DON'T HAVE A COW MAN

The prospects for lab grown meat

By Jamie Hollywood & Dr Madsen Pirie

BRIEFING PAPER

INTRODUCTION

The concept of manufacturing meat might seem like a new and futuristic prospect, but it has a rather long history. The first landmark experiment leading to the development of in-vitro meat is the 1912 experiment performed by Nobel Prize winning scientist Alexis Carrel. In these tests, Carrel took tissue culture from an embryonic chicken heart, and used a mechanism of structuring and providing this culture with the nutrients necessary for continued growth, aiming to prove that living cells could survive indefinitely under the right conditions.[1] While the results of his experiments were anomalous and were never successfully repeated, the logic behind the experiment is the same as the logic behind modern attempts to grow meat in the lab.

Winston Churchill foresaw the massive potential for in vitro meat two decades later, in his 1931 article "Fifty Years Hence". In one paragraph, Churchill writes: "We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium". [2]

Not quite the fifty years he predicted, but eighty-two years later, the first public trial of lab-grown meat (hereafter referred to using the more accurate term, cultured meat) for human consumption was broadcast to the world. In 2013, a group of three food critics tested the quality of lab-grown meat live on television. At that time the cost of one burger was around £215,000 – funded in part by Sergey Brin, co-founder of Google.[3] However, since then, the costs have plummeted. Peter Verstrate, the head of Mosa Meats (a company which is planning to mass commercialise cultured meats), said in April 2015 that he was confident that the commercialisation of lab-grown meat will happen within five years – and he is likely to be correct.[4] Since the 2013 test, the cost of one burger has fallen from that £215,000 price tag to around £8 per piece.[5]

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1 Carrel, A. (1912) "On The Permanent Life Of Tissues Outside Of The Organism". Journal of Experimental Medicine, 15(5), pp.516-528.

2 Churchill, W. (1931) The Contingency of What Lies Ahead / Churchill's "Fifty Years Hence". The International Churchill Society.

3 BBC News. (2013) World's first lab-grown burger eaten.

4 BBC News (2015) Team wants to sell lab grown meat in five years.

5 Morgan, R. (2018) Bill Gates and Richard Branson are betting lab-grown meat may be the food of the future. CNBC.

ADAM SMITH INSTITUTE – THE FREE-MARKET THINKTANK
23 Great Smith Street,
London, SW1P 3BL
+44 (0)20 7222 4995
www.adamsmith.org

With an ever-growing global demand for meat and the mounting environmental concerns around sustaining current agricultural practices, cultured meat is a welcome and positive innovation that can (and no doubt will) revolutionise the food industry. The cost of meat could be reduced to an all-time low as the technology evolves, with a wide variety of beneficial health implications – particularly for developing countries. The growing demand for meat, the ability for current and new markets to reliably sustain growth without long term ecological damage, and the impacts that cultured meat will have on the current agricultural industries and society as a whole are explored in this report.

MEAT CONSUMPTION

It comes as no surprise to discover that as economies grow meat consumption increases. The wealthier that individuals are, the greater their autonomy and spending power, and thus consumption of food, and meat specifically, will increase. Additionally, with greater GDP, a nation's infrastructure and ability to import and grow meat more efficiently rises; nations which are developed have a greater capacity to increase meat production or imports. In layman's terms: the more developed a country gets the more access its citizens have to affordable meat.

What has been seen, with the increase in GDP in major developing countries, is the lifting of millions of people from absolute poverty and away from subsistence farming. Collated data of meat consumption per kilogram and GDP per capita shows a trend of increasing meat consumption, seen in Table 1.

