Research Paper

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Meat Analogues
Considerations for the EU

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Summary

- Consensus is building across the scientific, environmental and public health communities that a radical shift away from excessive meat-eating patterns is urgently needed to tackle the unsustainability of the livestock sector.
- Recognizing the scale of the challenge ahead, public policymakers, civil society and innovators have increasingly sought to prompt shifts in consumer food choices, away from the most resource-intensive meat products and towards more sustainable alternatives.
- Meat analogues – plant-based 'meat' and cultured meat – mark a departure from traditional meat alternatives. Both are intended to be indistinguishable from – and, in the case of cultured meat, biologically equivalent to – animal-derived meat and are marketed principally at meat-eaters.
- Innovation and investment in meat analogues have increased significantly, but the direction and pace of growth in the meat analogue industry will depend upon a multitude of factors, including public acceptance, civil society support and incumbent industry responses.
- Policymakers in the EU, where many of the frontrunners in plant-based 'meat' and cultured-meat innovation are located, will need to respond imminently to new production methods and products. The decisions that they take now – on the regulation, labelling and marketing of meat analogues, for example – will have a significant influence on the industry's direction and pace of growth.
- Decisions on labelling requirements for meat analogues will be particularly important in determining consumer acceptance of plant-based 'meat' and cultured meat as substitutes for animal-derived meat. These decisions will be based not only on technical factors but on political considerations of the future of the meat industry in the EU.
- In order to meet its climate change commitments, the EU will need to change European eating patterns, including a reduction in meat consumption. Meat analogues have the potential to contribute to existing EU climate mitigation strategies and EU priority policy initiatives in areas including reduced antibiotic use, improved public health and sustainable resource management. To achieve this, EU policymakers will need to promote a clear, transparent and inclusive regulatory environment and invest public capital in research, development and commercialization.

1. Introduction

Consensus is building across the scientific, environmental and public health communities that a radical shift away from excessive meat-eating patterns is urgently needed to tackle the unsustainability of the livestock sector. Meat production is a principal driver of environmental change and natural resource depletion: the livestock industry accounts for an estimated 40 per cent of global arable land, 36 per cent of crop calories produced, 29 per cent of agricultural freshwater use,[1] and 14.5 per cent of all human greenhouse gas (GHG) emissions.[2] To meet global climate targets, per capita consumption of meat would need to fall drastically: the average global citizen would need to eat 75 per cent less red meat, while citizens of the western hemisphere would need to reduce consumption by 90 per cent.[3]

Excessive levels of individual meat consumption are associated with overweight, obesity and diet-related non-communicable diseases, including cardiovascular disease, type-2 diabetes and certain cancers.[4] It has been predicted that in 2020 consumption of red and processed meat could lead to 2.4 million deaths globally and total healthcare costs of $285 billion.[5] Furthermore, the inappropriate use of antimicrobials in animals is recognized by the UN as a leading cause of the increased occurrence of antimicrobial resistance,[6] while the intensification of livestock production raises serious animal welfare concerns.[7]

Recent years have signalled a step-change in public awareness of the health (and, to a lesser extent, environmental) risks associated with overconsumption of meat, particularly red and processed meat, and an increased trend towards 'flexitarian' diets, in which meat intake is reduced in favour of plant-based sources of protein. Many of the larger environmental groups are actively promoting plant-based diets – Greenpeace, for example, has called for a 50 per cent reduction of meat and dairy

[1] Mottet, A., de Haan, C., Falcucci, A., Tempio, G., Opio, C. and Gerber, P. (2017), 'Livestock: On our plates or eating at our table? A new analysis of the feed/food debate', *Global Food Security*, *14*: pp. 1–8, doi:10.1016/j.gfs.2017.01.001 (accessed 15 May 2018); Cassidy, E. S., West, P. C., Gerber, J. S. and Foley, J. S. (2013), 'Redefining agricultural yields: from tonnes to people nourished per hectare', *Environmental Research Letters,* 8(3), doi:10.1088/1748-9326/8/3/034015 (accessed 15 May 2018); Gerbens-Leenes, P. W., Mekonnen, M. M. and Hoekstra, A. Y. (2013), 'The water footprint of poultry, pork and beef: a comparative study in different countries and production systems', *Water Resources and Industry*, *1–2*: pp. 25–36, doi:10.1016/j.wri.2013.03.001 (accessed 15 May 2018).

[2] Gerber, P. J., Steinfield, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. and Tempio, G. (2013), *Tackling Climate Change through Livestock: A Global Assessment of Emissions and Mitigation Opportunities,* Rome: UN Food and Agriculture Organization.

[3] Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B. L., Lassaletta, L., de Vries, W., Vermeulen, S. J., Herreo, M., Carlson, K. M. and Jonell, M. (2018), 'Options for keeping the food system within environmental limits', *Nature,* 562: pp. 519–25, doi:10.1038/s41586-018-0594-0 (accessed 19 Nov. 2018).

[4] Popkin, B. M., Adair, L. S. and Ng, S. W. (2012), 'Global nutrition transition and the pandemic of obesity in developing countries', *Nutrition Reviews*, *70(1)*: pp. 2–21, doi:10.1111/j.1753-4887.2011.00456.x (accessed 19 Nov. 2018); Rouhani, M. H., Salehi-Abargouei, A., Surkan, P. J. and Azadbakht, L. (2014), 'Is there a relationship between red or processed meat intake and obesity? A systematic review and meta-analysis of observational studies', *Obesity Reviews*, *15(9)*: pp. 740–48, doi:10.1111/obr.12172 (accessed 19 Nov. 2018); Bouvard, V., Loomis, D., Guyton, K. Z., Grosse, Y., El Ghissassi, F., Benbrahim-Tallaa, L., Guha, N., Mattock, H. and Straif, K. (2015), 'Carcinogenicity of consumption of red and processed meat', *The Lancet Oncology*, *16(16)*: pp. 1599–1600, doi:10.1016/S1470-2045(15)00444-1 (accessed 19 Nov. 2018); Micha, R., Wallace, S. K. and Mozaffarian, D. (2010), 'Red and processed meat consumption and risk of incident coronary heart disease, stroke, and diabetes mellitus: a systematic review and meta-analysis', *Circulation*, *121(21)*: pp. 2271–83, doi:10.1161/CIRCULATIONAHA.109.924977 (accessed 19 Nov. 2018).

[5] Springmann, M., Mason-D'Croz, D., Robinson, S., Wiebe, K., Godfray, H. C. J., Rayner, M. and Scarborough, P. (2018), 'Health-motivated taxes on red and processed meat: A modelling study on optimal tax levels and associated health impacts', *PLoS ONE*, *13(11)*: pp. 1–16, doi:10.1371/journal.pone.0204139 (accessed 19 Nov. 2018).

[6] Van Boeckel, T. P., Glennon, E. E., Chen, D., Gilbert, M., Robinson, T. P., Grenfell, P. T., Levin, S.A., Bonhoeffer, S. and Laxminarayan, R. (2017), 'Reducing antimicrobial use in food animals', *Science*, *357(6358)*: pp. 1350–52, doi:10.1126/science.aao1495 (accessed 19 Nov. 2018).

[7] Mason, P. and Lang, T. (2017), *Sustainable diets: How ecological nutrition can transform consumption and the food system*, London: Routledge.

and a significant increase of plant-based foods in terms of both production and consumption by 2050,[8] and the conservation organization WWF-UK's Livewell dietary guidelines encourage healthy and sustainable eating by focusing on moderating meat consumption[9] – while the scientific community is advocating for meat reduction as a core principle of healthy and sustainable global diets.[10]

Many European consumers are increasingly concerned about the impact of their current meat consumption. In 2018, an open public consultation carried out by the European Commission in member states showed that over 80 per cent of respondents were willing to 'consider the impact of their food purchases on greenhouse gas emissions' and 74 per cent would 'consider changing their diets'.[11] Globally, however, meat consumption continues to rise. Between the early 1960s and the early 2010s, worldwide availability of meat per capita almost doubled, and the Food and Agriculture Organization of the UN (FAO) expects that, by 2030, global consumption will be 76 per cent higher than it was in 2005.[12]

Recognizing the scale of the challenge ahead, public policymakers, civil society and innovators in the agricultural sector and beyond have increasingly sought to prompt shifts in consumer food choices, away from the most resource-intensive meat products and towards more sustainable alternatives.

Recognizing the scale of the challenge ahead, public policymakers, civil society and innovators in the agricultural sector and beyond have increasingly sought to prompt shifts in consumer food choices, away from the most resource-intensive meat products and towards more sustainable alternatives. For some, the priority lies in encouraging reduced red meat consumption and greater demand for poultry, the emissions footprint of which is lower than that of beef or lamb.[13] For others, the aim is to encourage a shift away from meat consumption altogether and to promote vegetarian or vegan lifestyles. For others still, the most promising opportunity lies in substituting meat produced through conventional means with meat produced in an entirely new way.

Meat analogues are plant-based and cultured products that are (or aim to be) equivalent substitutes for animal-derived meat, and are produced from plant or animal cells cultured in a laboratory or bioreactor. Meat analogues are the latest in a long history of meat alternative products that are intended to replace conventionally produced meat in a meal or diet. What sets meat analogues apart from well-known meat alternatives – Quorn, for example, or tofu and wheat-based processed 'meat' products – is that they are aimed at meat-eaters rather than vegetarians or vegans. They are designed

[8] Greenpeace (2018), 'Greenpeace calls for decrease in meat and dairy production and consumption for a healthier planet', 5 March 2018, https://www.greenpeace.org/international/press-release/15111/greenpeace-calls-for-decrease-in-meat-and-dairy-production-and-consumption-for-a-healthier-planet/ (accessed 21 Nov. 2018).
[9] WWF (2017), *Eating for 2 degrees: new and updated Livewell plates. Summary Report (Revised edition)*, August 2017, https://www.wwf.org.uk/sites/default/files/2017-09/WWF_Livewell_Plates_Summary_Report_Sept2017_Web.pdf (accessed 21 Nov. 2017).
[10] Willet, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Jordan, L. J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J. A., De Vries, W., Majele Sibanda, L., Afshin, A., Chaudhary, A., Herrero, M., Agustina, R., Branca, F., Lartey, A., Fan, S., Crong, B., Fox, E., Bignet, V., Troell, M., Lindahl, T., Singh, S., Cornell, S. E., Srinath Reddy, K., Narain, S., Nishtar, S. and Murray, C. J .L. (2019), 'Food in the Anthropocene: the EAT-*Lancet* Commission on healthy diets from sustainable food systems', *The Lancet Commissions*, doi:10.1016/S0140-6736(18)33179-4 (accessed 22 Jan. 2019).
[11] European Commission (2018), *In-Depth Analysis in Support of the Commission Communication COM (2018) 773: A Clean Planet for all. A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy*, p. 295.
[12] Alexandratos, N. and Bruinsma, J. (2012), *World Agriculture Towards 2030/2050. The 2012 Revision*, ESA Working paper No. 12-03, Rome: FAO, http://www.fao.org/3/a-ap106e.pdf (accessed 10 Jan. 2019).
[13] Gerber et al. (2013), *Tackling Climate Change through Livestock: A Global Assessment of Emissions and Mitigation Opportunities.*

to achieve an unprecedented degree of mimicry that enables consumers to continue experiencing the 'sensory pleasures' of conventional meat.[14]

Interest in meat analogues – from innovators, investors and the public – is rapidly growing. In recent years, meat analogue start-ups have gained increasing amounts of attention from the global media, helped along by investments and endorsements from high-net-worth individuals including Bill Gates, Richard Branson and Leonardo DiCaprio. In September 2018, two plant-based 'meat' manufacturers, Beyond Meat and Impossible Foods, were jointly presented with a Champion of the Earth Award, the UN's highest environmental honour.[15]

For policymakers, civil society and industry incumbents, meat analogues raise a number of challenging questions: do meat analogues belong in the realm of meat alternatives or that of conventional meat? How should they be defined and regulated by lawmakers? And what place do they hold in a sustainable, healthy and equitable food system? With innovation continuing to happen at pace, policymakers in key markets will need to respond imminently to new production methods and products to ensure that human, animal and environmental health are protected. Decisions taken today by those actors, on how meat analogues can and should be regulated and marketed, will likely have a formative impact both on the pace of industry scale-up and on the degree to which the public, civil society and industry incumbents either accept or resist their uptake.

This paper considers the two principal categories of meat analogues: advanced plant-based 'meat' and cultured meat. It explores the challenges that innovators face in scaling up production and generating demand, regulatory frameworks to which they will be subject, and implications of regulatory decisions for the future of the meat industry. The paper focuses on the European Union, which is a hub of research and development in plant-based 'meat' and cultured meat and a region where demand for meat alternatives is experiencing rapid growth.

[14] Sexton, A. (2016), 'Alternative Proteins and the (Non)Stuff of "Meat"', Gastronomica: *The Journal of Critical Food Studies*, *16(3)*: pp. 66–78, doi:10.1525/GFC.2016.16.3.66 (accessed 18 Jan. 2019).
[15] UN Environment Programme (2018), 'Outstanding environmental changemakers receive UN's Champions of the Earth Award', 26 September 2018, http://web.unep.org/championsofearth/outstanding-environmental-changemakers-receive-un%E2%80%99s-champions-earth-award (accessed 21 Nov. 2018).

2. Innovation in Meat Analogues

Meat alternatives – non-traditional protein sources intended to be used and consumed in a similar way to meat products – are available around the world. Some of these have long been readily available in certain regions. For example, the Quorn meat substitute brand, launched in the UK in 1985, uses fermentation technology to create mycoprotein (a type of single-cell protein) from the soil fungus *Fusarium* and is well established in many Western markets.[16] Insect proteins, already in the mainstream in some Asian markets, are used by a growing number of companies in Europe and North America in products for human consumption and in animal feed.[17]

In recent years, the interest, innovation and investment in meat analogues – non-traditional protein sources that are designed to be direct, imitative substitutes for conventionally produced meat – have increased significantly. Technologies are delivering, or are expected to deliver, products that have the potential to reduce traditional meat consumption without a drastic shift in eating behaviours. These developments coincide with the growing realization that, for environmental and public health reasons, reducing global traditional meat consumption is both necessary and desirable.

Two broad categories of meat analogues – advanced plant-based 'meat' and cultured meat – mark a particularly radical departure from the traditional meat and non-meat options seen to date. The driving principles in their production are mimicry and efficiency – principles identified by Mark Post, the innovator behind the first lab-grown burger in 2013,[18] as the two key requisites for the acceptance and industrialization of a meat alternative.[19] Both raise challenging questions for producers, policymakers and consumers alike around how 'meat' should be defined and regulated, and around the possibility of satiating the world's growing demand for meat while dramatically scaling back animal agriculture.

Plant-based 'meat'

Advanced plant-based 'meat' products are those that use plant-derived ingredients to directly mimic animal-derived meat and which are designed to be indistinguishable from their animal-based equivalents. Drawing a clear line between plant-based 'meat' and the plant-based meat alternatives that have come before is not straightforward. The distinction on which plant-based 'meat' innovators have patented – or sought to patent – their products and processes lies in the versatility and sensory experience of cooking and eating. They are marketed predominantly as processed meat products – burgers, sausages, meatballs – but are distinct from more mainstream plant-based meat alternatives in that they contain novel ingredients or use innovative processes intended to achieve an unprecedented degree of mimicry in taste, texture, look and cooking qualities. Advanced plant-based 'beef' burgers,

[16] Wiebe, M. G. (2002), 'Myco-protein from Fusarium venenatum: A well-established product for human consumption', *Applied Microbiology and Biotechnology*, *58(4)*: pp. 421–27, doi:10.1007/s00253-002-0931-x (accessed 22 Nov. 2018).
[17] Verbeke, W., Spranghers, T., De Clercq, P., De Smet, S., Sas, B. and Eeckhout, M. (2015), 'Insects in animal feed: Acceptance and its determinants among farmers, agriculture sector stakeholders and citizens', *Animal Feed Science and Technology*, *204*: pp. 72–87, doi:10.1016/j.anifeedsci.2015.04.001 (accessed 17 May 2018); Stice, C. and Olson, S. (2014), *WhooPea: Plant Sources Are Changing the Protein Landscape,* Lux Research, December 2014.
[18] Post, M. J. (2013), 'Cultured beef: Medical technology to produce food', *Journal of the Science of Food and Agriculture*, *94(6)*: pp. 1039–41, doi:10.1002/jsfa.6474 (accessed 17 May 2018).
[19] Post, M. J. (2012), 'Cultured meat from stem cells: Challenges and prospects', *Meat Science, 92(3)*: pp. 297–301, doi:10.1016/j.meatsci.2012.04.008 (accessed 14 May 2018).

for example, developed by companies such as Beyond Meat, Impossible Foods and Moving Mountains, comprise a unique set of ingredients that, in combination, produce a patty whose texture resembles that of minced beef, has a pink hue that turns brown on cooking, and exudes liquid on eating (see Figure 1).

