. To reduce the cost of production even further, there is a need to consider the various technical challenges across the manufacturing process.

…however, technical challenges remain

Despite there being a variety of expectations relating to the pricing of cultured meat, the consistent thread across them all remains the need for additional manufacturing efficiency and increased commercial scale. As production facilities improve in design and grow in scale, the required inputs and end-pricing will likely also come down. Our discussions with industry experts suggest there are a handful of technical challenges that are sizeable enough to materially move the dial going forwards. These include the pricing and availability of cell culture media, the design of large-volume perfusion bioreactor systems, cell line engineering and 3D bioprinting – Figure 8.

FIGURE 8. **Manufacturing of cultured meat: technical challenges & emerging solutions**



Source: Barclays Research

1) Cost of cell culture media (growth factors make up 99% of costs)

Cell culture media are comprised of a combination of compounds and nutrients designed to support cellular growth. The typical composition of a culture medium includes: 1) the basal medium, which contains the essential nutrients (glucose, salts, vitamins, etc.) and 2) growth

factors. Cell culture media represent ~99% of baseline production costs, with recombinant proteins, in particular Fetal Bovine Serum (FBS), and growth factors being the dominant cost drivers.

Historically, the industry has used FBS, but many argue against its use, given the concerns relating to food safety and animal sourcing, alongside the costs given its limited supply. Today, companies are opting for serum-free cell culture media. Mosa Meat, for example, announced in July 2020 that it has reduced its medium costs by 88x, with the main cost-saving driver being elimination of FBS. While the availability of serum-free media has considerably improved in recent years, the industry is now trying to replace growth factors with plant-based alternatives and exploring technology that would allow cell culture media to be recycled or adapted to further accelerate cell proliferation.

2) Design of large-volume perfusion bioreactor systems

The purpose of a bioreactor is to generate a controlled environment suitable for the management of the animal cells, with the two sequential cell culture phases of proliferation and differentiation forming the foundation of the overall design. In the expansion phase, the desire is to maximise biomass yields and minimise by-product yields, while also considering the total protein yield (*Allan et al, 2019*). Growing cultured meat at scale will require the use of bioreactors in volumes up to or beyond several thousands of litres, with a variety of methods being piloted in the market today.

Currently, no large-scale bioreactor exists that would accommodate commercial scaling for cultured meat. Research is currently investigating how to scale contemporary bioreactors and the extent to which the design parameters relating to cell biology and engineering optimisation impact the roadmap to scaling cultured meat and market readiness. A handful of companies in 2021 have started to provide additional colour on their production capabilities, including UPSIDE Food's announcement of a US EPIC facility with a future capacity of 400,000 pounds of cultured meat per year (refer to the UPSIDE Foods company profile for further information).

Based on our discussions with industry experts, we see four key challenges to consider when assessing the design of bioreactors at commercial scale: i) **Mode of operation** – how to feed the cells (fed-batch vs. continuous); ii) **Shear stress & mixing techniques** – how to provide a well-mixed environment using mechanical or hydraulic agitation (stirred vs. rocking), iii) **Vessel size** – how to minimise cell damage when calculating cell density & production yields and iv) **Sterilisation & seal cleaning mechanisms** – how to meet food-grade standards on product hygiene.

3) Cell line development – long-term replication

While many cell types can be used as the starting point for cultured meat production, all will vary in respect to underlying growth rates, differentiation capacity and stability characteristics. More research needs to be done with regards to which cell types are best suited for each type of product, as well as which would perform better for large-scale production and long-term replication. We see the industry mainly focusing on two challenges: i) improving access to cells via cell banks and ii) enhancing cell line stability and reducing the possibility of genetic drift. A possible solution would be cell engineering, as it could help create optimal cell lines that would be suitable for large-scale cultured meat production; however, the industry appears divided, with some companies stating they will not use genetic engineering for ethical reasons and others having filed several patents hoping regulation will also evolve to cover genetically engineered cultured meat products.

4) 3D bioprinting & scaffold innovation

The production of fully structured cultured meat products such as cultured chicken breast or premium steaks will depend on the technological advances of scaffolding and 3D bioprinting.

Innovation to date has focused largely on trialling different scaffold materials, given they essentially provide the support cells need to form shapes and differentiate into muscle, fat and other tissues. Some scaffolds are being designed to be biodegradable, so by the time the product is ready they are not present, while others are designed to represent a significant part of the final product. Plant-based scaffolds seem to be one of the most prominent areas of development as they could reduce costs when compared to animal-based or synthetic scaffolds. We also expect to see advances in the development of different food-grade bioinks and bioprinting methods better suited for large-scale production (i.e. extrusion, droplet-based, laser-assisted).

FIGURE 9. Case Study: MeaTech & 3D bioprinting

Case Study: MeaTech & 3D bioprinting

MeaTech (NASDAQ: MITC) develops 3D printing techniques to achieve texture and appearance of meat, mainly focusing on chicken and beef. In 2020, the company announced the success of 'Project Carpaccio', after having successfully printed a 100g thin steak layer. The milestone for the company required having differentiated stem cells into muscle and fat and producing an efficient bioink that combined the right proportions of both muscle and fat cells to simulate traditional meat.

MeaTech acquired in December 2020 cultured fat producer Peace of Meat to leverage their 3D bioprinting capabilities with Peace of Meat's bioreactor technology, aiming to launch the first hybrid product (plant-based with cultured fat) in early 2022. In June 2021 MeaTech filed a patent for their new bioprinting method claiming it will allow the company to produce premium and thicker products by achieving a higher control of the bioink during the multi-layered process and increasing printing speed.

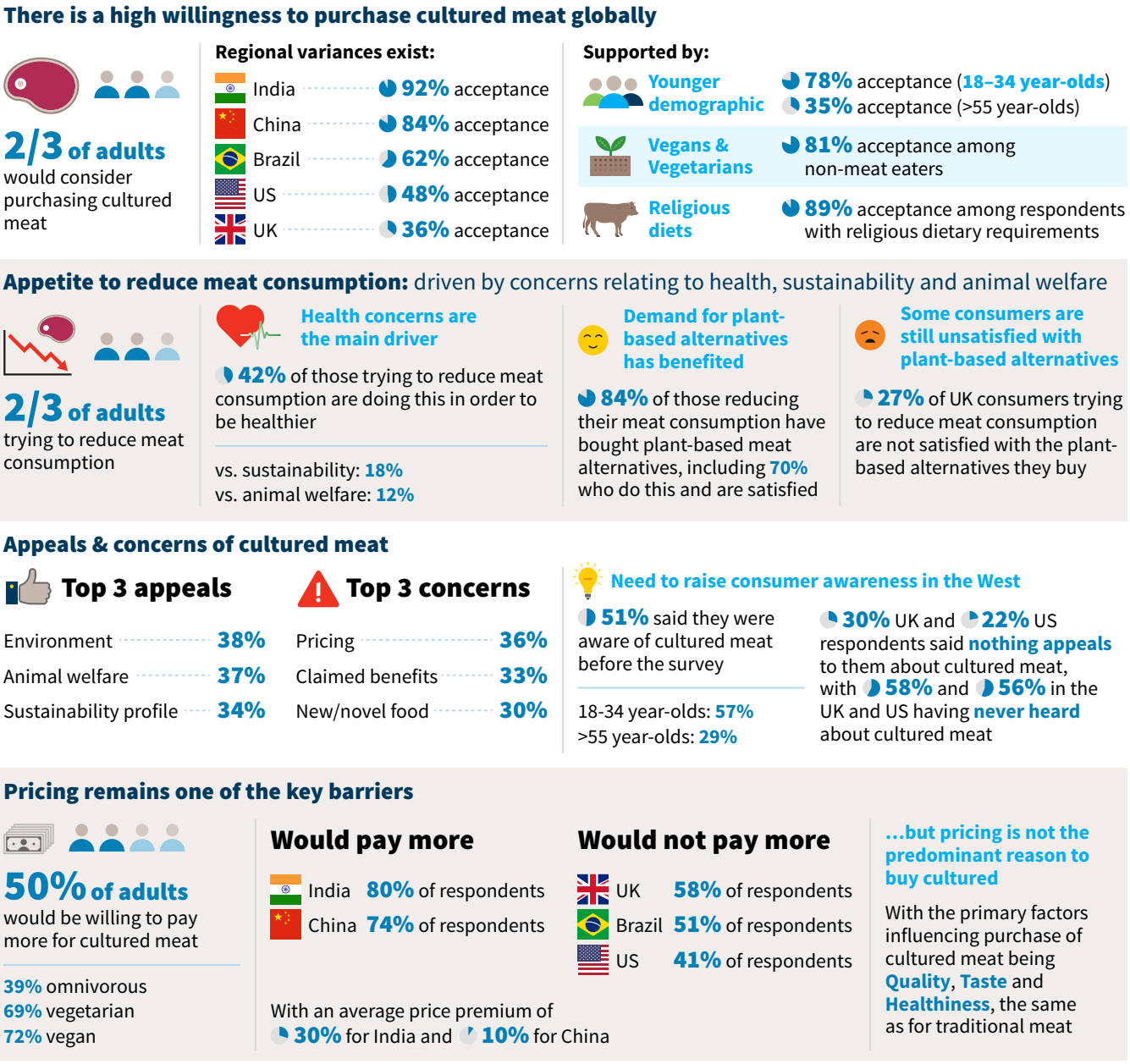
Source: Barclays Research

Variable 3: Consumer acceptance (Barclays Global Survey)

To understand consumer preferences and attitudes to cultured meat, we conducted a survey of c.5000 adults in August 2021 across five countries (China, India, Brazil, the US, the UK). Our analysis of the survey results highlighted there is an appetite for cultured meat at the global level. Encouragingly, by region, India and China show the highest consumer acceptance, while globally the younger demographic seems to be driving the consumer push.

In Figure 10, we summarise the key results – before outlining in further detail additional insights across key areas such as i) willingness to buy, ii) sustainability and iii) pricing.

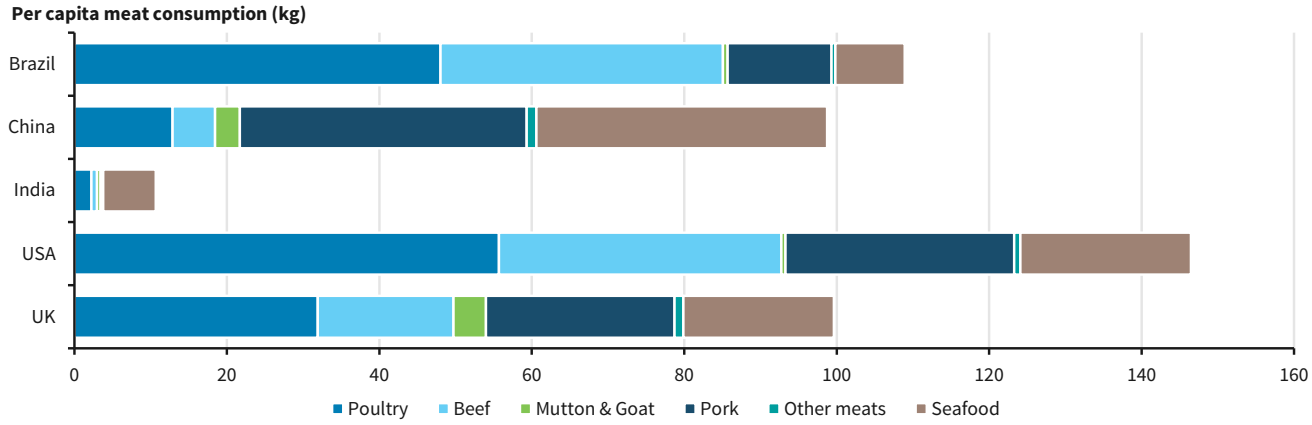
FIGURE 10. **Barclays Consumer Survey on Cultured Meat – Key takeaways**



Source: Barclays Research

To establish a benchmark of how perceptions towards meat and cultured meat differ across geographies, as seen in the survey results, we first briefly assess how meat consumption per capita differs materially across these countries. While consumers in Brazil, the US and the UK rely heavily on poultry and beef, consumers in China are more reliant on pork and seafood. In India, where per capita meat consumption lags other countries, seafood is the most consumed meat.

FIGURE 11. **Per capita meat consumption breakdown**



Source: Our World in Meat, FAO, Barclays Research. 2017 data

Appetite to reduce meat consumption

- **Omnivores (51%) and flexitarians (24%) continue to make up the majority:** Half of adults (51%) consider themselves omnivores and eat meat, fish and plants, with a further 24% saying they are 'flexitarians' who eat meat occasionally but not as the main part of their diet. Only 15% said they do not eat meat in any capacity.

- **Two-thirds are trying to reduce the meat they consume:** Two-thirds of adults (66%) who eat meat or fish say they are reducing the amount of meat they consume, including a third (34%) who are actively trying to, and a further third (32%) who are occasionally doing so. Those in the UK (49%) and the US (47%) are most likely not to be trying to cut down on their meat intake (vs. Brazil 38%, China 18% and India 12%). Despite having some of the largest per capita intakes, UK and US consumers appear less likely to cut down their meat intake vs. India, where per capita meat consumption is significantly lower on a relative basis.

- **Health was the primary reason for reducing meat consumption:** Among those who are reducing how much meat they eat, health was the primary reason across all countries, with over two-fifths (42%) saying they are doing this in order to be healthier. Concern over sustainability and the environment (18%) was the next most cited reason, followed by animal welfare (12%).

- **UK consumers are the least satisfied with plant-based alternatives:** Over four-fifths (84%) of those reducing their meat consumption have bought plant-based meat alternatives, such as soya, including 70% who do this and are satisfied with it. Those in the UK are least satisfied with the plant-based alternatives they buy (27%), followed by those in Brazil (16%), while 94% of those in India buy and are happy with the meat substitutes they buy.

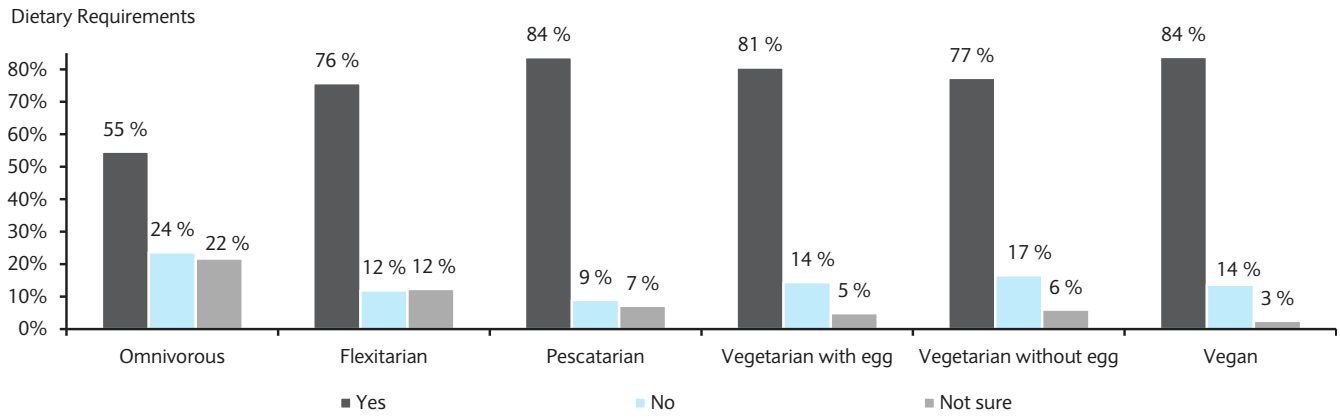
Willingness to try cultured meats

- **Two-thirds of adults would consider purchasing cultured meat if it became commonly available:** This includes 40% who would view it as a substitute for traditional meat, and 25% who would buy it in addition to traditional meat. In comparison, a fifth (19%) would

not consider this and a further 16% are not sure whether they would buy cultured meat.

