



On the Intertwining of Cellular Agriculture and Animal Agriculture: History, Materiality, Ideology, and Collaboration

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This review essay documents continuities between (industrial) animal agriculture and cellular agriculture and raises key questions about whether or not the technology might be able to deliver on its promise of food system transformation. It traces how industrial history, connections to the livestock industry, and disavowal are extended through the innovation of cellular agriculture. In particular, it is shown that cellular agriculture has had connections to (industrial) animal agriculture since its very beginning and at nearly every step since then. I argue that cellular agriculture can be positioned as the epitome of (industrial) animal agriculture in terms of history, material practices, and ideology. Such a critique of cellular agriculture has become somewhat commonplace but while a number of papers have raised similar concerns individually, there exists no sustained focus on such similarities to make this point holistically. Such connections are important in framing the future of cellular agriculture and the fate of farmed animals and the environment. Carefully considering the continuities between cellular agriculture and animal agriculture is crucial when considering whether promoting cellular agricultural is a prudent approach to addressing problems associated with animal agriculture. The cumulative number and extent of connections covered in this essay leads to questions of who will benefit with the advent of cellular agriculture.

Keywords: cellular agriculture, transitions, meat, industrialism, animal agriculture

OPEN ACCESS

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Specialty section:

This article was submitted to
Social Movements, Institutions and
Governance,
a section of the journal
Frontiers in Sustainable Food Systems

Received: 29 March 2022

Accepted: 12 May 2022

Published: 02 June 2022

Citation:

Poirier N (2022) On the Intertwining of
Cellular Agriculture and Animal
Agriculture: History, Materiality,
Ideology, and Collaboration.
Front. Sustain. Food Syst. 6:907621.
doi: 10.3389/fsufs.2022.907621

INTRODUCTION

While the immediate ethical advantage of reducing the consumption of animals by promoting consumption of *in vitro* meat should, I think, be obvious, we will need to pay attention to the complexities generated by a practice that obscures the origins of killing... Contemporary industrial processes employed in the production of commercial imitation meats were developed early in the twentieth century to improve the productivity and profitability of livestock. We should consider how this industrial history is extended by the innovation of *in vitro* meat in terms of what I'm tempted to call its seductive power. We should consider as well its relationship to disavowal.

-Terhaar (2012, p. 75)

This essay answers Terhaar's call to show how industrial history, connections to livestock, and disavowal are extended by the innovation of *in vitro* meat (IVM).

To date, I am not aware of a published peer-reviewed paper that answers Terhaar's call to explicitly trace out how IVM falls neatly in line with animal agriculture. The connections between IVM and industrial animal agriculture have been noted by several authors (Jönsson, 2016; Guthman and Biltekoff, 2020; Helliwell and Burton, 2021; Howard et al., 2021; Lonkila and Kaljonen, 2021; Poirier, 2021). This current article expands upon those inquiries by offering a more systematic analysis of those connections. In particular, this essay will argue that IVM has had connections to (industrial) animal agriculture since its very beginning, and at nearly every step since then. This work is part of a broader conversation about whether IVM does or does not have transformative potential, and its unique contribution to this conversation is tracing the historical links between IVM and (industrial) animal agriculture. IVM is a technological approach to creating meat without (or nearly without) the use of nonhuman animals. The dominant production process involves taking a biopsy of a living animal (Melzener et al., 2021) and isolating either stem cells or muscle cells. These cells, along with nutrients to promote cell growth, are placed in a bioreactor which keeps conditions ideal for cell formation and overall cleanliness of the process. Cells adhere to a scaffold mechanism as a growth platform and helps myoblasts to fuse together to form myotubes (Edelman et al., 2005, p. 660). Finally, myotubes are exercised to create myofibers which are used in meat emulsion and form the basis of IVM products which can be formed into various types of meat to be cooked and eaten as such (Pandurangan and Kim, 2015; Bhat et al., 2020).

Thus, despite the differences between cellular and animal agriculture, this paper argues that IVM could be positioned as the epitome of (industrial) animal agriculture in terms of ideology, materiality, and history when viewed by its many similarities to animal agriculture. To be clear, this is not to say that IVM necessarily or absolutely *is* the epitome of animal agriculture, but that it is not unreasonable to view it as such. To this end, it is not particular differences this paper is concerned about. Rather, it focuses on the many similarities. This is because, admittedly, the differences of cellular agriculture from animal agriculture potentially leave room for IVM to significantly reduce harm to humans and nonhumans if developed in a critical manner that is oriented around social justice and consciousness raising (Poirier, 2018a). As I see it, the similarities are where potential problems lie and thus they are the focus of my interrogation. I approach this review essay from a vegan perspective that disapproves of all animal use by all who have a choice (except in extreme and absolutely necessary circumstances). Thus, veganism, as defined and operationalized in this essay (see overview below), is critical of both IVM and animal agriculture and is concerned about who benefits and who is harmed by social practices. My concern is that IVM will not, ultimately and despite its many seemingly promising potential benefits, serve the interests of nonhumans, and the number and strength of connections to animal agriculture will influence this likelihood.

Unlike most review essays that cover the general lay of the land regarding IVM (e.g., Stephens et al., 2019; Chriki and Hocquette, 2020), this review essay has a narrower aim of providing an overview and discussion of the literature on IVM that makes

connections to animal agriculture, and to argue that these connections pose significant challenges for IVM to significantly diminish, let alone replace, (industrial) animal agriculture. Articles in this review essay were largely chosen based on the list of articles from my comprehensive examination that focused on the topic of IVM and included some history of animal agriculture. Articles were compiled along the lines of the following criteria: (1) earlier articles I consider particularly foundational to the study of IVM, (2) relatively recent publications on IVM that present the most recent thought on the subject, (3) articles in between "early" and "recent" periods that are of particular importance to the field of IVM as a whole, and (4) Google Scholar searches (under various names of IVM) for articles that somehow mentioned or indicated connections to animal agriculture in their titles or abstracts. My initial list was revised slightly after input from all four of my committee members. In reading these articles, I kept track of which peer-reviewed articles and books mention connections between IVM and (industrial) animal agriculture, and these sources were read with special attention paid to these connections. For the purposes of this review essay, "connections to animal agriculture" is conceived of broadly and include any mention of the practice of animal agriculture, the use of animals in IVM production (either direct or indirect), the (recent or historical) role of farmers, financial or strategic collaborations with the meat industry, or statements that alluded to some sort of potential alignment with animal agriculture [such as Shapiro (2018) referring to cellular agriculture as a "second domestication"]. Not wanting to be bound to a list created for a comprehensive exam, several additional works were chosen beyond this list *via* prior knowledge of their content, as well as through keeping up with recent publications on the topic of IVM. Sources that do not make the aforementioned connections are generally not discussed. Connections between cellular agriculture and animal agriculture were loosely grouped into categories of ideology, history, materiality, and collaboration with sections dedicated to expanding on these themes.