For the most part, these products use non-genetically engineered ingredients such as beetroot juice to achieve these qualities, while Impossible Foods' 'Impossible Burger' contains soy leghemoglobin (SLH), a plant protein. SLH is isolated from the root of the soybean plant and, like haemoglobin in blood and myoglobin in muscles, it is a molecule that carries oxygen, storing it in the roots of legumes. When the 'Impossible Burger' is cooked and eaten, SLH is exuded as a red-tinted liquid – comparable to myoglobin, the substance that 'bleeds' from minced beef – and gives a metallic iron-like (and thus meat-like) flavour to this product.[20]

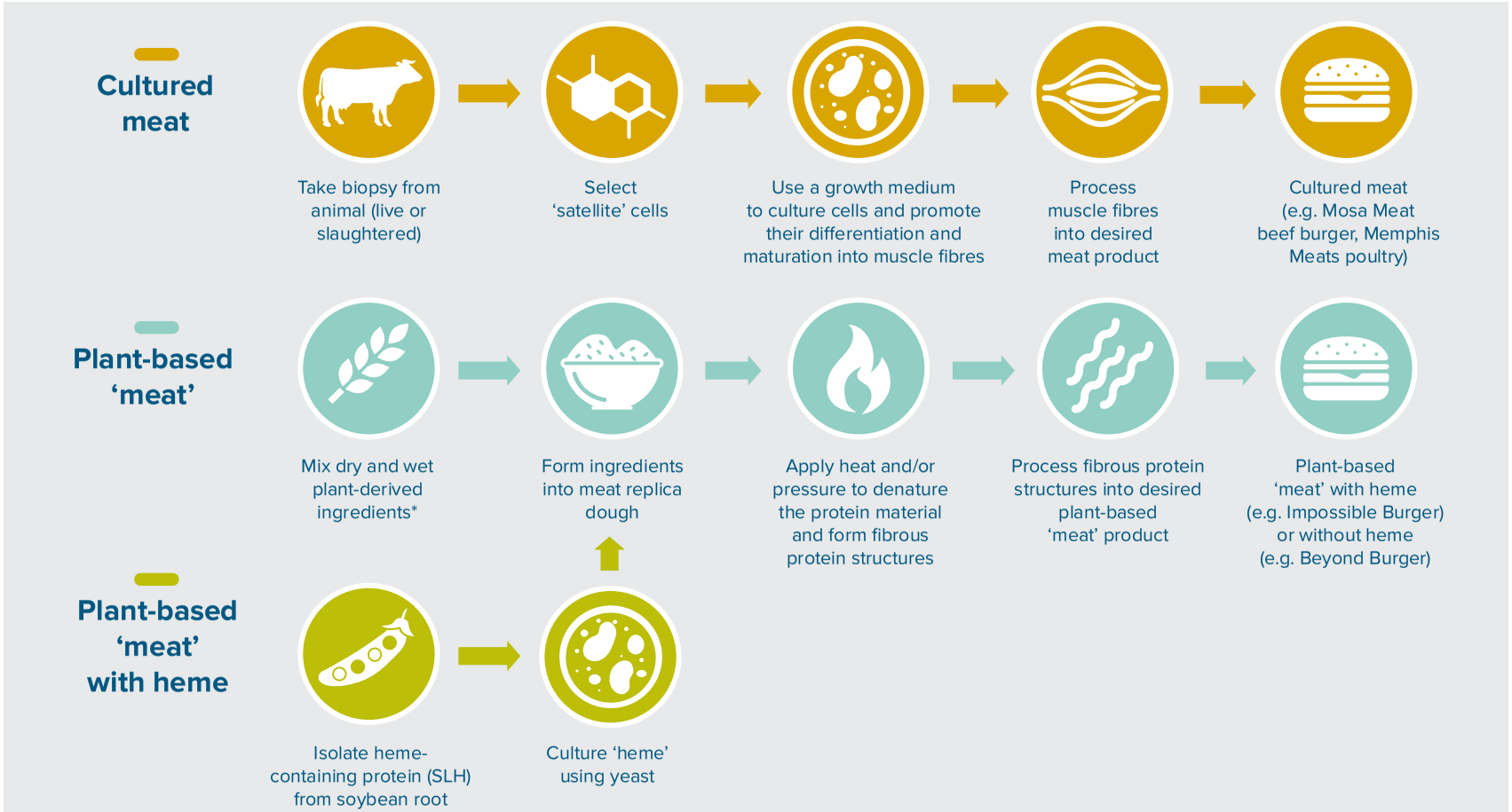
Cultured meat

Cultured meat is grown *in vitro* from animal-derived stem cells using a growth medium (Figure 1). It is 'biologically equivalent'[21] to meat but is not harvested from a living animal. Culturing meat involves biotechnological processes borrowed from regenerative medicine (the branch of medicine that aims to develop ways to regenerate cells, tissues or organs)[22] and aims to scale up these approaches to manufacture meat through cellular and tissue culture, termed 'cellular agriculture'. Although no agreement has yet been reached on the definition for this process, cellular agriculture entails using a 'set of technologies to manufacture products typically obtained from livestock farming, using culturing techniques to manufacture the individual product'.[23]

The cells used to initiate the cell culture can be sourced from primary animal tissue through a biopsy procedure; alternatively, cell lines (stem cells) that can replicate indefinitely can be produced via genetic engineering, gene editing or through induced or spontaneous mutations.[24] Cells are cultured within specific liquid media, which provide the conditions needed for tissue growth. The exact media used will depend on the cell species and tissue type, but the process requires nutrients (supplied by foetal calf or horse serum, chicken embryo extract, collagen, serum-free media, etc.).[25] Other inorganic and organic components (antibiotic/antimitotics or carbohydrates, amino acids and vitamins) can be added to the media to enable cell growth.[26] A scaffold is required for cells to proliferate and develop the structure required for producing a tissue (for example, a muscle) instead of an unorganized collection of muscle cells. The components used in these processes are dependent on their stages of development, and research in this area is still in its infancy.[27] For example, even though a few companies, such as Higher Steaks and Aleph Farms, already use only animal-free growing media, more research is needed for lowering the costs of serum-free processes.[28]

[20] Fraser, R. Z., Shitut, M., Agrawal, P., Mendes, O. and Klapholz, S. (2018), 'Safety Evaluation of Soy Leghemoglobin Protein Preparation Derived from *Pichia pastoris*, Intended for Use as a Flavor Catalyst in Plant-Based Meat', *International Journal of Toxicology, 37(3)*: pp. 241–62, doi:10.1177/1091581818766318 (accessed 31 May 2018).
[21] Stephens, N., Dunsford, I., Di Silvio, L., Ellis, M., Glencross, A. and Sexton, A. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture', *Trends in Food Science & Technology, 78*: pp. 155–66, doi:10.1016/j.tifs.2018.04.010 (accessed 19 Nov. 2018).
[22] Post, M. J. (2012), 'Cultured meat from stem cells: Challenges and prospects'.
[23] Stephens et al. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture'.
[24] Ibid., p. 157.
[25] Ibid., p. 159.
[26] Ibid., p. 159.
[27] Ibid., p. 159.
[28] Higher Steaks (2018), 'About us', https://www.highersteaks.com/about-us/ (accessed 12 Dec. 2018); Michail, N. (2018), 'Aleph Farms CEO on its 3D cultured beef: "Unlike other companies, our meat grows together like real meat"', FoodNavigator, 2 May 2018, https://www.foodnavigator.com/Article/2018/05/02/Aleph-Farms-CEO-on-its-3D-cultured-beef-Unlike-other-companies-our-meat-grows-together-like-real-meat# (accessed 14 Jan. 2019).

Figure 1: Cultured meat and plant-based 'meat' production processes



* Plant protein (e.g. pea or wheat protein); fibrous component (e.g. bamboo or carrot); flavouring (e.g. iron salt or vegetable extract); water; fat (e.g. coconut or sunflower oil); binding agent (e.g. xanthan gum or egg albumin); colouring (e.g. beet or turmeric juice).

Note: Mycoprotein-based plant-based meat alternatives involve a different production process to that detailed above. See Finnigan, T. J. A. (2011), 'Mycoprotein: origins, production and properties', in Phillips, G. O. and Williams, P. A. (eds), *Handbook of Food Proteins*, doi:10.1533/9780857709369.335 (accessed 29 Jan. 2019).
Source: Based on information drawn from Mosa Meat (2018), 'Meat Analogues: What do they mean for the EU?', presentation delivered at Chatham House expert roundtable, London, 12 September 2018; Impossible Foods Inc. (2015), 'Ground meat replicas', patent number WO2015/153666 A1, 8 October 2015, https://patents.justia.com/patent/10172380 (accessed 29 Jan. 2019); Savage River Inc. dba Beyond Meat (2015), 'Plant-based meat structure protein products', patent number WO2015/161099 A1, 22 October 2015, https://patentimages.storage.googleapis.com/6c/c9/ed/7d334d7f49cf7b/WO2015161099A1.pdf (accessed 29 Jan. 2019); Kyriakopoulou, K., Dekkers, B. and van der Goot, A. (2018), 'Plant-Based Meat Analogues', in Galanakis, C. (ed.), *Sustainable Meat Production and Processing*, Cambridge, Massachusetts: Academic Press.

The current market landscape

Much of the development in the field of cultured meat has been driven by start-up companies and university laboratories, with funding from large corporations (see Annex 1).[29] Products are mainly at the prototype stage and are not yet available for purchase in restaurants or retail outlets. It is estimated that the value of the global cultured-meat market could reach $20 million by 2027, primarily driven by increases in meat consumption and innovation in the technology necessary to scale up from laboratory to factory production.[30]

The global market for plant-based meat alternatives was estimated to be worth $4.63 billion in 2018 and, according to business information providers Research and Markets, is projected to reach $6.43 billion by 2023 (growing at a compound annual growth rate – CAGR – of 6.8 per cent).[31] Research published in March 2018 by Mordor Intelligence put the expected CAGR of the market over the 2018–23 period at a slightly lower 5.8 per cent. According to Mordor, Europe presented the largest regional market for meat substitute products in 2017, with 39 per cent of global market share,[32] while the Asia-Pacific market is estimated to be the fastest growing due to rising levels of economic development and to its large population.[33] According to research undertaken by Nielsen for the US Good Food Institute, plant-based meat analogues still accounted for less than 1 per cent of the value of the total US retail market for meat as of 11 August 2018, but had risen in value by 23 per cent since the equivalent period of 2017. The worldwide market for meat has been valued at $1 trillion.[34]

> The food service sector is also offering plant-based meat alternatives. The 'Beyond Burger' is already sold in over 25,000 restaurants, hotels and universities worldwide. The 'Impossible Burger' is available in more than 4,000 locations in the US. Moving Mountains' products are stocked at over 500 locations in the UK and are also available in the Netherlands.

Regionally, North America is projected to dominate the cultured-meat market in 2021, as the region is characterized by significant investment in the development of meat analogues.[35] The market is also expanding into Asia, since China's signature in 2017 of a $300 million agreement to import cultured-meat technologies from Israel, and the Japanese government's participation in May 2018 in a $2.7 million funding round for a new 'clean meat' start-up, Integriculture.[36]

In major Western markets the retail sector is both responding to and helping to drive this rising acceptance of plant-based meat alternatives. Major grocery retailers selling plant-based meat analogues

[29] Stephens et al. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture'.
[30] AP News (2018), Cultured Meat (Poultry, Pork, Beef, Duck) Market – Global Forecast to 2027 – ResearchAndMarkets.com', 11 May 2018, https://www.apnews.com/e46c4b5af8854db7bfa158005e27fae1 (accessed 15 Nov. 2018).
[31] PR Newswire (2018), 'Meat Substitutes Market 2018 – Global Forecast to 2023', News provided by Research and Markets, 23 March 2018, https://www.prnewswire.com/news-releases/meat-substitutes-market-2018---global-forecast-to-2023-300618746.html (accessed 19 Nov. 2018).
[32] Mordor Intelligence (2018), 'Meat Substitute Market – Growth, Trends and Forecasts (2019–2024)', https://www.mordorintelligence.com/industry-reports/meat-substitute-market (accessed 2 Jan. 2019).
[33] Ibid.
[34] The Good Food Institute (2018), 'The Plant-Based Alternatives Market is Skyrocketing', https://www.gfi.org/images/uploads/2018/09/Good-Food-Institute-Plant-Based-Nielsen-Data-Sheet-2018-0911-v3.pdf (accessed 27 Nov. 2018); Michail, N. (2018), 'Mosa Meat CEO on clean meat, competition and disrupting a $1 trillion market', FoodNavigator, 16 January 2018, https://www.foodnavigator.com/Article/2018/01/16/Mosa-Meat-CEO-on-clean-meat-competition-and-disrupting-a-1-trillion-market (accessed 27 Nov. 2018).
[35] Ibid.
[36] Starostinetskaya, A. (2017), 'Israel and China sign $300 million lab meat deal', Veg News, 13 September 2017, https://vegnews.com/2017/9/israel-and-china-sign-300-million-lab-meat-deal (accessed 15 Nov. 2018); Starostinetskaya, A. (2018), 'Japan part of $2.7m investment in new clean meat brand', Veg News, 4 June 2018, https://vegnews.com/2018/6/japan-part-of-27m-investment-in-new-clean-meat-brand (accessed 15 Nov. 2018).

include UK-based Tesco, Sainsbury's, Waitrose & Partners and Ocado, and Whole Foods, Target, Safeway, Kroger and Walmart in the US.[37] Around the world, there has been an increase in the number of all-vegan grocery stores, which also serve as retail channels for plant-based 'meat' products: these include Naturalia Vegan (France), Sweet to Lick (US), Veganz (Germany and the Czech Republic), and Vegan Supply (Canada).[38] Certain brands have been successful in penetrating multiple markets: Beyond Meat's plant-based 'Beyond Burger' recently launched in Tesco, the UK's biggest retail supermarket, with the same market strategy used in the US, whereby the product is sold alongside animal-based meat patties.[39]

The food service sector is also offering plant-based meat alternatives. The 'Beyond Burger' is already sold in over 25,000 restaurants, hotels and universities worldwide, including in major restaurant chains such as TGI Fridays and BurgerFi, in the US, and Honest Burgers and All Bar One, in the UK.[40] The 'Impossible Burger' – the 'bleeding plant-based burger' mentioned earlier – is available in more than 4,000 locations in the US (including in two major chains – Bareburger and White Castle), and has been launched in Hong Kong and Macau, with plans to expand worldwide.[41] British company Moving Mountains' products are stocked at over 500 locations in the UK and are also available in the Netherlands.[42] The Vegetarian Butcher, a Dutch supplier of plant-based meat alternatives, has expanded to 3,000 sales outlets in 14 countries.[43] The Asian market already has cultural ties with vegetarian food, and recent campaigns by restaurants, food bloggers and start-ups have contributed to an increase in consumption of meat alternatives. Hong Kong-based start-up Right Treat has developed a plant-based pork substitute, branded 'Omnipork', with the intention that it can be widely used within Asian cuisine.[44] Shifts in dietary habits towards vegetarianism and a reduction in meat consumption have been a major driver behind these launches.

[37] Von Alt, S. (2018), 'Vegan at Walmart? Here Are 10 Delicious Plant-Based Finds', Chooseveg, 27 April 2018, http://chooseveg.com/blog/vegan-at-walmart-10-delicious-plant-based-foods/ (accessed 19 Nov. 2018); Chiorando, M. (2017), 'Vegan Growth Driving Meat-Alternative Market To Exceed $6 Billion By 2023', Plant Based News, 29 March 2018, https://www.plantbasednews.org/post/vegan-growth-driving-meat-alternative-market-to-exceed-6-billion-by-2023 (accessed 19 Nov. 2018); Beyond Meat (2018),'Store Locator', http://beyondmeat.com/store-locator; (accessed 19 Nov. 2018); Butler, S. (2018), 'Quorn invests £7m into R&D on back of veganism boom', *Guardian*, 23 July 2018, https://www.theguardian.com/business/2018/jul/23/quorn-invests-7m-r-and-d-veganism-boom (accessed 19 Nov. 2018); Smithers, R. (2018), 'Vegan burgers: now juicy, pink and bloody', *Guardian*, 19 May 2018, https://www.theguardian.com/lifeandstyle/2018/may/19/fake-steak-supermarkets-flexitarians-meat-free-burgers (accessed 19 Nov. 2018); Senthilingam, M. (2017), 'Are Germans leading a vegan revolution?', CNN, 31 July 2017, https://edition.cnn.com/2017/05/03/health/germany-vegan-vegetarian-diets/index.html (accessed 19 Nov. 2018).

[38] Krantz, R. (2017), '11 All-Vegan Grocery Stores Around the World You Should Visit', Chooseveg, 18 July 2017, http://chooseveg.com/blog/11-all-vegan-grocery-stores-around-the-world/ (accessed 19 Nov. 2018).

[39] Graham, R. (2018), 'Beyond Burger on way to UK freezers as Authentic Food Co distribution deal agreed', *The Grocer*, 30 May 2018, https://www.thegrocer.co.uk/home/topics/future-of-meat/beyond-burger-on-way-to-uk-as-distribution-deal-agreed/567624.article (accessed 2 Jan. 2019); Smithers, R. (2018), '"Bleeding" vegan burger arrives on UK supermarket shelves', *Guardian*, 12 November 2018, https://www.theguardian.com/food/2018/nov/12/bleeding-vegan-burger-arrives-on-uk-supermarket-shelves?CMP=fb_gu&fbclid=IwAR2FxIpfpiRgP1VxJDIhXPNq9IYxODLMAg8HpLJhf5Jxn50khO27ZfvpS_s (accessed 19 Nov. 2018).

[40] Beyond Meat (2018), 'Store Locator', https://www.beyondmeat.com/store-locator (accessed 22 Jan. 2019).

[41] Lee-Zogbessou, J. (2018), 'Impossible Foods: the rise of the meat-free plant-based burger', Verdict Foodservice, 2 October 2018, https://www.verdictfoodservice.com/insight/impossible-foods-plant-based-burger/ (accessed 19 Nov. 2018).

[42] Moving Mountains (2018), https://movingmountainsfoods.com/(accessed 19 Nov. 2018).