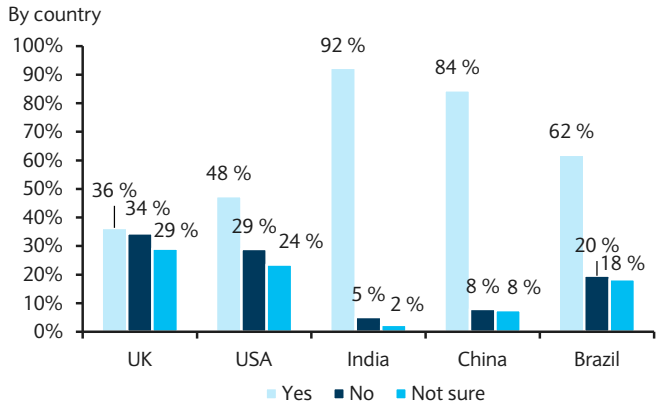
- **Surprisingly, vegetarians and vegans also keen to try:** Survey results show that 81% of non-meat-eaters would be willing to purchase cultured meat if it became widely available, representing a substantial opportunity for this market. Those identifying themselves as vegetarians and vegans represented 15% of the total number of c.5,000 respondents.
- **India and China have the highest consumer acceptance:** Those in India are most likely to consider cultured meat, with nine in ten (92%) mentioning that they would purchase it, compared to just over a third of those in the UK (36%). Interestingly, India and China also show the highest level of respondents currently attempting to reduce meat consumption (88% and 82%, respectively), in contrast to the UK (51%), US (53%) and Brazil (62%) where these levels are significantly lower. Globally, the main reason for lowering meat consumption is health. While India and China already have the lowest per capita meat consumption across our surveyed countries, and the lowest beef penetration coupled with the highest willingness to purchase cultured meat, the opportunity to reduce the high meat consumption in Brazil, the UK and the US remains.
- **Unsurprisingly, the younger demographic is driving the consumer push for cultured meat:** Young people are also more likely to consider buying cultured meat, with over three-quarters of 18-34-year-olds (78%) saying they would, compared to just over a third (35%) of over-55s. However, 52% of respondents aged 35-54 said they would purchase cultured meat as substitute to traditional meat (vs. 44% 18-34-year-olds), with a further 20% saying they would purchase it in addition to traditional meat.
- **Cultured meat seems to be accepted within some religious dietary requirements:** Among the respondents that follow a religious dietary requirement, 89% said they would purchase cultured meat if it became widely available. We view it as encouraging that religion seems not to be a constraint on the adoption of cultured meat in the countries included within our survey methodology.
- **Consumers look for the same factors when comparing traditional meat with cultured:** Quality, taste and healthiness are the top factors that would influence consumers to purchase cultured meat. However, we see the importance of sustainability rising among the younger demographic (18-34), with 30% placing sustainability/environment as a top 3 factor (vs. 15% for those aged 55+).

FIGURE 12. **81% of non-meat eaters would consider purchasing cultured meat**



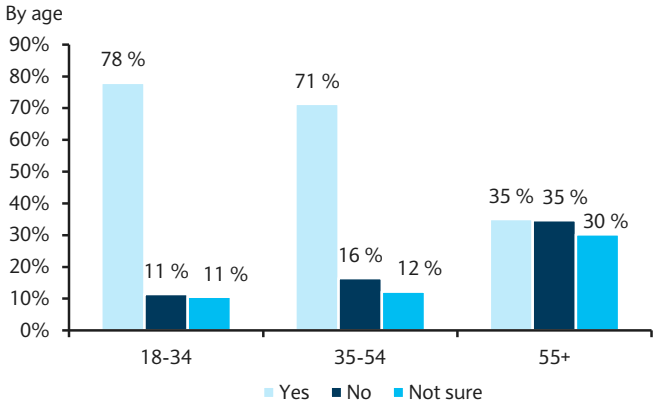
Source: Barclays Research, Opinium survey of 5,012 adults on cultured meat. Question: Would you consider purchasing cultured meat products if they were commonly available?

FIGURE 13. India and China are the regions with highest consumer acceptance



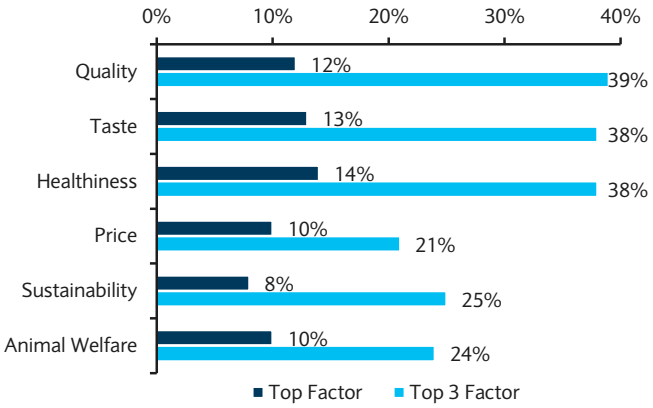
Source: Barclays Research, Opinium survey of 5,012 adults on cultured meat.
Question: Would you consider purchasing cultured meat products if they were commonly available?

FIGURE 14. Young people are more likely to consider buying cultured meat



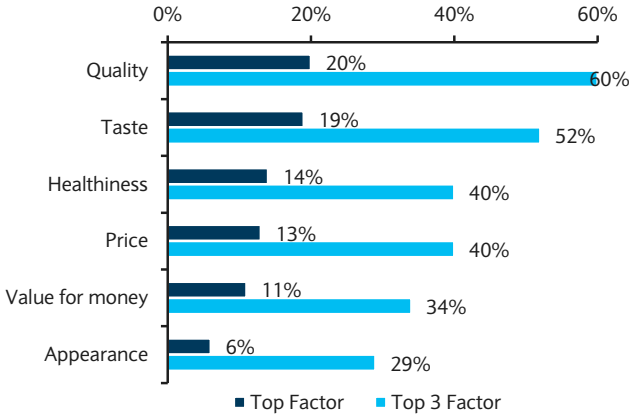
Source: Barclays Research, Opinium survey of 5,012 adults on cultured meat.
Question: Would you consider purchasing cultured meat products if they were commonly available?

FIGURE 15. Top 3 factors that would influence the decision to purchase cultured meat



Source: Barclays Research, Opinium survey of 5,012 adults on cultured meat.
Question: What top 3 factors would influence your decision to purchase cultured meat?

FIGURE 16. Top 3 factors that influence the decision to purchase meat



Source: Barclays Research, Opinium survey of 5,012 adults on cultured meat.
Question: When selecting meat to eat, what top 3 factors influence your decision the most?

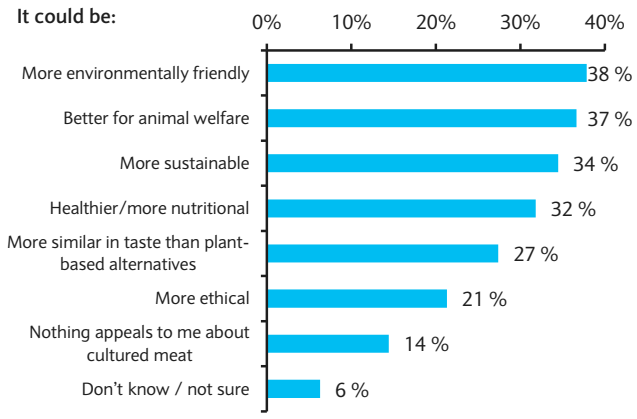
Further consumer awareness is needed while consumer concerns remain

- **Consumer attraction – environment, animal welfare and sustainability:** The environment and animal welfare were the main appeals of cultured meat, with nearly two-fifths (38% and 37% respectively) saying this was one of their top 3 draws to it. This was followed by this meat substitute being more sustainable (34%) and belief it would be healthier or more nutritional (32%). One in seven (14%), though, say nothing appeals to them about cultured meat, with this figure being notably higher in the UK (30%).

- **Consumer concerns – worries over pricing and claimed benefits remain:** By contrast, cost and doubts over the claimed benefits of synthetic food were the largest concerns, with 36% saying that one of their top 3 issues was that they imagined cultured meat would be expensive and 33% being concerned that claims over the perceived benefits of these products may be untrue. In addition, 3 in 10 respondents (30%) indicated they were concerned about cultured meat being an unproven food type.

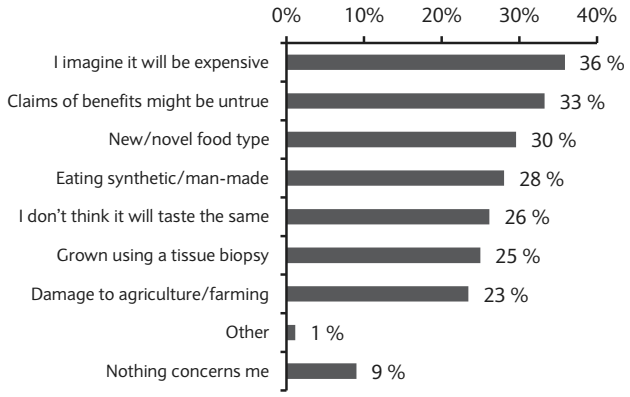
- **Awareness of cultured meat needs to be raised in the West:** 30% of British respondents and 22% of US respondents said nothing appeals to them about cultured meat. Surprisingly, more than half of the respondents in each country (58% and 56% in the UK and US, respectively) had never heard about the concept before, indicating there is still a lot to do from the industry to raise consumer awareness. Knowledge of cultured meat is significantly different in the East, with 86% of Indian respondents and 54% of Chinese respondents having heard about this term before, which we attribute to their regional location given the level of investment activity in the alternative meat space in Asia.

FIGURE 17. **Appeals of cultured meat**



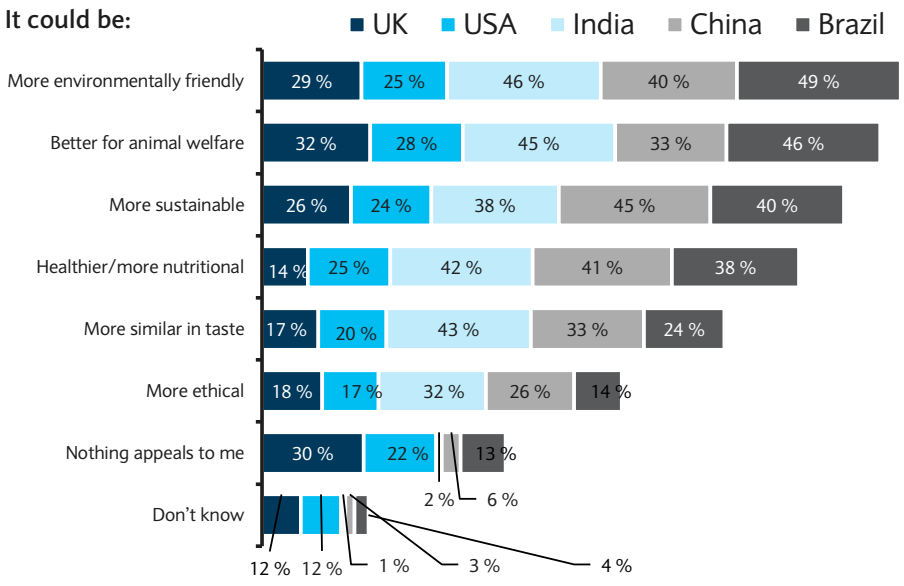
Source: Barclays Research, Opinium survey of 5,012 adults on cultured meat. Question: What appeals to you the most about cultured meat, if anything? Please select up to 3 responses.

FIGURE 18. **Concerns over cultured meat**



Source: Barclays Research, Opinium survey of 5,012 adults on cultured meat. Question: What concerns do you have about cultured meat, if anything? Please select up to 3 responses.

FIGURE 19. **Appeals of cultured meat broken down by country**



Source: Barclays Research, Opinium survey of 5,012 adults on cultured meat. Question: What appeals to you the most about cultured meat, if anything? Please select up to 3 responses.

Pricing remains a key factor, but is not the predominant factor

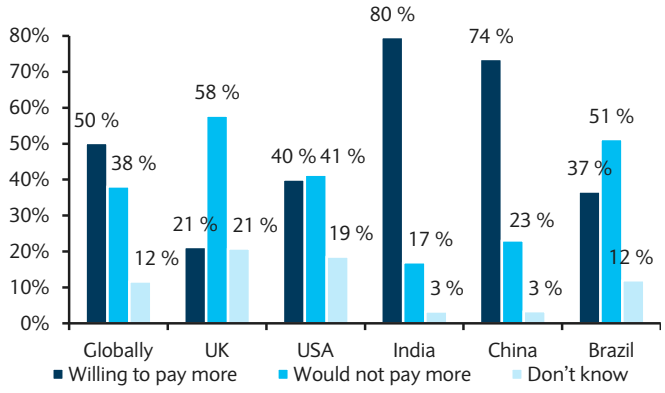
- **Pricing remains one of the key barriers:** Nearly two-fifths of adults (38%) would not be willing to pay more for cultured meat, including nearly a fifth (22%) who would pay the same amount and 16% who would only pay less. In comparison, 15% would be willing to pay up to 5% more than for traditional meat with a further 15% willing to pay between 6% and 10% more.

- **Price elasticity varies by region, with only India and China willing to pay more for cultured meat:** Those in India and China would be most willing to pay more for the substitute (80% and 74%, respectively), along with those aged 18-34 (63%).

- **Price parity will be important to win consumers in the West:** While the majority of respondents in India and China would be willing to pay a premium for cultured meat – an average Indian adult would pay up to 30% more for it and a Chinese adult up to 10% more – UK, US and Brazilian respondents said they would only pay the same or less. This could be related to the fact that consumers in these countries are not as willing as consumers in India and China to reduce their meat intake.

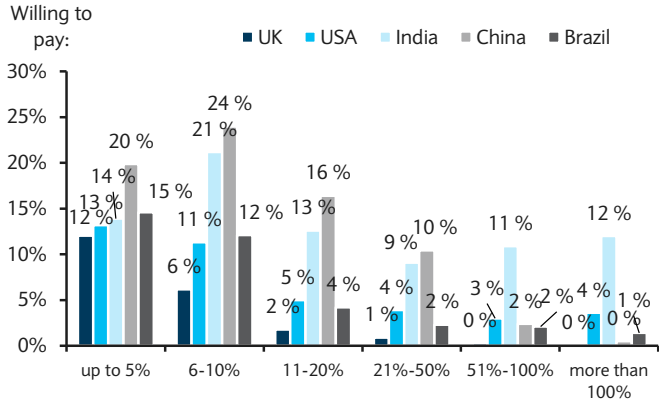
- **Pricing is not the predominant reason that would influence people to buy cultured:** However, price is not the predominant reason that would influence people to buy such a product, with the most common top 3 factors being quality (cited by 39% of respondents, with 12% citing it as their top factor), taste and healthiness (both cited by 38% of respondents as a top 3 factor). By region, 58% of Chinese respondents placed healthiness as a top 3 factor, while only 22% in the UK placed it as top 3. A greater number of adults ranked taste and healthiness as the top factors that would influence their decision to purchase cultured meat (14% compared to 13% for taste).