Some preliminary notes should be set forward before proceeding. First, I refer to animal cells grown in a lab by tissue engineering and cell culturing techniques as *in vitro meat*, IVM for short. This is because (1) *in vitro* highlights this distinction with *in vivo* which refers to work that is done with or within a living organism and (2) IVM is the original term, even though the industry widely eschews it now for multiple reasons (see Friedrich, 2019). The second note is that I view the roles of both nonindustrial animal agriculture and industrial plant agriculture as intrinsically posing problems from a vegan perspective (see below). Thus, IVM is problematized against all *industrial* agriculture, whether animal- or plant-based, and all *animal* agriculture, industrial or otherwise. Hence the phrase (*industrial*) *animal agriculture* will be used throughout this paper to highlight this orientation. When viewed through a vegan and total liberation lens as this essay does (see below), all connections between IVM and (industrial) animal agriculture are problematic and especially so when taken together. Others have critiqued IVM from a vegan perspective, as exemplified by the website <https://www.cleanmeat-hoax.com/>. While this website provides much useful information, it is not itself peer-reviewed and

contains information from a number of sources which were not peer-reviewed, as well as a number of quotes taken out of context. This review article extends such arguments by presenting newer information gleaned from peer-reviewed sources.

Total liberation is a concept theorized and empirically grounded by Pellow (2014) to refer to a politics that aims for maximal emancipation for humans, nonhuman animals, and the environment. Liberation in each of these domains is seen as essential to the others and conversely, any perceived liberation is incomplete if others are oppressed. Total liberation is rooted in an anarchist conception of autonomy such that individuals are viewed and treated as possessing and able to act under their own wills but not to an extent to which they impinge upon others' ability to do so. A similar concept to total liberation, known as "consistent anti-oppression" has been developed by Brueck and McNeill (2020). In Feliz's conception, consistent anti-oppression refers to the acknowledgment of interconnections between social justice groups (human and nonhuman) to consistently and effectively achieve liberation for all. In both Pellow's and Feliz's terms, total liberation/consistent anti-oppression implies a holistic, ethical veganism. Although views on veganism vary from a diet, to lifestyle, to social movement (Dutkiewicz and Dickstein, 2021; Lipnevič, 2021), many animal rights activists, especially in the more radical domains, view veganism as much more than a diet but as a political platform to resist all forms of exploitation. In particular, many Black and indigenous vegans "affirm that veganism is one key aspect of social justice needed to destabilize the same oppressive systems that keep us bound to it as marginalized people through the use of nonhuman animal exploitation" (Brueck and McNeill, 2020, p. 12). That is, while veganism can be expressed as an abstention of consuming animal products, it also entails abstaining from consuming products that exploit human animals (Pedersen and Stanescu, 2014). Thus veganism, as used in this paper, implies more than a diet, but a political movement and broader cultural critique of injustice (Giraud, 2021).

The paper proceeds with a short review of the IVM literature that presents its basic contours, then a short review of the literature on social transitions. For the purposes of this paper, social transitions refers to a body of literature on how structural changes happen in societies. This could be in terms of whole societies themselves, or substitute commodities such as new energy sources or food products, and the effects such substitutions have on social systems and the body politic. Next is a review and expanded discussion of a subset of IVM literature that focuses on connections between IVM and (industrial) animal agriculture. Then the essay sketches some major threads in the history of animal product development since the advent of modernity. Lastly there is discussion as to why such connections should be viewed as problematic especially, but not only, from a vegan viewpoint.

REVIEW OF THE LITERATURE ON IVM

The first academic articles appeared in 2002 and present contrasting narratives on IVM. Benjaminson et al. (2002) was a

NASA funded study researching ways to feed astronauts in space. The authors, all biologists, speak of meat and space exploration in glorious terms and a sense of belief in technological progress is noticed, along with an inevitability of meat consumption by humans. The article by artists Catts and Zurr (2002) was performative and philosophical, particularly aimed at challenging the nature-culture dualism. Catts and Zurr, unlike Benjaminson et al., are much more cautious and critical and ask if IVM technology should be used just because it can. Benjaminson et al. also killed the fish used for their experiments whereas Catts and Zurr obtained cells from a frog who was present—alive—at their tasting of IVM. That Benjaminson et al. are cited much more frequently than Catts and Zurr (who have several publications on the topic) may suggest a degree of fetishization of technology and meat rather than a propensity for caution and skepticism (Jönsson, 2017).

Since this pair of papers, the literature on IVM has evolved in a number of directions. Early publications largely consisted of overviews of the general IVM production process (Edelman et al., 2005; Hopkins and Dacey, 2008; Datar and Betti, 2010; Bhat and Fayaz, 2011; Post, 2012), environmental impacts (Tuomisto and Teixeira de Mattos, 2011; Tuomisto et al., 2014), or ethics (Pluhar, 2010; Welin and Van der Weele, 2012). These articles tended to present IVM in overall positive terms. For example, Hopkins and Dacey (2008) consider 13 possible objections to IVM and dismiss all of them. Similarly, Welin and Van der Weele (2012) ask if IVM will separate humans from nature and conclude that it will not.

It is also interesting to note that recent review papers of IVM deviate little if at all from earlier summary papers. Bhat et al. (2020) reads like that of Datar and Betti (2010). Stephens et al. (2019) mention that current industry challenges are essentially the same as those at the first IVM conference in 2008. Giles (2019) characterizes papers coming out at that time as repetitive. All of this leads Chriki and Hocquette (2020) to conclude in their own review article that IVM research and production has made no major advancements despite numerous publications.

The first openly critical peer-reviewed article on IVM appears to be that of Miller (2012). Like other critical papers that followed (Metcalf, 2013; Wood, 2014; Jönsson, 2016; Lee, 2018), Miller argues that the basis of the problems IVM purports to solve are left unchallenged if not strengthened. He also makes several theoretical connections to animal agriculture such as entrenching "carniculture" in terms of centering meat within human meals and minds, an instrumentalist approach to nonhumans, "real" meat becoming associated with (the upper) class while IVM is "relegated" to the lower classes, and questions the capitalist nature of technoscience to solve, frankly, anything. Similarly, more recent environmental evaluations of IVM have been less optimistic than the studies led by Tuomisto cited above (see Mattick et al., 2015; Lynch and Pierrehumbert, 2019).

Beginning around 2015, there began to be a suite of papers investigating consumer perceptions and possible acceptance of IVM (see Bryant and Barnett, 2018, 2020 for reviews). The most recent trend in the literature appears to be voices critical of the promises (and silences) of IVM proponents, the use of capitalism to drive IVM production and businesses, and partnerships with animal agriculture (Sexton, 2018; Sexton et al., 2019; Guthman

and Biltekoff, 2020; Helliwell and Burton, 2021; Howard et al., 2021; Lonkila and Kaljonen, 2021; Poirier, 2021). It is this concern of similarities and continuities of IVM with (industrial) animal agriculture that is the focus of this paper.