[43] The Vegetarian Butcher (2018), https://www.thevegetarianbutcher.com/about-us/vegetarian-butcher-production-plant (accessed 19 Nov. 2018).

[44] Wan, L. (2018), 'Alternative protein firms need to rethink Asian preferences and nutrition priorities', FoodNavigator, 18 June 2018, https://www.foodnavigator-asia.com/Article/2018/06/18/Alternative-protein-firms-need-to-rethink-Asian-preferences-and-nutrition-priorities (accessed 19 Nov. 2018); Watson, A. (2018), 'Right Treat Turning Asian Pork Lovers on to the Virtues of Plant-Based Protein', Sustainable Brands, 7 August 2018, https://sustainablebrands.com/read/behavior-change/right-treat-turning-asian-pork-lovers-on-to-the-virtues-of-plant-based-protein (accessed 19 Nov. 2018).

Summary

- Two broad categories of meat analogues – advanced plant-based 'meat' and cultured meat – mark a particularly radical departure from the traditional meat and non-meat options.
- Producers of both plant-based 'meat' and cultured meat aim to deliver products that are indistinguishable from conventional meat.
- Markets for meat analogues are growing in Europe, North America and Asia where both the retail and food service industries are increasingly selling plant-based 'meat'. Cultured meat is not yet on the market but significant scale-up of investment has been seen in Europe, North America, China and Israel.

3. Factors in the Growth of the Meat Analogue Industry

The direction and pace of growth in the meat analogue industry will depend upon numerous factors affecting prospects both for commercially viable production systems at scale and for acceptance and demand among target consumer segments. Despite increasing consumer awareness of the environmental and animal welfare impacts of eating meat[45] and the growing market for reduced-meat diets,[46] the degree of consumer acceptance of meat analogues is uncertain,[47] as is the likely level of support from Europe's civil society groups. The role of the incumbent industry in supporting or hindering the growth of meat analogues is also unclear: while some major players in the meat industry are investing in meat analogue innovations themselves, others are actively resisting the up-swell of start-ups marketing their products as meat substitutes.

This chapter explores the ways in which consumer perceptions, civil society and incumbent industry responses, technical challenges and meat consumption trends may influence the growth of the meat analogue industry in the EU before considering, in Chapter 4, the complexities of the regulatory questions to which meat analogues give rise.

Consumer perceptions of meat analogues

Producers of meat analogues actively target their products at meat-eaters. They have aligned their marketing with that of conventional meat products – emphasizing the taste and experience of eating meat through carefully chosen language and imagery – while innovators in cultured-meat products emphasize their ability to deliver meat 'as we know it', without the negative environmental and welfare impacts.[48] The mission statement of San Francisco-based Memphis Meat encapsulates this concept, with the slogan 'Better meat, better world'.[49] Deep-set personal preferences for meat in Europe are nevertheless expected to present a significant obstacle to generating widespread

[45] Bailey, R., Froggatt, A. and Wellesley, L. (2014), *Livestock – Climate Change's Forgotten Sector: Global Public Opinion on Meat and Dairy Consumption*, Chatham House Report, London: Royal Institute of International Affairs, https://www.chathamhouse.org/sites/default/files/field/field_document/20141203LivestockClimateChangeForgottenSectorBaileyFroggattWellesleyFinal.pdf (accessed 19 Nov. 2018).
[46] Waitrose & Partners (2018), 'Food And Drink Report 2018–19: The era of the mindful consumer', https://www.waitrose.com/content/dam/waitrose/Inspiration/Waitrose%20&%20Partners%20Food%20and%20Drink%20Report%202018.pdf (accessed 19 Nov. 2018); Eating Better Foundation (2017), 'The future of eating is flexitarian: companies leading the way', https://www.eating-better.org/uploads/Documents/2017/Eating%20Better_The%20future%20of%20eating%20is%20flexitarian.pdf (accessed 19 Nov. 2018).
[47] Apostolidis, C. and McLeay, F. (2016), 'Should we stop meating like this? Reducing meat consumption through substitution', *Food Policy (65)*: pp. 74–89, doi:10.1016/j.foodpol.2016.11.002 (accessed 4 Jan. 2019); Schösler, H., De Boer, J. and Boersema, J. J. (2012), 'Can we cut out the meat of the dish? Constructing consumer-oriented pathways towards meat substitution', *Appetite*, *58 (1)*: pp. 39–47, doi:10.1016/j.appet.2011.09.009 (accessed 19 Nov. 2018); Hoek, A. C., Pearson, D., James, S. W., Lawrence, A. and Friel, S. (2017), 'Shrinking the food-print: A qualitative study into consumer perceptions, experiences and attitudes towards healthy and environmentally friendly food behaviours', *Appetite,* 108: pp. 117–31, doi:10.1016/j.appet.2016.09.030 (accessed 19 Nov. 2018); Vanhonacker, F., Van Loo, E. J., Gellynck, X. and Verbeke, W. (2013), 'Flemish consumer attitudes towards more sustainable food choices', *Appetite*, *62*: pp. 7–16, doi:10.1016/j.appet.2012.11.003 (accessed 19 Nov. 2018); Schösler, H., De Boer, J. and Boersema, J. J. (2014), 'Fostering more sustainable food choices: Can Self-Determination Theory help?', *Food Quality and Preference*, *35*: pp. 59–69, doi:10.1016/j.foodqual.2014.01.008 (accessed 19 Nov. 2018).
[48] Wellesley, L. (2017), 'What's cooking? The future of meat', Hoffmann Centre for Sustainable Resource Economy, Chatham House, 12 June 2017, https://hoffmanncentre.chathamhouse.org/article/whats-cooking-the-future-of-meat/ (accessed 29 May 2018).
[49] Memphis Meats (2018), 'Better Meat, Better World', http://www.memphismeats.com/home/#aboutus (accessed 19 Nov. 2018).

demand for plant-based 'meat' and cultured meat.[50] A number of studies undertaken into consumer attitudes to meat analogues specifically, and plant-based diets more generally, indicate that those already seeking to reduce their meat consumption are the most likely to purchase plant-based meat alternatives, while so-called 'meat-believers' – those who regularly consume meat and who do not display any active intention of shifting their diets – are less likely to be tempted by new meat substitute options.[51]

> Those already seeking to reduce their meat consumption are the most likely to purchase plant-based meat alternatives, while so-called 'meat-believers' are less likely to be tempted by new meat substitute options.

Familiarity, sensory attractiveness and the prevalence of food 'neophobia' are all likely to play a role in strengthening or dampening public interest,[52] particularly among meat-eaters at whom novel meat analogues are aimed. The cultivation of recognizable whole cuts of meat – as opposed to muscle cells that can be used in minced-meat products (sausages, burgers, etc.) – in a way that is economically viable at scale remains a long-term goal.[53] The technological process involved in producing a steak *in vitro*, for example, requires culturing a more complex tissue, including multiple cell types, and considerable progress is needed to achieve a steak or similar whole-cut of meat that achieves the colour, flavour and nutritional profile of meat harvested from an animal – and to do so in a manner that is economically viable is even more challenging,[54] and therefore significantly further from market. Even with further technical breakthroughs, consumer concerns over the 'naturalness' of cultured meat are expected to be a major obstacle to the future widespread adoption of cultured-meat products.[55]

[50] Van der Weele, C. and Driessen, C. (2013), 'Emerging profiles for cultured meat; ethics through and as design', *Animals*, *3(3)*: pp. 647–62, doi:10.3390/ani3030647 (accessed 19 Nov. 2018); Stephens et al. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture'; De Boer, J. and Aiking, H. (2017), 'Pursuing a low meat diet to improve both health and sustainability: How can we use the frames that shape our meals?', *Ecological Economics*, *142*: pp. 238–48, doi:10.1016/j.ecolecon.2017.06.037; Mintel (2015), 'The Protein Report: Meat Alternatives – US – January 2015', https://store.mintel.com/the-protein-report-meat-alternatives-us-january-2015 (accessed 29 May 2018); Bryant and Barnett (2018), 'Consumer acceptance of cultured meat: A systematic review', *Meat Science*, 143: pp. 8–17, doi: 10.1016/j.meatsci.2018.04.008 (accessed 21 Jan. 2019); Stoll-Kleemann and Schmidt (2017), 'Reducing Meat Consumption in Developed and Transition Countries to Counter Climate Change and Biodiversity Loss: A Review of Influence Factors', *Regional Environmental Change*, *17(5)*: pp. 1261–77 (accessed 21 Jan. 2019); Apostolidis and McLeay (2016), 'Should we stop meating like this? Reducing meat consumption through substitution'.

[51] Hartmann, C. and Siegrist, M. (2017), 'Consumer perception and behaviour regarding sustainable protein consumption: A systematic review', *Trends in Food Science & Technology, 61:* pp. 11–12, doi:10.1016/j.tifs.2016.12.006 (accessed 17 Jan. 2019); Vainio, A., Irz, X. and Hartikainen, H. (2018), 'How effective are messages and their characteristics in changing behavioural intentions to substitute plant-based foods for red meat? The mediating role of prior beliefs', *Appetite*, *125:* pp. 217–24, doi:10.1016/j.appet.2018.02.002 (accessed 17 Jan. 2019); Graça, J., Oliveira, A., Manuela Calheiros, M. (2015), 'Meat, beyond the plant. Data-driven hypotheses for understanding consumer willingness to adopt a more plant-based diet', *Appetite*, 90: pp. 80–90, doi:10.1016/j.appet.2015.02.037 (accessed 17 Jan. 2019).

[52] Hoek, A. C., Elzerman, J. E., Hageman, R., Kok, F. J., Luning, P. A. and de Graaf, C. (2013), 'Are meat substitutes liked better over time? A repeated in-home use test with meat substitutes or meat in meals', *Food Quality and Preference*, *28(1)*: pp. 253–63, doi:10.1016/j.foodqual.2012.07.002 (accessed 19 Nov. 2018); Hoek, A. C., Luning, P. A., Weijzen, P., Engels, W., Kok, F. J. and de Graaf, C. (2011), 'Replacement of meat by meat substitutes. A survey on person- and product-related factors in consumer acceptance', *Appetite, 56(3)*: pp. 662–73, doi:10.1016/j.appet.2011.02.001 (accessed 19 Nov. 2018); AP News (2018), 'Cultured Meat (Poultry, Pork, Beef, Duck) Market – Global Forecast to 2027 – ResearchAndMarkets.com'.

[53] Kadim, I., Mahgoub, O., Baqir, S., Faye, B. and Purchas, R. (2014), 'Cultured Meat from Muscle Stem Cells: A Review of Challenges and Prospects', *Journal of Integrative Agriculture*, *14(2)*: pp. 222–33, doi: 10.1016/S2095-3119(14)60881-9 (accessed 25 Jan. 2018); Stephens et al. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture'.

[54] Hocquette, J.-F. (2016), 'Is in vitro meat the solution for the future?', *Meat Science*, 120: pp. 167–176, doi:10.1016/j.meatsci.2016.04.036 (accessed 17 Jan. 2019); Bhat, Z. F., Kumar, S. and Fayaz, H. (2015), 'In vitro meat production: challenges and benefits over conventional meat production', *Journal of Integrative Agriculture*, 14: pp. 241–248, doi:10.1016/S2095-3119(14)60887-X (accessed 17 Jan. 2019); Kadim et al. (2015), 'Cultured meat from muscle stem cells: a review of challenges and prospects'.

[55] Bryant and Barnett (2018), 'Consumer acceptance of cultured meat: A systematic review'; Siegrist, M., Sütterlin, B. and Hartmann, C. (2018), 'Perceived naturalness and evoked disgust influence acceptance of cultured meat', *Meat Science*, *139*: pp. 213–19, doi:10.1016/j.meatsci.2018.02.007 (accessed 18 May 2018).

Early research indicates that cultured meat can evoke feelings of disgust and strangeness – often referred to as the 'yuck' factor – and that many consumers may view *in vitro* products as 'freakish'.[56]

The (perceived) nutritional quality of meat analogues and their safety compared with conventional meat is also likely to be an important factor in their uptake.[57] Relative to the conventional processed meat products that they are intended to replace (including burgers, sausages, nuggets, and so on), plant-based 'meat' products tend to contain lower levels of saturated fat, cholesterol and calories, and often contain higher levels of micronutrients such as zinc, iron and calcium.[58] Beyond Meat and Impossible Foods both report that their burgers have a protein content comparable to that of an average conventional beef burger.[59] Some studies have nevertheless demonstrated that individuals are worried about the production process and ingredients involved in manufacturing – for instance, over processing and high use of salt and genetically modified organisms (GMOs)[60] – while others perceive meat analogues to be lacking nutritionally as compared with conventional meat.[61]

In the case of cultured meat, the controlled conditions for production raise the possibility of meat that is free from food-borne disease and that is at low risk of contamination. Furthermore, tightly controlled production procedures obviate the need for antibiotics while creating new opportunities for the addition of desirable vitamins and the reduction of fat and fatty acid content.[62] Perceptions of the health impacts of consuming cultured meat vary considerably, in part due to a high degree of uncertainty among the public surrounding both the relevant technology and the production processes.[63] While studies have indicated that some consumers acknowledge the potential health benefits and increased food safety of cultured meat compared with conventional meat, others argue that there persist several 'unknowns' about the long-term side-effects of eating cultured meat. Such arguments place particular emphasis on the risks of developing cancer and of catching food-borne diseases such as zoonoses (infectious diseases that are transmitted naturally between animals and humans).[64] Another study demonstrated that those individuals with a greater degree of concern for the environmental impacts of meat consumption were more likely to express an interest in eating cultured meat.[65]

[56] Van der Weele and Driessen (2013), 'Emerging profiles for cultured meat; ethics through and as design'; Verbeke, W. et al. (2015), '"Would you eat cultured meat?": Consumers' reactions and attitude formation in Belgium, Portugal and the United Kingdom, *Meat Science*, *102*: pp. 49–58, doi:10.1016/j.meatsci.2014.11.013 (accessed 19 Nov. 2018); Siegrist et al. (2018), 'Perceived naturalness and evoked disgust influence acceptance of cultured meat'.

[57] Verbeke, W., Pérez-Cueto, J. B., de Barcellos, M. D., Krystallis, A. and Grunert, K. G. (2010), 'European citizen and consumer attitudes and preferences regarding beef and pork', *Meat Science*, *84*: pp. 284–92, doi:10.1016/j.meatsci.2009.05.001 (accessed 19 Nov. 2018).

[58] Kumar, P., Chatli, M. K., Mehta, N., Singh, P., Malav, O. P. and Verma, A. K. (2017), 'Meat analogues: Health promising sustainable meat substitutes', *Critical Reviews in Food Science and Nutrition*, *57(5)*: pp. 923–32, doi:10.1080/10408398.2014.939739 (accessed 29 May 2018); Bohrer, B. M. (2017), 'Review: Nutrient density and nutritional value of meat products and non-meat foods high in protein', *Trends in Food Science & Technology*, *65*: pp. 103–12, doi:10.1016/j.tifs.2017.04.016 (accessed 30 May 2018).

[59] Beyond Meat (2019), 'The Beyond Burger', https://www.beyondmeat.com/products/view/beyond-burger (accessed 6 Feb. 2019); Impossible Foods (2019), 'Frequently Asked Questions', https://impossiblefoods.com/faq (accessed 6 Feb. 2019).

[60] Mintel (2015), 'The Protein Report: Meat Alternatives – US – January 2015'; Crawford, E. (2015), 'Alternative proteins gain popularity, but long-term viability of some questioned', FoodNavigator-USA, 21 October 2015, https://www.foodnavigator-usa.com/Article/2015/10/21/Alternative-proteins-gain-popularity-long-term-viability-questioned (accessed 29 May 2018); Frewer, L. J. (2017), 'Consumer acceptance and rejection of emerging agrifood technologies and their applications', *European Review of Agricultural Economics, 44(4):* pp. 683–704, doi: 10.1093/erae/jbx007 (accessed 4 Jan. 2019); Apostolidis and McLeay (2016), 'Should we stop meating like this? Reducing meat consumption through substitution'.

[61] Mancini, M. C. and Antonioli, F. (2018), 'Exploring consumers' attitude towards cultured meat in Italy, *Meat Science*, 150: pp. 101–10, doi: 10.1016/j.meatsci.2018.12.014 (accessed 21 Jan. 2019).

[62] Bhat, Z. F. and Bhat, H. (2011), 'Animal-free Meat Biofabrication', *American Journal of Food Technology 6(6)*: pp. 441–59, doi:10.3923/ajft.2011.441.459 (accessed 17 May 2018).

[63] Bryant and Barnett (2018), 'Consumer acceptance of cultured meat: A systematic review'.

[64] Ibid., p. 14.

[65] Slade, P. (2018), 'If you build it, will they eat it? Consumer preferences for plant-based and cultured meat burgers', *Appetite*, *125*: pp. 428–37, doi:10.1016/j.appet.2018.02.030 (accessed 17 Jan. 2019).