There are several outliers on the table, but much of this can be attributed to cultural phenomena. One such example is Japan which, despite having one of the highest GDP per capita, has a below average carcass mass availability (a proxy measure for meat consumption) for its GDP. Traditionally fruit, fish and rice were the main staples of Japanese cuisine. While that remains true today, even in Japan trends in food consumption are changing, driven by Westernisation. Reasons such as these can help to explain why meat consumption in Japan is significantly lower than in other nations of similar GDP per capita, such as the US or the UK.[6]

Similarly, a place like Chile has much higher than average carcass mass availability per capita than the average for a nation of its GDP per capita. This is again due to factors such as culture, but also the quantity and quality of arable land, weather patterns and so on. Even so, Chilean meat consumption over the last twenty years has more than doubled, from 36.9kg per person in 1991, to 84.2kg per person in 2011.[7] In the decade spanning 2000 to 2010, Chilean poultry consumption increased by 21%, and consumption of pork meat increased by 48%. [8]

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6 Chern, W., Ishibashi, K., Taniguchi, K. and Tokoyama, Y. (2018) Analysis of food consumption behaviour by Japanese households. Food and Agriculture Organisation

7 MercoPress. (2012). Chilean per capita meat consumption has doubled in the last two decades.

8 USDA Foreign Agricultural Service (2011). Chilean Meat Consumption Reached Record Highs in 2010. US Department of Agriculture

From 1990 to 2015, the number of people living in extreme poverty has fallen from 36% to 15%.[9] The general trend for global growth rates year-on-year is upwards. With millions being lifted out of absolute poverty items such as meat, which could formerly be considered luxury items, will be consumed more readily. This gives rise to several problems: with meat consumption increasing exponentially in emerging economies, the ability for supply to keep up with demand comes under question in the absence of technological change.

Forest Conversion, the practice of deforesting areas in order to create pastures and agricultural land, is one of the biggest contributors to ancient forest and rainforest deforestation.

Between the years 1964 and 1966, average meat consumption per person per kg in East Asia was 8.7kg. From 1997 to 1999, that value increased to 37.7kg.[10] This represents an increase of over 330%. At current rates of farming efficiency, the number of people that can be fed per hectare of produce will decrease as demand for meat increases. Per hectare of potatoes, 22 people can be fed, from rice, 19, from lamb, 2, and from beef, just 1. This fact illustrates the colossal task that society has to overcome to satiate demands for meat from ever-growing populations in ever-wealthier nations. If production methods do not undergo innovation and change then the cost of meat will rise.

Only improved technology will allow us to satisfy the world's growing demand for meat. This new innovation is likely to be commercialised cultured meat, and with that prospect comes a whole host of additional beneficial implications for society.

THE METHOD

In current methods of culturing meat, scientists biopsy stem or satellite muscle cells from a group of general muscle cells taken from the animal of choice. The cells taken are responsible for the natural process of repairing the muscle in the original donor animal. These cells are then immersed in a nutrient-rich medium which encourages their potentially indefinite growth. To put this growth into context, there can be hundreds of the stem repair cells responsible for muscle repair in just a few strands of muscle tissue, and estimates have suggested that as few as ten of these cells could, under the maximum ideal conditions, produce 50 tonnes of meat.[11]

Next in the process to create lab grown meat, comes an area that scientists have not yet fully mastered: lab-grown cells, much like naturally grown cells, need exercise and general wear and tear to form the same texture as "actual" meat. This problem additionally comes in the structuring of the growth of cells. It has thus far proven difficult to structure the lab-grown cells in such a way that they produce any three-dimensional form of structure, as they would when grown naturally in a real

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9 United Nations (2015) The Millennium Development Goals Report.

10 World Health Organisation (2018) Global and regional food consumption patterns and trends.

11 Gayle, D. (2012). Artificial meat grown in a lab could become a reality THIS year. The Daily Mail.

animal. This three-dimensional structure, as well as exercise in general agriculture creates a specific mixture of fat, muscle, sinew and cell types which alter the flavour and taste of the final product. The procedure creates a thin layer of matured cells, which can be removed and turned into what is essentially a minced meat type substance. To produce a fully formed chicken breast or steak, it would require far more development, but this problem is feasible and we are likely to see progress as the technology matures.