Jönsson (2016) gives some direct attention to the main theme of this paper. The present paper builds on Jönsson's argument and differs significantly by making different points, providing further details, and includes more recent developments. In his paper, he noted that historical developments in meat production create a continuous story with IVM as the latest point in this trajectory and even points out how IVM can be positioned as the logical endpoint of (industrial) animal agriculture, while citing Driessen and Korthals (2012) who say this explicitly. Jönsson, though, rests his argument on the supposed human "need" for meat and focuses more on IVM's ontology, and the ambiguity therein, to show how IVM both continues and breaks from previous discourses of meat. Jönsson also balances the similarities and differences of IVM to traditional meat to examine continuities and contrasts. In this review essay, I depart from Jönsson by focusing on the continuities. In 2016, Jönsson also published before cellular agriculture industries began partnering with (industrial) animal agriculture for financial investment and development assistance. Jönsson focuses on how promissory discourse of IVM draw on the history of traditional meat whereas this review essay will examine how likely such promises are to be fulfilled based on this same continuity. In these ways, this review essay extends and elaborates on Jönsson's earlier paper.

SOCIAL TRANSITIONS

Before moving into the review essay proper, I first introduce the theoretical viewpoint in which IVM will be evaluated, that of social transitions. In sociology, there is a classic model known as "stadial progression" that hypothesizes that societies transition from certain modes of productivity to more advanced ones. A typical progression might be: gatherer-hunter to agrarian to industrial to post-industrial. At each step, productivity increases and humans are said to become more "civilized." This model also envisions this order to be linear and essentially inevitable. However, Graeber and Wengrow (2021) recent book upends these assumptions by showing that such a model is socio-politically contrived and historically inaccurate. Historically, there are not energy transitions but successive additions of "new sources of primary energy" (Bonneuil and Fressoz, 2017, p.101). At best, the stadial progression model reveals that newer stages industrialize previous stages but do not replace them (Marouby, 2020).

Environmental sociologist Richard York, over a series of papers, has written on "transitions" and substitutions of energy sources and meat consumption. He makes a distinction between energy additions (new sources of primary energy) and substitutions (genuine decline of energy use) (York and Bell, 2019). From his research, he concludes that energy "transition" is a misnomer in that these claims tend to focus on proportional use of a particular energy source, not overall energy use, echoing Marouby's account of stadial progression. Reasons for this lack of

proper transitions lie in the complexity of economic and social systems. Various social dynamics create and sustain hegemonic trajectories. Various paradoxes also help to explain why increased efficiency or the existence and even use of substitutes often do not proportionally displace previous resources and may even increase their use (Greiner et al., 2022). Instead, there is a global and historical trend for new resources to act as additions to overall consumption.

Closer to the relevance of this paper, York (2021) presents case studies as examples of the failure of alternate resources to displace previous ones. One is that lower environmental impact meat sources (chicken, invertebrates) only marginally displaced higher environmentally impactful meat sources (cows, pigs); another is that aquaculture has failed to decrease wild caught fish. Both scenarios have acted more as additions to overall consumption rather than replacements. The concept of transitions has also been used by IVM proponents to encourage development and eventual consumption of IVM. As covered elsewhere (Poirier, 2021), IVM proponents have proffered the advent of automobiles and petroleum as replacements for horse carriages and whaling, respectively. Both are claimed as major victories for nonhuman animals. Yet both uncritically neglect the myriad widespread negative effects resulting from automobile and petroleum extraction, production, and use, specifically to nonhuman animals and the environment (but also to human animals, see Poirier and Tomasello, 2017). Also, not incidentally, "Preventing the extinction of whales required the suppression of whaling, not per se the development of substitutes for whale products" (York, 2017, p. 2).

CELLULAR AGRICULTURE AS THE HISTORICAL OUTGROWTH OF (INDUSTRIAL) ANIMAL AGRICULTURE

To understand how IVM can represent the epitome of (industrial) animal agriculture it is helpful to look at the history of animal agriculture. For much of human history, raising, butchering and consuming animals was a private affair. This began to change with the advent of modernity in the nineteenth century. Buscemi (2018) notes two historical themes in the history of meat production centuries in the making: the separateness and opposing characterization of nature and culture, and the separation of animals from meat. As the latter happened, meat became more cultural, increasingly viewed as a human construct apart from nature. Such trends have occurred at multiple sites: on the table, in the kitchen, at the market and in the slaughterhouse (Buscemi, 2018, p. 29). Each subsequent stage in the evolution of meat—hamburgers, fast food, cutification of animals, tinned/boxed meat—helped separate animals from meat (Buscemi, 2018, p. 81). Such developments also reduce animals more toward objects, or, one might say, toward IVM.

The same trends are seen in the development of the modern slaughterhouse (Lee, 2008) and milk production (Nimmo, 2010). Sociologist Nimmo (2010) study tells the history of modern dairying in the UK. He focuses specifically on how diseases associated with dairy production were controlled in an effort to

“purify the social,” retain the uniqueness of human agency, and (re)establish human supremacy over nonhumans, particularly bacteria. Analogously, chapters in Lee’s edited book present the history of development of modern slaughterhouses over nearly the same time period as Nimmo, roughly 1800-1900. The histories presented by Nimmo and the contributors to Lee’s volume coincide in many respects. Slaughterhouses and dairy production became centralized, scientifically managed, public facilities supplying urban areas with “clean” meat and milk. The dominant discourse was directly tied to public health with public officials often overseeing funding, construction, and regulation. Rhetoric of cleanliness and disease control drove the removal of slaughterhouses from urban centers to the periphery (Vialles, 1994; Lee, 2008). This reasoning was also used to justify using technology to more humanely and hygienically slaughter animals and produce meat and milk. All of this was done largely, although not entirely, to enforce human mastery over nonhumans, reinforcing and reifying the human-nonhuman and Nature-Culture binaries (Nimmo, 2010). Removing slaughter from view created a distance between people and meat (Lee, 2008). Moreover, locating slaughter facilities closer to areas of production was considered more efficient, “the reason being that transporting” inanimate animal products “tends to pose fewer practical problems than transporting live cattle” (Vialles, 1994, p. 10). Echoing Buscemi (2018), Rochechouart was the last slaughterhouse to retain visual notions of the animals; going forward, “the slaughterhouse had to become a factory system, casting cows and sheep not as animals but as meat waiting to be harvested” (Lee, 2008, p. 61, 62).

All this is to say that, when viewed historically—the reduction of animals to meat, increased technological control over animal bodies, the removal of slaughter from sensory experience—these trends and characteristics point to IVM as an outgrowth of (industrial) animal agriculture. Given the centuries long and ever greater separation of humans from animal slaughter and meat production, even an apparent unnaturalness of IVM may be a benefit to (industrial) animal agriculture as this overcomes physical constraints of traditional meat: “In fact, what *in vitro* meat would do is to create a new physical reality that actually does match up with the self-deceptive and self-serving situation many consumers already imagine when they buy meat at a grocery store” Hopkins and Dacey (2008, p. 594). Jönsson (2017, p. 851), adds that “Cultured meat attempts to subsume animal bodies to animal-agricultural priorities.” Galusky (2014) connects IVM and control to the history of meat production by noting how simplified animals and animal products are only possible through increasingly complex human systems premised on more control. It would seem as if IVM has been what the meat industry has been developing toward historically, albeit without necessarily knowing it.