FIGURE 20. **Prince-sensitivity of cultured meat**



Source: Barclays Research, Opinium survey of 5,012 adults on cultured meat. Globally refers to our entire survey sample. Question: How much more, if anything, would you be willing to pay for cultured meat than you would for similar traditional meat products from animals?

FIGURE 21. **Price premium consumers are willing to pay for cultured meat vs. traditional meat**



Source: Barclays Research, Opinium survey of 5,012 adults on cultured meat. Question: How much more, if anything, would you be willing to pay for cultured meat than you would for similar traditional meat products from animals?

THEMATIC WILDCARDS

While investment will likely remain focused on the scaling of cultured meat, we also put forward 3 thematic wildcards for investors to consider when assessing potential long-term upside/downside scenarios. These include wildcards that have the potential to broaden the application of cellular agricultural technology to other end-markets, and on the flipside a wildcard that may reduce the long-term market opportunity if sustainability credentials fail to materialise.

1. **Fish, dairy & fats:** To what extent can cellular agriculture be applied to other animal products and how quickly?
2. **Specialisation vs. vertical integration:** To what extent will companies across the value chain specialise (e.g. provider of cell culture media, cell lines, scaffolding), pursue vertical integration or enter marquee partnerships?
3. **Environmental claims:** To what extent will cellular agriculture be better for society in terms of sustainability, given the industry has yet to achieve commercial production?

Wildcard 1: Cellular agriculture tech – fish, dairy & fats

Given the complexity in creating cultured meat, many cultured technology companies have been keen to leverage their IP to cover other animal products including seafood, dairy and fats. As one of our thematic wildcards, we think it likely that some of these products will become a mainstream reality ahead of traditional meat types such as beef, though the market will remain smaller in comparison given the current regulatory focus on cattle. Other areas of investment include gelatin, egg and wool, though cell culture in such areas remains in its relative infancy alongside the growth in precision fermentation within dairy.

Cultured seafood – the next catch of the day?

In the race to meet consumer demand, aquaculture (farmed seafood production) has emerged as one of the fastest-growing areas within food production. However, this pressure has resulted in the industry adopting a number of unsustainable practices, which could threaten future expansion and further harm biodiversity. These threats have manifested in the form of declining fish health, a rise in antimicrobial resistance, fish feed pricing shocks and increased cases of food fraud – all of which have negative financial and ESG implications – *Sustainable & Thematic Investing – Sustainable Seafood: What's the Catch?* (4 March 2021).

To satisfy growing demand for fish without the environmental issues of the fishing industry, seafood companies have responded by investing in plant-based alternatives. This includes Thai Union's (public, not covered) upcoming plant-based shrimp and Tyson Foods' investment in plant-based shellfish company New Wave Foods in 2019. While the science for propagating fish cells is relatively new (vs. mammalian cell culturing), companies across the value chain have also been keen to consider whether cellular technology can be deployed within the seafood industry. A range of private companies exist today focusing on cellular aquaculture, including BlueNalu, Wildtype, Avant Meats and Finless Foods, and partnerships with seafood companies are already emerging. Nomad Foods (NOMD), parent company of frozen food brands Bird Eye and Aunt Bessie's, partnered with BlueNalu in 2021 to explore bringing cultured seafood products to Europe (refer to the US Foods sector implications for further information).

According to the Good Food Institute, cultured seafood could reach the market before cultured meat, given its various technical advantages. For example, cultured seafood can grow in lower temperatures, can grow in low-oxygen conditions and is quicker to produce given its simpler structure relative to muscle tissues found in many land-based animals. Such advantages have

supported rapid market growth, with more than $80m invested in alternative seafood companies in 2020, almost 3x the amount invested in 2019.

FIGURE 22. **Private disruptors: BlueNalu, Wildtype, Finless Foods, Avant Meats**

Case Study: Private disruptors: BlueNalu, Wildtype, Finless Foods, Avant Meats

BlueNalu: BlueNalu: Based in San Diego, BlueNalu is a cellular aquaculture company that has raised over $85m in total funding since 2017. The company is currently building a pilot plant at a 40,000 square foot facility, hoping to get its first product (mahi mahi) into a small number of US restaurants by 2022, pending FDA approval. BlueNalu can proliferate stable cell lines for multiple species, including red snapper, yellowtail amberjack and bluefin tuna. Given that the texture and structure of many seafood products is different from beef steaks, BlueNalu does not use scaffolding in the manufacturing process as the desired shape is achieved using 3D printing. The company also does not use genetic modification and is able to grow cells without Fetal Bovine Serum.

Wildtype: Based in San Francisco, Wildtype is focused primarily on 'sushi-grade' cultured salmon. In 2021, Wildtype announced the opening of its first operational pilot plant, which it expects to produce upwards of 200,000 pounds of cultured seafood per year when at maximum capacity. The cells are harvested from the bioreactor and seeded into plant-based structures, where they are guided to become salmon cuts.

Other players within the cultured seafood space include Finless Foods (US), Avant Meats (China), Shiok Meats (Singapore) and ArtMeat (Russia).

Source: Barclays Research

Cultured dairy – an alternative route alongside precision fermentation

Another area of application is within the dairy industry, where various alternative methods of production are being explored including cultured and precision fermentation-based technologies. Compared to cultured meat and seafood, cultured dairy technology will likely take longer to become a commercial mainstream reality, in our view, given the regulatory momentum is less advanced. Relevant products include milk components, such as whey, casin proteins, lipids and lactose.

A key player within this space is BioMilk (public, not covered). Based in Israel, BioMilk aims to produce milk that approximates the composition of commercial cow milk, free of synthetic or plant additives, and with lower hormone and antibiotics content than the traditional product. In July 2021, the company received R&D funding from Coca Cola Israel to expedite the arrival on the market of products based on cultured milk. Refer to our company profile (Figure 31) on BioMilk for further information. Other notable players in this space include, TurtleTree Labs (Singapore) and Biomilq (US).

Cultured fats – a solution to the plant-based sensory gap?

Using cultured animal fat in a plant-based product has the potential to minimise the number of binding agents, flavours and other ingredients traditionally used in the segment. Cultured fat is not vegan, given the fat is produced by growing animal fat cells in a nutrient solution. Based in Belgium, Peace of Meat is a cultured fat producer that is a subsidiary of the cultured meat provider MeaTech 3D. Peace of Meat has developed a proprietary, stem-cultured bioreactor technology for cultivating animal fats from chicken and ducks, without harming animals.

The company believes there is a strong incentive for makers of plant-based meat to integrate cultured fat into their products, given it has potential to alleviate the number one concern associated with plant-based protein: taste. According to a survey of 50 plant-based companies conducted by Peace of Meat, 58% agreed they would be happy to include cultured material in their plant-based matrices. Peace of Meat expects to have a product range commercially available in 2022, which will likely be at a premium price to begin with.

Other notable players include Cubiq Foods, which makes omega-3 fatty acids cultured from duck cells (Spain), Mission Barns (US) and Hoxton Farms (UK).

Wildcard 2: Supply chain specialisation & marquee partnerships

The vast majority of companies within the cultured meat industry have specialised in particular types of meat, with cultured seafood producers in particular working on vertically integrated systems. With increased maturity, it is likely we will also see more companies emerge hoping to serve the cultured meat industry as a core part of their business (e.g. B2B companies supplying cell culture medium or bioreactors). To help illustrate, a variety of companies are focused on providing low-cost, serum-free cell culture media or media ingredients, such as growth factors, in the cultured meat field (refer to our company landscape, Figure 25, for a full list).

In our view, specialisation of this nature will further support industry scale and lead to additional entry points across the value chain (Figure 23), alongside ongoing industry consolidation and marquee partnerships. According to the Good Food Institute, B2B activity will be a valuable force multiplier for the industry, as such services and expertise will benefit multiple clients rather than staying siloed in a single company.

FIGURE 23. **Multiple entry points for B2B specialisation across the value chain**

Cell sourcing & cell line development	Cell culture media	Bioreactors	Scaffolding
Stable storage & shipping	Growth factor engineering & production	Cell harvesting	3D printing & photopolymerisation
Cell banking, maintenance & verification	Sterilisation & certification	IoT sensors for adaptive control & in-line monitoring	Tunable hydrogels & self-directed architecture
Non-GM, footprint-free immortalisation	Custom formulation	Media recycling & filtration	Biodegradable materials
Novel/exotic cell line isolation	Differentiation triggers	Control systems & software	
Automated image analysis for cell screening	Fermentation	Piping & instrumentation	
Genetic engineering	Ingredient discovery software		
	Small molecule screening		
	Microfluidics		

Source: Good Food Institute (2019)

Marquee partnerships suggest listed players are positioning strategically

- **Nestle & Future Meat Technologies:** In July 2021, Nestle confirmed it is "exploring technologies" linked to cultured meat and cultured meat ingredients production and is working with several external partners and start-ups to develop its capability. For example, the Nestle Research division in Switzerland is working with Future Meat Technologies (based in Israel) to explore the potential of non-GMO cultured meat components that do not compromise on taste and sustainability.

- **Tyson & UPSIDE Foods (formerly known as Memphis Meats):** In 2018, Tyson Ventures, the VC arm of Tyson Foods, invested in cultured meat provider Memphis Meats. To date the company has raised over $200m in funding, with other high-profile investors including Cargill, Bill Gates, Richard Branson and Kimbal Musk. The company changed its name to UPSIDE Foods in 2021 and is poised to bring its first cultured meat product to market by 2022, pending regulatory approval.

- **Merck & Mosa Meat:** In 2018, M Venture, the VC arm of Merck, invested $9m in Mosa Meat. Based in the Netherlands, Mosa Meat is considered the 'founding father' of cultured meat as it introduced the world's first cultured beef hamburger in 2013. From a strategic perspective, it is likely that Germany-based Merck is keen to understand the market in further detail,

given it makes cell culture media. The company has also mentioned it is interested in helping to find solutions to other technical challenges as well, including growing cells at scale in industrial perfusion bioreactors and the use of cutting-edge technologies such as 3D printing and edible scaffolds. Refer to the sector contribution from our EU Pharma team and Figure 34 for our company profile on Mosa Meat.

Wildcard 3: Addressing the bears – is it environmentally better?

The cultured meat industry has suggested that, by bypassing the natural biological process of raising an animal, cultured meat can result in lower emissions per unit of meat produced when compared to traditional farming. However, such environmental claims have proven challenging to validate as, to date, no cultured meat company has achieved production at commercial scale. A small number of studies have undertaken speculative life-cycle assessments (LCA) to predict the environmental footprint of cultured meat, with the suggested GHG emissions per unit of cultured meat produced varying significantly as they are based on different production systems and assumed inputs. These include assumptions relating to the use of renewable energy, the type of GHG metrics used and technological decisions relating to bioreactor design.

To illustrate further, we summarise below two key studies performed separately by Oxford Martin University (2019) and the GFI (2021). The consistent threads across both studies were: i) the need for renewable energy and ii) varying emission benefits across meat type (e.g. beef, chicken, pork). The most recent study conducted by GFI benefited from incorporating industry data provided by 15 companies across the supply chain. In our view, conclusions on LCAs will continue to vary until theoretical assumptions are replaced with additional industry data. We also think it's important to not assess emissions alone, given there are also wider environmental benefits relating to land use and biodiversity protection that need to be assessed.

Oxford Martin University (2019): Cultured meat is not *prima facie* climatically superior to cattle, raising the importance of methane

In 2019, researchers from Oxford Martin School looked at the long-term climate implications of cultured meat vs. traditional meat (beef). The climate model found that in some circumstances and over the very long term, the manufacture of cultured meat could result in more warming. From our discussion with the research team, the 'true' climate impact of cultured meat production will depend largely on what level of renewable energy is used, as well as the efficiency of future culture processes. We highlight the following key takeaways from the underlying *study*:

- **Breaking down GHG gases is important for assessing climate impact:** The study analyses climate impact by assessing the different behaviours of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) as opposed to analysing climate impact based on carbon dioxide equivalent (CO_2e) metrics (a metric relating the emissions of different GHGs to carbon dioxide – the most popular metric used in cultured meat studies).

- **Cattle emissions typically have a shorter atmospheric life:** Cattle emissions are predominantly CH_4, while cultured meat emissions are CO_2 mainly. Per tonne emitted, methane has a much larger warming impact than carbon dioxide, but it has a shorter atmospheric life (12 years vs. 300-1,000 years for CO_2). Under continuous high global consumption, cultured meat results in less warming than cattle initially, but this gap narrows in the long term and in some cases cattle production causes far less warming, as CH_4 emissions do not accumulate, unlike CO_2.

GFI (2021): Renewable energy is key to realising cultured meat's full potential…

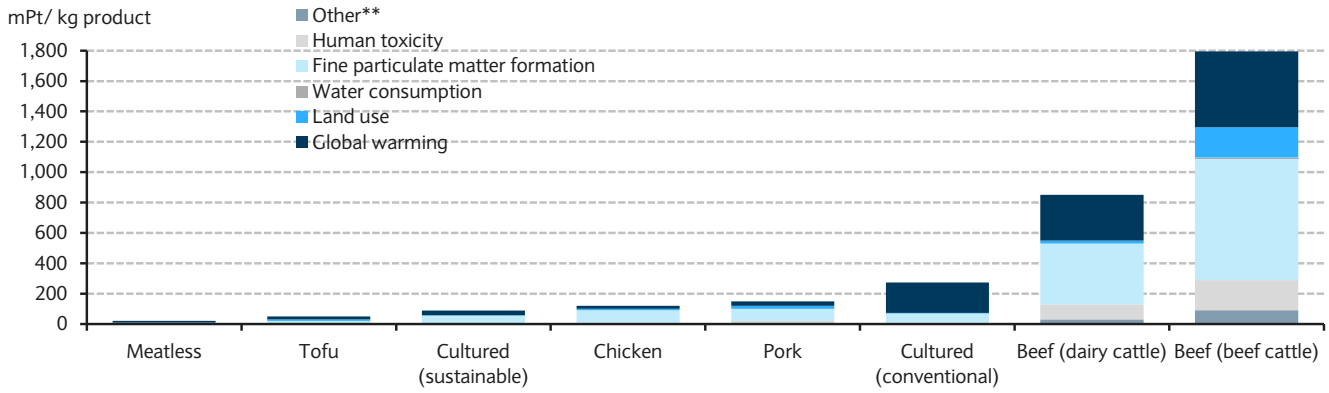
The GFI published in February 2021 a new *LCA* that modelled a production scenario of a hypothetical commercial-scale facility in 2030 and assessed its climate impact vs. traditional farming. The study used carbon dioxide equivalents (CO_2e) to analyse the carbon footprint and assumed two different scenarios for cultured meat: 1) a **conventional energy scenario**, with global stated policies governing electricity mix for 2030 and heat from natural gas, and 2) a **sustainable scenario**, with solar and wind electricity and geothermal heat.