The main issue is that this common procedure produces only muscle. There is yet to be a method developed to simultaneously grow different cell types (blood, fat, muscle etc) in a natural pattern. However, once these, and a few other obstacles have been overcome, cultured meat production could create meat which is identical to traditionally grown meat.

LAND USE

In the USA livestock is fed primarily with corn, with the crop accounting for up to 95% of total feed grain.[12] 90 million acres of farmland in the US are used to grow corn and the feed is the primary energy and food source for livestock and farm animals. While it will still be necessary to source the nutrient-rich medium in which cultured meat is developed, it will not take up 90 million acres of farmland, which would otherwise be used to grow food or other products, releasing land to be put to better use.

This inefficiency will not be a factor in cultured meat, and the land made available after the widespread introduction of the process will be vast. In the UK, 85% of the total land footprint is associated with animal products, with the land footprint of commercial lab-grown meat being 99% lower than for normal animal husbandry.[13] It follows that this land, which is currently either used to directly raise animals, or land where food is grown in order to produce feedstock, will be available to be used in other ways.

It is possible that such land could be used for reforestation, and could give rise to new, verdant forested areas within the UK, as land which has for centuries, even millennia, been used to grow food, will not be needed for such purposes. Current agricultural land in the UK tends to be a monoculture of single crops, with little biodiversity, high fertilizer, high pesticide and herbicide usage. With less land needed for the production of meat, natural woodlands and fields could return. Areas of outstanding natural beauty could arise again, and the United Kingdom could be a greener, more biodiverse country.

New land could also be used for residential development. Over a third of London's Metropolitan Green Belt is used for intensive farming.[14] Recent changes to the Na-

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12 *ibid.*

13 de Ruiter, H., Macdiarmid, J., Matthews, R., Kastner, T., Lynd, L. and Smith, P. (2017). "Total global agricultural land footprint associated with UK food supply 1986–2011." Global Environmental Change 43, pp.72-81.

14 Papworth, Tom (2015) The Green Noose Adam Smith Institute

tional Planning Policy Framework enable councils to approve developments with local support brought forward using a Neighbourhood Development Order.[15]

The latest Food and Agriculture Organization of the United Nations (FAO) figures suggest that the emissions from livestock equates to 7.1 gigatonnes of CO2-equivalent per year. This represents 14.5% of all total anthropogenic greenhouse gas emissions. Whilst the FAO has stated that emissions from the agricultural industry can, with the right implementation of waste reduction and energy saving techniques, be reduced by a third, it does not make an overall difference owing to the increasing demand for agricultural products with a rising population. By the year 2050, it is estimated that the demand for meat and milk will increase by 70%.[16] Duncan Williamson, the corporate stewardship manager at WWF-UK, has stated that "A staggering 60 percent of global biodiversity loss is down to the food we eat."[17] According to the WWF the net loss in global forest area during the 1990s was about 94 million hectares (equivalent to 2.4% of total forests). It is estimated that in the 1990s, almost 70% of deforested areas were converted to agricultural land.[18]

Whatever one's political position, it is difficult to comprehend the vast scale of the damage caused by the meat industry, and the potential benefits that producing meat in factories could have. An independent study from the Environmental Sciences & Technology Journal has shown that cultured meat lowers greenhouse gas emissions by 78-96% and uses 99% less land.[19]

One of the major criticisms of the practice is that since the levels of energy consumption that will be needed for cultured meat production on a commercial scale are not known, it is said that the solution could be just as polluting as the current meat industry, albeit indirectly. Yet, with advances in power generation and the emergence of cleaner fossil fuel power generation from carbon capture and sequestration – and cleaner means like nuclear, solar, and other renewable energy sources – high energy consumption does not necessarily indicate that the process is not "green" but that the current method of producing electricity is not.