Support among environmental and animal welfare groups

Public attitudes to meat analogues, and particularly to cultured meat, will be shaped to a significant degree by civil society narratives.[66] Civil society has played an important role in raising awareness among citizens about the impacts of their diets, and environmental groups in particular are deemed one of the most helpful sources of public information in Europe relating to meat consumption and the climate.[67] The growing number of meat reduction campaigns, such as 'Meat Free Monday' and 'Veganuary', among others, have also been influential in raising awareness of the benefits of eating less meat and fostering the consumption of more plant-based meat alternatives.[68] Yet past experience of civil society-led public discourse on GMOs in Europe, and its influence on low public acceptance of GM technologies in the EU, is indicative of the power of NGOs to shape both public opinion and public policy and regulatory responses.[69]

Plant-based 'meat' and cultured meat present a dilemma to NGOs advocating a shift in meat-eating habits.[70] For the most part, NGOs active on this issue promote messages of step-wise changes in diets, encouraging a flexitarian lifestyle and/or the substitution of ruminant meat (beef, lamb) for monogastric meat (chicken, pork). Few organizations – principally those concerned with animal welfare – are openly supportive of a shift to meat-free diets. Most NGOs, in shaping their campaigns around meat consumption, aim for moderate messaging that is accessible and appealing to mainstream audiences, and that avoid creating a perception of the organization as radical in its mission.[71] Manufacturers and marketers of meat analogues are, in their own way, promoting a shift away from conventional meat but the means of their production and the way in which they are marketed raise certain questions for environmental and animal welfare groups (see below). In addition, there are concerns that the promotion of cultured meat may yield an 'addition effect' (also known as the 'Jevons Paradox') in which these new products do not replace conventional meat but instead contribute to even higher levels of total meat consumption (cultured and conventional combined).[72]

Early assessments indicate that meat analogue production is significantly less resource-intensive than conventional meat production: based on current projections, a 50 per cent replacement of meat products by cultured meat, imitation meat (plant-based 'meat') and insects could be expected to yield a 38 per cent reduction in agricultural land demand.[73] In the case of cultured meat, the concentration of resources on producing only muscle tissue that will be eaten – and therefore avoiding the energy-, resource- and time-intensive production of waste or by-products – is one of its most important

[66] Bubela, T., Hagen, G. and Einsiedel, E. (2012), 'Synthetic biology confronts publics and policy makers: challenges for communication, regulation and commercialization', *Trends in Biotechnology*, *30(3)*: pp. 132–37, doi:10.1016/j.tibtech.2011.10.003 (accessed 1 Jun. 2018).
[67] Bailey, Froggatt and Wellesley (2014), *Livestock – Climate Change's Forgotten Sector: Global Public Opinion on Meat and Dairy Consumption*.
[68] Ryan, C. (2017), 'Brits carve their meat intake: 28% of Brits have cut back their meat consumption over the last six months', *Pig World*, 15 August 2017, http://www.pig-world.co.uk/news/brits-carve-their-meat-intake-28-of-brits-have-cut-back-their-meat-consumption-over-the-last-six-months.html (accessed 19 Nov. 2018).
[69] Ansell, C., Maxwell, R. and Sicurelli, D. (2006), 'Protesting food: NGOs and political mobilization in Europe', in Ansell, C. and Vogel, D. (eds), *What's the Beef*, Cambridge, MA: The MIT Press, pp. 97–122 (accessed 21 Jan. 2019).
[70] Böhm, I., Ferrari, A. and Woll, S. (2018), 'Visions of In Vitro Meat among Experts and Stakeholders', *NanoEthics, 12(3)*: pp. 1–14, doi:10.1007/s11569-018-0330-0 (accessed 19 Nov. 2018); Stephens et al. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture'.
[71] Laestadius, L. I., Neff, R., Barry, C. L. and Frattaroli, S. (2016), 'No meat, less meat, or better meat: Understanding NGO messaging choices intended to alter meat consumption in light of climate change', *Environmental Communication, 10(1): pp.* 84–103, doi:10.1080/17524032.2014.981561 (accessed 16 Jan. 2019).
[72] Stephens et al. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture', p. 162.
[73] Based on 2011 meat consumption patterns. Alexander, P., Brown, C., Arneth, A., Dias, C., Finnigan, J., Moran, D. and Rounsevell, M. D. (2017), 'Could consumption of insects, cultured meat or imitation meat reduce global agricultural land use?', *Global Food Security*, *15*: pp. 22–32, doi:10.1016/j.gfs.2017.04.001 (accessed 17 May 2018).

attributes, according to advocates.[74] Life-cycle assessments (LCAs) of the most well-known plant-based meat analogues indicate that plant-based 'meat' is, on the whole, significantly less emissions-intensive than conventional meat. The relative environmental impact of cultured-meat production compared with conventional-meat production is more uncertain. Cultured-meat production is expected to be less land- and energy-intensive than beef production, however, land requirements are anticipated to be similar to those of poultry production while direct energy inputs will be significantly higher.[75]

> Until such time as cultured meat is being produced at scale in industrial bioreactors it is not possible to assess fully the resource intensity of production.

LCAs of cultured meat at this stage are, however, highly speculative and are based on modelled rather than actual production methods. Until such time as cultured meat is being produced at scale in industrial bioreactors – at which point it may be assumed that cultured meat will have been approved under EU regulation and investments will have been made in the necessary infrastructure – it is not possible to assess fully the resource intensity of production. In addition, while assessments of actual production methods are possible with plant-based 'meat', producers have retained a degree of secrecy around the ingredients and techniques that achieve their unique degree of mimicry, meaning that the precise resource intensity of their production – embedded land use, for example – remains uncertain.

The 'clean' nature of meat analogues has also been questioned by civil society in response to the use of GMOs in certain plant-based 'meat' products and cultured-meat processes. In the US, civil society groups – including Friends of the Earth, ETC Group and PETA – have voiced concerns over the use of genetic engineering processes in the creation of the Impossible Burger[76] and in certain cultured-meat production methods,[77] and over the degree of processing involved in producing both plant-based 'meat' and cultured-meat products.[78]

Among the animal welfare and animal rights communities, the prospect of 'slaughter-free' meat has garnered considerable support for the nascent cultured-meat industry: in 2008, the US-based animal welfare NGO People for the Ethical Treatment of Animals (PETA) announced a $1 million prize for the first research team to produce commercially viable *in vitro* chicken cells;[79] more recently, in early 2018 Humane Society International/India launched a partnership with India's Centre for Cellular and Molecular Biology to encourage both an expansion in production and a growth in demand for cultured meat in India;[80] and other organizations, including Compassion in World Farming and Mercy for Animals, have publicly voiced their support for the scaling-up of cultured-meat production

[74] Arshad, M. S., Javed, M., Sohaib, M., Saeed, F., Imran, A. and Amjad, Z. (2017), 'Tissue engineering approaches to develop cultured meat from cells: A mini review', *Cogent Food & Agriculture, 3*: doi:10.1080/23311932.2017.1320814 (accessed 30 May 2018).
[75] Alexander et al. (2017), 'Could consumption of insects, cultured meat or imitation meat reduce global agricultural land use?'; Tuomisto, H. L. and Teixeira de Mattos, M. J. (2011), 'Environmental Impacts of Cultured Meat Production', *Environmental Science & Technology*, *45*: pp. 6117–23, doi:10.1021/es200130u (accessed 17 May 2018); Mattick, C. S., Landis, A. E., Allenby, B. R. and Genovese, N. J. (2015), 'Anticipatory life cycle analysis of in vitro biomass cultivation for cultured meat production in the United States', *Environmental Science & Technology, 49:* pp. 11941–11949, doi:10.1012/acs.est.5b01614 (accessed 6 Feb. 2019).
[76] Neimark, J. (2018), 'Europe Deals A Blow To CRISPR Technology, U.S. Approves "Bleeding" Veggie Burger', NPR, 4 August 2018, https://www.npr.org/sections/thesalt/2018/08/04/635109165/europe-deals-a-blow-to-ge-foods-u-s-approves-bleeding-veggie-burger?t=1540911352254 (accessed 19 Nov. 2018); Friends of the Earth US (2018), *From Lab to Fork: Critical Questions on Laboratory-Created Animal Product Alternatives*, http://foe.org/wp-content/uploads/2018/08/From-Lab-to-Fork_8-2-18.pdf (accessed 19 Nov. 2018).
[77] Stephens et al. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture'.
[78] Friends of the Earth US (2018), *From Lab to Fork: Critical questions on laboratory-created animal product alternatives*, Washington DC: Friends of the Earth, https://1bps6437gg8c169i0y1drtgz-wpengine.netdna-ssl.com/wp-content/uploads/2018/06/From-Lab-to-Fork-1.pdf (accessed 31 Jan. 2019).
[79] PETA (2014), 'PETA's "In Vitro" Chicken Contest', 4 March 2014, https://www.peta.org/features/vitro-meat-contest/ (accessed 29 May 2018).
[80] Humane Society International/India (2018), 'First collaboration to promote Clean Meat in India takes off', 28 March 2018, http://www.hsi.org/world/india/news/releases/2018/03/laboratory-grown-meat-india-032818.html (accessed 29 May 2018).

and consumption[81] as a means of reducing the number of animals slaughtered each year for meat (estimated at 7.5 billion animals each year in the EU, and 9.1 billion in the US).[82] The two longest-standing cultured-meat companies in Europe, Mosa Meat and Cellular Agriculture Ltd., currently harvest cells at the point of slaughter, however, and so are not 'slaughter-free'. The continued use of foetal bovine serum (FBS) by many of the major cultured-meat companies is also likely to present a barrier to generating support among the animal welfare community, owing to the effects on the calf foetus in the process of its extraction,[83] although serum-free media are already in use or in development by others in the sector.[84]

Economics of production

Currently, cultured-meat production is highly labour intensive. In shifting from the laboratory to industrial-scale bioreactors, cultured-meat producers should be able to achieve economies of scale, but tissue engineering to this extent is both unprecedented and unproven.[85] The price of production will need to fall dramatically if the end product is to be affordable and appealing for consumers:[86] the start-up Aleph Farms recently announced it had been successful in producing a small strip of beef steak for $50 – compared with the $330,000 it cost to produce the first cultured-meat burger in 2013[87] – while cultured minced meat also remains costly to produce at $11 per hamburger.[88] Technical breakthroughs will be needed before prices drop further: today, 80 per cent of the costs of the final product result from the need for expensive growth factor proteins.[89] Scale-up would also require associated investments in infrastructure and logistics, the cost and resource efficiency of which have yet to be examined.[90] Sector stakeholders anticipate that it will be between five and 10 years before industrial-scale cultured-meat production is possible.[91]

Industrial-scale production of plant-based 'meat' and cultured meat could bring fundamental changes to today's food system. Growth in demand for plant-based 'meat' will generate greater demand for plant protein crops such as pea and wheat, creating an incentive for some livestock producers to

[81] Lymbery, P. (2018), 'Meat without animals?', Compassion in World Farming, https://www.ciwf.org.uk/philip-lymbery/blog/2018/01/meat-without-animals (accessed 29 May 2018); Loria, J. (2018), 'Breaking: Tyson Foods Invests in Clean Meat Company', Mercy for Animals, 29 January 2018, http://www.mercyforanimals.org/breaking-tyson-foods-invests-in-clean-meat (accessed 29 May 2018).
[82] Humane Society of the United States (2015), 'Farm Animal Statistics: Slaughter Totals', http://www.humanesociety.org/news/resources/research/stats_slaughter_totals.html (accessed 29 May 2018); Eurostat (2016), 'Agricultural Production Animals', https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agricultural_production_-_animals&oldid=370518#Meat_production (accessed 21 Jan. 2019).
[83] Gstraunthaler, G., Lindl, T. and van der Valk, J. (2013), 'A plea to reduce or replace fetal bovine serum in cell culture media', *Cytotechnology*, *65*: pp. 791–793, doi:10.1007/s10616-013-9633-8 (accessed 16 Jan. 2019).
[84] Knowles, K. (2019), 'What's cooking in Europe's lab-grown meat startups?', *Sifted*, 18 January 2019, https://sifted.eu/articles/lab-grown-meat-startyups-higher-steaks-meatable-supermeat-fm-technologies/ (accessed 29 Jan. 2019).
[85] Stephens et al. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture'.
[86] The Good Food Institute (2017), 'Mapping emerging industries: opportunities in clean meat', 6 June 2017, https://www.gfi.org/images/uploads/2017/06/Mapping-Emerging-Industries.pdf (accessed 19 Nov. 2018); Verbeke, W., Sans, P. and Van Loo, E. (2015), 'Challenges and prospects for consumer acceptance of cultured meat', *Journal of Integrative Agriculture*, *14(2)*: pp. 285–94, doi:10.1016/S2095-3119(14)60884-4 (accessed 19 Nov. 2018); Bryant and Barnett (2018), 'Consumer acceptance of cultured meat: A systematic review'.
[87] Aleph Farms (2018), Aleph Farms promotional video, Youtube, https://www.youtube.com/watch?v=txFN1qr1dWU (accessed 18 Dec. 2018); Carrington, D. (2018), 'World's first lab-grown steak revealed – but the taste needs work', *Guardian*, 14 December 2018, https://www.theguardian.com/environment/2018/dec/14/worlds-first-lab-grown-beef-steak-revealed-but-the-taste-needs-work?CMP=share_btn_link (accessed 18 Dec. 2018); Brodwin, E. (2018), 'The startup behind the first lab-grown pork links let us see how their sausage gets made – and said it slashed the cost from $2,500 to $216 in a month', Business Insider, 7 November 2018, https://www.businessinsider.com/taste-test-lab-grown-meat-sausage-cost-2018-11?r=US&IR=T (accessed 21 Jan. 2019).
[88] Ibid.
[89] Bomgardner, M. M. (2018), 'The to-do list for "clean" meat', *Chemical & Engineering News*, 21 October 2018, https://cen.acs.org/business/food-ingredients/list-cleanmeat/96/i42 (accessed 19 Nov. 2018).
[90] Stephens et al. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture'.
[91] Insights from Chatham House expert roundtable, 'Meat Analogues: What do they mean for the EU?', held at Chatham House in London on 12 September 2018.

transition away from industrial animal farming.[92] While new jobs would be created with the scaling up of cultured-meat production, they would likely be far fewer in number with much of the production process automated, and those that are created may be located in the industrial heartlands of Europe rather than in its agricultural regions. Power balances among industry players may see less change, however: while it is predominantly start-up companies and universities leading innovation in the meat analogue industry, several major agribusinesses are moving to buy stakes in the 'disruptor' companies and to invest in in-house innovation in plant-based 'meat' and cultured meat.

Responses from industry incumbents

As in many sectors of the economy, incumbent meat industry has an important role to play in either accelerating or dampening innovation, depending on whether it views that innovation as a risk or opportunity.[93] Lessons from other sectors, including the energy and utilities sectors, show that the response of industry incumbents to innovation can influence to a large extent its nature and success, particularly when market power is concentrated (as it is in the food sector)[94] and when those incumbents take active steps to influence laws, regulations and public discourse.[95]

On the one hand, the rise of plant-based 'meat' and cultured meat poses a risk to conventional meat producers, and to processors, marketers and logistics operators along the supply chain: increased demand could prompt a shift among consumers away from conventional meat and could either incentivize more localized meat production or relocate production, all with potentially adverse implications for meat industry incumbents. On the other hand, meat analogues offer an opportunity for businesses in the meat industry to diversify their offering and spread their risk: early investment in meat analogue start-ups and in research and development (R&D) for proprietary meat alternatives could offer a means of hedging against future demand shifts. In 2016, a coalition of institutional investors, with assets worth a collective $5.3 trillion, called on meat companies to diversify the protein products they sell and invest in plant-based alternatives, outlining the multiple and growing investment risks associated with factory farming.[96] Analysts have also noted the relatively stable prices of meat alternatives compared with conventional meat, as they are less reliant on seasonal supply fluctuations and offer opportunities for (potentially) longer shelf-life and easier storage.[97]

Major players in the meat and food industries have already invested in plant-based 'meat' and cultured-meat start-ups – including Tyson Foods (with investments in Memphis Meats, Beyond Meat), Cargill (with investments in Memphis Meats), PHW (with investments in SuperMeat), Unilever (with investments in the Plant Meat Matters consortium and Vegetarian Butcher) and Jan Zandbergen (the company recently signed a distribution agreement with Moving Mountains) – though their investments remain small as a share of their overall R&D activities. Others in the industry have

[92] Clark, A. (2018), 'We need transition farming in the EU', EurActiv, 30 October 2018, https://www.euractiv.com/section/agriculture-food/opinion/tue-we-need-transition-farming-in-the-eu/ (accessed 6 Jan. 2019).
[93] Smink, M. M., Hekkert, M. P. and Negro, S. O. (2015), 'Keeping sustainable innovation on a leash? Exploring incumbents' institutional strategies', *Business Strategy and the Environment*, *24(2)*: pp. 86–101, doi:10.1002/bse.1808 (accessed 30 May 2018).
[94] Costa-Campi, M. T., Duch-Brown, N. and García-Quevedo, J. (2014), 'R&D drivers and obstacles to innovation in the energy industry', *Energy Economics*, 46: pp. 20–30, doi:10.1016/j.eneco.2014.09.003 (accessed 18 Jan. 2019).
[95] Smink et al. (2015), 'Keeping sustainable innovation on a leash? Exploring incumbents' institutional strategies'.
[96] FAIRR (2018), *Plant-Based Profits: Investment Risks & Opportunities in Sustainable Food Systems,* Farm Animal Investment Risk & Return (FAIRR), February 2018, http://www.fairr.org/resource/plant-based-profits-investment-risks-opportunities-sustainable-food-systems/ (accessed 3 Jan. 2019).
[97] Kumar et al. (2017), 'Meat analogues: Health promising sustainable meat substitutes'.

taken a more defensive approach to the rising number of meat analogue companies: some industry incumbents in the US have lobbied for a clarification of legal definitions of meat and for more stringent regulation of meat-alternative labelling.[98]

Meat consumption trends

Another likely factor in determining the scale of the future meat analogue industry lies in current trends in meat consumption, not only in Europe but globally. Since the 1960s, global patterns of meat consumption have shifted significantly. Worldwide demand for meat has steadily increased over this period, a trend that is expected to continue: the International Panel on Climate Change (IPCC) stated in a 2018 report that in the absence of proactive policy interventions to reduce meat consumption, 'prevailing trends are for increasing rather than decreasing demand for livestock products at the global level'.[99] This growth in overall consumption has been driven primarily by a rapid surge in consumption of poultry – the average per capita intake of which increased more than fourfold between 1961 and 2013 – with consumption of pork also showing a strong upward trend. By contrast, per capita consumption of meat from ruminants such as cattle, sheep and goats, plateaued over the same period.[100]

> Worldwide demand for meat has steadily increased since the 1960s, a trend that is expected to continue.