Unlike the study previously performed by Oxford, the GFI used industry data contributed by companies involved in the cultured meat supply chain. Over 15 companies and 1 government scientific body (from Singapore) participated, including five meat manufacturers. The study concluded that, in the conventional energy scenario, cultured meat had a carbon footprint that was lower than that of beef but higher than those of chicken and pork, while in the sustainable energy scenario cultured meat outperformed all meat products – Figure 24. If renewables are used, the carbon footprint of cultured meat production drops by 80%.

GFI's LCA also considered feed conversion ratio

The LCA also shows that cultured meat is 3.5 times more efficient than conventional chicken (the most efficient form of conventional meat production) at converting feed into meat. As a consequence, cultured meat production reduces land use by 63-95% compared to conventional meat.

FIGURE 24. **Environmental profile of cultured meat (at commercial scale) compared to ambitious benchmark for conventional products***



Source: CE Delft (LCA of cultivated meat 2021).* Intensive, West-European, circular agriculture with LUC-free soy. ** 'Other' includes 14 impact categories, among which other toxicity categories, acidification and resource depletion.

INVESTOR GUIDEBOOK

The growing recognition of the importance of protein diversification within climate-mitigation strategies has led to several avenues of opportunity within the alternative protein landscape. While near-term momentum will likely remain driven by plant-based products, we see the potential for 'future disruptors' also to scale over the next 5-10 years, including insects, precision fermentation and cultured meat.

While we acknowledge that cultured meat remains primarily in the trial/pilot phase, we have been encouraged by the regulatory momentum in recent months and the number of upcoming commercial launches globally. Ongoing regulatory approvals and the scaling of production capacity remain key factors influencing the road to price parity, with the potential for cultured meat to disrupt 20% of the traditional meat market by 2040E, based on our underlying market analysis.

Many public companies have started to invest to gain exposure to the cultured value chain, further supported by a sizeable landscape of private players. The latter includes B2C companies developing consumer brands based on specific end-markets (e.g. meat, dairy and/or seafood) and/or B2B companies that are providing key manufacturing inputs to the production process (e.g. bioreactors, cell medium). We anticipate the level of investment activity accelerating, with public company exposure likely to be catalysed by ongoing regulatory approvals.

In this chapter, we highlight the key potential entry-points for investors wanting to gain exposure to the investment theme. In our Cultured Meat Landscape (Figure 25) we identify the key public and private companies across the value chain, and, to aid company engagement, we highlight key ESG considerations, questions for management and SDG mapping.

How to gain exposure to the cultured meat opportunity…

Across the public and private space, we identify 3 ways to gain exposure to the cultured meat market opportunity. While our primary focus in this report is traditional animal husbandry (cattle, poultry etc.), we also highlight the key disruptors within cultured seafood, dairy, fat and gelatine to give investors a broader perspective on the application of cellular agriculture to various end-markets.

1) Public companies investing in private cultured companies

Many listed consumer and food manufacturers have gained exposure to the cultured meat industry by acquiring or directly investing in private cultured companies. Strategic R&D partnerships have also been formed, as listed companies look to better understand the scaling of cellular agricultural technology. We expect additional marquee partnerships between public and private companies to be announced, given the underlying company landscape within the private space is still ripe for industry consolidation ahead of large-scale commercial production.

- **Tyson's VC arm invests in UPSIDE Foods (formerly known as Memphis Meats) and Future Meat Technologies (January 2018):** Meat processor Tyson Foods announced several investments in 2018, including UPSIDE Foods and Future Meat Technologies – both of which are focused on scaling the production of cultured meats. *Refer to our company profile on UPSIDE Foods (Figure 33) and our US Americas Agribusiness sector contribution for further information on Tyson and BRF.*

- **Nomad Foods and BlueNalu collaborate to introduce cultured seafood into Europe (September 2021):** Within cultured seafood, one of Europe's largest listed frozen food companies, Nomad Foods, announced in September 2021 an agreement with BlueNalu (private). The agreement signifies a mutual interest in the commercialisation of cultured seafood in Europe. *Refer to our case study on BlueNalu (Figure 22) for further information on the cultured seafood market opportunity.*

- **Nestle begins cultured research with Future Meat Technologies (July 2021):** In July 2021, Nestle confirmed the company is "exploring technologies" linked to cultured meat and cultured meat ingredients production and is working with several external partners and start-ups to develop its capability. For example, the Nestle Research division in Switzerland is working with Future Meat Technologies to explore the potential of non-GMO cultured-meat components that do not compromise on taste and sustainability. *Refer to our EU Consumer sector contribution for further information on Nestle.*

- **Merck invests in Mosa Meat (July 2018):** In 2018, M Venture, the VC arm of Merck, invested $9m in Mosa Meat. Based in the Netherlands, Mosa Meat is considered the 'founding father' of cultured meat as it introduced the world's first cultured beef hamburger in 2013. From a strategic perspective, it is likely that Germany-based Merck is keen to understand the market in further detail given it makes cell culture media. The company has also mentioned it is interested in helping to find solutions to other technical challenges as well, including growing cells at scale in industrial perfusion bioreactors and the use of cutting-edge technologies such as 3D printing and edible scaffolds. *Refer to our EU Pharma sector contribution for further information on Merck and our company profile on Mosa Meats (Figure 34).*

- **DSM enters into a joint development agreement with Meatable (cultured meat start-up) to develop affordable growth media for cultured meat (September 2021):** The companies believe this collaborative approach will result in patentable findings that will help address the core challenge of making cultured meat affordable and accessible on a large scale. In addition to focusing on the cost-effective production of growth media, DSM and Meatable will focus on the development of meat-like taste and texture of the final product, which are important factors influencing the purchase decision of consumers. DSM Venturing, the VC arm of Royal DSM, was also a participant in Meatable's $47m raise in VC funding.

2) Pure-play listed companies (Agronomics, MeaTech, BioMilk)

With regard to pure-play exposure to the cellular agriculture investment theme, we highlight 3 key players: Agronomics (LON:ANIC), MeaTech (NASDAQ: MITC) and BioMilk (TLV: BMLK).

- **Agronomics (LON: ANIC):** Agronomics is a listed investment company that is focused on opportunities within the nascent industry of modern foods that are environmentally friendly alternatives to the traditional production of meat and plant-based sources of nutrition. The company aims to provide shareholders with exposure to a concentrated portfolio of companies in this area, with notable investments in the cultured space including: BlueNalu, CellX, Meatable, Mosa Meat, New Age Meats, Shiok Meats and SuperMeat.

- **MeaTech (NASDAQ: MITC):** Following its IPO in March 2021, Israel-based MeaTech is developing its proprietary cultured meat production processes based on 3D bioprinting and tissue engineering technologies. In 2020, MeaTech acquired a Belgian B2B startup – Peace of Meat – which develops cultured fats, as a taste-enhancing ingredient for 'hybrid' alternatives. Strategically the company's emphasis on B2B business models targets multiple revenue streams, including licensed production facilities, food technologies services, raw

materials and engineering services. *Refer to our company profile on MeaTech (Figure 30) for further information.*

- **BioMilk (TLV: BMLK):** Following its IPO in April 2021, Israel-based BioMilk is considered the world's first publicly traded cultured milk company. The company is focused on 3 main development tracks – cultured milk from animals, cultured human breast milk and high-grade human milk oligosaccharides (HMOs) – and plans to release its first samples in the next 2 years. Founded in 2018 by scientists at the University of Jerusalem, the company also signed a strategic investment term sheet with Coca-Cola Israel in July 2021 to trial pilot commercial production. *Refer to our discussion on cultured dairy (Thematic Wildcard 1) for further information and our company profile on BioMilk (Figure 31).*

3) Private companies across the value chain (B2C and B2B)

Cellular agriculture has generated significant amounts of VC funding (refer to the VC Funding section for a summary of key investment trends), for a range of companies across the entire value chain. While the industry has experienced a handful of acquisitions to date, we expect industry consolidation to gather momentum as financing matures. We distinguish private players across two key groups:

- **B2C brands vs. B2B suppliers:** While the majority of private companies in the cultured meat industry are B2C brands, we also note in recent years the growth in B2B companies focusing on scaling the underlying technology and/or inputs to the production process. Based on our discussions with industry experts, we highlight the key areas of specialisation within our Cultured Meat Landscape (Figure 25) in further detail, including suppliers providing inputs required for cell culture media, scaffolding and large-scale bioreactors. In the long term, we anticipate underlying business models within the B2B segment will increasingly adopt licensing models to benefit from industry outsourcing.

- **Specific end-markets within cellular agriculture:** The vast majority of companies within the cultured meat industry have specialised in particular types of meat, with cultured seafood producers in particular working on vertically integrated systems. With increased maturity, we would expect to see B2C companies within the cultured meat landscape expanding their product capabilities given the potential synergies and economies of scale to be realised with large-scale commercial production. For example, in 2021 Shiok Meats (cultured seafood) acquired Gaia Foods (cultured red meat). We highlight the key end-markets within our Cultured Meat Landscape (Figure 25), including beef, poultry, seafood and dairy.

Barclays Cultured Meat Landscape

Our Cultured Meat Landscape (Figure 25) highlights key companies linked to the theme by sub-sector, including public and private companies.

FIGURE 25. Barclays Cultured Meat Landscape

Full Stack

Beef, Poultry and Pork

Europe	North America
Alife Foods	Artemys Foods
Bene Meat	Balletic Foods
BioTech Foods	Because Animals
Bruno Cell	BioBQ
Gourmey	Blue Ridge Bantam
HigherSteaks	Good Meat
Innocent Meat	Fork & Goode
Ivy Farm Technologies	Lab Farm Foods
Meatable	New Age Meats
Mirai Foods	Ohayo Valley
Mosa Meat	Upside Foods
Asia	**Middle East**
Ants Innovate	Aleph Farms
CellMEAT	Future Meat Technologies
CellX	MeaTech
ClearMeat	SuperMeat
Diverse Farm	**Africa**
Gaia Foods	Mzansi Meat Co
IntegriCulture	**Oceania**
Joe's Future Food	Magic Valley
Nissin Foods	
Sea With	

Fats

Europe	North America
Cubiq Foods	Mission Barns
Hoxton Farms	

Seafood

Europe	Asia
ArtMeat	Avant Meats
Bluu Biosciences	Shiok Meats
North America	**Africa**
BlueNalu	Sea-Stematic
Cultured Decadence	
Finless Foods	
Wildtype	
Cell AG Tech	

Dairy

Middle East	North America
BioMilk	Biomilq
Asia	
TurtleTree Labs	

Other

Africa	Oceania
Mogale Meat Co	Vow
North America	
Orbillion Bio	

Eggs

Europe
Magic Caviar

Gelatine

North America
Jellatech

Pet Food

North America
Because Animals
Pristine Pet Food

Textiles & Materials

Europe
Furoid

B2B services

Cell Culture Media

Asia	North America
Biftek	Future Fields
Cellivate Technologies	Merck
Europe	Thermo Fisher Scientific
Cultured Blood	**LATAM**
Multus Media	Luyef Biotechnologies
Lonza	**Oceania**
	Heuros

Scaffolding

North America	Asia
Boston Meats	Myoworks
Matrix Meats	
Novel Farms	

Cell Lines

LATAM	Asia
Cell Farm Food Tech	Umami Meats
North America	
Bio-Rad	
Twist Biosciences	

Bioprocess Design / Bioreactors

Europe	Asia
Cellular Agriculture	SingCell
CellulaREvolution	
Unicorn Biotechnologies	
Sartorius	

Food producers & ingredients

Industry Exposure

Archer Daniels Midland
Bell Food Group
BRF
Cargill
Coca Cola
DSM
Givaudan
Ingredion
Nestle
Neto Group
NH Foods
Nomad Foods
PHW-Gruppe
Strauss Group
Tyson

VC Investors

Agronomics	Lever VC	208 Seed Ventures	Blue Horizon	Real Tech Fund
CPT Capital	VegInvest	Alumni Ventures Group	Humboldt	Siddhi Capital
Big Idea Ventures	KBW Ventures	Eat Beyond Global	Social Starts	Purple Orange Ventures
SOSV/ IndieBio	Bell Food Group	Green Monday	VU Venture Partners	Unovis Asset Management
Artesian	EIT Food			

Industry Initiatives

Alliance for Meat, Poultry and Seafood Innovation (AMPS)	New Harvest
Cultivated Meat Modeling Consortium (CMMC)	North American Meat Institute (NAMI)
Good Food Institute (GFI)	

Source: Barclays Research. Note: Companies in blue are listed companies and companies in black are private companies.

ESG Considerations

As regulation matures and costs decline, we believe cultured meat is another credible option within the alternative protein landscape, alongside our existing published work on plant-based and insect protein. While the traditional meat industry is exposed to material risks arising from environmental regulations and carbon taxes, we see cultured meat having the potential to provide significant environmental and social benefits at commercial scale. These include addressing concerns relating to biodiversity, animal welfare and human health. On the other hand, there are equally various challenges to consider including concerns surrounding energy usage, product safety and ingredients labelling. We put forward the following environmental and social considerations that we think are worthy of company engagement:

Environment

- **GHG emissions – assessing energy inputs remains tricky:** According to the LCA (life-cycle assessment) performed by the Good Food Institute (GFI) and CE Delft in March 2021, cultured meat outperforms all forms of conventional meat production when renewable energy is used. The environmental impact of cultured meat will be driven primarily by: 1) the amount of energy consumed during the production process (in turn driven mainly by the active cooling of the bioreactors), 2) the sourcing and production of the inputs in the growth medium, and 3) how effectively that medium is used (inefficient feed medium that requires higher amounts of fermented ingredients would result in a higher environmental impact, whereas an efficient medium could reduce the impact from the baseline by 12-21%, per the LCA). While the GFI analysis has been conducted taking input from cultured companies, it is not possible to practically validate given the industry has yet to commercialise production on a global scale.

- **Biodiversity – reducing the demand for soy:** A recent *report* by the WWF shows that the most damaging impacts from livestock production are on water quality, soil quality and biodiversity loss, caused in particular by intensive crop production for animal feed and the release of nitrogen and phosphorous pollutants. The WWF estimates that 60% of global biodiversity loss can be attributed to livestock farming. We see producing cultured meat as an opportunity to reduce deforestation, driven mainly by the potential to reduce the demand for soy. A decline in traditional meat could also allow land to be used for other purposes, including the broader call to develop more scalable regeneration practices.

- **Food waste – producing specific cuts of meat:** Unlike traditional meat, where utilisation is a big concern, cultured meat presents an opportunity to reduce food waste by producing an end-product (e.g. a prime cut) directly, without having to farm the whole body. It also removes company risks associated with animal carcass disposal, animal health and animal safety.