ANTIBIOTIC RESISTANCE

An increasingly significant problem is the growing rate of antimicrobial resistance in bacteria. Without effective antibiotics, many common medical procedures will become significantly more dangerous. The World Health Organisation has stated that without antibiotics, procedures such as "organ transplantation, cancer chemotherapy, diabetes management and major surgery (for example, caesarean sections

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15 National Planning Policy Framework. Ministry of Housing, Communities and Local Government

16 Alexandratos, N. and Bruinsma, J. (2012). World Agriculture Towards 2030/2050. UN Food and Agricultural Office.

17 World Wildlife Fund (2017). Overeating animal products is devastating wildlife.

18 World Wildlife Fund. Impact of habitat loss on species.

19 Tuomisto HL, Teixeira de Mattos MJ (2011): Environmental Impacts of Cultured Meat Production. Environmental Science and Technology. 45, 6117-6123

or hip replacements) become very high risk".[20] Common diseases such as pneumonia and chest infections could again become extremely lethal.

If there was a large rise in antibiotic resistance and crossover from domesticated animals there could be a significant increase in mortality rates and average length of stay within a hospitals. One of the best ways we could avoid this is to have a reduction in the usage of antibiotics – and that means taking a look at its widespread use across the agricultural sector.

Intensive farming is a key driver of antimicrobial resistance. Antibiotics are being used within intensive battery farming, not only to ensure that animals are able to survive in less hygienic conditions, but also because the use of antibiotics within livestock increases the produce yield. While this is a bad practice because of the rise of antimicrobial resistance, its use has meant farmers across the world have been able to supply meat at affordable prices for hundreds of millions of new consumers. But these practices face increasing regulatory and scientific scrutiny as to their long-term costs. Developments in cultured meat will hopefully lead to this practice becoming redundant, as costs of meat production from commercialised cultured meat drops below that of current farming methods.

According to the government's O'Neill Review on Antimicrobial Resistance, farming within the US uses up to 70% of antibiotics that are critical to medical use in human beings.[21] These antibiotics are used in healthy animals to both speed up growth, and as a preventative measure to stop disease spreading due to the conditions in which animals are kept. As a result, the levels of antimicrobial resistance are becoming ever more prevalent, especially within countries that have massively developed economically over the past 20 or so years.

Antibiotics which are kept as a last resort to save the lives of humans in case of ever more severe circumstances of antimicrobial resistance, are being used within the farming industry. The outcome is obvious, bacterial strains have become ever more likely to be resistant. A recent study from China has shown that some strains of E. coli have developed resistance to colistin, a form of polymyxin antibiotic.[22] This antibiotic is a last resort antibiotic, one of the last effective weapons in the antibiotics armoury.

The waste runoff from intensive farming is another major concern when antibiotics are used in farming. There is very little that can be done to prevent antibiotics used in commercial animal husbandry escaping into the environment, where they allow antimicrobial resistance in bacteria to occur. Analysis into sludge at wastewater facilities has shown a growing level of resistance amongst commonly-used antibiotics. A study into the occurrence of veterinary antibiotics, and of the resistance to antibiotics in E. coli found in water runoff in Northern China, showed

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20 World Health Organization (2018). Antimicrobial resistance.

21 The Review on Antimicrobial Resistance, Chaired by Jim O'Neill, 2016: Tackling Drug-Resistant Infections Globally: Final Report & Recommendations

22 MacKenzie, D. (2015). "Bacteria now resistant even to 'last resort' antibiotics" New Scientist.

that pollution from farming was likely the primary cause of antibiotics in rivers. It also showed that 88% of the 218 E. coli isolates taken from water samples in the study area exhibited some resistance profile to the eight different forms of antibiotics most commonly found in the polluted waters.[23]

With cultured meat there is no necessity to facilitate the rearing of animals, and thus there need not be any form of antibiotic use over the lifespan of any livestock. The effect that moving away from livestock to lab cultures would have on antimicrobial resistance is substantial, affecting the lives of millions. If there is a single overwhelming argument in favour of the development and use of commercially viable cultured meat production, the reduction in the impact and causes of antimicrobial resistance in bacteria is certainly a plausible candidate.

