Accepted: 13 May 2020

DOI: 10.1111/tran.12392

REGULAR PAPER

WILEY IBG Royal Geographical Society with IBG

On breweries and bioreactors: Probing the "present futures" of cellular agriculture

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Funding information
Svenska Forskningsrådet Formas [Grant number 2013-1510].

Set against the attention given to animal-agricultural geographies and animal agriculture's environmental impacts, proponents of cultured meat (i.e., biomass cultured from cells) and genetic modification-based "cellular-agricultural" technologies today promise that the production of animal products could become more sustainable if animals were taken out of the equation. Though future visions for such a shift have often centred on how much land could be saved through the deployment of new biotechnologies, proponents and researchers today increasingly also foreground the future economic geographies and sites of production that these should engender. In this paper I explore such envisioned geographies, building on 24 interviews with cellular-agricultural actors and on observations during meetings. Essentially echoing an ecomodernist embrace of the Anthropocene as a great opportunity, cellular-agriculturalists frequently promise that the technologies they advocate should offer the possibility to unfetter the production of animal products from spatial constraints. (Post-)animal products can now be produced anywhere. But in assuring that products and production processes should feel familiar, they frequently also describe a world where microbrewery-like facilities and transparent production processes supplant industrialised animal agriculture's remote slaughterhouses. Hence, a kind of craft-emphasising "recombinant" ecomodernism emerges. In exploring cellular-agricultural future visions, my aim is not to determine whether, or which, particular visions might be realised. Rather, I centre on descriptions of future spaces of production and economic geographies in order to explore contemporary biotech boosterism. Engaging with these visions, as well as the often unchronicled creative destruction that they could entail, thus allows me to contribute to an emerging set of texts that scrutinise the current and intended political economy (and ecology) of cellular agriculture, as well as texts emphasising the necessity of pondering Anthropocene spatialities.

KEYWORDS
biotechnology, cellular agriculture, future visions, meat, spaces of production, the Anthropocene

1 | INTRODUCTION

For his project "Feedlot," artist Mishka Henner stitched together hundreds of high-resolution satellite screenshots to depict one of US animal agriculture's quintessential spaces. This allowed him to reveal in detail landscapes marked by myriads of swarming cattle, the geometric grid of fences confining cows to their lots, and manure lagoons coloured in otherworldly shades of green and red. Henner thereby offered snapshots of a livestock sector whose landscape transformations result from how the sector itself has transformed. For more than a century, state regulations and subsidies, transport infrastructure innovations, and research efforts have turned previously mostly local, small-scale, operations into interlinked nodes within transnational systems (Boyd, 2001; Boyd & Watts, 1997; Freidberg, 2009; Weis, 2013). Claiming that his "images reflect a blueprint and a horror that lie at the heart of the way we live," it is a critique of these systems that Henner (2015) weaves his stitched-together images into.

His aim thereby resonates with the attention today given to animal-agricultural geographies. Pachirat (2011) has, for example, depicted the inner workings of a Great Plains slaughterhouse based on five months of undercover fieldwork. Meanwhile, Blanchette (2015) explores how plant-operators' efforts to maintain pigs' health generate attempts to organise human interaction, with workers from different facilities discouraged from socialising to avoid spreading diseases between porcine populations. Animal agriculture is simultaneously targeted both due to its role in spurring global warming (FAO, 2013), and due to how about 70% of all agricultural land is directly or indirectly devoted to the production of animal products (FAO, 2006; Weis, 2013).

Today, such reports also form the background for "cellular-agricultural" attempts to sustainably supplant conventional animal products with biomass cultured from cells (so-called "cultured," "clean," "cultivated," or "cell-based" meat) or to genetically modify yeast to produce, for example, egg whites or dairy protein. In presentations of this proposed field, Henner's photos repeatedly appear as illustrations of the landscapes that cellular agriculture would *not* produce (see for example Datar, 2016).

With early estimates hoping that culturing meat could require 99% less land than conventional meat production (Tuomisto & Teixeira de Mattos, 2011), cultured meat and cellular agriculture are frequently hailed as astonishingly land-saving technologies. But as cellular-agricultural start-ups and their allies today experiment with how to present producers and products, emphases on land freed up increasingly merge with descriptions of cellular-agricultural production sites.

While Henner's images of feedlots or Pachirat's gruesome account of life on the kill floor offer foundations for critiques of industrialised animal agriculture, these descriptions instead assure that cellular agriculture would enable more desirable food-production geographies. A "second domestication" (of cells rather than non-human animals; see Addady, 2016) is heralded as ushering in sustainable products alongside novel economic geographies of producers supplying these. It is such imagined geographies that I explore in this paper. In this I build on critiques of the relative inattention to spaces of production and political economy within early discussions on cultured meat (Jönsson, 2016) and on promising work that today addresses some of cellular agriculture's thornier questions (Mattick, 2018; Mouat et al., 2019; Newman & Powell, 2019; Sexton, 2018a; Stephens et al., 2018, 2019). Whereas many discussions on cultured meat and cellular agriculture have hitherto concerned *what* novel products are (Stephens, 2013; Stephens et al., 2018), it seems pertinent to simultaneously ask *where* they are (Jönsson et al., 2019). Cellular-agricultural visions convey a range of (not necessarily compatible) future geographies. Probing these enables scrutinising novel biotechnologies in relation to the mix of often acute anxieties and techno-optimist hopes that characterise contemporary discussions on the future.

Thereby, I want to contribute to discussions on the (so-called) Anthropocene (Crutzen, 2002). Exploring the prevalence of what Belasco calls "recombinant" visions, "blend[ing] the radicalness of the modern with the familiarity of the classic" (2006, p. 219), I elaborate on how beliefs in technological innovation and in craft-oriented production systems today merge as cellular-agriculturalists envision a kind of recombinant ecomodernism (cf. Asafu-Adjaye et al., 2015). Similar to how Matless conceptualises "The Anthroposcenic" as "landscape[s] emblematic of processes marking the Anthropocene" to "inject a more complex sense of landscape into Anthropocene debate" (2017, pp. 363–364), I can hence contribute to further discussions on decidedly techno-optimist Anthropocene spatialities.

In the next section I discuss temporality, geography, and political economy to frame my inquiry. Thereafter I cover cellular agriculture's history before devoting the remainder of this paper to cellular-agricultural future geographies. In this I emphasise four themes: (1) breweries as producers' and proponents' preferred analogy, (2) a focus on increased transparency, (3) the role of animal-agricultural actors within a cellular-agricultural food-production system, and (4) the future place of non-human animals therein. Chosen to capture prominent ways that cellular-agriculturalists frame future visions, exploring these illuminates how cellular-agricultural actors foreground particular features and processes while staying relatively silent on others potentially just as important.