Social

- **Labour – traditional farming to pivot towards organic and high-end farming:** Cultured meat could disrupt the traditional meat sector, driving down demand for traditional products and thus putting millions of jobs within the agriculture sector at risk. This has been a key area of concern for countries where agriculture is a significant proportion of overall GDP and where there are strong levels of agricultural lobbying. Our discussions with industry experts suggest the adoption of cultured meat won't affect all farming economies equally. For example, both New Zealand Wales are heavily grass-based farming economies where traditionally farmers have focused on dairy and forage. In addition, both are able to charge a premium for the products derived from the quality of their pastured cows and

sheep. We think it is plausible that demand for traditional meat in the long term could lead to a focus on organic and/or high-end animal welfare.

- **Product labelling – US Cattlemen's 2018 petition denied by the USDA and the declining use of Fetal Bovine Serum (FBS):** While cultured meat is biologically identical to traditional meat at the cellular level, it can also be modified to have a healthier profile – for example, by removing fats and including nutritional additives. While the industry has generally been exploring ways to reduce the reliance on Fetal Bovine Serum (FBS), the industry is still split on the use of GMO techniques to improve taste and enhance cell stability through cell immortalisation. A key takeaway from our consumer survey (Figure 10) was the need to provide additional transparency to build trust with consumers, within which product and ingredient labelling plays a key role. Most recently, the US Cattlemen's Association petitioned the USDA to prevent products of cellular agriculture from being labelled as 'meat' – this petition was denied in September 2021.

- **Food safety – avoiding future pandemics and reducing the risk food-borne illnesses:** FAIRR, an investor network focusing on ESG risks associated with animal production, has warned that antimicrobials used in farming could increase the risk of disease and infection to humans. According to the European Commission, antimicrobial resistance leads to approximately 33,000 human deaths in the EU each year. More recently, concerns relating to the ongoing growth in industrial animal farming have grown, given eating and farming animals is viewed as one of the riskiest human behaviours in relation to pandemics. We believe cultured meat reduces both risks.

- **Obesity – more meat:** As the production process of cultured meat involves extracting a muscle cell, fat and other additives are added to the product at a later stage, presenting an opportunity for cultured meat companies to make their products healthier than traditional meat. However, we also flag the potential related effect this could have on consumers. Positioning cultured meat as a healthier alternative could incentivise consumers to eat more meat, leading to overconsumption and again posing a risk to obesity.

Barclays SDG Wheel

To help translate the UN's Sustainable Development Goals (SDGs) into investment opportunities, we map how the scaling of cultured meat products could aid in the achievement of multiple SDGs. We must emphasise this list is not exhaustive, though it provides a starting point for investors who have an impact investing mandate or a framework based on the 17 underlying focus areas. We highlight SDGs number 2, 3, 6, 8, 12, 13, 14 and 15.

- **SDG 2 – Zero Hunger:** Cultured meat could play an important role in helping to feed the expected 10bn people by 2050, while also reducing carbon emissions; however, more investments will be required to help drive scale and cost competition. The World Economic Forum views all alternative proteins, including insect proteins and cultured meat, as a way to help achieve SDG 2 on Zero Hunger.

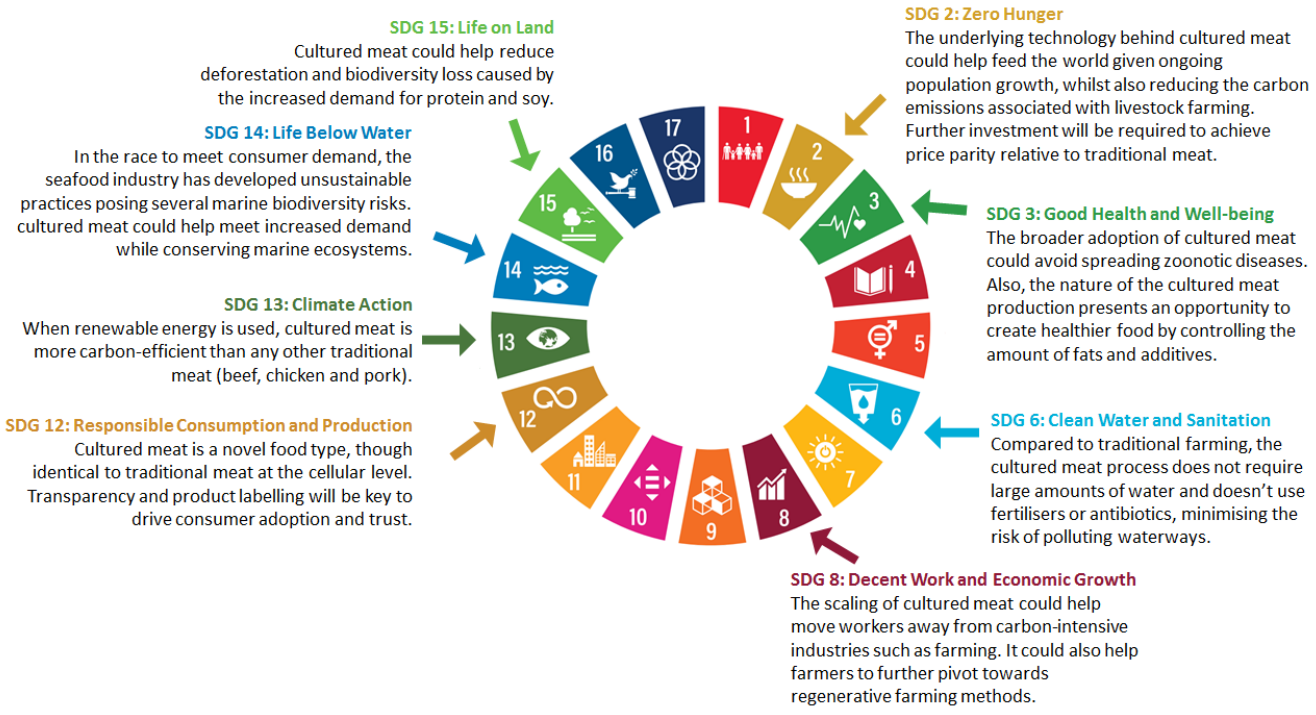
- **SDG 3 – Good Health and Well-being:** The broader adoption of cultured meat could avoid spreading zoonotic diseases, a key driver of the rise in pandemics in modern history. Moreover, the nature of cultured meat production presents an opportunity to create healthier food by controlling the amount of fats and additives that are included in the end-product.

- **SDG 6 – Clean Water and Sanitation:** Cultured meat production is projected to reduce up to 78% of blue water (freshwater) usage compared to beef production, according to the CE Delft LCA, freeing up water supply. Also, cultured meat does not require the use of fertilisers

or antibiotics; helping to reduce waterway pollution, which is caused mainly by traditional farming and agriculture.

- **SDG 8 – Decent Work and Economic Growth:** The scaling of cultured meat could help displace workers from carbon-intensive industries (traditional farming) into more sustainable business models. Moving from traditional farming could also help reduce modern slavery and unhealthy working conditions, both of which represent material risks to the industry.
- **SDG 12 – Responsible Consumption and Production:** We see product labelling playing a crucial role in ensuring transparency and building consumer trust going forward. Our discussion with industry experts suggest a rigorous regulatory process exists relating to food safety and food hygiene, with this being typically defined at the regional level by product.
- **SDG 13 – Climate Action:** According to the latest LCA by the Good Food Institute, cultured meat outperforms all types of traditional meat when renewable energy is used, reducing the carbon footprint of beef by 92%, pork by 52% and chicken by 17%. Cultured meat can also help restore soil health by reducing the need for traditional farming and agriculture.
- **SDG 14 – Life Below Water:** The increasing demand for ffish has pressured the seafood industry to adopt unsustainable practices, manifested in the form of declining fish health and food fraud. Cultured seafood would help meet global demand for seafood, while helping restoring the health of our oceans.
- **SDG 15 – Life on Land:** The UN stresses the need to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". The broader adoption of cultured meat presents an opportunity to reduce deforestation by reducing the land required for farming.

FIGURE 26. **Barclays SDG Wheel – Cultured meat**



Source: Barclays Research

Questions for Management

We provide a list of questions to help investors engage with companies and to assess sector-specific opportunities and risk arising from cultured products. We consider the following viewpoints:

1. **Cultured manufacturers:** The vertically integrated companies that are hoping to produce the meat themselves.
2. **Cultured suppliers:** Either the B2B companies that are hoping to provide specialised products and services to the cultured manufacturers and/or the cultured manufacturers themselves that are looking to further refine their underlying production processes.
3. **Food manufacturers:** The food manufacturers that are hoping to source cultured meat for potential consumer products.

Cultured manufacturers

- **Commercial availability:** When does the company expect to commercially launch products? What does the five-year product pipeline look like? Does the company have any specific product targets with regard to output, timing and revenue? What is the company's view on the total addressable market?
- **Price parity:** How has scale impacted the company's estimates on product pricing? When does the company expect to achieve price parity? What are the key factors influencing pricing today and what steps are being taken by the company to achieve price parity? To what extent is pricing impacted by the type of product being created? Is there anything to consider from a regional viewpoint?
- **Production & pilot facilities:** Does the company have a pilot facility? If so, what level of funding has been secured specific to production? What is the difference between current and potential capacity? What is the company's long-term view with regard to commercial production and the future expansion in production facilities? Are there certain geographical regions where the company is hoping to scale commercial production to begin with? To what extent will production capacity influence the company's view on commercial viability and price parity?
- **Production yields & feedstock requirements:** What is the 'feed' conversion ratio equivalent for cultured production? How would the requirements for cultured meat compare to traditional livestock and will this depend on the specific product line (e.g. do some varieties enable the nutrient uptake to be more efficient)?
- **Environmental credentials:** What are the company's key environmental credentials (e.g. emissions savings, land impact, water usage)? To what extent has the company conducted a life-cycle assessment vs. traditional meat? What are the key assumptions behind the company's life-cycle assessment?
- **Social credentials:** What are the company's key social credentials (e.g. animal welfare, food safety)? How does the company source animal cells?
- **Non-GM:** Does the company genetically modify any elements of the production process and the underlying cell source? If so, for which product and which region is this product aiming to be commercially available? Are there plans for the company to transition to non-GM pathways?
- **Animal sera & Fetal Bovine Serum (FBS):** Does the company's production process rely on

animal products within the cell culture medium (e.g. Fetal Bovine Serum)? If yes, is the company investing in animal-free serum alternatives? What type of animal-free serums exist today and are they readily available to the company? Are any animal extracts used (e.g. chicken embryo extract)? What implications (financially and strategically) does the transition to serum-free alternatives bring to the company? What about the use of antibiotics in cell cultures to control growth of unwanted microbes?

- **Consumer adoption:** Based on the company's understanding of the underlying market, what are the key challenges that may impact consumer attitudes and preferences with respect to cultured meat? Has the company conducted any consumer focus groups or consumer surveys to assess consumer attitudes? To what extent has consumer feedback impacted R&D and the company's go-to-market strategy to date?

- **Product certification & labelling:** What is the company's view on product certification and consumer labelling in the cultured industry? To what extent has the company's marketing and advertising strategy been impacted by regulatory or legal risks? Is there specific product wording or label transparency with which the company is hoping to provide consumers? What is the company's view on nomenclature (e.g. cultured, cell-based, cultivated)?

- **Regulation:** What impact has the current regulatory landscape had on the company? Are there certain products where the company is expecting to experience regulatory challenges in the future? What is the company's view on the regulatory momentum in key markets such as Singapore, China, the US and Europe?

- **Manufacturing R&D & technology innovation:** What innovative technology or production practices has the company utilised (e.g. bioreactor design, cell culture media composition)? Does the company use automation software or AI/ML to help improve the accuracy of cell sourcing? What upcoming technology is the company keen to utilise and what impact would this have on the production process (e.g. 3D printing, edible scaffolds)?

Cultured suppliers

- **Bioreactor design:** How is the company furthering the design of the bioreactor within the manufacturing process? Does the company provide IoT sensors for adaptive control? How does the current design support media recycle and filtration? How does the bioreactor monitor important parameters such as metabolite levels, pH and biomass accumulation? What performance metrics does the company utilise to assess underlying performance? What perfusion technologies are being considered by the company? What are the benefits and challenges in commercialising the use of the company's bioreactor design?

- **Scaffolding:** To what extent does the scaffolding material vary by the underlying meat that is being produced? Are there certain performance requirements with regard to how the scaffolding material influences the product's safety, digestibility, taste and nutrition? What biomaterials and hydrogels are widely used by the industry and what is potentially in the upcoming pipeline with regard to scaffolding innovation? Does the company provide 3D printing capabilities? What is the company's view on self-directed architecture? Does the company utilise computational modelling to assist in the selection of a scaffold material/shape?

- **Cell culture media:** What steps are being taken by the company to reduce the price of cell culture medium? How does the pricing of growth medium vary across species and cell types? What is the company's view on innovation within existing serum replacements? To what extent has the company used ingredient discovery software or growth factor engineering to enhance the efficiency and quality of cell culture medium? What is the disposal method for the spent media once the protein is extracted? Will it need to be

regulated or handled as a biohazard?

- **Cell sourcing:** How is the company addressing production concerns relating to genetic drift and cell line stability? Is the company deploying novel/exotic cell line isolation and biobanking? What is the company's view on broader developments relating to biorepositories, footprint-free immortalisation and genetic engineering? What upcoming innovation is the company pursuing with regard to cell line development and sourcing?

Food manufacturers

- **Hybrid products (cultured vs. plant-based):** What is the company's view on cultured meat relative to other types of alternative protein (e.g. plant-based, precision fermentation)? What concerns does the company have with respect to cultured meat? Has the company considered hybrid products (combination of both plant-based and cultured fats) to address consumer concerns relating to taste?

- **Consumer marketing:** How will such products be labelled and marketed to consumers on retail shelves and in restaurants and food service? How does the production process impact the ability for kosher or halal certification?

- **Addressable market & product timing:** Has the company made any investments in the cultured industry? If so, what type of companies and for what underlying end-product? What is the company's view on the addressable market and commercial availability? At what level of pricing will such products be available to customers?

- **Emerging areas (dairy, seafood, eggs):** What is the company's broader view on cellular agriculture technology and the application to other animal-based products such as dairy, seafood, eggs, fats and gelatine?

- **Pet food:** Has the company considered commercialising cultured meat for the pet food segment? If so, does this have an accelerated time-frame relative to human consumption? Are there any successful examples of where this is already being done in the world?

Industry collaboration and M&A

- **Competitive landscape:** Are there elements of the value chain where the company foresees additional competitive pressure? To what extent has competition impacted the company's targets and future growth projections?

- **In-house vs. industry M&A:** What is the company's view on external innovation and the role of private companies/startups? Are there elements of the value chain where the company sees additional industry consolidation? What impact would this have on the company's outlook and the potential addressable market?

SECTOR IMPLICATIONS

Compared to plant-based, we acknowledge our discussion on 'future disruptors' within the alternative protein landscape such as cultured meats remains nascent. As the cultured industry matures, we will continue to monitor: i) the number of regulatory approvals, ii) the development of large-scale commercial production and iii) consumer adoption – all are key to our expectation that price parity will be met by the end of the decade.

In collaboration with our sector analysts, we summarise which of the companies within our research coverage have gained exposure to cellular agriculture to date. We highlight sector contributions from Americas Agribusiness (BRF, Tyson), US Foods (Nomad Foods), EU Consumer Staples (Nestle), EU Pharma (Merck) and EU Chemicals (DSM)– Figure 27.