While there are precautions that government could put in place to stem the impact that animal husbandry and the farming industry has on antimicrobial resistance, this would raise the price of meat, and negatively impact the lives of the poorest in society. The advent of cultured meat should ensure that next to no antibiotics are misused in farming, while also safeguarding the ability of consumers across the planet to purchase cheap but high quality meat. There is the added advantage that cultured meat also prevents the rise of agriculture-related diseases such as foot-and-mouth disease, Bovine Spongiform Encephalopathy (BSE), H1N1 Swine flu and H7N9 Bird flu.

STERILE SURROUNDINGS

An additional benefit to cultured meat that is not present in conventionally reared and raised livestock is the ability to control the environment in which the product is produced. The sterile and aseptic environment that can be fostered around the creation and production of cultured meat would help lower the risk of zoonotic infection (infection that is transmitted to humans via animals).[24] Current regulations on medical procedures require any tissue samples to be screened and tested for infectious diseases prior to use within the cultured meat procedure.

Reducing the risk of infectious diseases being transmitted to humans will relieve pressures on healthcare system and lower the level of suffering which occurs both to people who contract such diseases and also animals within confined spaces and environments. In 2000, a Food Standards Agency report estimated the number of food poisoning cases in the UK to be as high as 4.5 million, including the loss of 60 lives.[25] In 2017 the Food Standards Agency found campylobacter alone cost the economy over £900m.[26] The cost to the economy of all zoonotic diseases is,

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23 Zhang, X., Li, Y., Liu, B., Wang, J., Feng, C., Gao, M. and Wang, L. (2014). Prevalence of Veterinary Antibiotics and Antibiotic-Resistant Escherichia coli in the Surface Water of a Livestock Production Region in Northern China. PLoS ONE, 9(11), p.e111026.

24 Alternative to Animal Meat: An Interview with Nicholas Genovese, PhD PETA." Institute of Ethics and Emerging Technologies. http://ieet.org/index.php/IEET/more/notaro20111005

25 Tough Targets on Food Poisoning, BBC News (2000)

26 Campylobacter, Food Standards Agency (2017) https://www.food.gov.uk/safety-hygiene/campylobacter

however, likely to be even greater. Workplace absences due to sickness cost the UK economy an estimated £73bn each year. If cultured meat enables us to reduce the prevalence of food-borne illnesses then it would significantly reduce the dead-weight loss of disease.[27]

ETHICAL ISSUES

Animal husbandry has led to many ethical issues being raised, including the mistreatment of animals intended for human consumption. Organisations such as People for the Ethical Treatment of Animals (PETA), and the spread of vegetarianism and veganism indicate quite widespread disquiet at the way farm animals are treated. Most people would want farm animals to be given decent lives and, as far as possible, reasonably natural lives. If they are treated decently and humanely, people in general accept their captivity as an acceptable price paid to have meat on the table.

Problems have arisen when the humane treatment of farm animals has been at odds with economic efficiency and reduced costs. It was found that raising chickens by battery farming—keeping them confined in small boxes with automated feeding—was significantly cheaper. This process turned chicken from being a special occasion luxury into an affordable everyday food. Eggs produced by battery hens were also much cheaper, and improved the diet of poorer people who were previously unable to afford many of them.

Many people felt disquiet at the unnatural and unpleasant lives imposed upon chickens, and as society has become richer, more and more people have turned to free-range chicken and eggs.

There have been concerns raised over the treatment of calves raised for veal, leading to the increased popularity of rosé veal, which is more calf-friendly. Similarly, allegations of cruelty to geese have led to a discussion as to whether foie gras should be banned from some restaurants and shops. There have also been reports of the ill-treatment of animals in slaughterhouses and issues raised over whether animals must be stunned before being slaughtered as demanded by some religious traditions.

All of these issues, and more, suggest that if there were some way of enjoying the product that involved no possibility of suffering to animals, it would satisfy many consumers' preferences for more ethical meat products. Cultured meats offer this possibility, since only a few animal cells are required at the start of the process of meat production.