The paper builds on 24 interviews with researchers and representatives of cellular-agricultural start-ups, with funders, and with NGO representatives. Interviews were combined with observations during conferences and symposiums in the Netherlands and USA, and with a close reading of publications on cellular agriculture.

2 | FACING THE FUTURE, TODAY

In this section, I discuss future visions and future geographies, centring on venture capital-backed biotechnology and the so-called Anthropocene. This, importantly, does not mean that I consider futures knowable. Rather, scrutinising future visions enables underlining *contemporary* concerns. Emphasis, in other words, lies on what Adam and Groves call "present futures"; "futures that are imagined, planned, projected, and produced in and for the present" (2007, p. 28).

At the heart of my framework sit two interrelated questions concerning the intersection of political economy and geography, and the relationship between past, present, and future therein. However, with capitalism a way of organising nature (Moore, 2015), locating an intersection *between* political economy and geography is essentially futile. In this sense, Henner's images merely underscore something inherent to *all* economic activities. They reorganise landscapes. As histories of animal agriculture furthermore exemplify, the scale and nature of such reorganisations continuously change, with producers and investors consequently forced to speculate on *which* future to work towards (Belasco, 2006; Freidberg, 2009). Contemporary processes in a very palpable way thus internalise "everything else going on around [them] in the past, present and even future" (Harvey, 2008, pp. 101–102). Within them, we encounter continuities and complex linkages, including how actors today strive to extend particular relations "forward" in time under the weight of hopes and worries about the future.

Future-orientation is furthermore amplified for what cellular agriculture is a subfield of: biotechnology. This is a field fuelled by high-profile description of a world to come (Rose & Rose, 2014). Cooper describes venture capital-driven biotech as "infused with the virtual temporality of speculation" (2008, p. 96). Thereby she emphasises the importance of initiating "new product lines before a market exists for them; to promote belief, euphoria, or panic in the face of an event that has not yet materialized" (2008, p. 96). Biotech start-ups must in other words both develop innovative technologies and craft seductive future visions to retain venture capitalists' interest (Dolgin, 2019; Jönsson, 2016; Sunder Rajan, 2006). But *which* visions become seductive unarguably vary. Seeing the emphasis on rendering spaces of production visible within critiques of animal agriculture (Henner, 2015; Pachirat, 2011), it seems necessary for cellular-agriculturalists to chronicle how they will offer something completely different from Henner's feedlots.

Today, such imagined worlds can productively be read in relation to what an increasing number of natural and social scientists label a new geological epoch: a dangerous and de-stabilised Anthropocene "age of mankind" (Crutzen, 2002). Biotechnologists' future visions hence become entangled with the Anthropocene as "itself an anticipatory designation, the only geological epoch in part prospectively defined" (Matless, 2017, p. 370).

Immersing "humanity into geologic time" (Yusoff, 2013, p. 784), warnings of the world ahead often usher in pleas to defend the current Holocene epoch (Crutzen, 2002; Rockström et al., 2009), or to acknowledge that the uncertainty of Anthropocene times signals the end of utopian dreaming (Scranton, 2015). But more in line with biotechnologists' seductive stories, pleas to safeguard present socio-geological relations or to acknowledge uncertainty are also accompanied by attempts to embrace the Anthropocene as an opportunity (Asafu-Adjaye et al., 2015). As Swyngedouw and Ernstson put it, the prospect of saving "the whole Earth" from the perspective of capital renders visible and within reach "an extraordinary new frontier" (2019, p. 34). Cellular-agricultural start-ups strive towards being at the forefront of this frontier.

Cellular-agriculturalists thus seek to amass resources, and to create their future world, at a point when fears of and hopes in the world to come colour a range of political and scholarly debates. In relation to such debates, cellular-agricultural endeavours can productively be read as ecomodernist ambitions to render the Anthropocene "great" (Asafu-Adjaye et al., 2015). Ecomodernist techno-optimism underpins cellular-agricultural ambitions, while cellular-agricultural developments provide ecomodernists with illustrative examples. Cultured meat has for example featured in the central ecomodernist think-tank the Breakthrough Institute's publications on the future of food (Swain, 2016).

Through labelling cellular agriculture an ecomodernist project, I want to underscore three facets. First, ecomodernism signifies an efficiency-oriented approach that "recognizes the structural character of the environmental problematique but none the less assumes that existing political, economic, and social institutions can internalize the care for the environment" (Hajer, 1996, p. 25). Within a cellular-agricultural "second domestication," novel food production systems should internalise such care. Second, ecomodernists see solutions as further down a path that we are broadly speaking already on. Though cellular-agriculturalists criticise industrialised agriculture, it is not considered a step too far. Rather, the solution should be *further* modernisation so that animals can be bypassed. Third, ecomodernism translates crisis into opportunity. In response to dystopian proclamations of the end of the world as we know it (Scranton, 2015), ecomodernists reawaken utopian thinking along techno-optimist lines. In portraying modernisation as a near-automatic progressive process that benefits all, such utopianism was for instance a striking feature of the influential *Ecomodernist manifesto* (Collard et al., 2015).

In seeing solutions ahead, ecomodernism entails a particular way of conceptualising temporal trajectories. But how such trajectories are presented unarguably matters immensely. Bonneuil and Fressoz (2017) criticise how "Anthropocenologists" reduce history to a set of exponential graphs illuminating rapid increases in "socio-economic trends" and "earth system trends" (Steffen et al., 2015). In cellular-agriculturalists' projections, we encounter similar trajectories (if reversed). Anthropocenologists' graphs are now mirrored by graphs depicting rapid cost decreases for cellular-agricultural products. When CEO and co-founder Uma Valeti in 2016 presented Memphis Meats to prospective investors, for example, he showed a graph projecting how their cultured meat would go from an estimated $40/g lab scale product in 2017 to a 2¢/g mass market product by 2021 (Memphis Meats, 2016).

For Bonneuil and Fressoz, the problem with Anthropocenologists' graphs was that these failed to capture the emerging epoch as less a product of "an unconscious slippage or even the simple result of technical innovation (the steam engine), [than] the result of a political defeat in the face of the forces of free-market economics" (2017, p. 258). Graphs were simplified because they depoliticised history, overlooking the processes simultaneously shaping current political-economic structures and environmental problems. The same simplification is evident in cellular-agricultural start-ups' graphs of products' route to market. Depoliticising future paths, these highlight innovation-driven trajectories enabling the omnipresence of new food biotechnologies, while overlooking possible barriers en route (Jönsson et al., 2019; Stephens et al., 2019).

