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The promised land? Exploring the future visions and narrative silences of cellular agriculture in news and industry media

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ABSTRACT

Cellular food technologies aim to decouple animal protein production from animal bodies and address the negative environmental, ethical, and human health implications of animal agriculture through its substitution. This marks a major rupture with previous expectations for agricultural biotechnology. If technically and commercially successful cellular agriculture could have far reaching effects that have yet to be the subject of concerted public or political discussion. These include, fundamentally altering human-nature relations, disrupting existing food systems, patterns of land use, rural economies, drivers of environmental change and biodiversity in terrestrial and aquatic ecosystems.

In this paper we explore the environmental and rural visions of cellular agriculture in mainstream news and industry media, their contestation and the narrative silences. These silences represent the under- and un-explored questions, contingencies, and eventualities of envisioned developments. Our analysis highlights how anticipated efficiency gains are central to the realisation of several interlinked but separate positive environmental visions. Notably, that cellular agriculture will be able to replace conventional agriculture and feed the future whilst reducing environmental burdens and land use pressures. However, these visions leave many potential consequences unaddressed. We therefore explore these narrative silences. In doing so we explore the creative and destructive potential of these technologies with a specific emphasis on their environmental, rural, and spatial implications. In conclusion, we identify and anticipate environmental and rural policy implications stemming from these technologies that require further consideration, public and political discussion.

1. Introduction

On August 5th, 2013, Mark Post, - a scientist from a research group at Maastricht University (now known as Mosa Meat) - unveiled the world's first laboratory grown burger at a press conference in London. What was once consigned to the pages of science fiction was suddenly a proven, if not particularly tasty, concept. Less than 6 years later, Perfect Day brought the first food product made from synthesised rather than natural animal proteins to consumers – an ice cream made available in the US as a limited run product. Retailing for $20 per tub it sold out almost immediately. A further landmark event came in November 2020 when the company Eat Just became the first company to receive regulatory approval from the Singapore Food Agency to sell its cell-cultured chicken to the public. At time of writing, cellular agriculture – "a field including tissue engineering, stem cell biology and in some cases also synthetic biology and genetic engineering, dedicated to produce animal products without using living animals" (Ferrari and Losch, 2017: p. 81) – involves over 50 start-up companies. In a very short timeframe cellular agriculture has gone from being considered an 'absolutely insane' proposition (Dance, 2017) to promising a diverse array of cultured products from beef to egg whites to leather, and delivering tangible (albeit still limited) consumer products that replicate the same proteins contained in their natural counterparts.

Despite a diversity of products being pursued by different clusters of scientists and investors, a shared promissory narrative has emerged around these efforts (O'Riordan et al., 2017). Set against animal agriculture's perpetuation of animal slaughter and suffering (PETA, 2017), potential for zoonotic disease and prolific antibiotic use (Bhat and Bhat, 2011; Bhat et al., 2017), and broad environmental impacts; pollution, green-house gas emissions, land, water and energy use (Tuomisto, 2019; Tuomisto and de Mattos, 2011), cultured animal products promise a safe, efficient, more environmentally sustainable, and humane system of animal protein production. Developing these technologies is supposedly made urgent by projections that agricultural production will have to rise

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by 70%–60% (much of it to meet increased meat demand) by 2050, massively increasing pressure on already scare land, water, and energy resources (FAO, 2009; Alexandratos and Bruinsma, 2012). Proponents of cellular agriculture position it as the only means of addressing the ethical and sustainability dilemmas of animal agriculture whilst maintaining and meeting new demand for animal proteins.

Although cellular agriculture is in its infancy, if technically and commercially successful it could initiate a major rupture in the 10,000 year trajectory of agricultural development, heralding a transition to a 'post-animal bioeconomy'. This also marks a significant departure from the trajectory previously envisioned for agricultural biotechnology in which genetic modification will generate more efficient, and resilient crops and animals, whilst biorefineries will process agricultural materials and wastes into value added products (e.g. Goodman et al., 1987). Specific elements might be appropriated and revolutionised by biotechnology (e.g. breeding), but the bioeconomy is broadly imagined as extending the capacity of existing bio-based sectors. Crops modified via biotechnology still need to be sown, watered, fertilized, harvested, and processed, and the animals must be fed, housed, cared for, and ultimately slaughtered. Through decoupling animal protein from animal bodies and producing it within the bioreactor, the explicit intention of many scientists and companies is the elimination of intensive livestock farming and the environmental and ethical problems deemed inherent to it (Mosa Meat, 2020; Perfect Day, 2020; Purdy, 2020).

Substitution of livestock farming, in whole or in part, would have considerable and wide-ranging implications. Of specific interest to this paper is exploration of the potential future environmental and rural impacts that might materialize due to these technologies. A topic with only limited scholarly engagement at present. Policy, regulation, and legislation has yet to engage with cellular agricultures' environmental or rural development implications. Where regulatory and legislative issues have been raised, they have emphasised food safety and labelling. The latter being an effort backed by farming organisations to head off competition with plant-based and synthetic animal protein products by trying to prevent them using terms such as 'meat' and 'milk'. Academic scholarship has begun to unravel the future visions, promises, metaphors, and narratives articulated within this innovation space (O'Riordan et al., 2017; Jönsson, 2016; Jönsson, 2017; Jönsson, 2020; Jönsson et al., 2019; Marcu et al., 2015; Broad, 2020; Broad, 2019) and mainstream media (Painter et al., 2020; Goodwin and Shoulders, 2013; Dilworth and McGregor, 2015). Its emphasis has been on examining how cellular food products and their production is being represented by innovators, advocates, and investors with an interest in its proliferation, the tone of coverage and areas of uncertainty. Contrastingly, the implications of cellular agriculture for the environment and rural communities has yet to be substantive topic of scholarship. Although a small number of speculative Life Cycle Assessments (Tuomisto, 2019; Tuomisto and de Mattos, 2011; Lynch and Pierrehumbert, 2019) have addressed these questions via LCA methodologies and in the process some have become enrolled in promissory narratives articulated by advocates for cellular technologies, as we will discuss.

The aim of this paper is to examine how future environments and rural landscapes are represented in the promissory narratives of cellular agriculture articulated within news and industry media, how these promissory narratives are contested, and the narrative silences. These silences represent the under- and un-explored questions, uncertainties, contingencies, and eventualities of these potential developments. Attention to these silences is important because, as noted by Jönsson (2016) the dominant promissory discourse is silent on how these technologies could *remake* the world. Emphasising only the seemingly significant environmental, ethical, and human health benefits to be gained from the substitution of animal agriculture, whereas a vision of what might be created in the wake is far more ambiguous. In short, the *creative* component of creative destruction remains under-articulated. At the same time the negative implications of substituting animal agriculture remains underarticulated due to an overwhelming emphasis on the positives to be derived from these technologies. By analysing these narratives, we seek to identify and anticipate environmental and rural policy implications stemming from these technologies that require further academic, public and political discussion.