The process raises several interesting questions that would have to be settled. For example, could vegetarians eat lab-grown meats with a clear conscience, satisfied that no suffering to animals had been involved? Could vegans? Would religious authorities accept that such meats could be kosher or Halal?

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27 Mercer (2017). Unhealthy employees costing British firms in productivity.

It is entirely possible that scientists could produce lab-grown rhinoceros horn and flood the markets in the East with the synthetic version to undermine the market for natural rhino horn, thereby removing its profitability to poachers and saving the animals from possible extinction.

While most lab-grown meat, when produced on an industrial scale in factories, could provide hungry populations with beef, pork, lamb and chicken, it is likely that the same techniques could be used to generate meat from less common and more exotic species. At the high price of cultured meat at present, these exotic animals could even make the product economically viable earlier. Some animals currently endangered or deemed 'at risk' could have meat generated from their cells to provide up-market diners with more exotic, and certainly more expensive, dishes. While poorer people might relish the ability to add low-cost conventional meats to supplement their diets, richer diners might prefer to flaunt their wealth by dining on meat produced from the cells of komodo dragons or giant pandas. No endangered animals would be threatened by having meat generated from their cells, and the exoticism might contribute to their fashionability.

It is even conceivable that curious diners could enjoy meat generated from the cells of extinct creatures such as the dodo or the woolly mammoth. These meats would be more expensive, of course, given the specialist skills needed to produce them and likely modest demand, but to people wanting to display their affluence that might be part of their appeal.

Meat generated from human cells would enable future diners to experience what human meat tastes of, without actually needing to become cannibals to do so. This is no longer an abstract point, scientists including Richard Dawkins have raised the idea online and discussed the potential ethical implications.[28] One company in California, BiteLabs, is advertising for celebrities to have their tissue cultured and turned into salami.[29] The point is that once the techniques are mastered, as well as mass production for the general populace, there would be specialist products from those prepared to pay more for something more expensive and not generally available. This happens with most products, and there is no reason to suppose it would not happen with lab-grown meats.

LOCATION & DISTRIBUTION

The advent of cultured meat will change the way food is produced and distributed, as normal methods of meat production become less viable and profitable. The implications of this will be wide-reaching. We speak of such meat as being 'lab-grown,' whereas when production increases in scale it will be grown in factories: ones that are vastly more hygienic and sterile than most farmyards of today.

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28 Dawkins tweeted "What if human meat is grown? Could we overcome our taboo against cannibalism? An interesting test case for consequentialist morality versus "yuck reaction" absolutism."

29 Although there remain questions over whether the business is serious. (See: "The Guy Who Wants to Sell Lab-Grown Salami Made of Kanye West Is "100% Serious" Motherboard)

There will be no need for such factories to be located in the countryside; they could be based nearer to where their markets are. Those catering for domestic consumption might be situated on low-cost land closer to the cities where demand for it is highest. This will lower the costs and pollution associated with the long-distance transport of animals or carcasses.

Those catering for export markets might well choose to locate near to ports or airports, to facilitate transport and to lower its associated costs. Although the UK is accustomed to importing a significant proportion of its food, including some from poorer countries, some developed countries of the future might even be net food exporters.

We should take account of the fact that there may well be political moves to impede the rise of this new technology, as latter-day Luddites stand up to protect failing industries. Furthermore, there is also a strange phenomenon in the UK wherein lobby groups sometimes campaign against some of the very developments that could achieve their objectives. Nuclear power, for instance, was opposed by many environmentalists even though it is clean and non-polluting compared to the fossil fuels it might supplant. Vaping, the most effective means yet found to help people to stop smoking cigarettes, was opposed by many anti-tobacco groups. Genetically modified crops, which can increase yields and reduce dependence on fertilisers and insecticides, are fanatically opposed by some environmentalist groups.