Furthermore, these graphs cannot capture how a cellular-agricultural shift would entail planetary "creative destruction" (Schumpeter, 2008). As Harvey remarks, this term captured the practical dilemmas facing the modernist project. "How could a new world be created, after all, without destroying much that had gone before?" (1990, p. 16). Or as Berman writes, in modernity all things produced "are made to be broken tomorrow, smashed or shredded or pulverized or dissolved, so they can be recycled or replaced next week, and the whole process can go on again and again, hopefully forever, in ever more profitable forms" (1988, p. 99). In probing intended cellular-agricultural geographies, this constant change should be acknowledged. Ecomodernist visions, marked by an "amnesia about the deeply uneven and violent nature of modernization" (Collard et al., 2015, p. 227), stay silent on what has been, or would be, destroyed to make room for innovative progress. But grasping what is at stake in how potential technologies are to reorganise nature arguably necessitates being less-than-silent on these issues.

3 | A BRIEF HISTORY OF CULTURED MEAT AND CELLULAR AGRICULTURE

The history of cultured meat production now spans two decades, while cellular agriculture as a broader biotechnological field has emerged during the last six years. Today we encounter a composite field characterised by the production of prototypes and "proofs-of-concept" (Post, 2014) on the one hand, and on the production of promises on the other.

Basing their argument on a critique of how animals are often held "under atrocious inhumane conditions" (van Eelen et al., 1999, p. 1), and in fears over population growth, disease outbreaks, health, and environmental problems, van Eelen, van Kooten, and Westerhof filed the world's first patent for "industrial scale production of meat from in vitro cell cultures" in 1999. A lesser known US patent was also filed around the same time (Vein, 2000). The first cultured meat, however, had little to do with any of these. In 2002, a National Aeronautics and Space Administration (NASA)-funded team of researchers published their findings from attempts to cultivate goldfish muscle explants as a potential protein source for a four-year Mars expedition (Benjaminson et al., 2002). But, lacking FDA approval to consume the experiments' results (Shapiro, 2018), these remained un-eaten. Some were, however, "marinated for 1 min in extra virgin olive oil, chopped garlic, lemon, and pepper […] covered in plain breadcrumbs and then deep-fried until golden brown" (Benjaminson et al., 2002, p. 883), before being presented to a four-person "odor and appearance panel" that smelled and visually inspected pieces to *deem* them "acceptable."

Instead, the first cultured meat eaten resulted from Oron Catts and Ionat Zurr's bioartistic experimentations. Serving "frog steaks" to diners at the 2003 L'Art Biotech exhibition in Nantes, Catts and Zurr sought to problematise beliefs in biotechnological innovations (Catts & Zurr, 2013). Such a register has, however, remained marginal within a cellular-agricultural discourse that instead frequently underline biocapitalistic salvation (Jönsson, 2016; Sexton, 2018a, see also Sunder Rajan, 2006).

Following this first tasting, we can divide the history of cultured meat and cellular agriculture into two phases. During the first phase (2004–2013), efforts were targeted at cultured meat primarily through publicly funded research. Here we also see the emergence of the first NGO devoted to furthering the field, New Harvest, founded in 2004.

The first bigger state-funded meat-culturing project ran 2005–2009, when the Dutch government devoted €2m to a consortium consisting of three universities alongside an industrial partner, meat producer Meester Stegeman (Haagsman et al., 2009). This project did not generate any edible products, nor sufficient private sector or public interest for the Dutch government to consider an extension warranted (Post, 2014, p. 1,040), though they did fund a smaller project (Stephens et al., 2019).

In 2011, the first commercial meat-culturing venture (Modern Meadow) was founded in the USA. Meanwhile, Mark Post, a professor of vascular physiology previously involved in the Dutch project, secured funding from Google co-founder Sergey Brin to produce a "proof-of-concept" beef burger (Post, 2014). The August 2013 public taste test of this burger is to date arguably the most famous example of cultured meat (O'Riordan et al., 2017).

Whereas the history of cultured meat until 2013 was a history of near-chronic lack of public funding, the second phase of its history (2014–2019) entails two important differences. First, teams of researchers repurposing tissue-engineering technologies to produce meat are now accompanied by companies utilising genetic modification to produce other animal products. The first company to initiate this broadening (and thus the emergence of cellular agriculture), Perfect Day (previously Muufri), initially aimed to modify yeast to produce milk. However, on releasing their first products in July 2019, they were producing casein and whey for ice cream. Clara Foods similarly utilise genetically modified yeast to produce egg whites, while Geltor have produced gelatine and collagen. Pembient instead strive to use such technologies to produce rhino horns in order to undercut the illegal international trade in these. With the exception of Perfect Day (graduating through an older European accelerator funded by the same venture capital firm), all of these have emerged through Indiebio, a San Francisco-based biotechnology accelerator that has played a crucial role, particularly in easing the entry of start-ups onto the cellular-agricultural field. This phase also includes the emergence of the field's second influential NGO, The Good Food Institute, founded in 2016.

Second, and equally important, the broadening of the field (not without its frictions; Jönsson et al., 2019) has been accompanied by a turn to venture capital. As of February 2020, Perfect Day was most successful in attracting such investments, amassing more than $200m, with Memphis Meats a close second at $180m. Meanwhile, the team that in 2013 produced the famous cultured beef burger has started a Maastricht University spin-off, Mosa Meat. In 2017, Just (formerly Hampton Creek) began conducting research on cultured meat. Already producing plant-based products, this was the first company with an established market presence to start its own cellular-agricultural R&D department.

From 2016 to 2018, the number of companies involved in the cultured meat proto-industry went from four to more than two dozen (Allen, 2018). By January 2020, futurefoodshow.com listed more than 40 companies active within the cultured meat space, although this list also included companies working on pet foods, technological platforms, and non-edible products. Moreover, funding was unconfirmed for close to half of the companies listed. Meanwhile, a handful more are engaged in genetic modification-based cellular agriculture.

Following the 2013 beef burger, several companies have presented prototypes (for detailed histories, see Shapiro, 2018; Stephens et al., 2018). In 2014, Modern Meadow served "steak chips" at Google's Solve For X, while Bay Area-based Memphis Meats in 2016 displayed their first product, a meatball, followed by beef fajitas and poultry products. In 2017, Japanese biohackers Shojinmeat held a small-scale taste test for cultured chicken liver cells, while Just also held a poultry taste test that same year. In 2018, Bay Area-based start-up New Age Meats presented a pork sausage, while Israeli start-up Aleph Foods presented the first textured products, a kind of small flat "steak."