2. Promissory narratives and opening-up the future

We situate our conceptual approach within social science literature, notably Science and Technology Studies and critical Future Studies literature, that has engaged with the future as constituting an important cultural resource, forming a crucial (and contested) part of social and political life. This is especially the case in the context of nascent techno-scientific innovations for which there is a lack of tangible products and production infrastructure. The future therefore becomes a space into which diverse imaginaries (Jasanoff and Kim, 2009; Jasanoff, 2015; Fortun and Fortun, 2005), expectations (van Lente, 2012; Borup et al., 2006), promises (Jönsson, 2016; Sexton et al., 2019; Fortun, 2008) and visions can be projected in order to generate (and justify) present actions that enable that future to materialize (Rajan, 2006; Brown and Michael, 2003). Even before an innovation has emerged and become embedded within socio-technical regimes these visions have 'real' implications, legitimizing certain trajectories over others, and directing research resources and focus. The core contention is that promissory narratives, future expectations and visions need to be taken seriously because they perform important political and material tasks in the present (Brown and Michael, 2003). Subsequently, although one cannot know the future, examining future visions, and explicitly anticipating the future making potentials of emerging innovations (Stilgoe et al., 2013; Owen et al., 2013) is central to understanding the social, material, and political significance of nascent science and technology, and developing regulatory responses.

Mapping these future orientated narratives has been a key focus of recent media studies and broader social science engagement with cellular agriculture (Jönsson, 2016; Jönsson et al., 2019; Jönsson, 2020; Stephens et al., 2018a; Sexton, 2018; Sexton et al., 2019; Stephens et al., 2019; Broad, 2020; Broad, 2019; O'Riordan et al., 2017; Hopkins, 2015; Mouat and Prince, 2018; Mouat et al., 2019; Goodwin and Shoulders, 2013; Dilworth and McGregor, 2015). The broad emphasis of this literature has been on examining how cellular food products and their production are being represented in news and industry media and by advocates of the technology (innovators, scientists, and investors with an interest in its proliferation).

These approaches have focused on the promissory discourses, their content, tone, and production context in addition to what is being revealed and hidden by dominant narratives. The work of Sexton et al. (2019) examined the broader promises being articulated around alternative protein technologies. It identifies a typology of promises including – 'healthier bodies', 'feeding the world', 'good for animals and the environment', 'control for sale', 'tastes like animals' and their contestation through narratives that they are – 'not a serious threat [to conventional food]', 'not real food' and 'not legally defined'. Despite the contestation of these promises, Painter et al. (2020) highlights how overall the media coverage of cellular agriculture is highly positive. More broadly, scholarship has consistently highlighted the articulation of a broader imaginary in which (profitable) biotechnology innovation enables environmental disasters to be averted whilst perpetuating capitalist political-institutional configurations and markets (Broad, 2020; Mouat and Prince, 2018; Mouat et al., 2019; Jönsson, 2016).

Although diverse in emphasis, previous work has repeatedly highlighted the limited consideration of certain elements of cellular agricultural futures, notably related to the impacts of these technologies for livestock production systems and value chains (Painter et al., 2020; Stephens et al., 2018b; Broad, 2019), the impacts of systems created to enable and supply cellular agriculture food systems (Stephens et al., 2018b) and the need for greater dialogue as to how cellular agriculture intersects with issues around agricultural political economies, inequity and power (Broad, 2019, 2020; Sexton et al., 2019). This paper seeks to contribute to and expand this body of literature through a detailed discussion of the creative and destructive potential of cellular agriculture for farming systems, rural communities and the environments and landscapes they produce. Specifically, we focus on the presentation of promissory narratives through publicly available media, including news articles, audio visual media, and company and advocate websites.

Public media is an important realm of discourse in which a politics of the future plays out. Different individuals, organisations and companies use news media as a forum through which to promote their problem framings, socio-technical visions, and convince others (consumers, policymakers, investors etc.) to mobilise support for their promoted solution(s). Cellular agriculture has been no different. For the protein start-ups creating an open dialogue in the media has been an important part of the commercialisation process paving the way to product release (New Harvest, 2016). Promoters have consistently utilised popular and industry media to articulate their vision for the future of food and the role of their technologies (and companies) in realising it (Sexton et al., 2019).

Due to our interest in media discourse, our use of visions sits alongside a broader body of work on media representations such as work on framing (Morris et al., 2016; O'Neill et al., 2015), metaphors (Nerlich and James, 2008; Broad, 2020), or narratives (Kruck and Spencer, 2013; Painter et al., 2020). These allied concepts share a similar focus on language and communication, but routinely emphasise the strategic, instrumental, and self-conscious use of language to structure understanding of these emerging techno-scientific and consumer products. In contrast, visions whilst not neglecting these elements attends to the more ambiguous role of imagination and speculation in producing representations of cellular agriculture and the material futures they encode.

Our analysis examines the environmental and rural landscape visions and their contestations in online and print media. In doing so we investigate how environmental futures are being represented within the prominent visions and promissory narratives circulating in discussions of cellular agriculture as well as elucidating some of the narrative silences, that is, the under- and un-addressed questions, uncertainties, contingencies and eventualities of these potential developments. We divide these narrative silences into two categories, 'destructive' and 'creative' to explore the future making potential of these technologies.

3. Method

This article is based on three main sources of data: (a) websites of synthetic animal protein start-up companies, (b) traditional and sectoral news media outlets' articles discussing synthetic animal proteins, and (c) audio-visual media of interviews with synthetic protein company CEOs. We identified a total of 49 companies now working on synthetic animal protein development directly. This total excluded companies attempting to develop non-animal mycoproteins or working to develop products (stem cell lines and growth serum) to support this nascent industry. Company websites mainly provided basic promotional material, although some provided more detailed elaboration as to the anticipated environmental benefits stemming from the development of cellular agriculture.

The search of online English language media was informed by these websites which provided links to media articles showcasing the companies' claimed successes, interviews with CEOs or broader sector news. In combination with a broader Google search, this enabled the identification of media outlets with an interest in synthetic animal proteins. We examined the following media sources that can be broadly classified as mainstream media (Washington Post, New York Times, The Guardian, Daily Mail, Jerusalem Times), food industry media (Food Navigator, Foodingredientsfirst, Foodive, New Food Magazine, BestFoodFacts), vegan and vegetarian media (Vegconomist, Vegnews), technology media (Thespoon.tech) and business media (Forbes, Bloomberg, Wall Street Journal, Globalaginvetsing, Agfundernews). This provided a broad sample of general media coverage from across the political spectrum, alongside media with a stated interest in new foods and food innovation, alternatives to animal protein consumption, new technologies, and start-up business ventures – all of which had shown interest in the topic of cellular agriculture in the last decade. Links to reports or materials within media articles were followed to identify further relevant sources. Direct searches of media websites were conducted to identify relevant articles published between January 2011 and September 2020. The following search terms were utilised to identify articles: cultured meat, clean meat, synthetic meat, in vitro meat, lab-based meat, artificial meat, cellular agriculture, and synthetic animal protein. The timeframe aimed to capture interest in synthetic animal proteins in advance of Mark Post's widely publicised media event to just prior to submission (For analysis of media prior to 2011 see Goodwin and Shoulders (2013)). Media articles (inc. interviews, editorials, reports and opinion pieces) and webpages were all extracted as PDFs.