Change over this period has looked very different from region to region. In Asia, per capita meat consumption grew significantly, driven principally by a surge in demand for pork and poultry. In South America, overall consumption has risen modestly but there has been a dramatic shift in demand from beef to poultry. In Europe and North America, poultry also took a growing share of total per capita meat consumption by the end of the 1961–2013 period, with a marked downturn in overall consumption occurring in North America from 2007 onwards (see Figure 2).

Total demand for meat in Europe has not dramatically changed in recent years although there has been a discernible shift away from the more resource-intensive ruminant meats (beef and lamb) and towards less resource-intensive monogastric meats (poultry and pork). In light of the reluctance of meat-eaters to shift to meat analogues, widespread growth in demand for plant-based 'meat' and cultured meat among target audiences may depend on a broader shift in social and cultural norms towards acceptance of flexitarian lifestyles and towards a food environment in which plant-based options are both more visible and more appealing.[101] For those EU companies looking to export their products, booming markets in South America and Asia present a promising opportunity,

[98] U.S. Cattlemen's Association (2018), 'Petition for the imposition of beef and meat labelling requirements: to exclude products not derived directly from animals raised and slaughtered from the definition of "beef" and "meat"', 9 February 2018, https://www.fsis.usda.gov/wps/wcm/connect/e4749f95-e79a-4ba5-883b-394c8bdc97a3/18-01-Petition-US-Cattlement-Association020918.pdf?MOD=AJPERES (accessed 18 Jan. 2019).

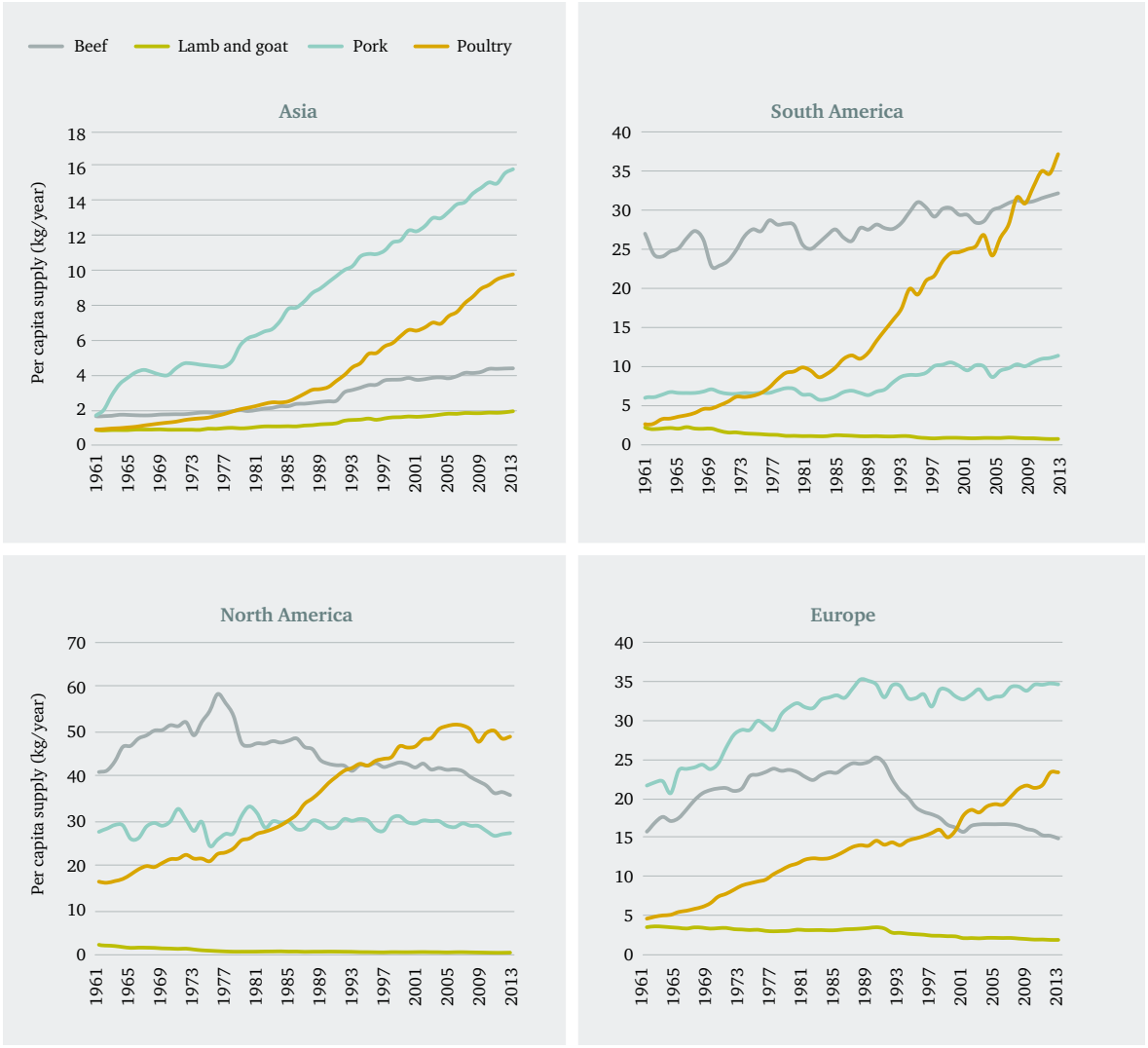
[99] Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., Handa, C., Kheshgi, H., Kobayashi, C., Kriegler, E. and Mundaca, L. (2018), 'Mitigation pathways compatible with 1.5°C in the context of sustainable development', in Masson-Delmotte, V. et al. (eds) (2018), *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty,* https://www.ipcc.ch/site/assets/uploads/sites/2/2018/11/SR15_Chapter4_Low_Res.pdf (accessed 19 Nov. 2018); de Coninck, H. et al. (2018), 'Strengthening and implementing the global response'.

[100] FAO (no date), 'FAOSTAT – Food Balance Sheets', http://www.fao.org/faostat/en/#data/FBS (accessed 10 Jan. 2019).

[101] Stoll-Kleemann and Schmidt (2017), 'Reducing Meat Consumption in Developed and Transition Countries to Counter Climate Change and Biodiversity Loss: A Review of Influence Factors'.

with growth in total consumption expected to remain strong and, in some countries (China and Singapore, for example), growth in the meat analogue industry is already underway.[102] An increasing preference for poultry in these markets is also likely to create more favourable market conditions for cultured-meat manufacturers; chicken and duck meat are expected to be the first cultured meats to be market ready.[103]

Figure 2: Meat consumption in Asia, South America, North America and Europe by type, 1961–2013



Source: FAO (no date), 'FAOSTAT – Food Balance Sheets', http://www.fao.org/faostat/en/#data/FBS (accessed 10 Jan. 2019).

[102] AgFunder (2018), 'The Growing Appetite for Meat Alternatives in China', 29 January 2018, https://agfundernews.com/meat-alternatives-china.html (accessed 18 Jan. 2019); Watson, A. (2018), 'The fight over meatless meat is starting to bite', Eco-Business, 16 May 2018, https://www.eco-business.com/news/the-fight-over-meatless-meat-is-starting-to-bite/ (accessed 18 Jan. 2019); Lupica, D. (2017), 'Singaporean Startup Developments Vegan Alternative to Lab Meat', Plant-Based News, 18 September 2017, https://www.plantbasednews.org/post/singaporean-startup-develops-vegan-meat-that-resembles-lab-meat (accessed 18 Jan. 2019).

[103] Birdsall, J. (2018), 'Is Lab-Grown Meat Ready for Dinner?', *The Wall Street Journal*, 16 October 2018, https://www.wsj.com/articles/is-lab-grown-meat-ready-for-dinner-1539701100 (accessed 17 Jan. 2019).

Summary

- Early studies of consumer attitudes to meat analogues suggest that concerns over the naturalness, healthiness and newness of meat analogues, together with high retail prices, may present a significant barrier to scaling up demand among meat-eaters, the target population segment for meat analogue producers.
- Among environmental and animal welfare NGOs, views on the merits of meat analogues are split. While many welcome plant-based 'meat' as a less resource-intensive alternative to conventional meat, others are concerned by the use of GMOs in the production of certain plant-based 'meat' products and cultured-meat products, and by the energy-intensive nature of cultured-meat production. Similarly, while cultured meat is welcomed by certain animal welfare groups, others criticize the continued use of FBS as a growth medium.
- Incumbent industry has responded to innovation in meat analogues in different ways. While certain companies – including major players such as Cargill and Tyson – have invested in the enterprises and technologies behind the growth in the meat analogue industry, others have called for more stringent regulation that would prevent meat analogue products from being labelled with meat-related names.
- Growing demand for meat in South America and Asia offers a promising export opportunity for European meat analogue producers if they are successful in achieving a high degree of mimicry of conventional meat. In Europe, where demand for meat remains strong, widespread uptake of meat analogues among meat-eaters may depend first on a broader shift in attitudes towards greater acceptability of plant-based diets.

4. The Regulatory Landscape in the EU

Public policymakers may take different approaches to encouraging – or inhibiting – innovation in the meat analogue industry. Firstly, they may impose strict rules on conventional corporate practices, forcing businesses to innovate. Secondly, they may create the conditions within which innovation brings a competitive advantage, for example, by introducing additional standards related to corporate practices or products, or through the introduction of sustainability criteria in public procurement policies – such that those who do not innovate risk missing out on market opportunities. Thirdly, they may introduce or maintain certain procedural, economic or political barriers to innovation and to the marketing of innovative solutions or products.[104]

In the EU, where many of the frontrunners in plant-based 'meat' and cultured-meat innovation are located, current regulation and policy are largely supportive of investments and innovation in alternative proteins. In 2012, the European Commission adopted a flagship strategy, Innovating for Sustainable Growth: A Bioeconomy for Europe,[105] in which it committed to developing new technologies, processes and markets in support of a sustainable, low-emissions, resource-efficient food system. A regulation adopted in 2017 has committed the European Commission to 'review the supply and demand situation for plant proteins in the EU and to explore possibilities to further develop their production in an economically and environmentally sound way'.[106] Moreover, in late 2018, the European Commission presented what has become known as its 'EU Protein Plan', which encourages the production of alternative proteins for human consumption, and notes that a number of existing EU policy instruments 'provide options for strengthening the development of EU-grown plant proteins'.[107] A 2018 expert report, commissioned by the Directorate-General of Research and Innovation, identified the development of new meat alternatives as an important pathway to achieving the EC's Food 2030 Initiative, to deliver a climate-smart, sustainable food system in Europe.[108]

> Public policymakers may take different approaches to encouraging – or inhibiting – innovation in the meat analogue industry.

The following section briefly outlines how plant-based 'meat' and cultured meat are – or may be – regulated by EU legislation. It identifies principal areas of uncertainty for regulators and meat-alternative developers with regards to their licensing and industrialization within the EU.

[104] Blind, K. (2016), 'The impact of regulation on innovation', in Edler, J., Cunningham, P., Gök, A. and Shapira, P. (eds), *Handbook of Innovation Policy Impact*, Cheltenham: Edward Elgar Publishing Ltd, doi:10.4337/9781784711856 (accessed 30 May 2018).
[105] Directorate-General for Research and Innovation (European Commission) (2012), 'Innovating for Sustainable Growth: A Bioeconomy for Europe', https://publications.europa.eu/en/publication-detail/-/publication/1f0d8515-8dc0-4435-ba53-9570e47dbd51 (accessed 19 Nov. 2018).
[106] It has done so through the adoption process for Regulation (EU) 2017/2393 of the European Parliament and of the Council of 13 December 2017; European Commission (2018), *Report from the Commission to the Council and the European Parliament on the development of plant proteins in the European Union*, 22 November 2018, COM (2018) 757 Final, p. 2, https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/plants_and_plant_products/documents/report-plant-proteins-com2018-757-final_en.pdf (accessed 1 Jun. 2018).
[107] European Commission (2018), *Report from the Commission to the Council and the European Parliament on the development of plant proteins in the European Union*.
[108] European Commission Directorate-General for Research and Innovation (2018), *Recipe for change: An agenda for a climate-smart and sustainable food system for a healthy Europe*, Brussels: European Commission, https://publications.europa.eu/en/publication-detail/-/publication/d0c725de-6f7c-11e8-9483-01aa75ed71a1/language-en (accessed 31 Jan. 2019).

EU regulation: the broad picture

EU Food Law (Regulation EC No. 178/2002) sets the general principles and objectives of protecting human life, health and consumer interests and ensuring fair practices in food trade, undertaking a precautionary approach and enabling the free movement of food within the EU.[109] Since its entry into force in 2002, innovation in the food sector has been tightly regulated across the EU. The 178/2002 Regulation was drafted in the wake of a series of food safety scares in the late 1990s and early 2000s, including the outbreak of bovine spongiform encephalopathy (BSE), and it established the European Food Safety Agency (EFSA), an independent body tasked with ensuring the safety of foods placed on the European market and of informing the development of EU-wide food policy.[110] Today, the EFSA supports the EC in the approval of 'novel' foods, being *inter alia* an adviser to the EC on the safety of products to be placed on the EU market.

EU Novel Food Regulation

Newly developed foods are regulated under the Novel Food Regulation.[111] 'Novel' foods are those that do not have a history of consumption in the EU before 15 May 1997 (the date on which the first Regulation on novel foods entered into force),[112] either owing to new ingredients or to previously unused production processes.[113] The Regulation is concerned with the safety of foods on the EU market and ensures that novel food products are: (a) safe to consume; (b) labelled properly so as not to mislead consumers; and (c) not nutritionally disadvantageous when compared with any existing food they seek to replace.[114] The approval of novel whole foods – as opposed to food allergens or chemicals contained in foods – is regulated using a risk-based approach; testing for the presence of hazardous elements is just one of several checks that novel foods must go through before they are licensed for the EU market.[115]

> Testing for the presence of hazardous elements is just one of several checks that novel foods must go through before they are licensed for the EU market.

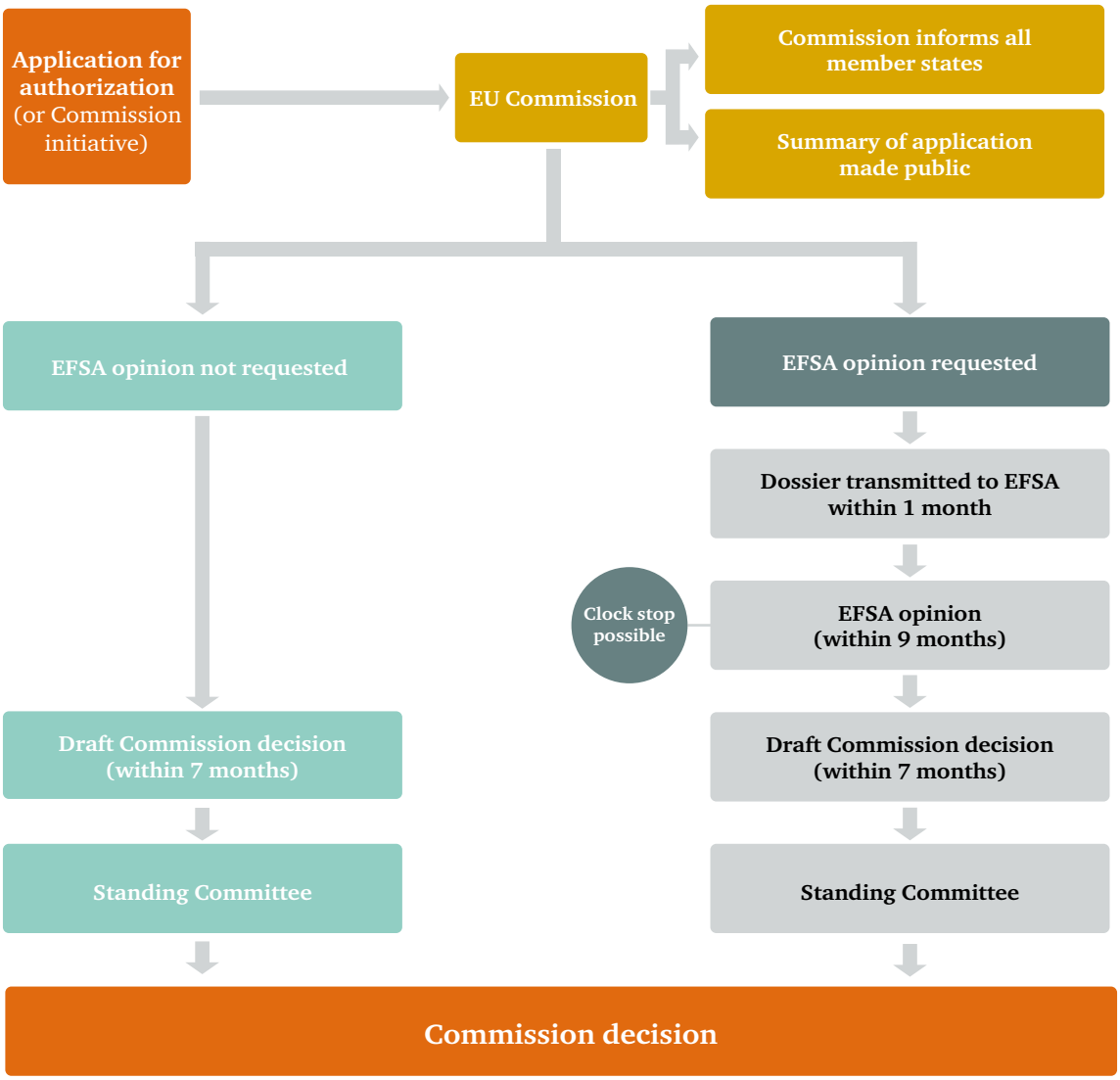
On 1 January 2018, a revised iteration of the Novel Food Regulation, (EU) No. 2015/2283 (replacing Regulation (EC) No. 258/97 and Regulation (EC) No. 1852/2001), entered into force. This aimed to address certain areas of ambiguity and to streamline and centralize the authorization process. Under the revised regulation, the average timeline for approval is expected to drop from 3–4 years to 1.5–2 years, and companies may now request that the data collated and used in support of their application – provided it is proprietary and exclusive – be protected for a period of five years. This process will, in theory, be more streamlined as a consequence of a shift away from an applicant-specific approach to approval towards generic product approval (reducing the long-