With the shift to venture capital, cellular agriculture's geographies have shifted from a Northern European "heartland" (primarily the Netherlands, but with activities also in Scandinavia) to a pattern where attempts scattered across Europe, Israel, and Japan co-exist with a strong Bay Area centre (Sexton, 2018a; Wurgaft, 2019). This shift, deeply tied to the prevalence of venture capital and the opportunity to appropriate infrastructure left under-utilised following the 2008 financial crisis and subsequent collapse of a Bay Area clean-tech sector (Interview, Indiebio organiser, 2016), not only adds new nodes to an emerging research-and-development network. Rather, this network mutates as research funding shifts from public to private, by what one cultured meat researcher jokingly called an inevitable shift "from a charitable, friendly, cooperative, sharing, naïve, idealistic community, to a more realistic community" (Interview, 2015). This in essence signals a transition from early stage altruism to more conventional competition, where one company's route to success might undermine many others'.

4 | ON CELLULAR-AGRICULTURAL FUTURES

An embryonic attempt to trace future cellular-agricultural geographies is apparent in McGregor and Houston's (2017) discussion on proposed (Australian) cattle futures. Herein "artificial" beef and dairy signals one of four propositions, alongside intensification of present production processes, a turn to caring consumption and quality agriculture, and veganism. McGregor and Houston underscore that their propositions "are neither true or false, nor merely discursive or material, nor human or non-human; instead they build on messy interactions to articulate different possibilities for thinking and action" (2017, p. 3). Their "artificial" meat proposition is summarised as follows: "The proposition is comprised by investors, universities, biotechnologists and biotechnology companies, labs, microscopes, stem cells, foetal bovine serum, 'schmeat,' computers, media releases, websites and academic papers" (McGregor & Houston, 2017, p. 10).

This passage, however, merely gives a vague outline of things somehow hanging together. It says little about *how* proponents of new products seek to reshape economic geographies and material landscapes (Ford, 2011; Mattick & Allenby, 2012). It conveys nothing about cellular agriculture's creative–destructive ambitions. Exploring such issues necessitates tracing how proponents and researchers envision cellular-agricultural geographies in more depth. This what I do below.

As Mouat et al. remark, it is too early to determine the nature of a cellular-agricultural "maybe industry." "The new industrial geographies this will involve and the changing agricultural geographies that will result are still to come, and only then will its significance be properly understood" (2019, p. 154). This is unarguably true. But scrutinising how future geographies are articulated none the less reveals the desirable *directions* that leading figures in the field today outline, and the stories that cellular-agriculturalists want to tell of themselves and their products. These shed light on future geographies *today*, on present futures (Adam & Groves, 2007).

4.1 | From space-exploration to microbreweries

Cultured meat might have slightly otherworldly roots, the topic of science-fiction speculations and suggested as astronauts' protein source. An evident embrace of a high-technological, space age aesthetic also lingers in Japanese biohackers Shojinmeat's Dubaiesque anime dreamscapes, integrating a cellular-agricultural production system "in a standalone floating city" (see https://shojinmeat.com/wordpress/en/, and Figure 1).

Visions for similarly abstracting food production are also carried forward by researchers framing cellular-agricultural developments as about "agriculture moving away from the land" (Interview, researcher, 2016) or as enabling production far removed from human settlements:

> The production of meat will be potentially more detached from where you want to produce the meat. You could do it in a container on the North Pole. You could do it in a container, as long as you have water, in the Sahara as well. And traditional meat production needs more ground, needs more resources, is more dependent on the environment. (Interview, researcher, 2016)

FIGURE 1 "Isolated urban system".
Source: Image courtesy of the Shojinmeat Project. [Colour figure can be viewed at wileyonlinelibrary.com]

Such visions echo ecomodernist desires to concentrate production on particular pieces of land to provide space for "nature" elsewhere, while Shojinmeat recycles a belief in cities as providing solutions that was prominent in the ecomodernist manifesto (Asafu-Adjaye et al., 2015). The vision, in other words, is that new food-production technologies should unfetter production from spatial constraints, engendering the very opposite of the landscape-entangled animal-agricultural systems that Henner depicted. Alongside beef not tied to pastures, we here encounter fish that is strictly speaking no longer seafood, since cell-culturing technologies have "no tie to the shoreline and no tie to fisheries" (Finless Foods, 2017). Indeed, based in these hopes, one could justifiably question whether cellular agriculture remains "agriculture," given how food production is to be decoupled from the "agri" (i.e., the field).

But in communicating appetising visions for cellular agriculture, proponents and producers (including the researcher discussing Saharan facilities above) frequently circulate much more down-to-earth scenarios. Decoupling production from *inescapable* connections, these instead emphasise the kind of *desirable* connections, relations, and geographies that novel technologies should engender. Stephens et al. (2018) speculate that the return per animal might rise if small herds of cell-donors supplant massive livestock herds. This, for Stephens et al., could usher in the (re)utilisation of more traditional livestock alongside craft-oriented production systems:

> There is also opportunity for each producer to create their own version of the product (much like craft brewers, farmhouse cheesemakers and charcuterie producers now), therefore giving them diversity and competitiveness in the market, as well as engaging in higher skilled jobs in a new knowledge economy. (Stephens et al., 2018, p. 158)

Such descriptions of a possible continuation of (or a return to) small-scale, artisanal food production is outlined by several cellular-agriculturalists.

In underling craft-based production systems, such visions give rise to a kind of recombinant ecomodernism where microbreweries function as anchoring points for claiming that novel technologies should feel familiar. Moreover, through tying visions to microbreweries, proponents and producers draw on a kind of production geography familiar within the Bay Area as central to *both* biotech and micro-breweries The probable pinnacle herein is reached in Datar and Bolton's (2014, p. 152, see also Notaro, 2011) description of a "carnery" to open in London, 2025:

> The restored 1970s-era English brewpub boasts an expansive bar of reclaimed mahogany and booths upholstered with magnificent in vitro leather. Steaks are grown to precision inside giant steel vats, decorated (functionally) with illuminated green algae tanks. A disorientating mingling of global spices flavour varieties of exotic and heritage meats like boar and Berkshire, all of which are cultured on site.

Exemplifying a "recombinant" (Belasco, 2006) vision, this excerpt highlights several prominent features within promissory cellular-agricultural discourse. Algae are, like in Tuomisto and Teixeira de Mattos' (2011) optimistic evaluations of cultured meat's environmental impacts, to figure in a production system borrowing its aesthetics from upscale brewpubs. Meanwhile, meat is sourced from both exotic animals and heritage breeds, illuminating how cellular agriculture is supposed to render the exotic everyday (Jönsson, 2016).