Initial sorting of the print media data was conducted to remove duplicates and articles that solely covered plant-based meat and milk substitutes. After this process 876 articles were identified. A second sort was conducted to remove articles that did not contain explicit or implicit assumptions about the future environmental, agricultural or spatial assumptions of cellular agriculture, e.g. articles that solely reported new investment, the emergence of new start-ups, or concerned with consumer reaction, palatability and acceptability of the proposed products. This reduced the total number of articles to 455.

Identifying audio-visual material began by selecting established companies across a range of production types. The final selection consisted of Memphis Meats, Mosa Meat (land-based meat protein), Perfect Day (dairy protein), BlueNalu, Finless Foods (fish protein), Geltor, Clara Foods (gelatine and albumin respectively), and Bond Pet Foods (pet food). This group represents some of the longest established and best funded companies, including the only company with a commercial product (Perfect Day), the company founded by the team who first publicly demonstrated the technology (Mosa Meat) and the longest established cellular meat company (Memphis Meats). Following the selection of the companies a web search was conducted for online material of publicly accessible events, publicly available online podcasts, and company promotional videos involving representatives from said companies – almost all videos were accessed via YouTube. Often the participant was involved in a panel discussion, therefore data assessment was limited to the discussant of interest and estimates of length of the interview adjusted accordingly. In total over 26 hours of video material was viewed and verbatim data of relevance to the themes of interest were transcribed.

The data base was thoroughly searched for portrayals of contemporary animal agriculture, its environmental and spatial implications, and the contrasting visions of future environments under cellular agriculture. For all sources, a textual analysis using a combination inductive and deductive approach was employed (Bryman, 2012; Strauss, 1987). The deductive approach was guided by our interest in representations of future environments and agricultural landscapes. For this we conducted key word searches to identify explicit references to "environment(al)", "rural", and "landscape", although the latter two search terms returned very few hits. The inductive approach was guided by a close reading of the articles and transcribed audio-visual material to identify further environmental, rural, and spatial assumptions that we not identified through the keyword searches. Examples include discussions of the spatiality and scale of production infrastructure of cellular agriculture, consequences for rural communities due to agricultural retreat, feedstock requirements of cellular agriculture and so on. These were then coded and organised thematically in two main ways, firstly to untangle the different environmental (e.g. climate change, pollution, biodiversity), spatial (e.g. local, global, urban production), and rural (e.g. landscape, communities, economy) claims being made with regards to these technologies and secondly whether claims were supportive/positive, sceptical, or contesting/negative the impacts of cellular agriculture. For each of these sub-codes a summary text was written that aimed to capture the key elements of the coded data and the relationships with other codes. These summaries were reviewed and revised by the co-authors to ensure consistency of approach and build a mutual understanding between the textual and audio-visual media elements of the data. These then formed the initial basis of the paper. Any quotes presented below are indicative of the key themes identified in the data and were selected following dialogue between the authors and with the aim of presenting quotes from a breadth of sources, authors/interviewees, and publications. However, the majority of quotes are drawn from articles published after 2016. This does reflect a trend in the data with the media discussion of environmental, rural, and spatial dimensions starting to grow in coverage and nuance from 2016 onwards.

It is important to note that developments in cellular agriculture are occurring rapidly and, at the same time, it is not possible to keep revising the paper on a daily basis up to the publication date. Thus, the announcement in December 2020 that Eat Just had secured regulatory approval from the Singapore Food Authority to manufacture and sell cultured chicken (a world first for cultured meat) (Scattergood, 2020) and the subsequent media coverage have not been included in the paper. However, given that this approval nor the coverage surrounding it does not challenge the visions outlined here – but, provides more evidence of the rapid market development of the product – it is unlikely that including this additional data would change the outcome of the analysis. In addition, our study is qualitative rather than quantitative. The rationale for this is that our key interest regards which arguments are present/absent and how they are constructed and portrayed – not the extent to which the arguments are being covered in the media nor the tone/degree of balance the media takes on the issue. A topic already covered in depth by Painter et al. (2020). Furthermore, we did not cover social media representations, nor the representation of cellular agriculture through images, and although we included a small subset of the audio-visual material being produced (interviews with company representatives), there is a growing body of video material being produced including news segments, documentaries, and promotional media. These may provide a rich vein for future research in this area.

4. Examining the promised lands of cellular agriculture

Our empirical material is organised as follows. Firstly, we examine the more prevalent environmental, rural, and spatial visions identified in the data. In doing so we highlight how anticipated efficiency gains are central to the realisation of several interlinked but separate visions. Secondly, we unpack some of the narrative silences of these supportive visions by exploring the creative and destructive potential of these technologies with a specific emphasis on their environmental, rural, and spatial implications.

Although some of these visions and expectations are well established prior to our timeline (see Goodwin and Shoulders 2013), our analysis indicates that a broader discussion of the environmental, rural and spatial implications of cellular agriculture starts to build from 2016 onwards. This likely reflects growing momentum and more voices seeking to shape the discourse as the number of companies and scale of investment has grown. Whereas the experience of the dairy industry with plant-based milks and the emergence of tangible alternative meat products might have begun to puncture what Sexton et al. (2019) identify as a 'not a threat' narrative.

4.1. Cellular agriculture and replacing inefficient bodies

Efficiency is central to the environmental benefits promised by cellular agriculture and anchors a number of interlinked visions. Claims that cellular agriculture would be significantly more efficient and thus environmentally beneficial versus conventional agriculture were well established in the public media prior to 2011 as evidenced by Goodwin and Shoulders (2013) who studied US and European media from 2005 to 2013. The highly influential anticipatory life-cycle assessment by Tuomisto and de Mattos (2011) has proven to be an enduring and re-occurring anchor for many positive environmental claims. This LCA study modelled cellular agriculture as vastly more efficient than conventional European livestock farming; having 7–45% lower energy use (only poultry has lower energy use per kg protein), 78–96% lower GHG emissions, 99% lower land use, and 82–96% lower water use.

These efficiency savings are realised through decoupling animal protein production from 'inefficient' animal bodies.

> "… conventional meat production is also notoriously inefficient. For every 15 g of edible meat you need to feed the animals around 100 g of vegetable protein" Stellan Welin a bioethicist at Linkoping University in Sweden, reported in the Jerusalem Post (2012).

For example, Uma Valeti of Memphis Meats observes on the Sam Harris podcast:

> "it takes 23 calories of grain to make one calorie of beef and the process that we are modelling out now takes about 3 calories of energy input to make one calorie of beef. So we are hugely more efficient." (Harris, 2018)

While speaking on the This Week in Startups podcast Mike Seldon CEO of Finless Food similarly suggests:

> "Agriculture is a system of inputs and outputs and you want to maximise your outputs and minimise your inputs and so, these animals, they're doing things that we don't need them to do. Animals, in terms of fish, they move around and in terms of all animals they blink, they have heartbeats, they have organs that do all sorts of things that we don't need." (This Week In Startups, 2017)

Culturing cells in a bioreactor excises many of the 'inefficiencies' of living bodies, enables the production of only the 'useful' edible proteins and consequently eliminates the emissions/pollution/waste involved in producing parts of the animal that are only useful to the animal. This also marks a rupture with previous narratives regarding the effects of biotechnology on agriculture and aquaculture, in which efficiencies through modifying the animals (e.g. through genetic engineering) or the outputs from the system (e.g. through waste valorisation) would deliver more incremental improvements in environmental performance (Diakosavvas and Frezal, 2019).