It is worth noting that the point could be raised that IVM would theoretically drastically reduce (if not eliminate) animal slaughter and animal suffering. *Theoretically*, yes. This is why the ethical grounding for IVM seem so strong and may even be viewed as in line with vegan values (I am currently developing a paper on this). But the main point of this paper is to highlight why that outcome is not likely to materialize (see also Poirier, 2021).

Secondly, this paper would argue that the continuities of cellular agriculture outweigh the value of theoretical discontinuities. Even if such an outcome were to be achieved, there are still pragmatic and ethical grounds for skepticism in terms of reducing human impact on earth and other nonhuman animals (see Poirier and Russell, 2019 for such a critique) especially if an IVM transition is not accompanied by a revolution in human consciousness toward nonhumans, which IVM does not currently seem to promote.

IVM causes animals to lose their “otherness” and this is an extension of technologically driven meat production. Given this trajectory, Buscemi states that “It [IVM] may be the final stage of the separation between meat and the animal” (2018, p. 143). Likewise, Neo and Emel (2017, p. 1) present three “turning points” of animal agriculture. The first is domestication, then industrialization, and finally IVM. They state: “The detachment of animals from humans and ‘nature’, as well as their progressively intensified commodification, arguably comes to its most extreme conclusion with the introduction of synthetic meat.” Similarly, Shapiro (2018, p. 10) uses the term “second domestication” to describe the turn toward IVM, creating linguistic continuity between traditional agriculture and IVM (also sometimes referred to as “cellular agriculture”).

DIRECT CONNECTIONS BETWEEN IVM AND (INDUSTRIAL) ANIMAL AGRICULTURE

There have been connections between IVM and animal agriculture at almost every step of IVM’s history. A major link is the use of calves’ blood, also known as fetal bovine serum (FBS). FBS is obtained by draining blood from fetal calves of dairy cattle at slaughterhouses. The blood is allowed to clot and is then centrifuged to remove the clot and any remaining red blood cells. The clear yellow substance left over is fetal bovine serum (Jochems et al., 2002). FBS was used and sourced from slaughterhouses in the first test case of IVM (Benjaminson et al., 2002), the first time IVM was consumed (Catts and Zurr, 2002), in the 2013 London tasting event of the first cultured burger (Simonsen, 2015), and in the first IVM products sold commercially in December 2020 (Stephens, 2021). Regarding the 2013 IVM public tasting event, Posts’s research leading to the tasted burger was built on research that included Dutch meat producers Meester Stegeman (Jönsson, 2016). O’Riordan et al. (2017, p. 151) further note that egg and butter were used in the burgers for this event. Thus, FBS has played a fundamental role in building and IVM industry while simultaneously helping (industrial) animal agriculture.

Vasile Stanescu pushes the connection to FBS further in the 2019 debate on IVM at the Conscious Eating Conference (United Poultry Concerns, 2019). FBS requires killing a pregnant cow and draining the blood from her fetus. Thus, animal agriculture and slaughterhouses are necessary components of IVM that uses FBS. Stanescu says that to produce enough FBS to culture IVM presently, 200 million fetuses are needed per year (and growing). Since the advent of IVM research, factory farms have increased their price for FBS by 300% and FBS is “currently the

single most profitable item that a factory farm sells” (Stanescu, quoted in United Poultry Concerns, 2019). In this way, IVM has been beneficial for animal agriculture. Thus, Simonsen (2015) argues that scaling up of IVM would necessitate a large animal agriculture industry from which to obtain FBS. In a similar vein but from a different angle, Mouat and Prince (2018, p. 319) state that “Animal-free food as we know it does not exist without large-scale animal agriculture.”

It is imperative to acknowledge that the cellular agriculture industry has repeatedly stated that IVM will not be viable without a plant-based alternative to FBS, and that nearly everyone involved in the research and industry landscape of IVM is working on various forms of plant-based alternatives. In fact, Mosa Meats has announced they have found a plant-based alternative to FBS (Messmer et al., 2022). However, a close reading of this article reveals that the serum-free media helped in cell proliferation but failed to substantially produce myotubes. In muscle development a cluster of muscle cells is not sufficient, cells must come together and form myotubes which are the structure of muscle. The study is also limited in that it applies to a single species. Messmer et al. (2022) note both limitations, as well as others. While the authors conclude that a plant-based culture medium “is an important step toward the realization of cultured meat” (Messmer et al., 2022, p. 81), it does not yet indicate that the industry as a whole can cleave itself away from its tether to (industrial) animal agriculture *via* FBS. An important point here is that—at least from the author’s perspective on total liberation—it cannot be considered vegan to create an IVM industry having built its foundation on FBS, even if it is eventually abandoned (see also Simonsen, 2015; Poirier and Russell, 2019 for fuller arguments on this point). This constitutes the knowing financial support of an industry whose sole purpose is to slaughter nonhuman animals for/as food. A key notion of total liberation is to not aid in the oppression of some while attempting to liberate others. There is a fundamental ethic of non-harm as no one is in a place where they can objectively say that some lives are expendable and others are worthy of protection.

Numerous papers note the various animal agriculture investments in various IVM companies and technology, as well as collaborations between these two sectors (Mouat and Prince, 2018; Burton, 2019; Stephens et al., 2019; Painter et al., 2020; Purdy, 2020; Howard et al., 2021; Poirier, 2021). Stephens et al. (2019, p. 7) remark that this trend has been emerging since 2017 and that “These developments represent strategic investments by the major incumbent players to keep track of the emerging sector; to ensure they are the disruptors, not the disrupted.” There has also been a concomitant softening of rhetoric to “transform” the food system rather than disrupt it. Similarly, to help guard against being disrupted and to bring IVM into their business models, animal processors have begun a change in rhetoric, referring to themselves as “protein” companies (Purdy, 2020, p. 166; Howard et al., 2021). This is corroborated by Broad (2020) who says that a goal of alternative animal product companies is to get in with “dominant structures of the food system” (927), and quotes Tyson’s chief investment officer as saying their investment in alternative animal products is to protect their own long-term sustainability. Poirier (2021) found identical results at the 2018

and 2019 Good Food Conferences and provides many explicit quotes from industry insiders to this effect.