Importantly, the kind of breweries regarded as inspirational in stories such as these are, again, small-scale craft operations. As one researcher commented, regarding post-animal milk:

> Because our process is really akin to a microbrewery process it's really amenable to small-scale artisans opening up their own microbreweries, and producing their own customised artisan batches of milk. For instance, you could go down the block and try Joseph's milk and if you go down the block in the other direction Sharlene's milk tastes completely different. It's like the whole microbrewed beer industry. That's the kind of thing we envision. (Interview, researcher, 2014)

Simultaneously others speculate that we might one day have meat-makers alongside bread-makers and ice cream-makers as unremarkable kitchen features (Shapiro, 2018, p. 23).

In such visions, mentions of cultured meat as lab-meat are anathema. As one researcher remarks, laboratories are sites where nature is tampered with: "[Nature] has the aspect of, it's not easy to mess with, whereas in a lab people are by definition messing up things" (Interview, researcher, 2015). The difference in the kind of production spaces underlined thus pertain to a difference between two kinds of spaces of experimentation. The laboratory as a "placeless" (Koehler, 2002) site where authority is built through severing it "from everything at or near its location" (Gieryn, 2018, p. 167), a site where nature is "messed" up or with, and breweries or kitchens as sites for more locally rooted, homely, experimentations.

Inherent to the emphasis on small-scale production systems is also that a cellular-agricultural shift should mean that the rigid biosecurity protocols currently striving to keep industrial animal agriculture reasonably pathogen-free could be done away with:

> Unlike conventional meat, which is typically so riddled with bacteria that you have to decontaminate countertops that raw meat has touched, clean meat is perfectly safe to handle in raw form, with a greater risk of contamination coming from your own hands than the meat itself. (Shapiro, 2018, p. 49)

Cultured meat would thus invite safe everyday engagements. But, as I will return to, there is reason to question how at least some prominent trends within the cellular-agricultural field resonate with the kind of artisanal, small-scale activities and facilities discussed above.

4.2 | Promising transparency

Studying plant-based, insect-based, and cellular-agricultural "alternative protein," Sexton (2018b) underscores how the application of a molecular lens in narratives might be unappetising:

> [R]educing food to its molecular components and building it from the bottom-up tests the boundaries of acceptability. It introduces unfamiliar actors, materials and practices into the intimate relationship between eater and eaten, asking the eater to accept and ultimately embody them – both ideologically and materially – through ingestion. (Sexton, 2018b, p. 592)

This emphasis on relationships mediated through unfamiliar actors, materials, and practices echoes how previous research suggests that consumer acceptance might be hindered by cellular-agricultural products' perceived unnaturalness (Siegrist & Sütterlin, 2017; Verbeke et al., 2015). Proponents are, however, acutely aware of such concerns. Emphasising breweries is one prominent strategy through which proponents seek to counter notions of cellular agriculture as unnatural or unfamiliar. As I elaborate on in this section, further strategies include promising that prospective consumers will be able to fully familiarise themselves with these food-production technologies. Transparency is, for example, outlined in an artist's rendition of Just's proposed plant, which includes a skybridge from which visitors can view manufacturing and production (Figure 2).

A shift to cultured meat, proponents hope, should mean that nothing would be deemed out of bounds to consumers:

> We want to offer a level of transparency that is unheard of in the meat industry today. We imagine meat breweries that would be open to public tours. And certainly nobody would ever be touring a slaughterhouse today. And so we think that this is kind of an interesting way first and foremost to just depict the reality and depict what our vision is. (Interview, start-up representative, 2017)

Emphasising transparency thus becomes another way to contrast cellular agriculture with industrial animal agriculture, a sector characterised by a struggle between activists seeking to expose the industry's inner workings, and industry interests trying to minimise the extent to which less appetising details are made public (Pachirat, 2011). But the question is just what has to be hidden in slaughterhouses as places where animals are killed *and* where people work under often appalling conditions (Pachirat, 2011; Wadiwel, 2015).

As White underscores, there is a need to challenge "the uncritical reflection that all vegan food is cruelty-free" (2017, p. 286). Instead, he emphasises a responsibility "to be active in learning about the (exploitation of) labor and the environment, in the production and distribution of 'vegan' foods" and a "critical vegan gaze" questioning "the conditions of which the food was produced and harvested." Rather than equating cellular agriculture with the end of secrecy, taking our cue from White underlines the necessity to acknowledge that a production-technological shift does not *in itself* mean that there would be nothing to hide. Taking the craft-brew industry so inspirational to cellular-agriculturalists as an example, it seems worth mentioning that labour conflicts have plagued one of its most famous companies; San Francisco's Anchor Steam brewery