Removing animal bodies is not simply about efficiency, it is also a key ethical and moral motivator for many of the scientists who, concerned with animal welfare in livestock production aim to produce 'slaughter free' animal proteins through these cellular technologies. However, these arguments rather awkwardly juxtapose a purely technocentric, reductive and utilitarian perspective on animal bodies[1] with a strong concern for animal lives and welfare.

4.2. Substitution of livestock farming

By realising new levels of efficient protein production cellular agriculture is expected to have a significant competitive edge over commercial livestock production and aquaculture. As Bruce Friedrich, the executive director of The Good Food Institute (an advocacy and cellular investment group), claims during an interview in The Washington Post:

> "At scale, it [cultured meat] will be cheaper than beef, because it's so much more efficient." (Manteuffel, 2016)

The consequence of this competition is expected to be the

[1] It also reflects a very narrow, westernised food culture which largely rejects offal (liver, heart, pancreas, kidneys etc.) as a desirable or legitimate food product.

substitution of conventional animal protein production systems.

> "'Cultured meat will completely replace the status quo. … (with) a process that is healthier, safer, and more sustainable than conventional animal agriculture" Uma Valeti, Memphis Meats CEO reported in the Daily Mail (Liberatore, 2016)

Furthermore, company representatives make reference to a strategy of specifically targeting industrial agriculture, cast as the most environmentally destructive and ethically problematic system, while leaving more benign forms of livestock farming intact. For example:

> "*What we are doing, it's to replace industrial agriculture* (emphasis original). I don't like animal cruelty … Industrial agriculture does animal cruelty on a massive scale" Mike Seldon CEO of Finless Foods interviewed by (This Week In Startups, 2017)

> "We're against unsustainable and unethical farming practices, which are often used in factory farms. But we wholeheartedly support the countless dairy farmers across the globe that use sustainable farming practices and genuinely care for their animals" Perfect Day CEOs reported in PYMNTS.com (PYMNTS, 2018)

Despite these attempts at clarification and reassurance, this idealised vision of co-existence with 'sustainable farming practices' lacks any reference to how it might be reliably achieved.

Furthermore, as Stephens et al. (2019: p.13) observe, in the visions of actors in the cellular space "'intensive' and industrial 'factory' farming is conflated with all farming methods involving animals." Equally, such distinctions are not universally shared. As Mark Post observes in an interview in AgFunderNews "I don't have any illusion that smallholder farms are safe …"(Cosgrove, 2017). The journalist George Monbiot, a prominent advocate for cellular agriculture, explicitly embraces the prospect of complete substitution of livestock farming in the provocative article "Lab-grown food will soon destroy farming – and save the planet" (Monbiot, 2020). He goes on to suggest that existing farm subsidies should be re-invested in helping farmers into other forms of employment which implies that agricultural activity will fundamentally cease.

Environmentally this vision of substitution juxtaposes the over-fishing, environmental damage and climate change impacts of current fishing and livestock production systems with the efficiencies of cellular agriculture that are set to replace them. Consequently, terrestrial and aquatic environments that have been blighted or destroyed through commercial fishing, agricultural pollution, or to meet the resource needs of livestock farming will, according to the narrative, be released from these pressures and presumably flourish once more.

4.3. Environmental restoration

Cellular agriculture proposes to free animal protein production from earthly constraints.

> "… growing meat in space aimed to showcase the feasibility of reduced reliance on vast stretches of land, water, feed, antibiotics and other resources typically associated with traditional agriculture." Aleph Farms spokesperson reported in Jerusalem Post (Halon, 2020)

A key environmental implication is that cellular agriculture might offer an opportunity for a restoration of nature and biodiversity. Vast tracts of land are potentially no longer needed to support animal grazing or feed production and many species of fish and oceanic ecosystems could be freed from commercial fishing pressure. An article by in the Washington Post observes that

> "… the three bluefin species could begin to recover from decades of overfishing, which has decimated wild populations …" Tim Carman, food reporter (Carman, 2018)

Whereas George Monbiot writing in the Guardian envisions that:

> "Farm-free food will allow us to hand back vast areas of land and sea to nature" George Monbiot in The Guardian (Monbiot, 2020)

This is a long standing aspect of the discourse, as evidenced by the academic Hannah Tuomisto writing in The Guardian in 2012, over a year and a half prior to Mark Post's public demonstration of the technology:

> "The environmental benefits of cultured meat are even greater when the costs of land use are taken into account. Strategies for carbon sequestration could be used on the land freed from meat agriculture and would include growing new forests." Hannah Tuomisto writing in The Guardian (2012)

'Farm-free' highlights how cellular agriculture is anticipated as severing connections with 'farms' and the land, water and resources needed to support them. Environmental restoration interconnects quite closely with the vision of substitution outlined in the previous section. 'Handing back to nature' becoming possible because livestock production systems are in economic and spatial retreat. The suggestion from Monbiot in this instance is that land freed form cultivation to support animal farming could be 're-wilded' and returned to presumably desirable natural environments. Other authors, such as Tuomisto above and the ReThinkX report on the future of food suggest 'reforestation' (Tubb and Seba, 2019). This could be interpreted as a form of re-wilding or as indicating that land will transition to new forms of biomass production. In either instance, this suggests major changes to many of the landscapes that are constituted through livestock and arable agriculture.

4.4. Feeding the future

Efficient production is significant for further reasons, notably, it will enable us to feed the future whilst limiting the environmental toll of doing so. As Bill Gates argues in his 'Top 10 Breakthrough Technologies of 2019' reported in TheSpoon.tech:

> "By 2050, humans are predicted to eat over 70 percent more meat than they did in 2005. That's bad news for the environment …. [Bill] Gates posits that one of the best ways to limit the environmental toll of meat is to … turn to cell- and plant-based alternatives." (Lamb, 2019)

Whereas Eric Schulze, senior scientist at Memphis Meats claimed in a conference panel discussion:

> "On any given day, 96% of the U.S. is eating meat, and the global demand for meat will double by 2050." Schulze said this demand poses a huge market opportunity for protein producers." Reported in Food Dive (Beckett, 2017)

These claims appear to draw on projections made by the FAO and UN of large increases in future demand for animal proteins, although this is rarely made explicit. Nevertheless, figures projecting huge increases in animal protein demand are reified in these narratives.

Meeting this demand through conventional means is positioned as unsustainably increasing pressure on already scare land, water, and energy resources. But by meeting this envisaged demand with cellular technologies this environmental toll will be averted and food needs will be met. The vision of substituting animal agriculture softens considerably in this narrative. Instead of replacement, this anticipated growing demand becomes a future market space that cellular agriculture (and plant-based alternatives) can occupy alongside conventional production.