[109] EUR-Lex (2002), *Regulation (EC) No. 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety*, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32002R0178 (accessed 4 Dec. 2018).
[110] Byrne, D. (2014), 'The Genesis of EFSA and the First 10 Years of EU Food Law', in Alemanno, A. and Gabbi, S. (eds) (2016), *Foundations of EU Food Law and Policy: Ten Years of the European Food Safety Authority*, Abingdon and New York: Routledge.
[111] Regulation (EU) No. 2015/2283 of the European Parliament and of the Council of 25 November 2015 on novel foods.
[112] Regulation (EC) No. 258/97 of the European Parliament and of the Council of 27 January 1997 concerning novel foods and novel food ingredients.
[113] European Commission (no date), 'Novel food', https://ec.europa.eu/food/safety/novel_food_en (accessed 18 May 2018).
[114] Ibid.
[115] Barlow, S. M. et al. (2015), 'The role of hazard- and risk-based approaches in ensuring food safety', *Trends in Food Science & Technology, 46(2)*: pp. 176–188, doi:10.1016/j.tifs.2015.10.007 (accessed 21 May 2018).

term procedural burden for the European Commission by preventing duplicate applications), and also as a consequence of the centralization of the safety assessment process under the European Commission and the EFSA as opposed to its devolvement to member state authorities (Figure 3).

Other changes include the introduction of a light-touch process for approval of traditional foods that have a history of safe food use in non-EU countries, the explicit inclusion of whole insects as novel foods (only insect parts having been explicitly included under the previous iteration of the Regulation), and the introduction of a category for 'food consisting of, isolated from or produced from cell culture or tissue culture derived from animals, plants, microorganisms, fungi or algae'.[116]

Figure 3: Novel Food Regulation: overview of approval process under Regulation 2015/2283



Source: Nicolas Carbonelle (2018), 'Meat analogues: EU regulatory landscape', presentation, delivered on behalf of Bird & Bird LLP at Chatham House expert roundtable, 'Meat Analogues: What do they mean for the EU?', held at Chatham House in London on 12 September 2018.

[116] Article 3(2)(a)(vi) of Regulation No. 2015/2283.

What the Novel Food Regulation means for meat analogues

In 2007, an assessment of the EU Novel Food Regulation's impact on private-sector willingness to launch new food products identified four key characteristics of a regulatory environment that encourage innovation: firstly, efficient and transparent procedures for assessment and approval; secondly, a consistent and limited timeframe for approval; thirdly, financial incentives for innovation and approval, including the recouping of R&D costs; and fourthly, certainty regarding the legal status of the approved novel product.[117]

The 2018 revision of the Novel Food Regulation sought to ensure the first two of these conditions by setting out a clear process for product authorization and streamlining that process to enable more rapid approval of products for market. The third condition – financial incentives for innovation – lies outside of the scope of the Novel Food Regulation itself, though the provision for five years' data protection for proprietary, newly developed scientific evidence or data supporting the application offers a degree of financial assurance for manufacturers by protecting their competitive advantage for a time-limited period.

The fourth condition – certainty regarding the legal status of the approved product – is more readily met for manufacturers of cultured meat than plant-based 'meat' products. While cultured meat is mentioned explicitly under the Novel Food Regulation, there is less clarity around whether plant-based 'meat' products are considered as novel foods in the EU. For the majority of the plant-based 'meat' products currently available in the EU, the component ingredients have a long history of consumption in Europe or in third countries. What renders the products 'novel' is the innovative processes by which these ingredients are manipulated to create a product that is – or aims to be – indistinguishable from meat. These new processes raise questions regarding the appropriate quality and safety standards to be applied, including those relating to the ingredients. In cases where these starting materials do not themselves have a history of use in Europe or in third countries, plant-based 'meat' products may be considered a novel food and therefore subject to the Novel Food Regulation.

Product labelling

Rules on the labelling of food products in the EU are laid out in the Food Information to Consumers Regulation (FIC) (EU Regulation No. 1169/2011). The regulation on the provision of food information to consumers states that:

> Food information shall not be misleading … by suggesting, by means of the appearance, the description or pictorial representations, the presence of a particular food or an ingredient, while in reality a component naturally present or an ingredient normally used in that food has been substituted with a different component or a different ingredient.[118]

The FIC Regulation requires that clear, precise and easily understandable food labelling be provided to enable consumers to make an informed choice and to ensure the 'safe use of food, with particular regard to health, economic, environmental, social and ethical considerations'.[119] The name of the food

[117] Brookes, G. (2007), 'Economic impact assessment of the way in which the EU novel foods regulatory approval procedures affect the EU food sector', briefing paper prepared for the Confederation of the Food and Drink Industries of the European Union (CIAA) and the Platform for Ingredients in Europe (PIE), https://www.pgeconomics.co.uk/pdf/novelfoods.pdf (accessed 29 May 2018).
[118] Regulation (EU) No. 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers, *Official Journal of the European Union*, L 304/18 (accessed 21 Jan. 2019).
[119] European Commission (2016), 'Food information to consumers – legislation', https://ec.europa.eu/food/safety/labelling_nutrition/labelling_legislation_en (accessed 21 Jan. 2019).

should be its legal name (names that may only be used on a product if it meets certain conditions stipulated in the Regulation) but if there is no such name, then the name of the food shall be its customary name (a name by which it is commonly known by EU consumers, without need for further explanation). If neither a legal nor a customary name exists, then a descriptive name (a name describing what the product is or contains) of the food must be provided.

In the case of novel foods, further labelling requirements may be imposed on manufacturers. The Novel Food Regulation No. 2015/2283 states that, when a novel food is added to the EU list of authorized novel foods, further requirements may follow relating to product labelling to ensure that consumers are fully informed of its nature, either in the description of the food or in information on its composition.

What product labelling regulation means for meat analogues

Labelling is one of the main regulatory bottlenecks for plant-based 'meat' options already on the market and the same is likely to be true for cultured-meat products. Policymakers, meat analogue producers and incumbents in the meat industry alike all want to ensure – for cultural, health and safety, and marketing reasons – that their products are easily identified and attractive to consumers. The specific nature of meat analogue products, however, raises difficult questions with regard to the legal or customary name under which they may be marketed. In the absence of specific regulations on plant-based 'meat' or cultured meat, the general labelling rules laid out in the FIC Regulation will apply. While the basic principles of product information provided to consumers – that it be clear, precise, easy to understand and not misleading – apply equally to plant-based 'meat' and cultured meat, issues relating to product labelling differ considerably between the two.

Studies indicate that the way in which these products are marketed will have a material impact on consumer demand. Approaches to labelling and marketing that highlight the environmental benefits of meat analogues as compared with conventional meat is expected to be a particularly effective way of appealing to the preferences and values of meat-reducing consumers (as opposed to those already following a vegetarian or vegan lifestyle).[120] The legal, customary or descriptive name for cultured meat is likely to have a particularly marked impact on consumer demand: recent surveys have demonstrated that the use of the terms 'clean' and 'slaughter-free' has been shown to increase the acceptability of cultured meat,[121] while 'lab-grown' is more likely to deter potential consumers.[122] Any stipulations relating to the permitted positioning of meat analogues in-store – alongside conventional meat or separate to it – may similarly impact positively or negatively on sales.[123]

Plant-based 'meat'

The use of terms usually associated with conventional meat – 'steak', 'fillet', 'bacon', 'sausage', and so on – in the labelling of plant-based products has been subject to scrutiny and, in some cases, restriction in certain EU member states. Central to the argument against the use of meat-related

[120] Apostolidis and McLeay (2016), 'Should we stop meating like this? Reducing meat consumption through substitution'.
[121] Ibid.; The Good Food Institute (2018), 'Cellular Agriculture Nomenclature: Optimizing Consumer Acceptance', https://www.gfi.org/images/uploads/2018/09/INN-RPT-Cellular-Agriculture-Nomenclature-2018-0921.pdf (accessed 20 Nov. 2018).
[122] Watson, E. (2018), 'Cell-based meat cos: Please stop calling us lab-grown meat… and we don't use antibiotics in full-scale production', FoodNavigator-USA, 25 October 2018, https://www.foodnavigator-usa.com/Article/2018/10/25/Cell-based-meat-cos-Please-stop-calling-us-lab-grown-meat-and-we-don-t-use-antibiotics-in-full-scale-production (accessed 19 Nov. 2018).
[123] Gravely, E. and Fraser, E. (2018), 'Transitions on the shopping floor: Investigating the role of Canadian supermarkets in alternative protein consumption', *Appetite, 130(1):* pp. 146–56, doi:10.1016/j.appet.2018.08.018 (accessed 21 Jan. 2019).

terms such as 'burger' and 'Schnitzel' has been the assertion that their use risks confusing or misleading consumers.

In April 2018, the French National Assembly passed an amendment to the country's Rural Code, stating that designations associated with animal products cannot be used to market food products of which a significant part is vegetable-based.[124] To justify this change, members of Parliament referred to a decision by the European Court of Justice (ECJ) issued in June 2017 on the use of terms like 'soy milk' and 'vegan cheese'. In this case, concerning the German company TofuTown, the ECJ ruled that sales designations for dairy products cannot be used to market purely plant-based products since Regulation No. 1308/2013, establishing a common organization of the markets in agricultural products, defines 'cheese', 'milk' and similar designations as coming from an animal.[125] The ECJ did not, however, comment on meat products. Regulation No. 1308/2013 does not define meat-related terms such as 'steak' or 'burgers', and EU law does not explicitly forbid the use of these meat-related terms. These terms could, in principle, be used for plant-based products so long as their use does not mislead consumers.

> Arriving at a consensus among policymakers regarding a definition for meat analogues and requirements for their labelling is likely to be challenging.

In Germany, a 2017 appeal to the German Food Code Commission (DLMBK) by the German food minister and national farmers' and butchers' associations to restrict the use of terms such as 'vegan Schnitzel' and 'vegetarian Bratwurst' led to the publication of new guidance in August 2018. The guidance, from the DLMBK, indicates that terms relating to whole animals or to specific parts of animals – such as 'ham' or 'sausage' – may not be used for meat substitutes, and that references to names such as 'Schnitzel', 'goulash' or 'meatballs' may only be made if the substitute products are sufficiently similar in taste.[126]

In an opinion published in October 2017, the EC recognized that greater clarity is needed and, as part of its Regulatory Fitness and Performance Programme, it announced that a review of the labelling of vegan and vegetarian food will begin in 2019. The Commission will likely prepare an implementing act, specifying how these foods may be labelled, as indicated in Article 26 of the FIC Regulation.[127] In November 2018, the European Commission set in motion a European Citizens' Initiative on mandatory labelling of food as non-vegetarian, vegetarian or vegan to which Europeans may register their support.[128] Should one million statements of support be received within a year, from at least seven member states, the European Commission will be required either to commit to implementing such mandatory labelling or explain its reason for not doing so. Arriving at a consensus among policymakers regarding a definition for meat analogues and requirements for their labelling is

[124] Assemblée Nationale de France (2018), 'Amendement Nº CE2044', 13 April 2018, http://www.assemblee-nationale.fr/15/amendements/0627/CION-ECO/CE2044.asp (accessed 1 Jun. 2018).
[125] Court of Justice of the European Union (2017), 'Judgment in Case C-422/16', Press Release, 14 June 2017, https://curia.europa.eu/jcms/upload/docs/application/pdf/2017-06/cp170063en.pdf (accessed 1 Jun. 2018).
[126] European Vegetarian Union (2017), '"Vegan Schnitzel" stays "vegan Schnitzel". Big loss for German Federal Minister Schmidt', 19 October 2017, http://www.euroveg.eu/wp-content/uploads/2015/05/GFCC_PR.pdf (accessed 1 Jun. 2018).
[127] European Commission (2017), *Regulatory Fitness and Performance Programme – Refit Scoreboard Summary*, 24 October 2017, https://ec.europa.eu/info/sites/info/files/regulatory-fitness-and-performance-programme-refit-scoreboard-summary_en_3.pdf (accessed 1 Jun. 2018).
[128] European Commission (2018), 'European Citizens' Initiative: Commission registers "Mandatory food labelling Non-Vegetarian / Vegetarian / Vegan" initiative', 7 November 2018, http://europa.eu/rapid/press-release_IP-18-6317_en.htm (accessed 31 Jan. 2019).

nevertheless likely to be challenging for the EU multi-levelled governance system: labelling decisions will need to be coordinated with processes in all member states, where cultural views of meat and meat alternatives vary considerably.[129]

Cultured meat

The naming and labelling of *in vitro* meat raises two key issues: firstly, whether a product's name and label should be required to indicate clearly the process of its production; and secondly, whether *in vitro* meat can and should be referred to as 'meat'.

As *in vitro* meat is not yet authorized for the EU market, there is no agreement on its legal name. There are already a range of names given to meat products grown *in vitro* both by those developing the technologies and by social commentators: cultured meat, clean meat, lab-meat are all commonly used, but these are not 'customary names' as defined by the FIC Regulation. Given that the key objective of the FIC Regulation is to ensure that fair, clear and precise information is provided to consumers – including on the method of manufacture or production – it seems likely that operators in the EU will need to ensure that the consumer is made aware via the product label that the meat in question was grown *in vitro* rather than by conventional production processes, and that the legal name of the product will need to indicate this. This transparency requirement may be reinforced by the Novel Food Regulation: *in vitro* meat is a novel food and will require authorization under the procedure laid out under the Novel Food Regulation No. 2015/2283.[130] It appears likely, therefore, that the addition of *in vitro* meat to the EU list of authorized novel foods will be accompanied by a specification that the production process be evidenced on the product label.

Anticipating whether operators marketing *in vitro* meat will be permitted to label their products as 'meat' is more difficult. Under the FIC Regulation, for labelling purposes, meat is defined as 'skeletal muscles of mammalian and bird species recognised as fit for human consumption with naturally included or adherent tissues'. The application of this definition to *in vitro* meat will likely be up for debate: cultured meat may not be considered 'skeletal muscle' (which the Regulation in turn defines as 'muscles under the voluntary control of the somatic nervous system') nor does it consist of 'naturally included or adherent tissues' owing to the production process involved. If such a conclusion were reached, the term 'meat' could not be applied to *in vitro* meat under current EU legislation. If, on the other hand, it were determined that *in vitro* meat could be defined as 'meat' under the FIC Regulation, further issues would need to be addressed, not least whether operators would be required to indicate a country of origin or place of provenance of the slaughtered animal, as is expected of operators marketing meat produced by conventional means.

As noted in a recent article exploring the challenges in bringing cultured meat to market, the degree of contestation over how cultured meat should be referred to reflects a deeper disagreement over what exactly cultured meat is and how it should be positioned in relation to conventional meat.[131] Decisions relating to the terminology permitted in the marketing of future cultured-meat products will likely

[129] De Boer, J. and Aiking, H. (2018), 'Prospects for pro-environmental protein consumption in Europe: Cultural, culinary, economic and psychological factors', *Appetite*, 121: pp. 29–40, doi:10.1016/j.appet.2017.10.042 (accessed 21 Jan. 2019); Vanhonacker et al. (2013), 'Flemish consumer attitudes towards more sustainable food choices'.
[130] Official Journal of the European Union (2013) Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015 on novel foods, amending Regulation (EU) No. 1169/2011 of the European Parliament and of the Council and repealing Regulation (EC) No. 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No. 1852/2001, https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32015R2283 (accessed 21 Jan. 2019).
[131] Stephens et al. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture'.

be influenced not only by technical considerations but by political arguments too: permission for manufacturers of cultured meat to label their products as 'meat' with few additional caveats would likely meet with resistance from the traditional livestock industry; a decision to require that those manufacturers label their product as 'artificial muscle proteins'[132] or similar may be expected to prompt a similar degree of resistance from the meat analogues industry.