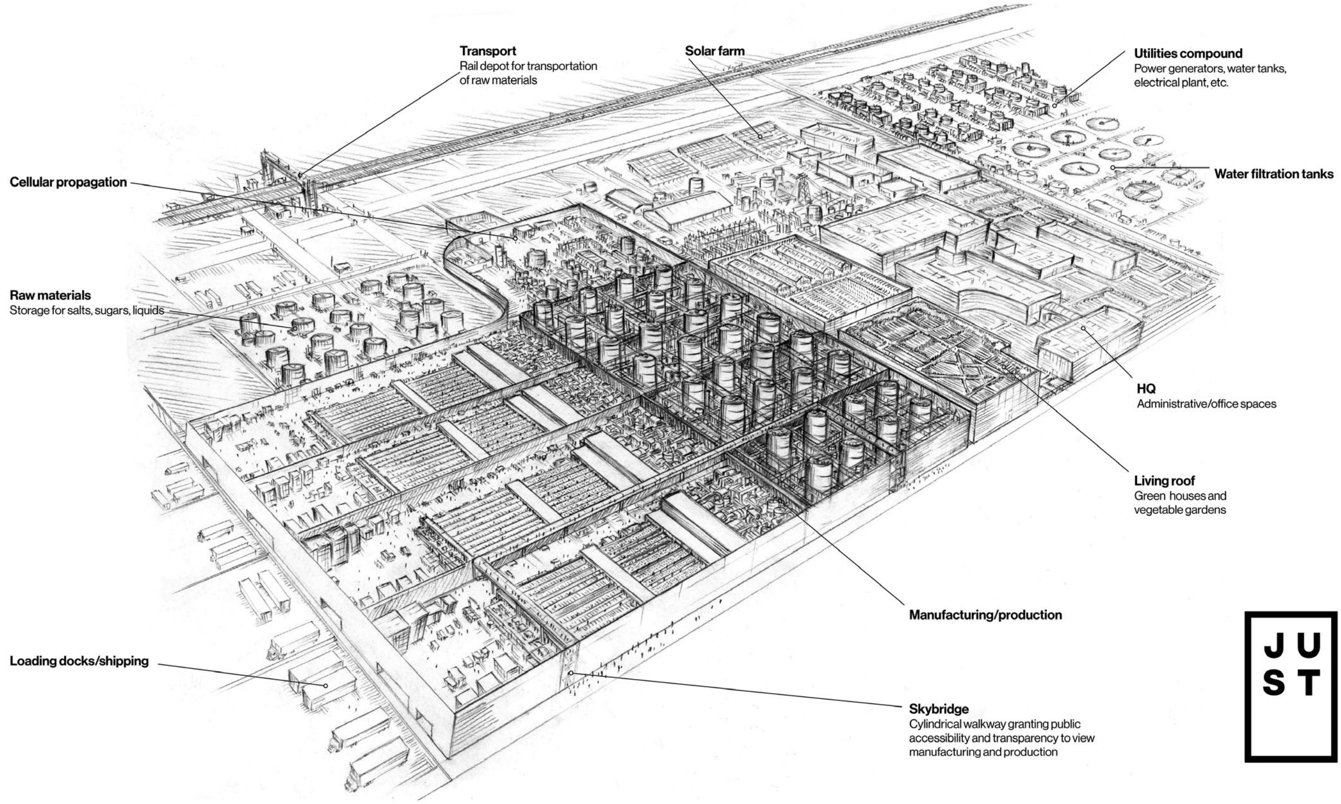

FIGURE 2 The Just Farm.
Source: Image courtesy of Just, Inc.

(Day, 2019). Before promising transparency, one would hence have to know who would work within the cellular-agricultural field, and how. A shift away from animals, or to more small-scale production systems, does not *in itself* ensure harmonious labour relations.

4.3 | Cellular agriculture and conventional animal agriculture

To New Harvest, "decoupling animals from the supply chain with biotechnologies" signals "the next and logical step in an agricultural (r)evolution" (Datar et al., 2016, p. 129, 122). That cellular agriculture would, if scaled up to the extent that proponents and producers hope, signal thorough global transformations constitutes the very *raison d'être* for this paper. But, rather than let revolutionary potential remain an unqualified signifier, I want to trace what producers and proponents imply in labelling technologies "revolutionary." What actors would/could/should participate in the intended revolution? Who could benefit, or suffer? Elaborating on these points further illuminates how an ecomodernist embrace of the Anthropocene underpins the cellular-agricultural field, engendering a firm belief in capitalism and technological innovation.

To illustrate: Identifying Norman Borlaug as "perhaps the most important person of the past fifty-sixty years," a NGO representative, though careful to underscore that cultured meat is not a panacea, regards it as offering the prospect of a new green revolution:

> We are in need of a new green revolution if we're going to try to mitigate climate change, if we're going to be able to feed a still growing population, if we're going to be able to have antibiotics that continue to work. All these things are, again, really serious threats to humanity. Clean meat is the answer to all this. It's so much more efficient. You can feed people, even feed many more people, concentrated protein and fat, on the same amount of land. It has much less greenhouse gas emissions than the current way we produce meat. It doesn't require antibiotics, so it's not going to continue to feed the evolution of antibiotics-resistant superbugs. So, clean meat, better ways of producing meat, is the ability for us to have a new green revolution, to answer all these terrible threats to humanity. (Interview, NGO representative, 2018)

Clean meat would, according to this NGO representative, thus enable revolutionary transformations. But it remains crucial to remember what the Green revolution offered an alternative *to*.

In coining the term "the Green Revolution," William S. Gaud envisioned an innovation-driven alternative to "a violent Red Revolution like that of the Soviets" or "a White Revolution like that of the Shah of Iran" (Gaud, 1968, n.p.). From the very beginning, the green revolution was thus a promise that political revolution was unnecessary. Similarly, cellular agriculture is today frequently framed as a set of biotechnological innovations enabling contemporary diets to be sustainably sustained. In this sense, cellular agriculture resembles the "non-disruptive disruptions" that Goldstein chronicles in his account of clean-tech: "technologies that can deliver 'solutions' without actually changing much of what causes the underlying problems in the first place" (2018, p. 10). Technological innovation is to ensure that production processes rather than contemporary diets are disrupted (Jönsson, 2016).

A fundamental belief underpinning celebrations of a second domestication is that conventional animal agriculture, because of its reliance on whole animal bodies, is *inescapably* inferior to working with cells or molecules (Jönsson, in press). This generates a palpable risk of upsetting conventional animal agriculture interests, and to a certain degree conflicts *have* indeed surfaced. In August 2018, Missouri became the first US state to ban the label "meat" for products "not derived from harvested production livestock or poultry" (Tsang, 2018, n.p.). Earlier that same year the United States Cattlemen's Association had already petitioned the USDA Food Safety and Inspection Service to ensure that the labels "beef" or "meat" should be reserved for products "derived naturally from animals as opposed to alternative proteins such as plants and insects or artificially grown in a laboratory" (United States Cattlemen's Association, 2018, p. 1). Attempts to halt cellular-agricultural developments are thus initiated by those who fear that their sector could be destroyed by the emergence of a novel food-biotechnological sector.

But several cellular-agriculturalists' visions simultaneously provide space for conventional animal agriculture interests. Whereas early support from actors such as animal liberation philosopher Singer (2013) and the People for the Ethical Treatment of Animals (2014) might give the impression that cultured meat is a vegan project, prominent actors now try to avoid this framing:

> So, if we come across as the vegans, and this is all vegan, vegan, vegan, then we are going to harm the progression of plant-based and clean meat. This is a point that we make over and over again with companies. If you want to reach meat-eaters, don't splash vegan on your product. You don't want them to think that this is for vegans, so it's not for me. […] [W]e go out of our way to try to make sure that we aren't coming across as strident anti-agriculture people. Tyson is not the enemy. Tyson is an organisation, a company that we want to move to producing meat in a better way. So instead of screaming 'Tyson is bad, Tyson is bad', Tyson is a partner. (Interview, NGO representative, 2018)

Proponents moreover underscore that conventional meat producers have a direct interest in following consumers shifting to cultured meat, and that these producers should feel welcome (Interview, NGO representative, 2018). Such emphasis on conventional meat producers as cellular-agriculturalists' allies today goes beyond questions concerning potential future roles. In January 2018, Tyson announced investments in Memphis Meats, labelling these "an example of Tyson Foods' commitment to explore innovative, new ways of meeting growing global demand for protein." This was, later that same spring, followed by investments in Israeli start-up Future Meat Technologies (Tyson Foods, 2018a, 2018b). Meanwhile, in 2017 Cargill had already invested in Memphis Meats. Thereby cellular agriculture is *already* permeated by direct ties to major animal agriculture interests. It is too early to tell just *how* this will influence the cellular-agricultural field's future geographies. But it is quite clear that it *will*. To return to Harvey's (2008) point about the present internalising the future, with new actors entering the cellular-agricultural field, this field internalises also *their* ambitions and desired futures. Furthermore, there are evident tensions between animal-agricultural giants' established structure and the kind of grassroots-experimental microbrewery-inspired visions so prominent within the cellular-agricultural field.