4.5. Localising animal protein production

The spatiality of synthetic protein production is expected to coalesce within urban and peri-urban areas drawing on local feedstocks. As Alexander Lorestani, CEO of Geltor observes in a recorded presentation for the sparks& honey consultancy:

> "ultimately [cultured meat] it is going to be a global manufacturing system that is bringing locally produced carbon sources – plants – feeding them into fermenters and then converting them into products that are valuable for local communities just like beer is made today." (sparks & honey, 2019)

Subsequently, cellular agriculture is positioned as re-localising food production, bringing the site of production closer to people and connecting them with food. For example, Lou Cooperhouse CEO of BlueNalu observed in an interview with food business reporter Elysabeth Alfano (2020):

> "One thing I really was part of in my career was this whole movement towards local foods. Know where your food comes from. … I think what BlueNalu is doing is redefining local when it comes to seafood."

It is important to highlight that this 'redefining local' vision is not necessarily about small scale production. Synthetic fish producer BlueNalu, for example, produced a draft design for a cellular aquaculture facility able to produce 7 million kgs of fish per year – enough, they contend, "to support initial seafood consumption needs for regional population centres of 20 million people." Lou Cooperhouse CEO of Blue Nalu, (The Ocean Exchange, 2019).

Mark Post, CSO of Mosa Meat, offers a more detailed neighbourhood vision of future production. At this scale cellular agriculture is envisioned as enabling urban populations to reconnect with animals as well as providing neighbourhoods with a reliable supply of protein. It is noted:

> "And even within cities … so one of the visions is that you have a small farm in a neighbourhood with just a couple of cows, pigs and chickens and the whole neighbourhood knows them … and then once and a while you get their stem cells and in a house or in a barn adjacent to the farm you culture the meat for the entire neighbourhood." Mark Post in a symposium presentation (Rittenau, 2017)

One of the founders of Perfect Day, Perumal Gandhi, takes this localism further and observed in an interview in 2019 that he would like to see people producing in vitro food in their own houses (The Spoon, 2019).

Across the industry, the vision is of a sector operating at two scales. A local scale involving boutique local production of synthetic animal proteins and a massively scaled production able to outcompete industrial agriculture. Although not contradictory, the craft brewery aesthetics of the former, being cultivated by several prominent advocates and companies, sits somewhat awkwardly alongside BlueNalu's draft designs for a single protein factory able to meet the demand of 20 million people, equivalent to the New York metropolitan area.

In both instances 'local' is about the ability to remake the diversity of animal products within the confines of a bioreactor, moving the site of product diversity from global food systems to local biorefineries adjacent to the urban areas. For example, by switching the yeast in the bioreactor from one that produces cow milk proteins to one that produces goat, sheep, or any other variety of milk protein, all the time using a single undifferentiated feed material such as sugar that can be produced through local agriculture, forestry, or even, as CEO Ryan Pandya suggests in a panel discussion, from recycled urban biowaste such as cardboard (Acceler8, 2020). The envisioned spatiality of production therefore reinforces expectations of environmental restoration and human retreat as sprawling agricultural systems are remade in biorefineries concentrated around and within urban areas.

5. Exploring the narrative 'silences' of cellular agriculture

Our study indicates that explicit contestation of cellular agriculture was less prevalent within the data corpus, a finding also identified by other authors. Notably, the work of Painter et al. (2020) who identified 49% of the articles they analysed as positive compared with just 3% showing a negative tone and the remainder being coded as balanced or neutral. The reasons for this are likely multifaceted. Hype around plant-based meat alternatives such as the Impossible Burger, which are already commercially available, has perhaps limited the attention given to cultured meats that are unproven at scale, with the first consumer products only recently receiving regulatory approval for sale. Agricultural organisations have been slow to respond to cellular technologies, which may be a result of a current pre-occupation contesting food terminology principally with plant-based alternatives, complacency, or the engagement of some of the major agri-food corporations with the new technologies. Similarly, several NGOs support cellular agriculture as an alternative to intensive agriculture. PETA for example offered a cash prize to the organisation developing the first commercially viable cultured chicken meat product (PETA, 2014).

Significantly, news media coverage is dominated by the perspectives of industry-affiliated scientists, advocates, and company representatives who have a strong vested interest in driving positive coverage to attract continued investor interest (Painter et al., 2020; Stephens et al., 2018b). Overall, previous research has highlighted the lower presence of oppositional voices within media coverage, and our qualitative findings support this further in the context of environmental and rural narratives.

In this following section we aim to elucidate some of the silences of these promissory narratives, that is, the areas of uncertainty, under-articulated and unaddressed questions, contingencies, and eventualities of these developments. To do this we draw together different elements from across the data to begin the work of elucidating the promised lands of cellular agriculture in more detail. In doing so we both draw attention to some of the contesting voices that are present in the data, but also unpack some of the eventualities and contingencies implied by the promissory narrative that we have outlined above.

Key narrative silences that we detail relate to both the creative and the destructive consequences of innovations such as cellular agriculture. Underlying the promised environmental benefits of cellular agriculture is the anticipated substitution of livestock farming (either in part or its entirety). This narrative leaves much unsaid concerning not only how the sustainable elements of livestock farming might be protected but also what negative environmental and landscape implications might arise from the loss of an economic sector and the communities it supports. Simultaneously, the nature of supply chains, energy systems and material infrastructures that will be created to support animal protein biorefineries is, at best, under-articulated, whilst the types and extent of wastes and pollution resulting from these processes is entirely absent from discussions.

5.1. *Exploring the destructive silences*

5.1.1. *What happens to rural communities?*

Cellular technologies are expected to create considerable opportunity for economic growth and value creation. However, the different spatiality of production means that these opportunities arise in different localities to those where value is destroyed. These concerns, that cellular animal proteins will exacerbate existing economic vulnerabilities, have motivated efforts by US and EU farming organisations to protect terms such as milk and meat from use by plant-based and (pre-emptively) cultured alternatives (Bromwich and Yar, 2019). The effect will vary between industry and region (Hostiou et al., 2020) but with an estimated 30 million jobs dependent on the livestock sector in Europe alone (Animal Task Force, 2017) the potential for widespread economic and employment disruption in rural areas is extremely high. What are the socio-economic and environmental impacts of displacing people from large swathes of countryside?

ReThinkX present a clear vision of what cellular agriculture might mean for rural communities (Tubb and Seba, 2019). Although their report is enthusiastic and highly optimistic about the revolutionary promises of cellular agriculture, it also outlines a bleak future for conventional agriculture.

> "The impact of this disruption on industrial animal farming will be profound. By 2030, the number of cows in the U.S. will have fallen by 50% and the cattle farming industry will be all but bankrupt. All other livestock industries will suffer a similar fate, while the knock-on effects for crop farmers and businesses throughout the value chain will be severe." (Tubb and Seba, 2019)

Historical examples show that such rapid declines can be devastating. The replacement of agriculturally produced dyes such as madder and indigo with alternatives synthesised through industrial processes in the late 19th Century provide examples of a 'worst case' scenario. In the case of madder the industry went from an annual production of 500,000 tons in 1874 and occupying "large tracts of fertile soil" (Schorlemmer, 1894) to being "practically extinct" 17 years later (Meldola, 1891). For indigo, over 360,000 people (*excluding* agricultural workers) were employed in the industry in India alone in 1880 and, at its peak in 1895, more than 1.5 million acres of land was given over to indigo production (Reed, 1992). But, the arrival of a cheaper synthetic product in 1897 saw a rapid decline such that by 1913 natural indigo production had practically ceased (Chavan, 2015). These collapses saw crops left to rot in fields, major changes to long established crop-rotation systems with implications for soil fertility and rural incomes, and infrastructure repurposed or demolished. However, in these historic instances the end of agricultural dye production was not accompanied by a wholesale collapse of the wider agri-food system.