Regulation of GMOs and good manufacturing practice

Food containing GMOs, or produced from a GMO source material, is subject to separate approval under Regulation No. 1829/2003 and does not come under the Novel Food Regulation. According to EU regulations, the decision to allow the import or production of a GM crop in any given member state may be taken on the basis of a risk-based safety assessment, as well as economic and consumer acceptance factors.[133] Depending on whether the production process of cultured meat is considered to approximate pharmaceutical production more than food manufacture, cultured-meat production plants may also be subject to good manufacturing practice (GMP) guidelines. (GMP is an international system for quality and consistency control that aims to mitigate residual risks arising from pharmaceutical production that cannot be ruled out based solely on final product testing).[134]

What GMO regulation and GMP guidelines mean for meat analogues

The decision to regulate either a plant-based 'meat' or cultured-meat product under GMO regulation would have implications for manufacturers, including specific stipulations for environmental and human safety assessments and product labelling. Perhaps more importantly, the use of GMOs in meat analogues is likely to dampen demand among European consumers who continue to negatively view genetic modification in food.[135]

For most plant-based 'meat', the component ingredients have a history of consumption in the EU and the production techniques are already commonly used. Companies including Beyond Meat and Moving Mountains are already selling their 'bleeding' plant-based 'meat' products in EU countries without prior authorization under the Novel Food Regulation, though a retrospective decision to require that they be assessed and approved under the Regulation remains a possibility. In the case of the plant-based 'Impossible Burger', it remains unclear whether the Novel Food Regulation or Regulation No. 1829/2003 on GM food and feed would apply. 'Heme' (the key ingredient in the 'Impossible Burger', which supplies the characteristic taste and aroma of meat and which is carried in SLH) is produced through cell culture using genetically engineered yeast.[136] Under the definition of the Novel Food Regulation, 'heme' may be considered a novel ingredient as it is produced 'from cell/tissue culture derived from plants, animals, microorganisms, fungi or algae'. But, while the burger

[132] Hocquette, F. (2016), 'Is in vitro meat the solution for the future?', *Meat Science,* 120: pp. 167–176, doi: 10.1016/j.meatsci.2016.04.036.
[133] Barlow, S. M., Boobis, A. R., Bridges, J., Cockburn, A., Dekant, W., Hepburn, P., Houben, G. F., König, J., Nauta, M. J., Schuermans, J. and Bànàti, D. (2015), 'The role of hazard- and risk-based approaches in ensuring food safety', *Trends in Food Science and Technology, 46(2a)*: pp. 176–88, doi: 10.1016/j.tifs.2015.10.007 (accessed 21 Jan. 2018).
[134] World Health Organization (2018), 'Essential medicines and health products', http://www.who.int/medicines/areas/quality_safety/quality_assurance/gmp/en/ (accessed 11 May 2018).
[135] Lucht, J. M. (2015), 'Public Acceptance of Plant Biotechnology and GM Crops', *Viruses*, *7(8)*: pp. 4254–4281, doi:10.3390/v7082819 (accessed 18 Jan. 2019).
[136] Impossible Foods Inc. (2016), Patent application WO2016183163A1, 'Expression constructs and methods of genetically engineering methylotrophic yeast', https://patents.google.com/patent/WO2016183163A1 (accessed 1 Jun. 2018); Impossible Foods Inc. (2013), Patent application WO2013010042A1, 'Methods and compositions for consumables', https://patents.google.com/patent/WO2013010042A1 (accessed 1 Jun. 2018); Impossible Foods Inc. (2017), Patent grant US9700067B2, 'Methods and compositions for affecting the flavor and aroma profile of consumables', https://patents.google.com/patent/US9700067 (accessed 1 Jun. 2018).

itself does not contain any genetically engineered material, its use in the production process will likely mean it must be regulated under the GMO Regulation. Certain methods of producing cultured meat also involve the use of GM organisms, raising similar questions around the regulatory pathway under which they would fall.[137] Until such time as meat analogues produced using GM organisms are authorized for sale and consumption the EU, their import from non-EU producers will not be permitted.

The use of FBS in manufacturing practices for medicinal products has been discouraged globally under GMP protocols and under the EU Good Cell Culture Principles (GCCP).[138] The use of FBS is further discouraged under EU regulations relating to the use of chemicals (Regulation No. 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals – REACH) and, where the foetus from which serum is harvested is not first killed, under regulations to protect animals used for scientific purposes (EU Directive No. 2010/63/EU).[139]

Summary

- In the EU, cultured meat will be regulated under the Novel Food Regulation unless GMOs are used in the production process. In this case, and in the case of plant-based 'meat' techniques that make use of GMOs, products will likely be controlled under Regulation No. 1829/2003 on GMOs in food and feed.
- Plant-based 'meat' may not require authorization under the Novel Food Regulation if the component ingredients and processing techniques have a history of use in the EU. In the case of the Impossible Burger, which contains plant 'heme' produced using GM yeast, authorization under either the Novel Food Regulation or the GMO Regulation is likely to be required.
- Labelling requirements and restrictions are regulated under the FIC Regulation but there remains a high degree of uncertainty around how plant-based 'meat' and cultured meat may be named and marketed. Restrictions on the use of meat-like names for plant-based products in France and Germany indicate that future decisions taken at the EU level on meat analogue labelling are likely to be highly politicized.

[137] Stephens, et al. (2018), 'Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture'.
[138] Ibid.
[139] Van der Walk, J. et al. (2017), 'Fetal Bovine Serum (FBS): Past – Present – Future', *ALTEX, 35(1)*: pp. 99–118, doi:10.14573/altex.1705101 (accessed 21 May 2018).

5. Looking Ahead: Considerations for EU Policymakers

As innovation continues in plant-based 'meat' and cultured meat, European policymakers will need to consider how the EU positions itself in the nascent global meat analogue industry. Certain European universities and companies have been central in the early development of meat analogue techniques but, with markets in North America, Asia and Israel growing rapidly, further financial investment and the resolution of outstanding regulatory uncertainties will be needed if the EU is to be a significant global player in this space. Perhaps more importantly, EU decision-makers and member states will need to consider if and how meat analogues contribute to the realization of existing policy strategies and priorities, not only in terms of environmental governance but also public health and the transition to a circular economy.

Considering the role of meat analogues in broader food system reform

The strength of incumbent industry and the perception of the livestock sector's cultural importance have made meat consumption a politically sensitive issue in the EU and, in the absence of effective policy interventions to promote a large-scale shift away from conventional meat production and consumption, public investment in meat alternatives has been relatively muted. Despite the considerable negative externalities associated with meat production and consumption, EU efforts to promote a more sustainable food system are not without political challenges. Environmental concerns have at times clashed with economic and political priorities[140] among the many formal and informal actors and networks that interact to define European regulation,[141] and the EU's first draft sustainable food strategy, developed in 2013, was not published.[142] Moreover, efforts to reform the Common Agricultural Policy (CAP) have repeatedly been slowed owing to strong economic and political support from EU member states for maintenance of the existing system – the CAP received approximately 38 per cent of the EU budget for 2014–20 (€408.31 billion over that period).[143]

As the EU looks to meet its ambitious commitments on climate change mitigation, sustainable consumption and public health in the coming decades, it is crucial that public policymakers view meat analogues and their regulation within the broader context of food system reform. Meat analogues have the potential to galvanize the EU's success in meeting many of its more ambitious policy goals, including the EC's Food 2030 Initiative.

The EU's plan to reduce GHG emissions under the UN Framework Convention on Climate Change (UNFCCC), for example, is among the most progressive in the world, and research has illustrated the

[140] Rayner, G., Barling, D. and Lang, T. (2008), 'Sustainable Food Systems in Europe: Policies, Realities and Futures', *Journal of Hunger & Environmental Nutrition*, *3(2-3)*: pp. 145–68, doi:10.1080/19320240802243209 (accessed 1 Jun. 2018).
[141] Jordan, A., Huitema, D., van Asselt, H. D., Rayner, T. and Berkhout, F. G. H. (eds) (2010), *Climate Change Policy in the European Union: Confronting the dilemmas of mitigation and adaptation?*, Cambridge: Cambridge University Press.
[142] Clark, A. (2018), '"Denial" – is meat the new climate change?', *EUObserver*, 20 March 2018, https://euobserver.com/opinion/141344 (accessed 1 Jun. 2018).
[143] Members' Research Service (2016), 'How The EU Budget Is Spent: Common Agricultural Policy', European Parliamentary Research Service Blog, 20 July 2016, https://epthinktank.eu/2016/07/20/how-the-eu-budget-is-spent-common-agricultural-policy/ (accessed 19 Nov. 2018).

vital importance of a reduction in meat consumption in the EU in meeting these climate targets.[144] In 2018, new analysis from the RISE Foundation found that EU livestock production and consumption are currently exceeding sustainable levels for Europe and identified the substitution of conventional meat for cultured meat and plant-based alternatives are as a potential strategy for adjusting current livestock consumption patterns.[145] Further research is needed to assess the resource footprint of cultured meat and plant-based 'meat' production at scale, and to develop a low-carbon energy source for the production of cultured meat.[146] Early studies indicate that meat analogues could play a key role in satisfying current and future demand for meat in the EU, while significantly reducing the emissions and resource intensity of production and freeing up much-needed land for use in renewable energy production and carbon capture.[147]

Early studies indicate that meat analogues could play a key role in satisfying current and future demand for meat in the EU, while significantly reducing the emissions and resource intensity of production and freeing up much-needed land for use in renewable energy production and carbon capture.

Meat analogues could play a similar role in delivering improved public health targets at the European and national levels. In 2015, European health ministers committed to the European Food and Nutrition Action Plan 2015–2020, which aims to create healthy food environments and tackle diet-related non-communicable diseases.[148] As a result, several EU member states have taken steps to promote reduced consumption of meat in their national dietary guidelines,[149] recognizing the links between excessive consumption of red and processed meat and diet-related diseases including obesity, type-2 diabetes, heart disease and certain cancers.[150] Theoretically, cultured-meat cells may be engineered to create a healthier product, altering the balance of harmful components – saturated fats, for example – with desirable components such as poly-unsaturated fatty acids, while plant-based 'meat' products, unless highly processed, tend to contain relatively low levels of saturated fat, cholesterol and calories.[151] At the EU level, the One Health Action Plan against Antimicrobial Resistance seeks to position the EU as a 'best practice region' in the fight against unsustainable antibiotic use, including through boosting innovation: if its producers succeed in scaling up

[144] Bryngelsson, D., Wirsenius, S., Hedenus, F. and Sonesson, U. (2016), 'How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture', *Food Policy*, 59: pp. 152–164, doi:10.1016/j.foodpol.2015.12.012 (accessed 22 Jan. 2019); Röös, E., Bajželj, B., Smith, P., Patel, M., Little, D. and Garnett, T. (2017), 'Protein futures for Western Europe: potential land use and climate impacts in 2050', *Regional Environmental Change*, *17(2)*: pp. 367–377, doi:10.1007/s100113-016-1013-4 (accessed 22 Jan. 2019); Westhoek, H., Lesschen, J. P., Leip, A., Rood, T., Wagner, S., De Marco, A., Murphy-Bokern, D., Pallière, C., Howard, C. M., Oenema, O. and Sutton, M. A. (2015), *Nitrogen on the Table: The influence of food choices on nitrogen emissions and the European environment, European Nitrogen Assessment Special Report on Nitrogen and Food*, Edinburgh: Centre for Ecology & Hydrology, https://www.pbl.nl/sites/default/files/cms/publicaties/Nitrogen_on_the_Table_Report_WEB.pdf (accessed 22 Jan. 2019).

[145] Buckwell, A. and Nadeu, E. (2018), What is the Safe Operating Space for EU Livestock?, Brussels: RISE Foundation, http://www.risefoundation.eu/images/files/2018/2018_RISE_LIVESTOCK_FULL.pdf (accessed 22 Jan. 2019).

[146] Alexander et al. (2017), 'Could consumption of insects, cultured meat or imitation meat reduce global agricultural land use?'.

[147] Tuomisto, H. L. and Roy, A. G. (2012), 'Could cultured meat reduce environmental impact of agriculture in Europe', 8th International Conference on LCA in the Agri-Food Sector, Rennes, France, 2–4 October 2017, https://www.researchgate.net/publication/255179690_Could_cultured_meat_reduce_environmental_impact_of_agriculture_in_Europe (accessed 22 Jan. 2019); Alexander et al. (2017), 'Could consumption of insects, cultured meat or imitation meat reduce global agricultural land use?'.

[148] WHO Regional Office for Europe (2015), *European Food and Nutrition Action Plan 2015–2020*, Copenhagen: WHO Regional Office for Europe, http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/publications/2015/european-food-and-nutrition-action-plan-20152020-2014 (accessed 22 Jan. 2019).

[149] Gonzalez Fischer, C. and Garnett, T. (2016), *Plates, pyramids and planets – Developments in national healthy and sustainable dietary guidelines: a state of play assessment*, Rome: FAO, http://www.fao.org/3/a-i5640e.pdf (accessed 22 Jan. 2019).

[150] Willet et al. (2019), 'Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems'.

[151] Kumar, et al. (2017), 'Meat analogues: Health promising sustainable meat substitutes'; Bohrer, B. M. (2017), 'Review: Nutrient density and nutritional value of meat products and non-meat foods high in protein', *Trends in Food Science & Technology*, 65: pp. 103–12, doi:10.1016/j.tifs.2017.04.016 (accessed 30 May 2018).

production in a sterile environment, cultured meat could offer a means of delivering a product that is healthier for consumers and produced without the need for antibiotics.

More broadly, investment in research, development and innovation in the meat analogue industry could form a keystone of the EU's Circular Economy Action Plan and its Food 2030 Initiative, which both prioritize research and innovation in circularity and resource efficiency in the food system. Under the Circular Economy Action Plan, the EU has committed to implementing an ambitious package of measures aimed at promoting a 'sustainable, low carbon, resource efficient and competitive economy' in which innovative new ways of producing and consuming are promoted as a means of protecting the environment, buffering businesses against resource scarcity and price volatility, and unlocking new jobs.[152] The development of a meat analogue industry that encourages the use of plant protein crops for direct human consumption rather than as animal feed, and creates new economic opportunities for European farmers outside conventional livestock production, may boost EU policymakers' efforts to deliver on the circular economy.

Ensuring a clear regulatory framework and evidence-based decision-making

EU regulation has the potential to affect the nature, scale and pace of innovation, from the research and development stage right through to commercialization.[153] Consumer safety and good manufacturing standards must remain the priority of regulators as they consider whether novel meat alternatives should be licensed for sale, and under what conditions. But, with legal definitions of meat and meat-related terms already being debated in European courts, EU policymakers will need to consider the broad range of issues and concerns surrounding meat analogues if they are to ensure a clear, transparent and evidence-based regulatory framework.

As it stands, the Novel Food Regulation provides for a technical assessment of the safety of meat analogues for humans, animals and the environment. The EFSA undertakes an assessment of potential nutritional, toxicological or allergenic hazards and recommends a decision to the Standing Committee, after which the European Commission and member states may raise specific safety concerns as they see fit before a final decision on approval is made. Less transparent is the process for deciding on specific stipulations regarding product labelling that may accompany an approval under the Novel Food Regulation, and on the process for determining legal, customary and descriptive names under the FIC Regulation on product labelling.

Insights from research into the labelling and marketing of vegetarian products and the impact of these activities on sales indicate the importance of labelling decisions and regulation in determining the future of the meat analogue industry. Clear and consistent product packaging and nutritional labels are vital to enabling consumers to make informed decisions and to fostering consumer trust in the European food system, particularly in the wake of the 2013 European horsemeat scandal: many consumers report paying more attention to labels on meat products, while others report a lack of

[152] European Commission (2015), 'Closing the loop – An EU action plan for the Circular Economy, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions', 2 December 2015, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0614&from=EN (accessed 22 Jan. 2019).
[153] Pelkmans, J. and Renda, A. (2014), 'Does EU regulation hinder or stimulate innovation?', Centre for European Policy Studies, Special Report No. 96, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2528409 (accessed 30 May 2018).

confidence in the honesty and accuracy of labels.[154] The European Commission, recognizing that greater clarity is needed for innovators, incumbent industry and consumers, is set to undertake a review of the labelling of vegan and vegetarian food, for which preparatory work will start in 2019.

In order to ensure that product labelling prioritizes consumer information and trust, and is not co-opted by lobbyists from industry or third parties, European consumer watchdogs and government regulators should commission market research to explore consumer attitudes towards plant-based 'meat' and cultured meat, their labelling, and the information that consumers need to make an informed purchasing decision. Beyond technical considerations, the future growth of the meat analogue industry will depend on a host of social, economic and political factors.[155] Any review process should involve engagement with the public, producers, specialists in environmental and human health, and experts in product labelling and consumer behaviour.

The same process should apply to cultured meat. In recognition of the European Commission's reactive rather than proactive approach to novel food safety assessments (the process of assessment and approval is initiated only when an application is formally submitted by a producer), it may be necessary to establish an independent advisory committee to ensure timely consideration of the complex regulatory questions concerning cultured-meat products. This committee could be tasked with reviewing developments in the meat analogue space, considering likely safety concerns and labelling requirements arising from new techniques or products, and engaging with producers early on in the approval process to provide support and ensure that policymakers are kept abreast of developments. The generation of research data to support the EFSA assessment of novel foods and their safety will also be important to avoid bottlenecks in the approval process.[156]

Beyond technical considerations, the future growth of the meat analogue industry will depend on a host of social, economic and political factors.

Furthermore, in taking early action to create a clear regulatory landscape, the EU could pioneer international standards for this new industry, thereby strengthening its position as a hub of innovation and contributing to a supportive global environment for European meat analogue companies wishing to export overseas.