In relation to ambitions to collaborate with established meat producers, the allure of cultured meat furthermore goes beyond following consumers shifting to new protein sources. As proponents and researchers assert, a shift to cultured meat should also enable the continuation of processes geared at ensuring as much control as possible within animal agriculture. Here there would, proponents argue, also be much to gain for conventional animal-agricultural interests (Datar et al., 2016). Whereas Wadivel underlines the resistance of non-human animals taken to slaughter to describe factory-farming as "a monstrous deployment of violence and extermination" (2015, p. 6), producers and proponents hope that a cellular-agricultural shift should enable a reliable flow of meat and animal products (Jönsson, in press).

In their emphasis on technological innovation, the ways that future geographies are articulated in promissory cellular-agricultural discourse frequently give the impression that the solution to pressing environmental problems would simply spread out from the Bay Area, spurred by celebrity capitalists such as Richard Branson (2018) and established meat producers. Analysing Silicon Valley as a "socio-cognitive space," (see also Longhurst, 2015) in her study of "alternative protein" development, Sexton similarly emphasises the "Nerd's burden" to "signify the longstanding Western-led enterprise of global civilisation and 'development' being passed to the hands of a specific geographical hub of largely male, Valley-based elite, armed with technofixes that promise a better world for all" (2018a, p. 127, see also Wurgaft, 2019, p. 16).

Consequently, the Global South can easily become regarded as either recipient or raw-material supplier. In discussing sugar as a key input within genetic modification-based cellular agriculture, Newman and Powell (2019) for instance emphasise how cane sugar from the Global South is to feed an expanding Global North cellular-agricultural sector. Thus, they argue, questions not only concerning whether land will be spared but *whose* land will be spared must be asked for a field whose impact on rural land will be huge. But other cellular-agriculturalists want to ascribe a more central position to Global South facilities. Marianne Ellis (2018), for instance, considers what she calls Cellular Agriculture Lifecycle pods the future nodal points for entrepreneurial communities inhabiting places such as the Kakuma refugee camp in Northern Kenya:

> Now picture a building at the edge of the camp. It is the size of six shipping containers stacked three layers high, covered in solar panels. Walk through the small door and in front of you are a series of horizontal tubes. These are bioreactors growing muscle cells – a complete protein product and form of clean meat. […] Once the facility is in place, a workforce of farmers, producers, suppliers, and distributors will form, creating a locally-sustained economy built around an environmentally-sustainable process. We can imagine the social benefits this could bring about: schools and education, job prospects, better health and quality of life. (Ellis, 2018, n.p.)

In a system based on these pods, otherwise economically marginalised populations, such as the refugees populating the Kakuma camp, would actively participate in cellular-agricultural production. But how would the kind of bioreactors that Ellis imagines relate to the companies now at the forefront of the cellular-agricultural proto-sector, and in relation to those meat producers now investing in it? Would pods be akin to the Zimbabwean water pump famously described by de Laet and Mol (2000), a technology that, because of the possibilities of adapting it to local circumstances, the authors claim could constitute village communities, even build nations? This pump's significance, importantly, was premised on its inventor not utilising intellectual property. Or would pods rather become a technology through which ties of unequal exchange are woven? And what would the difference be between placing pods in a refugee camp, already intimately entangled with the Global North, and placing pods in a village in the Kenyan countryside? In phrasing such questions, cellular agriculture's "maybe industry" (Mouat et al., 2019) qualities become evident.

Complementary to such questions are discussions on the kind of workforce bioreactors would require. In discussing cultured meat-production's future work force, Stephens et al., in line with their emphasis on meat production possibly becoming more of a knowledge economy, anticipate:

> The need for a workforce with a range of skills and knowledge levels that extend beyond more traditional roles of, for example, agriculturalists and veterinarians to also include chemists, cell biologists, material scientists, chemical engineers, skeletal muscle scientists, technicians, meat scientists and food technologists. (Stephens et al., 2018, p. 162)

Importantly, the list provided here describes a system staffed by relatively well-educated labourers, far removed from how slaughterhouses are today often characterised by hard work and high rates of employee turnover (Pachirat, 2011), and from Ellis' descriptions of cellular agriculture life-cycle pods. The way that a future labour force is described varies between accounts, making *certain* estimates of cellular agriculture's desirability virtually impossible.

4.4 | The future of animals

Above, I accounted for how producers and proponents assert that cellular agriculture should permit producers to create steady flows of (post-)animal products. Thereby they hope to escape having to deal with whole animals bred, fed, and killed. But whereas proponents celebrate the control that such a shift would enable, others instead fear that a cellular-agricultural turn would create a world bereft of animals.

As a *New York Times* editorial proclaimed more than a decade ago, in response to PETA's advertised $1m prize for the "first person to come up with a method to produce commercially viable quantities of in vitro meat at competitive prices by 2012" (PETA, 2014, n.p.):

> Historically speaking, [domesticated animals] exist only because of the uses we have found for them, and preserving their existence means, in most cases, preserving the uses we have made for them. It will be a barren world if the herds and flocks disappear in favor of meat grown in a laboratory tank. (New York Times, 2008, n.p.)

Resembling Ford's (2011, p. 46) caution that livestock is raised not just for meat but to manage the land, this fear of a world without animals is understandable given how cellular agriculture is sometimes presented a food system where animals are taken "out of the equation" (Interview, NGO representative, 2015). Whereas proponents dream of craft-based production systems, we here encounter fears of destroyed rural livelihoods and lifeless landscapes. The possibility of fully eliminating animal presence has furthermore become a selling point for some start-ups, evidently signalled through Geltor's early production of Mastodon gelatine (i.e., based in genetic sequences from an extinct mammal).

The disappearance of non-human animals is however not the only scare generated by cellular-agricultural developments. Viewing the promise of cultured meat as the "elimination of animal agriculture," one veterinarian in 2017 argued that if proponents' aversion to the killing of animals within animal agriculture was extended, this would lead to an excess of wildlife:

> If there is no 'need to kill any animals', one would assume that hunting will be included. And if man is eliminated as a predator, wildlife overpopulation would soon occur. So, there would still be a need to kill animals, unless we sterilize a percentage of them so they can't reproduce. But many animals will still die a much more violent and painful death than at man's hands, because man is not their only predator. (Sjeklocha, 2017, n.p.)

The main problem would then not be too few non-human animals, but too *many*.