Despite the expressed desire to 'target' industrial agriculture as opposed to sustainable small scale agriculture, proponents of cellular agriculture have no mechanism to do so. Cellular agriculture is motivated by a market driven approach that does little to alter the broader political economy of food systems and the inequities and vulnerabilities it produces (Broad, 2019). Consequently, the emergence of synthetic protein is likely to place substantially greater pressure on marginal livestock agriculture, much of which is already vulnerable under existing market arrangements. Small scale extensive livestock producers in Europe are already experiencing difficulties continuing family farming due to low profitability and demanding job requirements (e.g. Bertolozzi-Caredio et al., 2020) and are vulnerable to global market forces (Beilin et al., 2014).

Suffice to say, this 'disruption' is not a desirable future to everyone. A spokesperson for Copa-Cogeca (a major interest group representing European farmers and agri-cooperatives) recently observed that social and landscape consequences of cultured proteins "are currently forgotten in the public debate around meat alternatives" adding:

> "Who will take care of pasture land and mountain territories? … How will we prevent rural exodus? The bright new world promised by in vitro promoters might not be the one expected by consumers." Copa-Cogeca spokesperson reported in euractiv.com (Foote, 2020)

Whereas the National Farmers' Union of England and Wales, alluded to similar concerns in their response to the documentary Apocalypse Cow:

> "Farming is not just an industry, it is the lifeblood of Britain's rural heritage" (NFU, 2020).

These comments emphasise the interlinkage between rural communities, cultural landscapes, economies, and environments as well as the plight of livestock farming operating on the margins. Furthermore, they emphasise connection to 'the land' as an important cultural and societal value maintained through conventional agriculture, a notion largely antithetical to the vision of cellular agriculture (Dilworth and McGregor, 2015). These dynamics of disruption, rural decline and desertion could have broader knock-on consequences for delivering on the environmental promises of cellular agriculture which we will now explore.

5.1.2. Who cares for the countryside?

The contestation of the promissory vision holds that some forms of animal agriculture are important to achieving sustainability and biodiversity. If these systems of production are lost how will it effect biodiversity? Tuomisto (2019) observes that "a complete elimination of all livestock production [due to cellular agriculture] is not reasonable from the perspective of biodiversity conservation." Studies have shown that farms managing low-productivity meadows are particularly important in the preservation of species biodiversity (Marini et al., 2009). Conservation of farmland birds is predicated on integration of food production with wildlife management (Wilson et al., 2010) and the re-introduction of traditional agricultural practices (Royal Society for the Protection of Birds, 2020). These claims has recently also been picked up by the scientific literature. Klerkx and Rose (2020) observe, for example, that in articulating visions of our food future we need to also consider how cellular agriculture fits in with other notions in sustainable agriculture such as agroecology and regenerative farming.

How is 're-wilding' or 're-forestation' going to manifest in a context of major rural decline and economic devastation? If effective rewilding proves contingent on certain types of rural and agricultural infrastructure, knowledge, and services (Wynne-Jones et al., 2018) romantic notions of rewilding as encompassing simply extensive forms of farming and forestry (Taylor, 2015) may struggle to see fruition. In many places land abandonment might leave rural landscapes littered with derelict infrastructures and deserted towns, delivering outcomes that bear more of a resemblance to Chernobyl than the pristine wilderness suggested by 're-wilding'. Similarly, many cultural landscapes important to regional identities and heritage – e.g. the Pyrenees National Park in France/Spain, the Burren in Ireland, the Lake District National Park in the United Kingdom, and the Massif Central in France – are produced through livestock farming but are already experiencing problems maintaining their populations (Burton, 2018). What would the decline of animal agriculture mean for these landscapes, the tourist, and recreational activities that they support?

5.1.3. What happens to the animals?

What happens to agricultural animals within cellular agricultural systems? In some scenario's livestock are kept alongside bioreactors to connect people with bioreactor protein (e.g. Mark Post of Mosa Meat's vision) leading to the preservation of some farm animals. However, companies are already emerging that are focused on optimising cell-lines for quick growth (Cell Farm, 2020), or that seek to identify and produce proteins based not on the animal they came from, but on their functionality (e.g. Jasmin Hume of Shiru - Pothering, 2019). Ultimately it may be possible to produce a cell line that can exist without any living animal. Co-founder of Memphis Meats Nick Genovisi observed in a presentation hosted by the National Academy of Sciences in 2017:

> "I wanted to create a livestock independent stem cell source so that meat didn't come from an animal, it came from a cell line that could be expanded for biomass." (Distinctive Voices, 2017).

While there is the potential to preserve the genetic material of many protected species – with agriculture shifting to farming optimised cells, there is, in effect, little need to maintain the animals themselves. This latter vision taking the desire to remove animals from animal protein production to its extreme endpoint.

Arguably, this is the continuation of established agricultural industrialisation trajectories which have proved highly adept at removing certain animal bodies from production systems. Notably, work animals and human labour has been replaced by powered machinery, and many thousands of specific regional breeds by, for example, Holstein-Friesian (dairy), Black Angus (beef) or Cornish Cross (broiler chicken) to deliver the narrow productive traits demanded by industrial systems. As a result, many breeds selected over thousands of years of domestication in a wide range of environments have become endangered or extinct in less than a century (Bett et al., 2013). Cellular agriculture could continue and exacerbate the ongoing extinction of agricultural breeds or see the revival of currently marginal breeds as livestock farming moves to recapture values of local distinctness and cultural heritage to distinguish its products.

Animal protein production is not solely predicated on domesticated animals. Fishing in one such space where synthetic proteins offer opportunities for new abundance (or a return to past abundance). Reversing species decline has already been mentioned. However, synthetic products also run the risk of damaging attempts to preserve ecosystems that are already out of balance due to species introductions. For example, the Arctic red king crab (*Paralithodes camtschaticus*) (introduced to Russia) was first found in Norway in 1977 and has since spread dramatically to occur in dense populations along the coasts and fjords of Finnmark. As a valuable commercial species, efforts to control its westward and southward spread have been centred around the establishment of an open-access fishery – a measure that appears to have been largely successful (Sundet and Hoel, 2016). The arrival of bulk cheap synthetic crab meat or other crustaceans on the markets could decrease the efficacy of such measures and lead to the abundance of invasive species.