This includes: investing in private cultured companies, agreeing R&D partnerships with private cultured companies and/or joining industry initiatives.

FIGURE 27. **Sector implications for covered companies**

Sector name	Key company mentions
Americas Agribusiness	**BRF:** Partnership with Aleph Farms (2021) **Tyson:** Investments in Upside Foods (2018), Future Meat Technologies (2018)
US Food	**Nomad:** Partnership with cell-based seafood BlueNalu (2021)
EU Consumer Staples	**Nestle:** Partnership with Future Meat Technologies (2021)
EU Pharma	**Merck:** Key R&D partner for cell culture medium, investment in Mosa Meat (2018)
EU Chemicals	**DSM:** Partnership with Meatable (2021)

Source: Barclays Research

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From plant-based to cultured, the alternative meat game is on

Meat companies have been heavily investing in broadening their meat portfolios by entering the alternative meat space via plant-based meat, in an effort to capture what looks like a trend. While most companies continue improving their health, taste and quality capabilities, as well as cost structures, we consider that their eyes should also target cultured meat. With only a few exceptions, most of our covered Americas Agribusiness haven't entered the space.

As discussed throughout this report, we think cultured meat has a solid outlook ahead, and we consider that, if companies focus only on plant-based meat, they could miss out an even larger opportunity. In our view, these companies would be well advised to start investing in cultured alternatives, so that entering the cultured meat space doesn't become a better-now-than-never strategy, as plant-based meat has become in some cases.

Strategic investments led by BRF and Tyson

In the Americas Agribusiness space, companies have understandably been working on entering the alternative meat space, in a strategy that we think could serve as a hedge if animal-based meat consumption declines amid different drivers (health & wellness, environmental and animal welfare, etc.). While plant-based was the initial alternative to enter the space, given its higher penetration and scale vs. other alternative meat products, cultured meat has started to gain traction across the companies' investments.

BRF

Earlier this year, BRF entered into a partnership with Aleph Farms, an Israeli startup that develops proteins in the laboratory from animal cells, investing US$2.5mn in Aleph Farms. Under this agreement, both companies will co-develop and produce cultured meat using Aleph's patented production platforms, and BRF will distribute Aleph-backed cultured beef products in Brazil. BRF aims to expand its product portfolio and venture into new markets, expecting to launch cultured meat products by 2023 or 2024, with a sustainable vision.

With Didier Toubia as a CEO, and with famous celebrities on its Advisory Board such as Leonardo DiCaprio (investor as well), Aleph Farms is planning to use the funds to scale its business, aiming at commercialising its steak products by 2022. A key component of the company is its sustainable program called '*Aleph Zero*', aiming to produce meat with zero resources, regardless of climate conditions or availability of resources. For instance, in September 2019, the company produced the first cultured meat in space with 3D Bioprinting Solutions as a partner. Additionally, the company also has the objective of running a long global portfolio expansion, including entering into new types of animal protein with the fund. *(Refer to the Aleph Farms company profile on Figure 35).*

Tyson

Tyson has been investing in startup companies involved in alternative proteins via its venture capital fund, Tyson Ventures. As aforementioned, Tyson invested in cultured meat producers Memphis Meats (now UPSIDE Foods) and Future Meat Technologies, which are reviewed throughout the report.

Drivers of cultured meat

We identify the following as the main drivers of cultured meat, focused on key concerns faced in the Agribusiness industry, besides the greenhouse gas emissions point reviewed earlier. Meat companies that create and sell cultured meat would face less exposure to the high fixed costs related to contaminated products, including recalls, plant clean-ups, wasted product and fines, and the industry as a whole could offset some of the main push-backs received over the years.

Land usage

If cultured meat achieves a relevant market share in the meat space, it could prevent some of the problems currently faced regarding land usage. Whether land is destined for crops or livestock, the increase in human population and meat consumption has led to pushback on the impact from deforestation; currently, 40% of the world's 37bn acres of land are used for livestock raising and related activity, approximately 14.8bn acres.

Cultured meat uses significantly fewer land resources, as it is grown in labs and factories, not requiring feed. According to the GFI, 95% less land could be needed to produce cultured meat when compared to traditional meat, implying about 148mm acres for every 1% of market share. With meat being produced at cultured facilities, land could be used for better purposes, or left alone.

Agricultural water usage

It takes approximately 15,415 m^3 of water to produce a ton of beef, 6,000 m^3 of water to produce a ton of pork and 4,325 m^3 of water to produce a ton of poultry. Although these numbers appear extremely high at face value, they drop when broken down by water type. The majority of water used is green water (i.e. rain water in plants and soil). The environmental focus is placed on the use of blue and grey water (i.e. freshwater used that cannot be renewed). When looking exclusively at blue and grey water usage, it takes 1,000 m^3/ton for beef, 1080 m^3/ton for pork and 780 m^3/ton for chicken. This water is used for an assortment of agricultural purposes, such as growing feed, sanitation, cooling and drinking. The 'true cost' of water (see *Global Consumer Staples: Water: The True Cost*, June 2021) is estimated by our analysts to be $15 per m^3, accounting for the costs needed to prepare for issues relating to water shortages and scarcity. Cultured meat cuts down on water usage by about 85%, as the only main uses for water are for cleaning and for cell health. Lower reliance on water should also reduce meat price volatility caused by water scarcity affecting crops.

Foodborne illness

A majority of foodborne illness derive from farms, where live animals in tightly packed spaces provide an easy conduit for diseases such as salmonella. As well as being spread from animal to animal, diseases can spread through saliva, faeces and consumption of contaminated product. This can lead to a trickle-down effect that contaminates water and soil, leading to infected fruit and vegetable crops.

The costs of foodborne illness are high. The USDA and CDC estimate that the direct economic burden in the US totalled $17.6bn in 2018, including medical costs and lost wages. These costs soar after including indirect factors, with other models adding in detriments such as reduced quality of life. Indirect costs contribute an additional $37.9bn in economic harm, leading to a

total loss of $55.5bn, which includes lost productivity, lost wages and decreased life expectancy, among other things.

Cultured meat grown in laboratories under close supervision and in sterile conditions does not foster the spread of foodborne illness. Although there is still risk of disease through improper storage or cooking, the primary risk is mitigated.

Fewer product recalls

Meat companies that create and sell cultured meat should face less exposure to the high fixed costs related to contaminated products, including recalls, plant clean-ups, wasted product and fines. The direct costs of a food product recall averages out at $10mm, and does not include indirect costs such as reputational damage and loss of future business. Cultured meat should be able to avoid these expenses and focus on the product. Additionally, other businesses in the supply chain should benefit from this reduction in product recalls. Supermarkets, restaurants, cafes and food product companies all incur losses during product recalls due to reduced stock and customer hesitation. Losses should be reduced across the supply chain as cultured meat becomes more mainstream.

Antibiotics

Farmers use a vast amount of antibiotics within the livestock raising process, both to treat disease and to promote growth of the animals. The use of antibiotics has led to a relevant pushback as it means consumers can build up resistance to vital drugs, and the loss of effectiveness of antibiotics can lead to severe health problems. Cultured meat in a closed system does not require antibiotics and several cultured startups have made pledges not to use antibiotics in their products.

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European Food & Food Ingredients

Given the increasingly well understood environmental damage caused by intensive livestock farming (GHG emissions, deforestation, potential for new pandemics), efforts to use cell culture techniques to produce animal proteins commercially have understandably been gaining significant interest and investment. Cultured animal protein production could play a key role in helping European Food companies achieve long-term decarbonisation and biodiversity goals, in our view.

We highlight four ways in which the scaling of cellular agricultural technology may impact our coverage universe, including the development of cultured meat, dairy and seafood. Within our expectation that price parity will be met within the next 5-10 years, we believe there is a role for 'hybrid' products in the interim (both plant- and cultured), with Nestle's recent partnership being a potential blueprint for others to follow. We are encouraged by the momentum from an ingredients perspective, but it is still too early to tell on cultured dairy given the potential for alternative pathways such as precision fermentation.

Cultured meat – Nestle's partnership with Future Meat could be a blueprint for 'big food' to follow

In December 2020, Nestle announced new interim targets on climate change. In addition to its net zero emissions target by 2050, it has set an interim target of 50% reduction by 2030 and 20% reduction by 2025. It will invest a total of CHF3.2bn over the next 5 years, mostly in the P&L (i.e. 3.8% of FY20E sales), which will be funded by structural savings and operational gearing and be margin/earnings-neutral (i.e. almost 80bps per annum in savings/efficiencies).

Nestle indicated that one key initiative to achieve this ambition would be to expand and reformulate its plant-based offering to consumers – e.g. Garden Gourmet plant-based food and Garden of Life in VMS to be carbon-neutral by 2022. In July 2021, Nestle confirmed it is "exploring technologies" linked to cultured meat and cultured meat ingredients production and is working with several external partners and start-ups to develop its capability. For example, the Nestle Research division in Switzerland is working with Future Meat Technologies to explore the potential for non-GMO cultured-meat components that do not compromise on taste and sustainability. Based in Israel, Future Meat Technologies has the capability to produce 500kg of cultured products a day, equivalent to 5,000 hamburgers. We think it likely that Nestle plans to produce a hybrid plant-based and cultured meat product under the Garden Gourmet brand.

Ingredient suppliers – could play a key role given expertise in cell culture medium and fermentation capabilities

We find it interesting that **Cargill**, through UPSIDE Foods, **ADM**, through Perfect Day, and **Ingredion**, through Clara Foods, have all made early-stage investments in both cultured and the precision fermentation protein space. If technologies are to scale and reduce cost enough to become commercially viable, it is likely that ingredients players with commercial scale fermentation experience will be required. Indeed, GFI's 2020 State of the Industry Fermentation report highlighted Cargill, IFF (DuPont N&B), AB Enzymes, Biocatalysts, Novozymes, Kerry, ADM, DSM, Amano and Ajinomoto as players with deep expertise in fermentation and large-scale manufacturing that could potentially be used in time to help commercialise this opportunity.

Kerry is also a key existing supplier of cell culture media to the biopharma industry today through its pharma ingredients business. Barclays asked Albert McQuaid, Kerry's Chief Innovation Officer, about the growth outlook for cultured protein and what role Kerry could play at the company's recent CMD in October 2021. He pointed out that Kerry already supplies

around 30 different companies operating in the nascent cultured space. His view is that initial commercial applications are likely to be hybrid cultured and plant-based protein products, but that over the next decade stand-alone cultured protein products could increasingly be available at scale.

> "We are already working with over 30 different companies that operate in this (cultured) space. You may know we're a major media provider to the pharma industry. And one of the biggest challenges in the cell culture arena is how do you get the cost efficiency in the media to drive a product that actually can be competitive with the mainstream animal-based protein that it is trying to replace. So we've huge skills in that. We understand the whole meat protein arena. That combination of knowledge of what is meat and how you make meat taste great for consumers aligned with that media capability is where we think we've got a real role to play in this industry as it evolves. So we are active in that today. I'd say we see that happening as a first phase in a hybrid model. We think it will happen actually pretty soon that we will see products coming to market where they're combined as an ingredient into a plant-based solution. Then in the next phase as the technology progresses, more mainstream evolution of full-on cell culture, meat derived products into the industry."
>
> *- Albert McQuaid Kerry CMD 13th October*

Cultured seafood – could play a role in improving the sustainability of seafood

Our Sustainable and Thematic team's report *Sustainable Seafood: What's the Catch?* (March 4, 2021) highlighted that, despite the potential for fish production to be sustainable, the rapidly growing demand for seafood has embedded some problematic practices into the supply chain. The FAIRR initiative, an investor network focusing on ESG risks associated with animal production, has warned that several factors including unstable feed supply and antibiotic resistance could undermine the industry.

Indeed, in our recent initiation on Norway's largest Salmon farmers (*Fishing for sustainable returns*, 27th September), we highlighted that leading independent aquaculture industry forecaster Kontali Analyse expects global farmed salmon supply growth to slow to 4% between 2020-24 from +6% over the past decade. The key reasons for the expected slowdown in industry supply growth are constrained coastal site supply and biological challenges associated with increasing density at these sites.

As well as emerging aquaculture production methods such as land-based and offshore aquaculture, cultured seafood could have a role to play in increasing fish protein at lower environmental cost. Indeed, as we have pointed out in this report, while the science for propagating fish cells is relatively new (vs. mammalian cell culturing), companies across the value chain have been keen to consider whether cellular technology can also be deployed within the seafood industry. A range of private companies exist today focusing on cultured aquaculture, including BlueNalu, Wildtype, Avant Meats and Finless Foods, and partnerships with seafood companies are already emerging.

Cultured dairy – one to keep an eye on

As illustrated on the Thematic Wildcards section another potential cultured protein application is within the dairy industry, where various alternative methods of production are being explored, including cultured and precision-fermentation-based technologies. Compared to cultured meat and seafood, cultured dairy technology will likely take longer to become a commercial mainstream reality, given the regulatory momentum is less advanced. This includes milk components, such as whey, casin proteins, lipids and lactose.

At its H1 21 results, we asked Glanbia, one of the world's largest commodity cheese and whey protein producers, for its view on the nascent cultured dairy industry. While Glanbia does not currently see this as a material competitive challenge, the CEO did confirm it is something the company monitors closely and could be an opportunity in time. Barclays' question to Glanbia CEO August 2021 "We are seeing growing momentum in the synthetic bio industry. When you think about Nutritional Solutions long term and your legacy whey protein exposure there, how are you viewing that trend? Is there a competitive risk in whey or a potential opportunity for Glanbia to get involved maybe at some point?" Glanbia CEO "*It is interesting of course the evolution of the synthetic bio industry. We don't see it as a fundamental risk to our whey, dairy propositions and absolutely we will and do keep an eye to the evolving moves in that area and in that space and it may well be an opportunity for us*."

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Consumers are increasingly factoring into their purchase decisions manufacturers' ESG credentials while investors are tracking ESG KPIs. As such, not surprisingly, we have seen packaged food companies expand and accelerate their environmental and social initiatives. In theory the discussion on cellular agriculture and more broadly synthetic biology could be a significant boon to manufacturers' ESG efforts, with an urgent need to consider pathways to reduce carbon emissions, water usage and deforestation – especially for participants upstream in the supply chain – *Mission Possible: How Synbio Can Drive Sustainability & Disrupt Manufacturing* (10.11.21). There are also additional value propositions to be explored if engineering techniques are used to enhance attributes relating to taste and nutrition – factors that were key to consumer perceptions of cultured meat, according to our global survey of c.5,000 adults.

While cultured meat remains nascent relative to the mainstream availability of plant-based products, we are gradually beginning to see our covered companies getting involved with cultured meats through partnerships. The most notable example is Nomad's recent partnership with BlueNalu – a private cultured seafood company – to explore the introduction of products in Europe. We anticipate the potential for additional partnerships to be announced by companies as the underlying technology matures.

Nomad and BlueNalu collaborate to introduce cultured seafood

In September 2021, Nomad, one of Europe's largest frozen food companies, agreed to explore the introduction of cultured seafood in Europe with US cultured meat seafood developer BlueNalu. Europe is the largest importer of seafood in the world due to high consumption rates, with EU citizens consuming more than 3 times as much as they produce, according to the EU Blue Economy Report. As such, this cultured offering would help Europe meet the rising demand for fish and support wider efforts to safeguard the long-term availability of quality, affordable seafood that is healthy for people and sustainable for the planet.