Taken together, this presents clear evidence that (industrial) animal agriculture, as a whole, does not plan on significantly reducing the number of animals they slaughter, so it would seem unwise (and certainly anti-vegan) to pursue some sort of animal liberation through industries staunchly premised on slaughtering animals. The rhetoric used by industry stakeholders suggest IVM would function as an addition to existing animal meat, not a transition away from it. Guthman and Biltekoff (2020), like Jönsson (2016), discuss the theme of alternative animal products being promoted as similar to yet different from traditional animal products, easily representing the logical endpoint of current meat production: IVM is both similar enough to retain the positive associations of traditional meat, while different enough to address animal welfare concerns and remediate environmental problems. So while there may be similarities and differences, the similarities appear to carry on many of the problematic aspects of meat consumption and do not encourage a shift in consciousness needed for systemic change. Helliwell and Burton (2021, p. 186) note a near complete silence on mechanism(s) of IVM proponents and startups to target (industrial) animal agriculture in order to disrupt or replace that industry. In short, IVM proponents do not outline how to transition beyond farming. A transition should be just for all parties, which necessitates a vision. A lack of a vision makes one wonder how such a “cellular revolution” will come about. Helliwell and Burton (2021, p. 183) observe that removing animals from the land based on ethical animal welfare and/or liberation concerns sits somewhat problematically alongside visions of “a purely technocentric, reductive and utilitarian perspective on animal bodies.” The authors note there are many uses for animal products, so abolition of animal agriculture also needs to be accompanied by an expansive vision that includes many social institutions. From a vegan and total liberation standpoint, the goal would be to abolish the meat industry, not help sustain it or its ideology. The lack of a vision around these issues is indeed troublesome.

Also of note is the collaboration of Memphis Meats (at the time, but now Upside Foods) and the North American Meat Institute (NAMI) in petitioning the U.S. government to set up federal regulations on IVM as meat (Stephens et al., 2019, p. 11; see also Howard et al., 2021, and Purdy, 2020, p. 176,177 on the Memphis Meats/NAMI collaboration). Gertenbach et al. (2021) note that IVM has somewhat split the vegan community and created alliances between some animal protectionists and animal agriculture, such as the Memphis Meats/NAMI collaboration (see also United Poultry Concerns, 2019; Poirier, 2021). Given the foregoing, it is not surprising when Mouat and Prince (2018) highlight the bind alternative animal products are in: they both reject animal agriculture yet depend on it for their existence, potential consumers, and financial support. It is difficult to see how the IVM industry would aim to replace (industrial) animal agriculture if it depends on it for its own existence. Bhumitra and Friedrich (2016) says animal agriculture developed through decades of putting profit before ethics but that IVM can help produce both. This sounds like the pinnacle of (industrial) animal agriculture thinking. Shapiro (2018, p. 24) makes the same point

in saying that maybe animal agriculture and activists can both win through IVM. Many of these connections are not incidental but strategic, as admitted by Friedrich, Shapiro and others (see also Garces in *United Poultry Concerns*, 2019). To wit, at 2018 Good Food Conference, GFI, whose president and CEO is Bruce Friedrich, began adopting the term “cell-based” meat in order to not offend the meat industry (Ong et al., 2020, p. 226).

Another point of connection between animal agriculture and IVM is that of cell biopsies. Stephens (2013) notes that the cell procurement process from living animals is not a part of the IVM production process that is likely to disappear. Ong et al. (2020) claim IVM should not be labeled animal free unless (1) cells used come from a single biopsy (immortal line) and (2) no other animal ingredients are used. Both of these conditions are still unmet. An immortal cell line has not yet been developed, nor has a growth serum alternative for FBS that is efficient and cheap enough to culture meat at appropriate scales to significantly “disrupt” animal agriculture. So far, IVM remains tethered to animal agriculture in at least two fundamental ways, even in light of potential plant-based culture media (Messmer et al., 2022). If biopsies are needed, this requires ready access to animals who will have to be suitable to extract cells from (cleanliness, healthy, etc). This will necessitate farming animals as cell “donors” and likely quite a few, as Melzener et al. (2021) suggest, to maintain genetically viable herds and to ensure cell supply for ever-growing meat consumption.

Stephens et al. (2019) raise the issue that IVM may end up just being an addition to traditional meat, which would void any environmental or animal welfare benefits. They admit that current IVM proponents are motivated by altruism but realize they may be swayed by other motives or new players (e.g., the meat industry) who may not be altruistic, and that proposed benefits are not inherent to the technology itself. Another point concerns regulation. In 2019, the United States decided that the FDA and USDA would share regulatory responsibilities for IVM. A potential issue is that the USDA has an obligation to promote animal agriculture which would give this sector influence in IVM regulation (Purdy, 2020, p. 170). Sexton et al. (2019) note that the US Cattlemen’s Association first said “meat” should exclude IVM but then explicitly said it should be called meat, albeit with conditions (61). Thus, the influence and control of the emerging IVM sector by the meat industry is cause for concern as the incumbent sector is likely to use the emerging sector for its own benefit (for an overview of this phenomenon, see LaVeck, 2006). IVM, under influence from (industrial) animal agriculture, could go the way of the electric vehicle which was bought up and stifled by the incumbent automobile industry a century ago. A subset of the literature on IVM concerns ways in which animal agriculture can remain viable if IVM were to capture a significant amount of the (industrial) animal agriculture market (Bonny et al., 2015; Burton, 2019; Melzener et al., 2021; Newton and Blaustein-Rejto, 2021).

There are many scenarios in which IVM and traditional meat are envisioned to coexist. Rather than eliminating (industrial) animal agriculture, Bonny et al. (2015) suggest ways for animal producers to deal with animal welfare to remain viable, including redesigning husbandry systems, using conventional breeding

technologies, genetic selection, cloning, genetic modification, and agroecology. Large enterprises are most able to incorporate alternative animal products and respond to consumers quicker which may lead to a further concentration of animal agriculture (Howard et al., 2021), a trend in animal agriculture that has been happening for some time (Howard, 2021). Burton (2019, p. 42) thinks that one key problem for livestock producers to retain viability is in retaining their “natural” appeal. He advises incumbent industries to prepare now, and not to be complacent and then surprised by a quicker transition. In interviews with 37 people involved in or concerned about alternative animal products, Newton and Blaustein-Rejto (2021) find more opportunities than threats for animal agriculture to remain viable given IVM. Opportunities consist of growing ingredients for plant-based meat, growing inputs for components of IVM production, raising cell donor animals, operating bioreactors on-farm, farmers could diversify or transition, rejuvenated value on high welfare farms, create blended products or products from cultured components, obtain jobs in alt-meat production facilities, improve pollution in rural environments from meat facilities, or receive payments for ecosystem services from freed up land. Allowing for a variety of scenarios to materialize, Melzener et al. (2021, p. 10) conclude that “In any of these scenarios, a combination of cultured meat production with ongoing conventional meat production can be considered.” Thus, there are many ways in which IVM could help sustain meat production. This is a troubling state of affairs for those wishing and working to dismantle the meat industry, especially in light of the fact that vegan food exists in relative abundance and, despite massive subsidies given to the meat industry, are already relatively cheap.