Cellular agriculture also opens other consumer trajectories. Not only promising that consumers can eat more of currently overfished species, but that species that have been overfished in the past and are currently not commercially available can return to menus. BlueNalu CTO Chris Dammann observes as an example:

> "There's a fish here on the West Coast called 'yellow eyed rockfish' it lives to almost 200 years old and really can't be farmed but it was really tasty and people loved it. So, if you go back to restaurant menus in the 30s and 40s you'll see it frequently cited there. But it was overfished, collapsed, is not available, small number of sports fisherman licences and that's it. So we have the opportunity to sort of revive culinary experiences" (Alternative Protein Show, 2019)

The culturing of cellular fish products has a distinct advantage over cellular meats in that, rather than being limited to a small range of commercial livestock types, there are literally thousands of fish species to select from, with some of the best eating species already being unavailable due to overfishing. In addition, as with the example of the yellow-eyed rockfish, synthetic production can return regionally available fish species to restaurant menus and dinner tables. The explicit environmental promise of cellular aquaculture companies is that they will be able to restore the health of the oceans by easing the pressure on fish stocks – both in terms of the overfishing of edible species and the fishing of smaller open-ocean species for the fishmeal used in aquaculture. However, while the vision is one of saving ecosystems and endangered species there may be other unintended consequences. Recreating demand for rare or protected fish species runs the risk that consumers will eventually not be satisfied with consuming the synthetic product. Thus, the creation of a market for the yellow-eyed rockfish, could simultaneously create a commercial demand for illegally caught wild specimens – or an increased interest in recreational fishing of vulnerable species. The provision of a synthetic alternative is not, therefore, a guaranteed means of preserving a desired species or ecosystem and, in some cases, the effect may even be negative.

5.2. Exploring the creative silences

5.2.1. Creating new monocultures?

What feedstock production chains will be needed to support cellular agriculture? Little is mentioned about the specific resource needs of these technologies. In part this is because developing an animal-free growth medium (serum) has been a significant technological hurdle and companies that claim to have solved this problem have remained tight lipped over the specifics of this proprietary knowledge. It is therefore difficult to know exactly what biomass inputs are likely to be required for cellular meat production. However, company representatives have mentioned cells could get their nutrients from "the same feedstocks that livestock consume such as soy, corn, blue-green algae and yeast." (Nick Genovisi of Memphis Meats presentation at the Beckman Center (Distinctive Voices, 2017)) and using a fermentation processes and genetically modified yeasts to produce the required serum (e.g. Nick Genovisi of Memphis Meats (Distinctive Voices, 2017); Mike Seldon of Finless Foods (This Week In Startups, 2017)). This is effectively the same "brewing" model employed by Perfect Day and, assuming a similar process is used, then the key input for all cellular meat production could be sugar – of which enormous quantities would be required to support a major global industry.

In Perfect Day's early model this was provided by corn sugar (Watson, 2017), but company representatives later observed in a podcast (Business For Good, 2019):

> "You can get it from sugar cane, you can get it from corn, you can get it from beet, it sort of depends on where you are in the world … things that are today thrown away – like as you remove the husk of corn, where does that go, right? There's a ton of cellulose in there. You can actually turn that into sugar which, through companies like Perfect Day, can use flora to turn that into whatever you want."

This provides three possible directions for the landscapes of cellular agriculture. The first is one where the need for sugar drives a new era of intensive arable production around the world. Productive land released from livestock feed production remains cultivated to meet the sugar needs of synthetic animal proteins. On a global level, rather than deforestation for soy, deforestation may be to meet increasing demand for sugar. Alternatively, land could also be given over to intensive forestry plantations – providing an efficient means of extracting sugar from wood can be developed.

The second recognises that there is no guarantee that all of this sugar will come from industrial agriculture. As Ryan Pandya points out, sugars can be produced from bio-waste. Urban areas are effectively awash with organic wastes that could act as a potential feedstock. The extent to which cellular agriculture becomes a component (or driver) of the circular economy is likely to impact these dynamics. From an environmental perspective these outcomes sit at opposite ends of the spectrum, with the direction followed largely dependent on whether the technical hurdles required to realise circular processing can be overcome, and the extent to which ethically concerned start-up companies can retain control over the production process and what their priorities are (animal welfare, environment and/or profit).

The third possibility is the use of bacteria grown from a combination of trace nutrients and carbon extracted directly from the air or from factory waste. Solar Foods, which produces such a product, has already observed that it could be used as a means of producing a serum for cultured meats. In an interview with foodnavigator.com Pasi Vainikka, the CEO of Solar Foods observed:

> "The consumer would [eat] real meat that was grown in a lab and fed with our protein ingredient. Therefore, we would be able to disconnect food production from agriculture." (Southey, 2020)

Other companies are developing similar protein products. Contingent on finding a process for creating serum through this method, success in these sectors could turn agriculture into a relatively insignificant production system (in terms of its economic and spatial reach) as it would disconnect a significant portion of food production from land almost entirely.

5.2.2. Creating new environmental problems?

Cellular agriculture proponents mobilise a well-established narrative of technological progress being fundamental to meeting the challenges of the future whilst solving the problems of the present. But as cattle rancher Doniga Markegard observes in response to a George Monbiot article in the guardian:

> "Frankly, I don't see examples of reductionist science leading to such optimistic results. Quite the contrary, the technocratic vision of viewing life in mechanistic terms has led to many of the environmental crises that seem so intractable." (Mangan, 2020)

This critique gestures towards an important issue, namely that proponents of cellular agriculture are silent on the long history of technological fixes generating new environmental problems. Current industrial systems of production have mobilised similar narratives of resource efficiency, improved biosecurity, and low consumer costs to justify a socio-material trajectory that has resulted in ever greater concentrations of animal life reared in shorter timescales with environmental problems arising from the resultant pollution and emissions.

The prospective energy demand of cellular agriculture is one of the few areas where the environmental promises are explicitly contested:

> "'The energy issue is indeed a big question over the cultured meat industry, …the power costs of running a cultured meat facility could make the industry quite environmentally damaging in terms of greenhouse gases, possibly even more so than conventional agriculture'" Dr Michael Dent of IDTechX interviewed in Food Navigator (Askew, 2019)

> "Scientists and companies working to grow meat from animal cells will need to minimise energy use and avoid fossil fuels if claims that cultured meat is better for the climate than real meat are to hold true," John Lynch, University of Oxford interviewed in Daily Mail (Rowling, 2019)

In short, cellular agriculture is not *prima facie* more energy efficient than conventional production systems, a point reflected in academic work that has conducted life cycle assessments of cellular agriculture to project energy and resource use. Although largely positive, this work has also highlighted how, especially in the context of GHG emissions, cellular agriculture is not necessarily more climatically sustainable than conventional livestock farming, particularly poultry (Tuomisto and de Mattos, 2011) but also potentially beef (Lynch and Pierrehumbert, 2019). The realisation of promised climate change benefits is contingent on the use of decarbonised energy. The need to accompany a synthetic protein transition with a decarbonised energy system is already recognised within some parts of the industry. In some cases, this is leading to efforts to decarbonise prior to production – as is indicated by Aleph Farms' (an Isreali cultured meat start-up) which aims to reach net-zero emissions across its supply chain (Vegconomist, 2020).

This raises questions as to what impacts the decarbonised energy infrastructures (assuming they are realised) might have? The shift from fossil fuel to renewable technologies is already recognised as requiring potentially major changes to land use and landscapes. This could lead to agricultural lands transitioning to commercial forestry plantations to meet the needs of bioenergy production. Alternatively, they could become sites for the deployment of wind or solar renewable energy technologies.

Waste recycling is another point of reflection. Finless Foods have already begun moves to increase recycling in their process. Whereas Mark Post has repeatedly argued that there is considerable potential to improve efficiency because 'closed system' processing facilitates the recycling of resources. However, with technologies currently limited to the laboratory scale, the topic of waste - how much is generated, its composition and safe disposal needs – is absent from the present discussion.