To proponents, a cellular-agricultural world is, however, neither to resemble the barren world described by the *New York Times* editorial, nor to be plagued by wildlife overpopulation. Rather, cultured meat should usher in a friendly coexistence with the animals from which cells are sourced. Partly, this opportunity to keep animals alive yet eaten feeds into the deliberately spectacular nature of cultured meat (Jönsson, 2016). As a Memphis Meats representative remarks: "The animal could stay there and be the spokesperson, the mascot. You could point to him and say, 'that's where the meat comes from.' We could have a pig mascot, and he'd still be alive" (cited in Shapiro, 2018, p. 147). A kind of real world example of this could be witnessed in 2018 at a trendy San Francisco brewpub, when New Age Meats displayed their first sausages next to images of the pig from which cells were sourced.

But beyond such spectacular displays lie hopes of creating less alienated relationships through reversing industrial animal agriculture's tendency to keep livestock out of sight and mind. The arguably most famous such scenario is the "pig in the backyard," emerging from workshops conducted by Dutch researchers Van der Weele and Driessen (2013). The main idea of this scenario was that:

> In the future we might all have a pig in our backyard or in our local community, from which some stem cells are taken every few weeks in order to grow our own meat, either in a machine on our kitchen sink or in a local factory. (van der Weele & Driessen, 2013, p. 655)

Providing an influential example of the artisanal practices frequently underlined in cellular-agricultural discourse, the pig in the backyard highlights how recombinant visions give "a glimpse of a possible world in which we can have it all: meat, the end of animal suffering, the company of animals and simple technology close to our homes" (van der Weele & Driessen, 2013, p. 656). This offers a scenario where continued meat consumption would usher in intimacy. But, lest readers are too carried away by this scenario, van der Weele and Driessen add that "the feeling that this prospect is almost *too good to be true* may help to explain the special atmosphere" (2013, p. 656; emphasis added).

And perhaps this "too good to be true"-quality really gets to the core of many of the most prominent cellular-agricultural scenarios? Instead of a sustained discussion on cellular agriculture as promising global-scale creative destruction, interested publics hear stories of friction-less innovation and of a world where meat-producing transnational corporations, Silicon Valley start-ups, and prominent vegan voices not only can but *should* share the same goals. Through exploring the sometimes harmoniously coexisting and sometimes contradictory future geographies described in discussions on cellular agriculture, it is such certainty that I want to trouble. The development of particular technologies does not itself lead to a future known beforehand. Rather, various actors today strive to fold *their* particular visions into the still unfilled future of a cellular-agricultural "maybe industry" (Mouat et al., 2019).

5 | CONCLUSIONS

As several scholars have commented, cellular-agricultural technologies are ontologically ambiguous (Stephens, 2013; Van der Weele & Driessen, 2013). Through engaging with cellular-agricultural future visions, in this paper I have illuminated how such ambiguity extends also to their future geographies. Researchers and proponents crafting visions for future cellular-agricultural geographies strive to determine what products *are* through describing *where* these would be produced. In accounting for these intended geographies, I undoubtedly introduce more questions than provide answers.

But nonetheless, I hope to have contributed to a discussion on cellular agriculture already increasingly acknowledging the tensions and conflicts permeating *both* the current state of cellular agriculture and cellular-agriculturalists' future visions. Centring on future geographies adds flesh to the bone for further discussions on these, and other, biotechnologies, particularly in light of current Anthropocene preoccupations with the times ahead. Building further from McGregor and Houston's (2017) explorations of cattle futures, I have emphasised not only how things are connected, but what different connections might mean concerning the actors involved in, benefitting from, or negatively impacted by a potential cellular-agricultural shift.

Increasingly prominent within a Bay Area biotech scene, cellular-agricultural products today become anchoring points for ecomodernist dreams of essentially escaping the earth. No longer should distance to water bodies determine the availability of fresh fish, nor should the location of pastures determine the geographies of beef production. In this sense, the future offered by cellular-agriculturalists promises economic geographies fully structured as networks unfettered to material landscapes anywhere.

But simultaneously, other prominent future visions assure that the ability to escape ties to particular landscapes would *not* lead to production processes completely unconcerned with local scales. Rather, fears of new products as "unnatural" or unfamiliar are countered by emphases that cutting-edge biotechnological R&D would not be dissimilar to breweries. "Recombinant" (Belasco, 2006) visions promise that biotechnologies could create a world where meat-consumers and the animals these consume could live in close proximity. Such visions, underlining future production spaces to reveal desired Anthroposcenes (cf. Matless, 2017), are what, following Belasco (2006), I label recombinant ecomodernism.

But there is simultaneously something slightly frustrating with how breweries and bioreactor-based facilities are likened to each other in such scenarios. Their similarity is above all aesthetic. Bioreactors could very well be built to *visibly* resemble brewery kettles. But what do such similarities signify? Much like earlier accounts of cultured meat reified "meat" as object at the expense of a fuller analysis of the new *relations* that new technologies should engender (Jönsson, 2016), cellular-agricultural fascinations with bioreactors resembling breweries risk reifying these as spaces curiously detached from their surroundings. Instead of promising that bioreactors could *look* like brewery kettles, more interesting questions concerning cellular-agricultural creative destruction arise if we emphasise the re-shaped relational geographies that brewery kettle-like bioreactor could sit at the centre of. Whose world, in other words, would be carried by these? In ending with this question, rather than with an answer, I want to again acknowledge cellular agriculture's "maybe industry" qualities (Mouat et al., 2019). But I also want to underline the importance of creative destruction as analytical lens for further explorations. Whereas texts such as the Ecomodernist manifesto underline utopian teleology, actual modernisation has entailed very real, and sometimes violent, impacts for people and societies to be modernised (Berman, 1988; Collard et al., 2015; Harvey, 1990). Though cellular agriculture's eventual impacts remains to be seen, this should be remembered. Otherwise, our explorations risk merely reproducing the hype so fundamental to biotechnology as a sector (Cooper, 2008; Rose & Rose, 2014).

ACKNOWLEDGEMENTS

First, I would like to thank the editors and the three reviewers for their constructive critique. I would also like to thank Johan Pries, Claudia Fonseca Alfaro, Maria Persdotter, and Wim Carton (together with the Lund University Political Ecology Network) for their patience in discussing my ideas as they have evolved and commenting on earlier versions of the manuscript. The research for this paper was made possible through a postdoctoral mobility grant from Formas (Grant number 2013-1510). I would also like to thank Michael Watts at UC Berkeley Geography for welcoming me as a visiting scholar during my periods in the Bay Area.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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How to cite this article: Jönsson E. On breweries and bioreactors: Probing the "present futures" of cellular agriculture. *Trans Inst Br Geogr*. 2020;45:921–936. https://doi.org/10.1111/tran.12392