Investing public funds in research and development

The costs associated with meat analogues, at the point of both production and retail, are likely to remain a significant barrier to widespread uptake in Europe in the near to medium term. Investments by traditional meat companies in plant-based 'meat' and cultured-meat companies may help to accelerate both innovation and the scale-up of production and distribution infrastructure.[157]

[154] Barnett, J., Begen, F., Howes, S., Regan, A., McConnon, A., Marcu, A., Rowntree, S. and Verbeke, W. (2015), '"Consumers" confidence, reflections and response strategies following the horsemeat incident', *Food Control,* 59: pp. 721–730, doi:10.1016/j.foodcont.2015.06.021 (accessed 22 Jan. 2019).
[155] Bubela, T., Hagen, G. and Einsiedel, E. (2012), 'Synthetic biology confronts publics and policy makers: challenges for communication, regulation and commercialization', *Trends in Biotechnology*, *30(3)*: pp. 132–137, doi:10.1016/j.tibtech.2011.10.003 (accessed 22 Jan. 2019).
[156] European Commission Directorate-General Research and Innovation (2018), *Recipe for change*.
[157] Shanker, D. (2018), 'Lab-Meat Growers Wants Help From Industry They Seek to Disrupt', BloombergQuint, 26 November 2018, https://www.bloombergquint.com/business/lab-meat-growers-seek-help-from-industry-they-seek-to-disrupt#gs.6WH3=g0 (accessed 30 Nov. 2018).

However, policymakers at the EU and member-state levels have a key role to play, for example, in lowering market barriers to entry for new producers and facilitating the commercialization of research.

As major food companies move into the meat analogue space, public support for non-exclusive research and for the sharing of research findings will be important in keeping the field open to new entrants, particularly to small- and medium-sized enterprises, which have driven innovation to date. Public capital will also be needed to bridge the gap between innovations developed in the laboratory and their commercial exploitation:[158] large up-front investments in the infrastructure to support the scale-up of new products or technologies are often difficult to secure from low-risk investors, particularly for small- and medium-scale producers; public capital can help to catalyse the commercialization of new innovations while mitigating against the risk that promising innovations are acquired and developed by actors outside the EU. This will be particularly important if the EU is to retain its position as a global hub of innovation in the meat analogue industry. The use of non-exclusive licensing arrangements with any third parties seeking to commercialize the end product can help ensure that foundational knowledge developed with public finance remains in the public sphere.

The EU has one of the world's largest public-sector R&D programmes and has already committed significant public funds to supporting meat analogue innovation. Between 2010 and 2013, the EU provided over €1 billion for research into high-quality plant-based 'meat' products under the 'LIKEMEAT' project[159] and, in 2017, it announced a further €1 billion investment in innovation in the agri-food sector under its Horizon 2020 R&D programme,[160] including a €32 million budget for innovation in 'alternative proteins for food and feed'.[161] In addition, a number of other budgets could be used to further R&D in the field, including anticipated funds with the explicit aim of supporting high-risk disruptive innovations.[162] Existing mechanisms can also support investment in research and innovation, including the European Fund for Strategic Investments (€500 billion), the InvestEU programme (€38 billion) and the Smart Specialisation Strategy (€41 billion).

A coordinated strategy at the EU level will be crucial to ensure that any funding resources channelled into meat analogue innovation are optimized efficiently and transparently and consistent with EU policy priorities. A unified research and innovation strategy for a climate-smart, sustainable food system[163] could steer the consolidation of the above funds and target related financing sources, for example, climate-related research (which is due to get 35 per cent of the proposed €100 billion Horizon Europe research

[158] UK House of Commons Science and Technology Committee (2013), 'Bridging the valley of death: improving the commercialisation of research', Eighth Report of Session 2012–13, London: UK House of Commons, https://publications.parliament.uk/pa/cm201213/cmselect/cmsctech/348/348.pdf (accessed 22 Jan. 2019).
[159] European Commission (no date), 'Final Report Summary – LIKEMEAT (High quality meat-like products – from niche markets to widely accepted meat alternatives)', https://cordis.europa.eu/project/rcn/97605/reporting/en (accessed 22 Jan. 2019).
[160] European Commission (2017), 'European Commission announces €1 billion funding for more sustainable agriculture, food and rural development', 27 October 2017, https://ec.europa.eu/info/news/european-commission-announces-eu1-billion-funding-more-sustainable-agriculture-food-and-rural-development_en (accessed 19 Nov. 2018).
[161] European Commission (2017), 'Alternative proteins for food and feed', Research and Innovation Participant Portal, http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/lc-sfs-17-2019.html (accessed 29 May 2018).
[162] European Commission (2018), 'The Commission presents strategy for a climate neutral Europe by 2050 – Questions and answers', http://europa.eu/rapid/press-release_MEMO-18-6545_en.htm (accessed 30 Nov. 2018).
[163] European Commission Directorate-General Research and Innovation (2018), *Recipe for change: An agenda for a climate-smart and sustainable food system for a healthy Europe*.

and innovation budget for the period 2021–27)[164] and innovation under the circular economy and One Health agendas. A core component of such a unified strategy should be the optimization of investment in meat analogues that offer sustainable and healthy alternatives to conventional meat.

Conclusion

Meat production and consumption are highly politicized issues in the EU and globally. Meat analogues, while in their infancy, are already the subject of much speculation and debate among innovators, incumbent industry, civil society and the public. As innovation continues to evolve at pace in Europe and around the world, it is crucial that EU policymakers take stock of this nascent industry and consider its place in EU-wide policy priorities and industrial strategies.

A thriving meat analogue industry in the EU has the potential to contribute to existing policy priorities in a number of areas, including climate mitigation, reduced antibiotic use, improved public health and more circular means of production. To harness this potential, early and sustained public investment is needed in research, development and commercialization to ensure that innovations transition from the laboratory to European markets. Equally important will be a proactive and inclusive approach to resolving outstanding regulatory uncertainties, particularly around product naming and labelling. In the absence of such an approach, there is a risk that key policy decisions – decisions that will likely have a material impact on the response of the public and civil society to novel products and production systems – are made in the courtroom and shaped by third-party interests rather than by policymakers in a timely, transparent and evidence-based manner.

Global efforts to promote sustainable and equitable food system reforms and mitigate the environmental impact of food – particularly meat – production on the environment and on public health are gathering momentum. A timely and coordinated strategy at the EU level to harness the potential of the nascent meat analogue industry within this context, and to promote a regulatory environment that is clear, transparent and inclusive, could help to cement the EU's place at the forefront of innovation in the sustainable resource economy and as a global leader in the meat industry of tomorrow.

[164] EURAXESS (2018), 'European Commission proposes 100 billion EUR research & innovation budget 2021–2027', EURAXESS, 11 June 2018, https://euraxess.ec.europa.eu/worldwide/asean/european-commission-proposes-100-billion-eur-research-innovation-budget-2021 (accessed 21 Nov. 2018).

Annex 1: Companies Active in the Production of Plant-based 'Meat' and Cultured Meat

Company	Founded	Origin	Funds raised	Investors	Activities
Plant-based 'meat' companies					
Beyond Meat	2009	US	$72m	Bill Gates; Tyson Foods; Twitter co-founders Biz Stone and Evan Williams; Leonardo DiCaprio; former McDonald's CEO Don Thompson.[165]	Retail distribution, particularly through Whole Foods Market Inc. On 12 April 2018, Germany's PHW Group announced it had become a strategic partner to Beyond Meat to launch its plant-based burger in Europe.[166]
ChickP	2016	Israel	$0.5m	Agrinnovation, an investment company that commercializes agricultural technologies generated by The Hebrew University of Jerusalem's faculty of agriculture.[167]	
Dao Foods	2018	China	Seed funding (undisclosed)	Dao Ventures; Moonspire Social Ventures; New Crop Capital.[168]	Venture group that aims to create meat alternatives for Chinese consumers.[169]
Gold & Green	2015	Finland	Paulig acquired a 51% stake for an undisclosed amount in 2016. Prior to this, the company had raised over €1m.	Finnish food company Paulig has been the majority shareholder since 2016.[170]	Gold & Green's products are made from oats as an alternative to mince or as an ingredient in salads or sandwiches. The company says it hopes to launch its products in the UK 'in the near future'.[171]
Impossible Foods	2011	US	$387m	Bill Gates; Open Philanthropy Project; Khosla Ventures; Google Ventures; UBS Group AG; Viking Global Investors; Horizons Ventures; Temasek; Sailing Capital.[172]	Supplying the food service industry; product available in more than 4,000 locations in the US, Hong Kong and Macao.[173]

[165] Glotz, J. (2018), 'Meat the disruptors: 15 startups shaking up the $90bn global meat industry', The Grocer, 13 April 2018, https://www.thegrocer.co.uk/home/topics/future-of-meat/from-plant-based-burgers-to-lab-grown-meatballs-15-startups-disrupting-the-global-meat-industry/565785.article (accessed 5 Jan. 2019).
[166] Ibid.
[167] Ibid.
[168] Ibid.
[169] Ibid.
[170] Ibid.
[171] Ibid.
[172] Ibid.
[173] Lee-Zogbessou, J. (2018), 'Impossible Foods: the rise of the meat-free plant-based burger', Verdict Foodservice, 2 October 2018, https://www.verdictfoodservice.com/insight/impossible-foods-plant-based-burger/ (accessed 5 Jan. 2019).

Company	Founded	Origin	Funds raised	Investors	Activities
Plant-based 'meat' companies (continued)					
Ojah	2009	Netherlands	Undisclosed	Korys; Kerry Group will become a shareholder pending merger approval from the European Commission.[174]	Ojah's technology enables the company to produce wet texturized plant protein with a meat-like taste and texture. The range is also gluten-free and additive-free. Ojah exports its products to more than 21 countries.[175]
Right Treat	2018	Hong Kong	Undisclosed	Undisclosed.	Developing a plant-based protein for Asian consumers. Plant-based 'Omnipork' launched in 2018, designed as a versatile product that can be used to cook a variety of Asian dishes.[176]
Sunfed Meats	2015	New Zealand	Undisclosed	Jeremy Coller of Coller Capital; New Crop Capital; 'angel investors' from New Zealand, the US and the UK.[177]	Established company in New Zealand, distributing frozen product through Countdown and New World supermarkets, among others. It emphasizes the chicken-like taste and texture of its products. The company is planning to expand internationally, with the UK as a key future market.[178]
The Vegetarian Butcher	2010	Netherlands	$10m	Private investors, who bought €2.5m in bonds; Triodos Bank.[179]	Innovative plant-based meat and fish substitutes, which are in several European countries through their own or third-party stores. The Vegetarian Butcher has expanded to 3,000 sales outlets in 14 countries and has its own production plant.[180] The company also has a partnership with UK-based Waitrose & Partners to supply the meat alternatives for its new plant-based range of ready meals.[181]

[174] Glotz (2018), 'Meat the disruptors: 15 startups shaking up the $90bn global meat industry'.
[175] Ibid.
[176] Right Treat (2018), https://www.linkedin.com/company/right-treat/ (accessed 5 Jan. 2019).
[177] Glotz (2018), 'Meat the disruptors: 15 startups shaking up the $90bn global meat industry'.
[178] Ibid.
[179] Ibid.
[180] The Vegetarian Butcher (2018), 'https://www.thevegetarianbutcher.com/about-us/vegetarian-butcher-production-plant' (accessed 5 Jan. 2019).
[181] Glotz (2018), 'Meat the disruptors: 15 startups shaking up the $90bn global meat industry'.

Company	Founded	Origin	Funds raised	Investors	Activities
Cultured-meat companies					
Aleph Farms	2017	Israel	Undisclosed	Aleph Farms was co-founded in 2017 by Technion and Israeli food-tech 'incubator' The Kitchen, a part of the Strauss Group, and is supported by US and European venture capital firms.[182]	The company uses 3D technology and applies the tools of regenerative medicine to produce cultured meat.[183]
Finless Foods	2017	US	$3.5m	A total of 13 investors, including Harrison Blue Ventures; Hemisphere Ventures; StarLightMedia; Olive Tree Capital; Softmatter VC; U-Start; Yakumi Investment; Blue Horizon Equity; Babel Ventures; Draper Associates.[184]	This biotechnology company is at an early stage of developing and mass producing pioneering marine animal food products for human consumption.[185]
Future Meat Technologies	2018	Israel	$2.2m	S2G Ventures; HB Ventures; Yissum (the technology transfer company of The Hebrew University); Neto Group; BitsXBites; Agrinnovation; Tyson New Ventures.[186]	The only company worldwide holding an unlimited cell source that was not genetically modified, capable of differentiating to both muscle and fat. The technology was exclusively licensed from The Hebrew University of Jerusalem.[187]
Higher Steaks	2017	UK	Undisclosed	Undisclosed	The company is developing a production method that substantially reduces the amount of media needed to produce cell-based meat; an intelligent in-process monitoring system to improve efficiency; and a biomaterial that allows the generation of more structurally complex products.[188]

[182] Leichman, A. K. (2018), 'Tyson Food invests in Israeli clean-meat startup', Israeli21c, 18 May 2018, https://www.israel21c.org/tyson-foods-invests-in-israeli-clean-meat-startup/ (accessed 5 Jan. 2019).
[183] Brodwin, E. (2018), 'The company behind America's favourite hummus has funded an under-the-radar effort to make lab-grown steak', Business Insider, 3 May 2018, https://www.businessinsider.com/sabra-company-funded-lab-grown-steak-clean-meat-2018-5?r=UK (accessed 5 Jan. 2019).
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[185] Ibid.
[186] PR Newswire. (2018), 'Tyson Ventures Announces Investment in Future Meat Technologies', PR Newswire, 2 May 2018, https://www.prnewswire.com/news-releases/tyson-ventures-announces-investment-in-future-meat-technologies-300641006.html (accessed 5 Jan. 2019).
[187] Ibid.
[188] Young, T. (2018), 'Cell-Based Meat Company Higher Steaks On What It Takes To Go From Lab To Table', Forbes, 13 November 2018, https://www.forbes.com/sites/tiffanyyoung1/2018/11/13/cell-based-meat-company-higher-steaks-on-what-it-takes-to-go-from-lab-to-table/#35363c9b447e (accessed 5 Jan. 2019).

Company	Founded	Origin	Funds raised	Investors	Activities
Cultured-meat companies (continued)					
Integriculture Inc.	2015	Japan	¥300m	Real Tech Fund; Beyond Next Ventures; A-FIVE (Agriculture, Forestry and Fisheries Fund Corporation for Innovation, Value-chain and Expansion Japan); MTG Co., Ltd.; euglena Co., Ltd.; Dr Hiroaki Kitano (CEO of Sony Computer Science Laboratories, Inc.); and other investors.[189]	Food tech company aiming to reform current agriculture through cultured-meat production, has developed patented general-purpose large-scale cell culture system, 'CulNet System'. Demonstrated a clean chicken foie gras product in 2017.[190]
JUST	2011	US	$220m	Temasek; Mitsui; Founders Fund; Li Ka-shing; the Heineken family.[191]	The company is still developing its lab-grown meat, but it is confident it can make scalable lab meat that is safe, free of antibiotics and carries less risk of food-borne illness.[192]
Memphis Meats	2015	US	$20.1m	Tyson Foods; Draper Fisher Jurvetson; Cargill; New Crop Capital; Richard Branson; Bill Gates.[193]	Considered the leading company in the cultured-meat market, the company has already cultured a 'clean' beef meatball and in 2017 unveiled lab-grown chicken and duck.[194]
Mosa Meat	2013	Netherlands	€7.5m	M Ventures; Bell Food Group.[195]	Dutch start-up co-founded by Mark Post, the scientist who invented the first lab-grown burger. It expects to introduce its first product made of lab-grown meat to the market by 2021.[196]
SuperMeat	2015	Israel	$3.5m	Stray Dog Capital; New Crop Capital. Germany's PHW Group, one of Europe's largest poultry producers, became a strategic investor in January 2018.[197]	Its technology relies on a single biopsy, which can allow for scaling up production of cultured-meat products.[198]
Wild Type	2016	US	$3.5m	Mission Bay Capital; Root Ventures; Spark Capital.[199]	The company aims to develop a technology that would multiply basic animal cells in the lab to create a technology that could be applied across all kinds of different animal species and culture all types of meat.[200]

[189] CrunchBase (2018), https://www.crunchbase.com/organization/integriculture#section-overview (accessed 5 Jan. 2019).
[190] Ibid.
[191] Glotz (2018), 'Meat the disruptors: 15 startups shaking up the $90bn global meat industry'.
[192] Ibid.
[193] Ibid.
[194] Ibid.
[195] Fernández, C. R. (2018), 'Lab-Grown Meat Will Be on the Market in 2021', LABIOTECH.eu, 18 Jul 2018, https://labiotech.eu/food/mosa-meat-lab-grown-meat-fundraising/ (accessed 5 Jan. 2019).
[196] Ibid.
[197] Glotz (2018), 'Meat the disruptors: 15 startups shaking up the $90bn global meat industry'.
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[200] Rodriguez, V. (2018), 'Wild Type – A Startup With The Mission To Feed The World with Lab-Grown Meat', foodabletv, 13 April 2018, https://www.foodabletv.com/blog/2018/4/13/wild-type-a-startup-with-the-mission-to-feed-the-world-with-lab-grown-meat (accessed 5 Jan. 2019).

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Cover image: The Impossible Burger 2.0, the new and improved version of the company's plant-based vegan burger that tastes like real beef is introduced at a press event during CES 2019 in Las Vegas, Nevada on 7 January 2019. Copyright © Robyn Beck/AFP/Getty Images

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