5.2.3. Substitution or addition?

On the one hand cellular agriculture will substitute intensive livestock farming with more efficient, environmentally friendly, and ethically acceptable alternatives. But on the other, it will feed the worlds growing demand for animal proteins. For the latter, the desirability of substitution of existing systems is far more ambiguous. Equally, expectations that cellular agriculture will replace *all* conventional animal agriculture are in the minority. Rather, it is anticipated that cellular and livestock farming will operate in tandem. This raises the questions: What will the role of cellular agriculture be in future food systems?

At present, the assumption that cellular technologies will have a significant substitution effect is not substantiated and addition is an under-considered dimension to these technologies (Stephens et al., 2018a). For instance, it is technically simpler to produce proteins suitable for highly processed foods than to produce the more complex structures of full cuts of meat - steaks, pork chops and fish fillets for example. Cellular agriculture might fulfil the market for highly processed low-quality proteins but leave the market for full cuts of meat intact (with current technologies at least). Such a scenario would indicate a prominent position for conventional livestock farming to meet that demand for whole cuts. Agricultural systems might be even less vulnerable if they sell the secondary qualities of the product such as naturalness, locality, or heritage connections. Perhaps through expanding the scope of already established regimes of food governance which provide protections to food and agricultural products, for example, through protected designations of origin and protected geographic indications. Equally, this assumes that cellular agriculture encroaches on human food markets. It could be that the cultured proteins due to issues of taste, texture and cookability instead become a replacement for protein feed in aquaculture and livestock farming, replacing the role of soy feeds for instance. The presumption that these technologies significantly challenge animal protein production might be misplaced.

Furthermore, the focus on the production of edible proteins somewhat distracts from the wider uses of the animal. Gelatine is one example, but animal bodies also provide a multitude of non-edible by-products most notably organic fertilizer, pet food, hides, and wool, but also many products critical for the cosmetics, pharmaceutical and medical sectors (e.g. surgical ligatures, antigens and testosterone) (Marti et al., 2011). This may result in a continuation or even intensifying of industrial animal production as animals become more a provider of spare parts for sectors other than food production. The industrial use of animals could thus effectively go underground in the same way the fur industry is currently not generally visible to the public. Alternatively, demand for non-edible animal protein products might open-up another niche for cellular technologies creating new resource demands and wastes in the process.

What implications might these scenarios have for patterns of environmental pollution and land use? Notably, what happens if cellular protein does not fundamentally destabilise conventional production systems? What futures are produced if the assumption that there is a lack of room for industrial and cellular agriculture to co-exist is misplaced? It is possible that cellular agriculture becomes an additive technology, where large quantities of natural meat are still produced but without the highly intensive systems of the last decades. Narratives of environmental restoration are linked in part to land being be freed from agricultural uses as livestock farming is replaced. If this does not occur cellular agriculture might add new waste streams to the existing patterns of pollution and emissions associated with animal agriculture.

6. Conclusion

Tenner (2001) observes that new technologies often inspire "lyrical utopianism and melancholy catastrophism" (p. 241). Cellular agriculture has so far inspired much optimism with relatively limited engagement with the more ambiguous consequences of the radical disruption it proposes. The prominence of scientists, company representatives and advocates within the media being a key factor in giving rise to what Stephens et al. (2018a) describe as the “abundance of aspiration rhetoric” (p. 161) circulating around this technology. However, if successful it is likely to have disruptive and uneven consequences over time and place as promises are fulfilled and different destructive and creative silences are realised. On the one hand, a key part of the vision is that new efficiency gains will trigger the substitution of industrial parts of livestock production systems which will be unable to compete with cheaper cellular products. But it remains silent on how to retain extensive, small scale farming. Neither does this vision have a realistic means of differentiating between the two. On the other, in elucidating the silences of these promissory narratives, we have foregrounded the embeddedness of livestock and fishing in broader rural economies, environmental and biodiversity conservation, *and* environmental damage and loss. Similarly, cellular agriculture will create its own production systems and value chains which will have varied consequences for environments and landscapes.

Yet these are emerging technologies and their impact is at present promissory and uncertain (Martin et al., 2008). The terminology of emergence places emphasis on the ‘process’ of coming into prominence (Rotolo et al., 2015), therefore emerging technologies require active management and anticipatory governance, with the assumption being that their formative status means management is still possible (Guston, 2008, 2010). By examining the promissory visions and narrative silences of cellular agriculture, the aim of this paper has not been to assess the veracity of these claims nor make our own predictions. Instead, we have aimed to move beyond a descriptive account of the binary promissory and counter narrative so as to elucidate some of the uneven and ambiguous environmental and rural implications that might result from the creative destruction caused by future cellular agriculture production systems. The motivation for doing so has been to highlight both underarticulated issues requiring further political discussion, and opportunities to actively anticipate and govern the emergence of these technologies to mitigate undesired outcomes.

A key conclusion to be drawn from our analysis is that there is a potential mismatch between current political assessments of the likely impact of biotechnology on agriculture and those of cellular agriculture companies. In a recent report for the OECD, Diakosavvas and Frezal (2019: p. 5) observed that the development of a bioeconomy (an economic sector based on the conversion of biomass via transformative biotechnologies) is generally seen as a stimulus to rural development noting there are:

> “high expectations that the bioeconomy can provide an important contribution to sustainable development of the agro-food system through the creation of new business and innovation opportunities and jobs; the increase in the efficiency and productivity of natural resources; and its help to agriculture to adapt to climate change.”

This is the perspective of most national bioeconomy strategies – strategies that began development in the first decade of the 21st century and *prior* to the emergence of in vitro animal proteins as a serious market proposition. These outcomes may now need to be reconsidered. Bioeconomy strategies were based on the notion that biotechnology will operate in an appropriationist fashion and “enhance the economic prospects of certain agricultural commodities” (Goodman et al., 1987: 9), reaffirming rural regions as the centre of food and fibre production. However, rather than offering exciting new opportunities for rural regions, substitutionist biotechnologies such as synthetic animal protein remove ‘nature’ as a binding constraint on the production process – threatening the rural base of agriculture and requiring us to “redefine notions of ‘agriculture’ and ‘industry’” (Goodman et al., 1987: 8–9).

Consequently, if technically and commercially successful, cellular agriculture innovators and policy-makers will be required to navigate the difficult question of – How to manage a transition to cellular agriculture without eliminating thousands of years of cultural landscapes and ecosystem development associated with agriculture? At present this question simply does not factor in the promissory narratives articulated by advocates for cellular technologies nor is it something grappled with by policy makers and regulators. In contrast to nanotechnology, GMOs and synthetic biology, cellular agriculture has triggered a relatively muted response from NGOs (many of whom are directly invested in realising the technologies), agricultural stakeholders (some of which are key investors) and science policy discourse (perhaps due to this area been primarily driven from Silicon Valley and a lack of publicly funded research explicitly on this topic). Yet these questions may ultimately prove more pressing and difficult to answer than those concerning the science of cellular agriculture – however difficult *they* may appear.

Author statement

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Declaration of competing interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

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