IDEOLOGY AND MATERIALITY: THE INDUSTRIAL LOGIC OF CELLULAR AGRICULTURE

IVM ideologically functions as an extension of industrial and animal science approaches to food production and environmental relations through continuities that exist between these technologies and meat production. From a perspective that takes this context and continuities seriously—such as a vegan and total liberationist lens—turning to IVM to address the various harms of (industrial) animal agriculture can be perceived as problematic in that proponents rarely encourage humans to view nature as anything more than a mere means of achieving human ends, or contest the notion that meat consumption will always be eminently and inevitably desirable. Whether implicitly or explicitly, IVM proponents generally endorse this instrumental conception of the natural world (Miller, 2012; Helliwell and Burton, 2021; Poirier, 2021). IVM attempts to solve many of the problems associated with the production and consumption of meat by furthering the logic that motivates and justifies the instrumentalization of animals. The technologies that made (industrial) animal agriculture possible are often considered the source of our crisis in current agriculture. In this context,

technology is viewed as both the problem and the solution (Anthos, 2018).

The logic of industrial agriculture is to maximize desired output (e.g., protein, calories, taste, amount of meat) while minimizing costs through greater efficiency. When this is applied to living animals, it results in the current inhumane system where animals have been bred to maximize edible meat (Neo and Emel, 201, p. 52–55). This instrumental logic encourages producers to shape and manipulate animal bodies to achieve their desired outputs. There are biological and constraints that limit how much animal bodies can be instrumentalized and controlled in this manner, however. For example, high rates of lameness and mastitis occur in dairy cows when producers breed cows to produce more milk at the expense of their welfare. Similarly, chickens bred for high egg production have weakened skeletal systems as calcium is leached from their bones during the production process (Twine, 2013, p. 145). In other words, (industrial) animal agriculture is becoming forced to consider animal welfare and/or alternative production methods in order to continue basic operations. Therefore, there are incentives for (industrial) animal agriculture to eliminate “inefficiencies” of using live animals in production and incorporate or transition to IVM.

The aim of industrialization is to “modify the problems out of the body” (Galusky, 2014, p. 936). IVM represents the epitome of this by attempting to eliminate animals from the meat making process. Instead of dealing with the various biological constraints and vicissitudes of animals piecemeal, IVM attempts to circumvent them all at once by eliminating the animal body. In (industrial) animal agriculture, many typical biological functions appear as problems to be overcome through scientific and technological ingenuity. Here, even the natural process of growing muscle is considered inefficient. Meat can be made more efficient by eliminating the practical and ethical messiness associated with housing, raising, transporting and processing living beings (Vialles, 1994; Anthos, 2018).

In (industrial) animal agriculture, whenever a perceived production or efficiency problem arises, the goal is to engineer the problem out of the animals themselves, rather than reflecting critically on the appropriateness of the expectations placed on the bodies of animals. Some examples include:

- Debeaking, de-toeing, dehorning, ear-cropping, tail-docking, castrating, and mutilating the teeth of animals to prevent them from hurting or killing each other in captivity (Davis, 2011).
- Making animals more docile by reducing sentience in cows, reducing nesting instincts in chickens, and producing pigs without legs (Fox, 1992).
- Creating a “featherless chicken” to produce animals more tolerant of hotter climates (Bennet, 2002).
- Breeding blind chickens who are less sensitive to overcrowding (Dickenson, 2007).
- An attempt to genetically engineer animals to not experience pain (Shriver, 2009).
- Breeding dairy cows to be emotionally indifferent to separation from their newborn calves (Gaard, 2017, p. 64).

Metcalf (2013) (p. 83) summarizes this logic:

If you want to make meat without feces in it, engineer a cow that has no digestive system. If you want to have meat without diseased brain matter, engineer a cow that has no brain. If abusive labor conditions in slaughterhouses result in poor food safety, then grow meat in a bioreactor factory.

Similarly, in investigating the growing trend of eating insects, Sexton (2018) finds that body parts not considered desirable are removed, a consumer-led phenomenon. What is important here is the parallel to animal agriculture: removing parts of animals deemed “undesirable,” for whatever reason (inefficiency, consumer disgust), leaving just the “meat.” In light of this, IVM represents the logical end point of (industrial) animal agriculture both ideologically and materially.

The above examples illustrate how animal bodies are engineered and mutilated so they are less sensitive to conditions of confinement and abuse; animal mental, emotional, and sensory capacities are recognized to the extent that they can be manipulated. In light of these efforts to control the bodies of animals, it seems that the ultimate goal of industrial farming culminates with the advent of IVM, which is characterized by the decoupling of animal bodies and their physiological constraints (and ethical concerns associated with sentience and sapience) from the desired industrial output—flesh. Thus, it is understandable why Marder (2016), in a chapter titled “Meat without Flesh” calls IVM “pure meat” and “meat to the nth degree.” Given the foregoing discussion, Poirier (2018b) “meat continuum,” in which IVM was positioned exactly in the middle of veganism and (industrial) animal agriculture could be conceptualized in an alternate way, with IVM positioned at the far (left) end of this continuum, representing (industrial) animal agriculture taken to its logical extreme. It is important to note here that this is not an idea that those in the (industrial) animal agriculture industry would likely support. The rhetoric from that community is closer to what was discussed earlier, in that they see IVM as potentially part of a broader stream of protein sources, rather than as the ultimate goal. However, I believe it is not erroneous to frame IVM in this way. There may be multiple ways to view and position IVM, and each may be valid [see comments on the meat continuum in Poirier (2018b), and above]. In terms of ideology, materiality, and history, the trends can be argued to point toward IVM even if the meat industry does not desire or want to acknowledge this, and even if they resist in practice.

This continuation of industrial logic sweeps aside the need to engage with important questions regarding non/human relations and how the goal of increasing efficiency for the sake of profit shapes these relations. In current discussions regarding the promise of IVM:

The ethical questions surrounding eating meat are not so much engaged as eliminated. People are not asked to confront the ethics of eating meat—whether in the basic question of killing animals, or in the technologically mediated question of the human, animal, and ecological stresses exacerbated by industrialized systems and capitalist logics (Galusky, 2014, p. 937).

Similarly, Metcalf (2013, p. 83) questions whether “our moral obligations to reduce suffering (and other harms) necessarily leads to a world in which *“organisms that can suffer are engineered out of it”* (emphasis original). In a sense, the history and practice of (industrial) animal agriculture is to remove every part of the animal—material and mental. At its base, all that really matters, or all that is really valued, is the meat. Simply put, there does not seem to be room for coexistence involving interspecies mutual autonomy. This sentiment may behind Simonsen (2015, p. 20,21) bleak dictum that: “[c]ruelty-free meat may simply be another element of the fantasy that humanity will ever be able to dwell with and among other species equitably.” To a significant extent, plant-based meat products and veganism have been co-opted by mainstream approaches involving capitalism and animal exploitation industries (Giraud, 2021; Howard et al., 2021). I see no reason why IVM would be different.