It is likely that the production and consumption of lab-grown meats will be opposed by some environmentalist campaigners on the grounds that it is "not natural," despite the obvious advantages it offers to improve the quality of the environment. They may well form an alliance with livestock farmers seeking to oppose technological changes that could impact upon their livelihood. There is a case for taking steps now to ensure that the UK fully grasps this new technology, and considers provisions to help those who otherwise would be negatively affected by the development of cultured meat in order to head off possible future opposition.

Government should also resist introducing regulation designed to stunt the emergence of the promising new industry, and act instead to encourage the UK to become a world leader. It should not back the development with financial resources. When governments have tried to "pick winners," they have displayed ineptitude on a grand scale, almost invariably subsidising losers. But government can cast its eyes onto any infrastructure that might be appropriate, and to making the regulatory framework surrounding the new industry as supportive and helpful as it can.

BIOTECH BARRIERS

Many regulatory barriers exist that are preventing and slowing down the development of cultured meat, including the question of whether it can really be called meat and debates about what standards such products should meet to ensure public safety. With food standards and safety authorities constituting some of the largest, slowest, and most inefficient government bodies, the hindrance caused by

unwieldy regulators is holding back an innovation that could save countless lives, meet the growing global demand for meat , and help prevent potential climate catastrophe.

One such barrier involves a conundrum that is currently challenging legislative bodies across the planet: whether cultured meat should be called "meat" at all. As has been discussed, this is one method by which protectionist lobby groups can and are swaying government policy in a way which backs the failing contenders. In the United States, the US Cattlemen's Association filed a petition to the government over the legal definition of terms such as "meat" and "beef".[30] Their petition aims to exclude "man made" or "lab produced" meat from the legal definition of meat, stating that for meat to be labelled as such, it must originate from a living, reared and exercised animal. If successful, a petition such as this will act only to help the interests of the small community of farmers who seek to remain a part of an industry that is in dire need of innovation.

Similar legislative proposals have been advanced to protect the industry against plant-based milk substitutes such as almond or oat milk, as well as vegan Mayonnaise alternative Just Mayo. Legislation is typically justified on the grounds of consumer protection, but as US Senator Mike Lee points out "No one buys almond milk under the false illusion that it came from a cow. They buy it because it didn't come from a cow."[31]

Additionally, approvals regulations on biotechnological innovations within the agricultural industry have and will continue to stifle the upcoming wave of revolutionary advances. We are on the cusp of genetic modification, and technologies such as CRISPR, changing the way that plants are grown, ensuring that there is greater immunity to disease and insects, increased crop yields, and improved health benefits and vitamin levels within produce. We have technologies such as cultured meat that could herald the demise of preventable food-poisoning, leading the way to help tackle climate change and antimicrobial resistance, being held back by approval bodies . The price of approval processes on industries such as these is extreme, with one crop which has undergone biotechnological changes costing up to $100m to bring to the market. The regulatory process alone can take years: existing on top of the necessary research and development to produce such a product in the first place.[32]

The scope and over-protective paternalistic nature of government regulations are the outcome of Luddite lobbying by large interest groups, keen only on protectionism within their industry and stifling innovation which could potentially undermine them. The myriad layers of bureaucracy that academics and world-changers have to navigate to bring about a product must be revised. Advancements which will eliminate countless cases of suffering should be incentivised, and for

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30 Johnson, H, (2018). Should lab-grown meat be labelled as meat when it's available for sale? The Conversation

31 Tully-McManus, Katherine (2018). Senators Ask 'What Is Milk?'. Roll Call

32 Fedoroff, N. and Van Eenennaam, A. (2018). Gene editing poised to revolutionize agriculture—if we can fix biotech regulations. Genetic Literacy Project.

technological innovation to thrive, legislators must create an environment which is open to change.

CONCLUSION

The world is on the cusp of an historic change. Animal husbandry, which has for millennia been the way in which meat was produced, now faces a viable alternative in the form of manufactured "lab-grown" meat. The new method will be cleaner, healthier, cheaper, and beneficial to the planet's environment. It will eliminate practices that involve the mistreatment of animals. It will halt the contribution made by current farming methods to the spread of antibiotic resistance. It will create a new, multi-billion-dollar industry.