The agreement represents the first of its kind in Europe between a consumer packaged goods company and a cultured seafood company, and underpins Nomad Foods' commitment to scaling emerging food technologies. It includes a collaboration to conduct market research and identify consumer insights, assess regulatory requirements and explore new business and product opportunities. The company has not disclosed whether any potential products will be sold under Nomad's brands, which include Birdseye, iglo and Findus.

With regard to cultured seafood varieties, BlueNalu has focused predominantly on fish species that are typically imported, difficult to farm-raise and/or contain higher levels of environmental containments. In the US, the company is planning to go to market first with mahi mahi, followed by bluefin tuna. The company has also previously announced collaborations with Mitsubishi and Thai Union, with the view that this will help to introduce products that better meet local consumer demand.

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Within the cultured meat investment theme, Merck is considered a key R&D partner, given the various research agreements the company has formed with universities, private companies and industry groups. Merck has indicated its R&D efforts aim to accelerate the commercial production of cultured meats, with the company acknowledging the need to further reduce costs to make the product more affordable.

Leveraging internal expertise on cell culture media and bioprocessing technologies, the company has focused on overcoming critical technological challenges. This includes working on serum-free formulations, accelerating virtual experimentation and exploring alternative methods of production (e.g. bioreactors, bioprocess design, biodegradable/edible scaffolds).

Bioreactor design and cell culture media remain key R&D priorities

In May 2021, Merck announced a three-year collaboration agreement to conduct fundamental research on next-generation, scalable bioreactor design to support industrial-scale meat and seafood manufacture. Research partners included Tufts University to enable the production of whole muscle cultured meat with textile bioengineering, and Technical University (TU) of Darmstadt to apply industrial printing technology for the production of textured meat. The primary focus of the collaboration between Merck and the two universities is the development of next-generation, scalable bioreactor designs that can support meat and seafood manufacture on a commercial scale.

Merck – founding partner of the Cultivated Meat Modeling Consortium

To help accelerate the R&D process, Merck has also explored the potential for virtual experimentation by running lab simulations and was one of the founding partners of the Cultivated Meat Modeling Consortium (CMMC) in 2020. The industry consortium is hoping to advance cultured meat through computation modelling to optimise growth processes and product characteristics. Various technical challenges are being explored, including controlling cell proliferation without differentiation, driving the cost of proliferation down and designing scaffolds for cells to adhere to and grow on. In particular, Merck has sponsored the CMMC's development of a stirred tank bioreactor model. The model serves as a proof-of-concept that novel computational modelling methods can recapitulate laboratory results of direct relevance to the industry.

Merck's venture capital arm has already invested in cultured startups

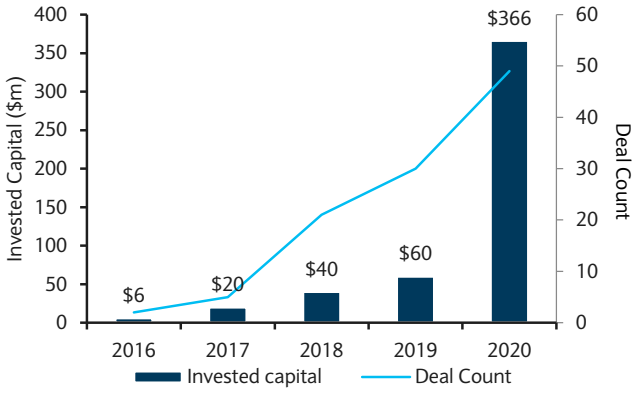
In 2018, M Venture, the VC arm of Merck, invested $9m in Mosa Meat. Based in the Netherlands, Mosa Meat is considered the 'founding father' of cultured meat as it introduced the world's first cultured beef hamburger in 2013. To date, the company has raised over $95m in funding and is currently developing its pilot facility. *Refer to Figure 34 for the Mosa Meat company profile.*

VC FUNDING & COMPANY PROFILES

VC activity for cultured continues to gather momentum

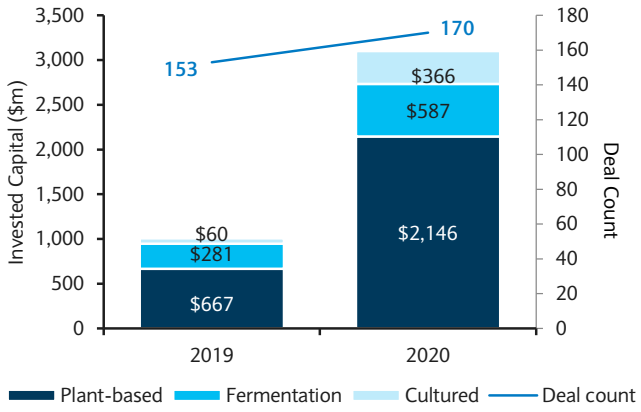
Investments in alternative protein companies remain buoyant, with almost $6bn in invested capital in the past decade (2010-20), over half of which was raised in 2020 alone, according to GFI. 2020 was a stellar year for cultured meat in particular, with total capital invested of $366 million and 49 deals, accounting for 72% of all-time investment and nearly six times the level of investment in 2019 (Figure 28). While year-on-year growth looks promising, much more is needed to continue driving down costs and compete with traditional meat pricing. We see additional opportunities within the B2B segment such as cell culture media, scaffolding or bioprocess designs, as these key technology providers remain underfunded with only $5 million received last year.

FIGURE 28. **Annual investment in cultured meat**



Source: Good Food Institute

FIGURE 29. **Annual alternative protein investment backdrop**



Source: Good Food Institute

2020 investment highlights – Series B funding emerges

- **Investment in cultured meat accounted for 14% of overall funding in the alternative protein sector:** While alternative proteins attracted a record $3.1bn investment in 2020, cultured meat still accounts for a small percentage of the overall investment (Figure 29). However, as regulation matures, we expect to see more investment flowing into cultured meat, particularly among B2B companies and cultured manufacturers.

- **UPSIDE Foods led with $186m Series B funding:** The cultured meat sector saw the first Series B fundraisings last year, with UPSIDE Foods securing $186m to build a pilot plant and Mosa Meat raising $75m to fund its launch of cultured beef. UPSIDE Foods, formerly Memphis Meats, announced in November 2021 the completion of its Engineering, Production and Innovation Center (EPIC). The 53,000 square-foot campus location in California has been designed to produce any species of meat – in both ground and whole-cut formats. *(Refer to the UPSIDE Foods company profile for further information – Figure 33).*

- **Cultured seafood raised 3x more money in 2020:** Cultured seafood began generating investor enthusiasm, with companies raising $45m in 2020 vs. $17m in 2019. This included BlueNalu's $20m Series A in February 2020 and Shiok Meats' $12.6m Series A in September 2020. *(Refer to the Shiok Meats company profile for further information – Figure 36).*

- **Cultured dairy remains nascent:** The sector experienced its first significant investments,

with TurtleTree Labs raising $9.5m and BioMilq raising $3.5m in pre-series A funding. As we outline below, during 2021 the cultured dairy industry delivered an IPO (BioMilk) and Series A funding for both TurtleTree and BioMilq.

2021 investment highlights – Industry's first IPOs & additional Series B

While 2020 was an exciting year for the cultured meat industry, momentum has continued in 2021 with several IPOs and additional Series B funding rounds being announced. Key investment highlights for 2021 include:

- **MeaTech $25m US IPO:** Israeli cultured meat company **MeaTech (TICKER: MITC)** announced in March this year its $25m US Initial Public Offering. The company, which initially listed in Israel in 2020 as the first public cultured meat company, develops 3D printing technology, biotechnology processes and manufacturing processes for cultured meat, focusing primarily on steak products. *(Refer to the MeaTech company profile for further information – Figure 30).*

- **First cultured milk company to go public:** Based in Israel, **BioMilk (TICKER: BMLK)** opened for trading in April this year on the Tel Aviv Stock Exchange. The company develops cultured cow milk from mammary cells, aiming to produce milk with a similar composition of commercial cow milk but with lower hormone and antibiotic content. BioMilk is also trying to develop breast milk. *(Refer to the BioMilk company profile for further information – Figure 31).*

- **TurtleTree Labs raises $30m in Series A funding to expedite full commercialisation of cultured milk:** The company expects to launch its first products in the US soon using cultured dairy ingredients through multiple B2B partnerships. The plan is to fully commercialise cultured milk within the next 4-5 years. The Series A fundraise was led by Verso Capital and will help to support the company's ongoing buildout of a manufacturing facility in California and the continued development of IP technologies.

- **Good Meat raises $170m and starts commercialisation in Singapore:** Good Meat, the Eat Just division that served the first cultured chicken at a restaurant in Singapore in December 2020, raised $170m in May 2021. Good Meat, which is already delivering its cultured chicken dishes through the foodpanda app, will use the funding to expand its product offering. *(Refer to the Good Meat company profile for further information – Figure 32).*

- **Aleph Farms completes a $150m Series B funding:** Aleph Farms, a non-GMO cultured company focusing on steaks, announced the completion of its Series B round in July 2021. Aleph Farms is planning to use the funds to scale its business, aiming to commercialise its steak products by 2022. Funding was led by L Catterton and DisruptAD, one of the largest VCs in the Middle East, to build up a strategic partnership with the idea of establishing a manufacturing facility in Abu Dhabi to incentivise cultured meat products across the UAE. *(Refer to the Aleph Farms company profile for further information – Figure 35).*

Key company profiles

FIGURE 30. **MeaTech**

MeaTech (NASDAQ: MITC)

Cultured meat & fats

Product: *Beef, chicken, pork*
Commercialisation: *pilot plant in 2022 – cultured fat*

MeaTech is a cultured meat company developing its proprietary cultured meat production processes based on 3D bioprinting and tissue engineering technologies. Following its IPO in March 2021, MeaTech became the first cultured meat listed company. After de-listing from the Tel Aviv stock exchange, MeaTech listed on the NASDAQ in March 2021. MeaTech has a particular focus on premium, centre-of-plate meat products, such as structured marbled steaks. In December 2020, MeaTech acquired Peace of Meat – a Belgian producer of cultured avian products – for €15m. Going forward, the company's priorities remain further developing its 3D bioprinting technologies across multispecies products, scaling the availability of ancillary products (e.g. cultured fat) for non-printed hybrid foods and progressing with the underlying B2B licensing business model.

Company positioning

Product roadmap: While the long-term goal is to further develop the company's 3D bioprinting technologies under a B2B licensing model, the company is also setting up a pilot plant to produce cultured chicken fat, with production expected in 2022. The company has also begun research into the best way to scale the 3D bioprinting of pork.

Manufacturing: In June 2021, the company filed a patent for a novel 3D bioprinting technology that could provide higher bio-ink control, focusing on further developing multi-layered production to create premium meat cuts.

Strategic M&A: In December 2020 the company acquired Peace of Meat, a Belgium-based cultured fat company. Peace of Meat has developed a stem-cultured bioreactor technology for cultivating animal fats from chicken and ducks. The technology's first expected application is in hybrid food products, combining plant-based protein with cultured animal fat, designed to provide meat analogues with qualities of 'meatiness' (taste and texture) closer to those of conventional meat products.
In September 2021, MeaTech announced that Peace of Meat had cultured just over 700 grams of pure chicken fat biomass in a single production run – providing further support to the company's plan to manufacture at industrial scale and cost parity in the future.

MeaTech – 3D printed meat

Source: MeaTech

Source: MeaTech, Barclays Research

FIGURE 31. **BioMilk**

BioMilk (TLV: BMLK)

Cultured dairy **Product:** *Milk* **Commercialisation:** *TBA*	**Founded in 2018, BioMilk is a cultured dairy company developing cultured cow milk from mammary cells. The company is aiming to produce milk with similar composition of commercial cow milk but with lower hormone and antibiotic content. BioMilk is also trying to develop human breast milk. It became the first cell-cultured milk company to go public in April 2021 on the Tel Aviv Stock Exchange, and aims to list in the US as the next step. BioMilk also entered into a $2m financial and strategic partnership with Coca-Cola Israel in July 2021 to scale production.** **The company's primary focus remains R&D, with plans to scale up the underlying technology ahead of commercial production. BioMilk plans to release its first sample over the next two years.**

Company positioning

Product roadmap: Through its strategic partnership with Coca-Cola Israel, BioMilk is planning to accelerate commercialisation with a view to being a key supplier of cultured ingredients for Coca-Cola in Israel and South Africa. Based on our discussions with the company, BioMilk is also looking to develop specialised milk products for the hypo-allergic and sports markets and highlights China's infant formula market as a potential future opportunity.

Manufacturing: The company is primarily in the R&D phase and has plans to move to laboratory scale following recent funding. BioMilk is focusing on developing proprietary cell lines for bovine and human mammalian cells as well as medium recycling.

Source: BioMilk, Barclays Research

FIGURE 32. **Good Meat (Eat Just)**

Good Meat (Eat Just)

Cultured meat **Product:** *Chicken* **Commercialisation:** *2021*	**Founded in 2016, Good Meat is a subsidiary of Eat Just, a US firm focused on alternative proteins. Good Meat, which focuses on cultured chicken, is the first company in the world to obtain regulatory approval from Singapore to commercialise its cultured chicken nuggets. Currently, the chicken nuggets are available at only one restaurant in Singapore, but the company is already working on other partnerships. For example, in April 2021 some of the cultured chicken dishes became available for home delivery on the foodpanda app in Singapore.** **Apart from chicken, the company is now working on other types of meat, including beef utilising cells from California pasture-raised cattle and Wagyu from the Toriyama farm in Japan.**

Company positioning

Product roadmap: In December 2020 Singapore approved the sale of Good Meat's cultured chicken nuggets, becoming the first country to approve a cultured meat product. The product is available at only one restaurant and the company is working on further partnerships as well as accelerating regulatory approval in other countries.

Manufacturing: The manufacturing process for Good Meat's chicken nuggets only takes a few weeks from an established and validated chicken cell bank, according to the company. Production with multiple bioreactors can occur concurrently and the process can be operated so there are multiple harvests during the same week. Since 2018, Good Meat has seen a 5-fold increase in cell density, a 6-fold decrease in media costs and a 40-fold decrease in total costs. Today, its cultured chicken plate at the restaurant is sold at USD $23. The company recently partnered with Doha and Qatar authorities to build the first cultured meat facility in the Middle East as the company anticipates regulatory approval there.

Source: Eat Just, Barclays Research

FIGURE 33. **UPSIDE Foods**

UPSIDE Foods

Cultured meat **Product:** *Meat, poultry and seafood* **Commercialisation:** *Pending US regulatory approval*	**UPSIDE Foods was one the first companies focused on growing real meat directly from animal cells. Since 2015, UPSIDE Foods has achieved producing multiple species of meat (beef, chicken and duck), as well as opening a production facility.** **UPSIDE Foods has raised over $200 million from a diverse coalition of investors including Atomico, Bill Gates, Cargill, CPT Capital, Fifty Year, KBW Ventures, Kimbal Musk, John Mackey, Norwest Venture Partners, Richard Branson, SoftBank, SOSV, Temasek, Threshold Ventures, Tyson Foods, and Whole Foods.**

Company positioning

Product roadmap: Pending regulatory approval from the FDA and USDA, UPSIDE Foods is planning to launch its cultivated meat products with chefs and restaurants in the US, and eventually expand to grocery stores and markets worldwide.