While many links to traditional agriculture have been pointed out in the literature, most papers tend to focus only on certain components. This essay aimed to go further by creating a comprehensive picture pointing out just how deeply IVM is connected to conventional systems and that it always has been. The purpose of drawing together all of these connections and making them explicit is to argue that, despite being promoted as transformative, revolutionary, and in square opposition to animal agriculture, IVM is not all that different from the existing meat industry in many important ways. Nor does it seem to envision separating these ties in the future. In terms of practice, it has never really been separate from it. In terms of history, it seems to fall right in line. Many authors critical of IVM do not state their ethical orientation, so it is difficult to tell if critiques come from an animal liberation perspective or one of defending animal agriculture. These are opposite viewpoints but both can critique IVM. Authors would do well to state their intentions and positionality when critiquing IVM.

DISCUSSION AND CONCLUSION

So, is cellular agriculture different from animal agriculture? Of course, in certain ways they are necessarily different. Indeed, some of the actors are different; IVM is more centralized around certain urban hubs such as Silicon Valley in California; IVM is only newly for sale (and therefore its share of the market is vastly smaller than that of animal agriculture); and some proponents of IVM do explicitly call for eliminating animal agriculture (Poirier, 2021). Particularly, IVM advocates emphasize how the mode of IVM *production* differs from traditional meat production—that the animal is (essentially) absent (Volden and Wethal, 2021). To be sure, this is a site of significant departure. Yet there is still nuance here. It matters on who is doing the producing, and different production methods as well as scale affect the efficacy of cellular agriculture production. If animal agriculture is doing the producing or has significant influence over it, the products will reflect their priorities. However, it is not particular differences this paper is concerned about. Rather, it focused on the many and problematic similarities. IVM proponents, taken together as an

industry, seem to be less concerned with diminishing animal agriculture than with building their own market sector. In light of prevailing sociological evidence of previous transitions (York, 2012, 2021), new sources of energy or food products often do little to reduce established energy or food sources. While these quantitative studies are (necessarily) more tangential to the situation of IVM (given its negligible commercial availability), qualitative empirical work focused on alternative animal products supports their general conclusions (Howard et al., 2021; Poirier, 2021).

Regardless of differences, this essay traced out connections between IVM and (industrial) animal agriculture. From a vegan perspective, animal agriculture is obviously problematic on many fronts. Therefore, it is the similarities that will likely be more concerning about the nascent IVM industry than its differences. Thus, based on an exploratory review and analysis of existing literature that spans twenty years of publications on IVM, this paper positioned IVM as the logical endpoint of (industrial) animal agriculture historically, materially, and ideologically. It was argued that this connection is important in framing the future of IVM and the fate of farmed animals and the environment. IVM has grown out of the same history and evolution of (industrial) animal agriculture and now also involves many (but not all) of those same players and tactics (e.g., capitalism). The thought process and materiality of reducing nonhuman animals to their meat are carried through to their logical extremes in IVM. These connections are too many and too close to believe that IVM will make any positive changes to the current environmental (which are really social) crises. It leaves one wondering how meaningful differences actually are (or will be). They also point to IVM likely acting as an addition to industrial animal agriculture. This sentiment was expressed clearly many times throughout the 2018 and 2019 Good Food conferences (see Poirier, 2021 for additional examples). For instance, during the 2018 panel titled “Building an Emerging Industry: Insights from Clean Meat Startups,” Niya Gupta of Fork & Goode (a cellular agriculture company) plainly states: “I wouldn’t see our industry supplanting or replacing much of traditional agriculture.” Therefore, IVM could act as a financial or geographical prop for the meat industry to grow by diversifying their “protein” offerings and projecting a message of sustainability in a co-optation of IVM rhetoric.

As IVM is a quickly evolving landscape, the similarities and differences discussed in this paper are open to change. In particular, animal-free growth serum could be developed as this is indeed a serious line of research (Ferrer, 2021), bringing IVM closer towards veganism. Also, innovations could lead to the possibility of an “immortal” cell line, cells that can multiply indefinitely from a single biopsy. Both developments, and their potential use in the industry, would constitute further differences between cellular and animal agriculture. Climate change will also likely be a highly variable influence on both cellular and animal agriculture. Climactic and land-based changes due to global warming may force the animal agriculture industry to downscale. This may help create a “natural” market for IVM products to

replace farmed animal products. By the same token, those in the IVM industry who resolutely call for the diminishment or disappearance of animal agriculture could change their rhetoric in the future, especially if faced with lucrative financial opportunities from meat processors (Stephens et al., 2018, p. 164).

Carefully considering the continuities between IVM and traditional meat is crucial when considering whether promoting IVM is a prudent approach to addressing problems associated with (industrial) animal agriculture. As industrial modes of thinking are already (and always have been) influencing IVM development, industrial priorities will shape it as well, making Terhaar's urging that opened this essay exceedingly important and deserving of focused and ongoing attention. The cumulative number and extent of the connections covered in this essay makes one wonder just who will benefit with the advent of IVM.

REFERENCES

- Anthos, V. (2018). *Meat Reimagined: The Ethics of Cultured Meat*. [master's thesis]. [Missoula (MT)]: University of Montana.
- Benjaminson, M. A., Gilchrist, J. A., and Lorenz, M. (2002). In vitro edible muscle protein production system (mpps, Stage 1, fish. *Acta Astronautica* 51, 879–889. doi: 10.1016/S0094-5765(02)00033-4
- Bennet, J. (2002). *Cluck! Cluck! Chickens in Their Birthday Suits!* *New York Times*. Available online at: <https://www.nytimes.com/2002/05/24/world/rehovot-journal-cluck-cluck-chickens-in-their-birthday-suits.html> (accessed January 5, 2021).
- Bhat, Z. F., Bhat, H., and Kumar, S. (2020). "Cultured Meat—A Humane Meat Production System," in *Principles of Tissue Engineering* (5th Edition), eds R. Lanza, R. Langer, J. Vacanti, and A. Atala (London: Academic Press), p. 1369–1388.
- Bhat, Z. F., and Fayaz, H. (2011). Prospectus of cultured meat—advancing meat alternatives. *J. Food Sci. Technol.* 48:2, 125–140. doi: 10.1007/s13197-010-0198-7
- Bhumitra, J., and Friedrich, B. (2016). "The future of animals, the future of food: two organizations endeavor to change public attitudes and appetites," in *The Future of Meat Without Animals*, ed. B. Donaldson and C. Carter (Lanham, MD: Rowman and Littlefield), 111–120.
- Bonneuil, C., and Fressoz, J.-B. (2017). *The Shock of the Anthropocene: The Earth, History and Us*. Brooklyn, NY: Verso Books.
- Bonny, S. P. F., Gardner, G. E., Pethick, D. W., and Hocquette, J.-F. (2015). What is artificial meat and what does it mean for the future of the meat industry? *J. Integr. Agric.* 14, 255–263. doi: 10.1016/S2095-3119(14)60888-1
- Broad, G. M. (2020). Making meat, better: the metaphors of plant-based and cell-based meat innovation. *Environ. Commun.* 14, 919–932. doi: 10.1080/17524032.2020.1725085
- Brueck, J. F., and McNeill, Z. (2020). *Queer and Trans Voices: Achieving Liberation Through Consistent Anti-Oppression*. London: Sanctuary Publishers.
- Bryant, C., and Barnett, J. (2018). Consumer acceptance of cultured meat: a systematic review. *Meat Sci.* 143, 8–17. doi: 10.1016/j.meatsci.2018.04.008
- Bryant, C., and Barnett, J. (2020). Consumer acceptance of cultured meat: an updated review (2018–2020). *Appl. Sci.* 10, 5201. doi: 10.3390/app10155201
- Burton, R. J. F. (2019). The potential impact of synthetic animal protein on livestock production: the new 'war against agriculture'? *J. Rural Stud.* 68, 33–45. doi: 10.1016/j.jrurstud.2019.03.002
- Buscemi, F. (2018). *From Body Fuel to Universal Poison: Cultural History of Meat, 1900-The Present*. Cham, Switzerland: Springer.
- Catts, O., and Zurr, I. (2002). Growing semi-living sculptures: the tissue culture and art project. *Leonardo* 35, 365–370. doi: 10.1162/002409402760181123
- Chriki, S., and Hocquette, J. F. (2020). The myth of cultured meat: a review. *Front. Nutr.* 7, 1–9. doi: 10.3389/fnut.2020.00007