The UK could become a world leader in the development of that industry, and a major producer and exporter of manufactured meats. Government should establish a new, user-friendly regulatory framework under which new businesses involved in manufactured meats can flourish and prosper. It should actively encourage and promote the research that will underpin that industry. It should facilitate visas for the talented individuals who will lead it. It should liaise with UK businesses to have prizes awarded to scientists who take the key steps to make the industry viable.

Government should consider the establishment of a tax structure that encourages start-up businesses in the sector to grow and develop, and provide a regulatory regime that facilitates innovation in the area, just as its "sandbox" rules liberate new firms in financial services to innovate and experiment.

We need to recognize in the UK that new technological developments are in the process of radically transforming the world economy, just as steam power and electricity did in the past. Self-driving vehicles and drones are among these developments, and cultured meat is another transformative innovation that will give shape to tomorrow's economy. We should take the steps now that can facilitate and encourage the new industry to locate and develop in the UK, and make the UK a world leader in it.

TABLE 1: COUNTRY BY GDP PER CAPITA (IMF) AND COUNTRY BY CARCASS MASS AVAILABILITY DIVIDED BY POPULATION (FOOD AND AGRICULTURAL ORGANISATION OF THE UNITED NATIONS, 2009).

COUNTRY	GDP PER CAPITA (2009)	CARCASS MASS AVAILABILITY (KG) (2009)
Algeria	3,886	19.5
Antigua and Barbuda	14,617	84.3
Australia	45,604	111.5
Austria	47,786	102
Bahamas	22,952	109.5
Bangladesh	728	4
Belgium	45,176	76.9
Brazil	8,625	85.3
Brunei	31,287	67.5
Bulgaria	6,860	53
Barundi	217	5.2
Cambodia	735	16.6
Cameroon	1,176	12.7
Canada	40,831	94.3
Chad	934	13
Chile	10,222	74.1
China	3,838	58.2
Costa Rica	6,897	51.1
Côte d'Ivoire	1,197	13.3
Cyprus	32,636	78.1
Denmark	58,287	95.2
Egypt	2,578	25.6

COUNTRY	GDP PER CAPITA (2009)	CARCASS MASS AVAILABILITY (KG) (2009)
El Salvador	3,365	28.3
Eritrea	358	7.7
Estonia	14,757	59.6
Ethiopia	398	8.5
Finland	47,338	74.8
France	43,234	86.7
Germany	42,578	88.1
Ghana	1,107	13.9
Greece	29,819	74.8
Hungary	12,956	76
Iceland	40,573	86.2
India	1,153	4.4
Indonesia	2,465	11.6
Ireland	52,113	87.9
Israel	27,722	96
Italy	36,850	90.7
Japan	41,014	45.9
Kenya	982	16.7
Kuwait	30,415	119.2
Liberia	315	10.4
Libya	8,525	33.5
Luxembourg	104,358	107.9
Madagascar	417	14.7
Malta	20,806	84.5

COUNTRY	GDP PER CAPITA (2009)	CARCASS MASS AVAILABILITY (KG) (2009)
Netherlands	52,033	85.5
New Zealand	28,100	106.4
Nigeria	1,959	8.8
Norway	79,787	66
Panama	7,387	63.5
Peru	4,158	20.8
Poland	11,454	76.9
Portugal	23,123	93.4
Russia	9,178	69.2
Rwanda	555	6.5
Saudi Arabia	16,095	54.4
Sierra Leone	435	7.3
South Africa	5,926	58.6
Spain	32,412	97
Sri Lanka	2,377	6.3
Sweden	45,998	80.2
Tanzania	684	9.6
Thailand	4,208	25.8
Turkey	8,882	25.3
Uganda	629	11
United Arab Emirates	30,920	73.8
United Kingdom	38,181	84.2
USA	46,909	120.2
Zambia	1,135	12.3