Manufacturing: UPSIDE opened in November 2021 its Engineering, Production, and Innovation Center (EPIC) in the US, a 53,000 square foot facility designed to produce over 50,000 pounds of cultured meat and with a future capacity of 400,000 pounds per year. The facility will be able to produce several different kinds of meat, including different meat styles and textures ranging from ground meat to whole cuts. The new plant will require UPSIDE Foods to hire more bioprocess engineers, tech development personnel and professionals to care for and maintain various equipment and functions in the facility. The company indicated 50 people will be working in meat production (source: Food Dive, 04.11.21).

To comply with local regulation, the facility also includes a quality assurance room where products are tested to ensure they are safe. An office will be made available for federal inspectors to oversee the process, built to regulatory specifications. From a sustainability perspective, the facility will be powered by 100% renewable energy and will help test out different efficiency upgrades, including wastewater management.

Source: UPSIDE Foods, Barclays Research

FIGURE 34. **Mosa Meat**

Mosa Meat

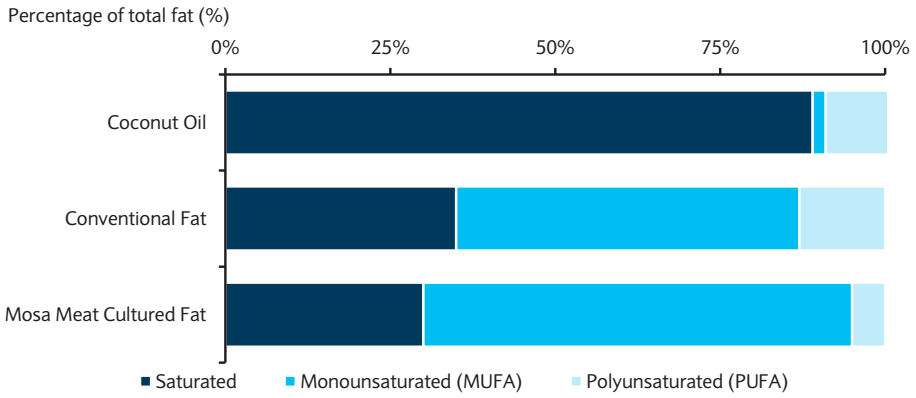
Cultured meat **Product:** *Beef* **Commercialisation:** *TBA*	**Founded in 2016, Mosa Meat is a cultured meat company in the Netherlands specialising in cultured beef. In 2013, the scientists who founded the company unveiled the world's first cultured beef burger costing EUR 250,000. 'Fat parity' has been a key focus area, and the company has been committed to cultivating fat and adding it to the underlying meat. From a manufacturing perspective, the company is now planning to extend its current pilot facility in Maastricht to scale production while awaiting regulatory approval. The company has also benefitted from the use of automation software and has reported significant milestones relating to reducing the cost of fat and cell culture media. Mosa Meat investors have included Bell Food Group, Nutreco, Merck and Leonardo DiCaprio.**

Company positioning

Product roadmap: Although no exact timeline has been given by Mosa Meat, the company is planning to start commercialisation in the next couple of years, pending regulatory approval. Mosa Meat will first sell its products at small scale in premium outlets and then through various restaurants with the aim of selling at grocery stores some years after that.

Manufacturing: In July 2021, the company added new space at its facility in Maastricht known as 'Phase 2,' which includes the use of larger bioreactors. Using process control software, the company has been able to automate media exchange in the different types of bioreactors. In October 2021, Mosa Meat secured a $2m grant for its 'Feed for Meat' project in partnership with aquafeed specialist Nutreco.

Fat parity – Similarity of cultured fat with conventional fat results in a similar taste



Source: Mosa Meat

Source: Mosa Meat, Barclays Research

FIGURE 35. **Aleph Farms**

Aleph Farms

Cultured meat **Product:** *Beef* **Commercialisation:** *2022*	**Aleph Farms is a cultured meat company founded in 2017 by the Israeli food-tech incubator 'The Kitchen' of food company Strauss Group. Focusing on beef, the company has already presented prototypes for thin-cut steak (2018) and ribeye steak (2021), and has also produced the first cultured meat in space (2019) under its Aleph Zero brand. Going forward, the company plans to expand its protein portfolio into lamb, chicken and pork – with the primary focus being high-end segments to begin with. The company is transitioning to its pilot facility financed by its latest Series B round and hopes to start commercialisation by 2022 in small quantities pending regulatory approval. Aleph Farm investors have included Strauss Group, Cargill and Leonardo DiCaprio.**

Company positioning

Product roadmap: With global ambitions, Aleph Farms is looking to further develop different regional partnerships to accelerate the commercialisation of cultured meat in APAC, Europe and Americas. The company has announced several partnerships in 2021: in January, the company partnered with Mitsubishi to bring cultured meat to Japan; in March it partnered with Brazilian meat company BRF, and in September it partnered with Thai Union. Aleph Farms is aiming to launch thin-cut steak products by the end of 2022 pending regulatory approval. Parallel to this, the company is also focusing on bringing cultured meat to space, with a successful experiment in 2019; the company has another trial planned at the International Space Station at the beginning of 2022.

Manufacturing: An Aleph Farms' steak can take 3-4 weeks to be produced, from cell sampling and isolation to shape design using 3D bioprinting tissue engineering techniques. The company is working with cell banks, which include cells from an American Angus cow with full genetic tracing and with full documentation regarding the health of the animal. The company has developed its own growth medium, with production based on non-GMO and non-immortalisation. The company is transitioning to its first production facility which it expects to be operational by early 2022.

In November 2021, the company announced a detailed roadmap for achieving net zero carbon within its own operations by 2025, and throughout its entire supply chain by 2030. The roadmap to reduce the company's carbon footprint includes optimising energy efficiency, transitioning to renewable energy, and offsetting and/or insetting unavoidable remaining emissions via reinvestment in decarbonising Aleph Farms' own production lines and supply chains. The company has also signed a Memorandum of Understanding with ENGIE Impact, the sustainability consulting arm of ENGIE, to work together to integrate energy efficiency and renewable energy across supply chains.

Aleph Farms aims to be carbon-neutral by 2025…

Source: Aleph Farms

Source: Aleph Farms, Barclays Research

FIGURE 36. **Shiok Meats**

Shiok Meats

Cultured seafood **Product:** *Crustaceans* **Commercialisation:** *2023*	**Founded in 2018, Shiok Meats is a cultured meat and seafood company based in Singapore. Benefiting from a favourable regulatory environment, the company focuses primarily on crustaceans like shrimps, crabs and lobsters. The company has explored strategic M&A, including the acquisition of Singaporean cultured red meat company Gaia Foods in August 2021. Shiok Meats is currently in the R&D phase and aims to commercialise in 2023. Our discussions with the company indicate that cultured minced shrimp will likely be the first product at high-end restaurants to begin with. The company has also indicated the building of their manufacturing plant in Singapore remains a key investment priority.**

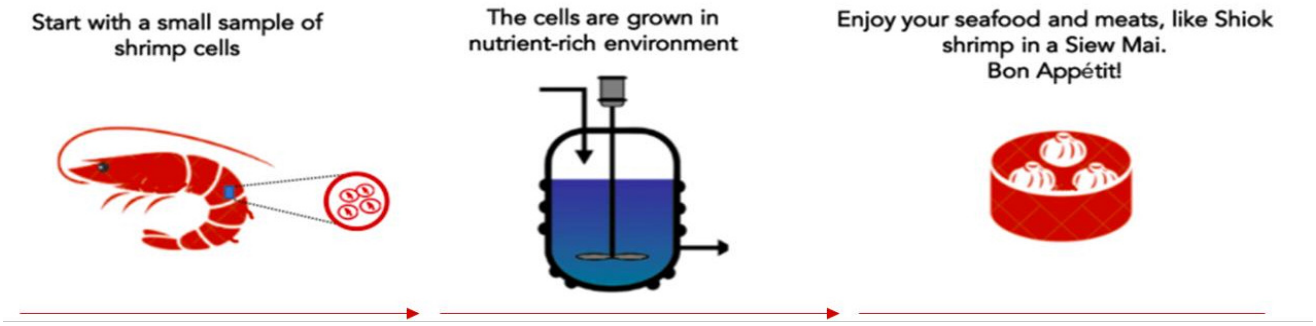
Company positioning

Product roadmap: Shiok Meats plans to make available minced shrimp in premium restaurant outlets by 2023. The process will involve applying for the relevant approvals from the Singapore Foods Agency. In August 2021, the company also presented its cultured crab prototype at a private event in Singapore. The company previously showcased its shrimp prototype in March 2019 and its first lobster prototype in November 2020. Our discussions with the company indicate that hybrid products are key with regard to the near-term go-to-market strategy. For example, the crab prototypes were created as a cultured and plant-based blend.

Manufacturing: Shiok Meats' focus currently remains on the downstream process as achieving lower pricing is key to competing with traditional food processes. While in-house development remains a priority, Shiok Meats continues to look for strategic partnerships. Last year, for example, the company announced a partnership with IntegriCulture to reduce the cost of the shrimp cultured media.

Strategic M&A: Shiok Meats acquired cultured red meat company Gaia Foods in August 2021 to diversify its product offering. While both companies will remain operationally independent, Gaia Foods brings many synergies into the manufacturing process as well as intellectual property as one of the companies most advanced in its cell lines.

Shiok Meats – Cultured seafood process



Source: Shiok Meats

Source: Shiok Meats, Barclays Research

Analyst(s) Certification(s):
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BRF SA (BRFS, 16-Nov-2021, USD 4.14), Underweight/Neutral, CD/CE/J/K/N

DSM (DSMN.AS, 16-Nov-2021, EUR 194.80), Overweight/Neutral, CD/J/K/M

Merck KGaA (MRCG.DE, 16-Nov-2021, EUR 215.60), Overweight/Positive, CD/J/K/M/N

Nestle SA (NESN.S, 16-Nov-2021, CHF 123.58), Overweight/Neutral, A/CD/D/E/J/K/L/M/N

Nomad Foods Ltd. (NOMD, 16-Nov-2021, USD 24.90), Overweight/Neutral, J/K/M/N

Tyson Foods, Inc. (TSN, 16-Nov-2021, USD 83.58), Overweight/Neutral, CD/CE/D/J/K/L/M/N

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AppHarvest, Inc. (APPH)
Arca Continental (AC.MX)
Archer Daniels Midland (ADM)
Becle SAB de CV (CUERVO.MX)
Benson Hill, Inc. (BHIL)
Beyond Meat, Inc. (BYND)
Bimbo (BIMBOA.MX)
BRF SA (BRFS)
Bunge Limited (BG)
Coca-Cola FEMSA (KOF)
FEMSA (FMX)
Gruma (GRUMAB.MX)
Hormel Foods Corp. (HRL)
Ingredion Inc. (INGR)
JBS SA (JBSS3.SA)
Marfrig Global Foods SA (MRFG3.SA)
Pilgrim's Pride Corp (PPC)
Sanderson Farms, Inc. (SAFM)
Tyson Foods, Inc. (TSN)

European Chemicals

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AkzoNobel (AKZO.AS)
Arkema (AKE.PA)
BASF (BASFn.DE)
Brenntag (BNRGn.DE)
Clariant (CLN.S)
Covestro (1COV.DE)
Croda (CRDA.L)
DSM (DSMN.AS)
Elementis (ELM.L)
Evonik (EVKn.DE)
Givaudan (GIVN.S)
Johnson Matthey (JMAT.L)
Lanxess (LXSG.DE)
Novozymes (NZYMb.CO)
Solvay (SOLB.BR)
Symrise (SY1G.DE)
Synthomer (SYNTS.L)
Umicore (UMI.BR)
Victrex (VCTX.L)
Wacker Chemie (WCHG.DE)

European Consumer Staples

AAK (AAK.ST)
Altria Group Inc. (MO)
Anheuser-Busch InBev (ABI.BR)
Associated British Foods (ABF.L)
Bakkavor (BAKK.L)
Barry Callebaut (BARN.S)
Beiersdorf AG (BEIG.DE)
British American Tobacco Plc (BATS.L)
C&C Group (CCR.L)
Carlsberg AS-B (CARLb.CO)
Chr. Hansen (CHRH.CO)
Coca-Cola Hellenic BC AG (CCH.L)
Corbion (CORB.AS)
Cranswick Plc (CWK.L)
Danone (DANO.PA)
Davide Campari N.V. (CPRI.MI)
Diageo PLC (DGE.L)
Essity (ESSITYb.ST)
Fever-Tree Drinks PLC (FEVR.L)
Glanbia (GL9.I)
Greencore Group PLC (GNC.L)
Heineken NV (HEIN.AS)
Henkel (HNKG_p.DE)
Imperial Brands Plc (IMB.L)
Japan Tobacco Inc. (JAPAY)
Kerry Group (KYGa.L)
L'Oréal SA (OREP.PA)
Leroy Seafood Group ASA (LSG.OL)
Lindt & Spruengli (LISN.S)
Mowi (MOWI.OL)
Nestle SA (NESN.S)
Ontex Group (ONTEX.BR)
Pernod-Ricard SA (PERP.PA)
Philip Morris International Inc. (PM)
PZ Cussons Plc (PZC.L)
Reckitt Benckiser Group PLC (RB.L)
Rémy Cointreau (RCOP.PA)
Salmar ASA (SALM.OL)
Scandinavian Tobacco Group (STOGR.CO)
Suedzucker AG (SZUG.DE)
Swedish Match (SWMA.ST)
Tate & Lyle (TATE.L)
Turning Point Brands (TPB)
Unilever PLC (ULVR.AS)
Unilever PLC (ULVR.L)
Vector Group Ltd (VGR)

European Pharmaceuticals

argenx (ARGX.BR)
AstraZeneca (AZN.L)
Bayer AG (BAYGn.DE)
Galapagos (GLPG.AS)
Genmab A/S (GMAB.CO)
GlaxoSmithKline (GSK.L)
Grifols SA (GRLS.MC)
H Lundbeck A/S (LUN.CO)
Hikma Pharmaceuticals PLC (HIK.L)
Idorsia (IDIA.S)
Ipsen SA (IPN.PA)
Merck KGaA (MRCG.DE)
MorphoSys AG (MORG.DE)
Novartis (NOVN.S)
Novo Nordisk (NOVOb.CO)
Recordati (RECI.MI)
Roche (ROG.S)
Sanofi (SASY.PA)
SOBI (SOBIV.ST)
UCB SA (UCB.BR)
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U.S. Food

B&G Foods (BGS)
BellRing Brands (BRBR)
Campbell Soup (CPB)
Conagra Brands (CAG)
General Mills (GIS)
Hain Celestial (HAIN)

Kellogg Co. (K)
Lamb Weston Holdings, Inc. (LW)
McCormick & Co. (MKC)
Mondelez International (MDLZ)
Nomad Foods Ltd. (NOMD)
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