AUTHOR CONTRIBUTIONS

NP wrote the draft of this manuscript, performed analysis, and approved the submitted version.

FUNDING

Publication of this research is supported by the Food and Agriculture Institute at the University of the Fraser Valley and the Social Sciences and Humanities Research Council of Canada but had no bearing on the content of the article.

ACKNOWLEDGMENTS

I would like to thank Richard Giles for reading and commenting on an earlier draft of this paper, and Evan Bowness for working on this special issue.

- Datar, I., and Betti, M. (2010). Possibilities for an in vitro meat production system. *Innov. Food Sci. Emerg. Technol.* 11, 13–22. doi: 10.1016/j.ifset.2009.10.007
- Davis, K. (2011). "Procrustean Solutions to Animal Identity and Welfare Problems," in *Critical Theory and Animal Liberation*, ed. J. Sanbonmatsu (Lanham, MD: Rowman and Littlefield), pp. 35–54.
- Dickenson, P. (2007). *Insight into Light and Reproduction: Researcher Delves into Why Blind Chickens Perform Better*. *Canadian Poultry*. Available online at: <https://www.canadianpoultrymag.com/insight-into-light-and-reproduction-861/> (accessed January 5, 2021).
- Driessen, C., and Korthals, M. (2012). Pig towers and in vitro meat: disclosing moral worlds by design. *Soc. Stud. Sci.* 42,797–820. doi: 10.1177/0306312712457110
- Dutkiewicz, J., and Dickstein, J. (2021). The ism in veganism: the case for a minimal practice-based definition. *Food Ethics* 6,1-19. doi: 10.1007/s41055-020-00081-6
- Edelman, P. D., McFarland, D. C., Mironov, V. A., and Matheny, J. G. (2005). Commentary: in vitro-cultured meat production. *Tissue Eng.* 11, 659–662. doi: 10.1089/ten.2005.11.659
- Ferrer, B. (2021). *Aleph Farms and Wacker to Eliminate Fetal Bovine Serum from Cell-based Meat Equation*. *Food Ingredients First*. Available online at: <https://www.foodingredientsfirst.com/news/aleph-farms-wacker-to-eliminate-fetal-bovine-serum-from-cell-based-meat-equation.html> (accessed March 17, 2022).
- Fox, M. W. (1992). *Superpigs and Wondercorn: The Brave New World of Biotechnology and Where It All May Lead*. New York, NY: Lyons and Burford.
- Friedrich, B. (2019). *Why GFI Uses the Term "Cultivated Meat."* *Good Food Institute*. Available online at: <https://gfi.org/blog/cultivatedmeat/> (accessed April 29, 2022).
- Gaard, G. (2017). *Critical Ecofeminism*. Lanham, MA: Lexington Books.
- Galusky, W. (2014). Technology as responsibility: failure, food animals, and lab-grown meat. *J. Agric. Environ. Ethics.* 27, 931–948. doi: 10.1007/s10806-014-9508-9
- Gertenbach, L., Lamla, J., and Laser, S. (2021). Eating ourselves out of industrial excess? degrowth, multi-species conviviality and the micro-politics of cultured meat. *Anthropologic. Theory* 1, 1–23. doi: 10.1177/1463499620981544
- Giles, R. (2019). The anthropocentricity of the future of food: a review of meat planet. *J. Critical Animal Stud.* 16, 29–37.
- Giraud, E. H. (2021). *Veganism: Politics, Practice, and Theory*. London: Bloomsbury.
- Graeber, D., and Wengrow, D. (2021). *The Dawn of Everything: A New History of Humanity*. New York, NY: Farrar, Strauss and Giroux.
- Greiner, P. T., York, R., and McGee, J. A. (2022). When are fossil fuels displaced? an exploratory inquiry into the role of nuclear electricity production in the displacement of fossil fuels. *Heliyon* 22, e08795. doi: 10.1016/j.heliyon.2022.e08795

- Guthman, J., and Bilteckoff, C. (2020). Magical disruption? alternative protein and the promise of de-materialization. *Environ. Plan. E. Nat. Space* 2, 1–18. doi: 10.1177/2514848620963125
- Helliwell, R., and Burton, R. J. F. (2021). The promised land? exploring the future visions and narrative silences of cellular agriculture in news and industry media. *J. Rural Stud.* 84, 180–191. doi: 10.1016/j.jrurstud.2021.04.002
- Hopkins, P. D., and Dacey, A. (2008). Vegetarian meat: could technology save animals and satisfy meat eaters? *J. Agric. Environ. Ethics.* 21, 579–596. doi: 10.1007/s10806-008-9110-0
- Howard, P. H. (2021). *Concentration and Power in the Food System: Who Controls What We Eat? (Revised Edition)*. London: Bloomsbury Publishing.
- Howard, P. H., Ajena, F., Yamaoka, M., and Clarke, A. (2021). “Protein” industry convergence and its implications for resilient and equitable food systems. *Front. Sustain. Food Syst.* 5, 1–14. doi: 10.3389/fsufs.2021.684181
- Jochems, C. E. A., Van Der Valk, J. B. F., Stafleu, F. R., and Baumans, V. (2002). The use of fetal bovine serum: ethical or scientific problem? *Alter. Lab. Anim.* 30, 219–227. doi: 10.1177/026119290203000208
- Jönsson, E. (2016). “Benevolent technotopias and hitherto unimaginable meats: tracing the promises of in vitro meat. *Soc. Stud. Sci.* 46, 725–748. doi: 10.1177/0306312716658561
- Jönsson, E. (2017). On resurrected nuggets and sphincter windows: cultured meat, art, and the discursive subsumption of nature. *Soc. Nat. Resour.* 30, 844–859. doi: 10.1080/08941920.2017.1304599
- LaVeck, J. (2006). Invasion of the movement snatchers: a social justice cause falls prey to the doctrine of ‘necessary evil. *Satya* 16, 18–23. Available online at: <http://www.satyamag.com/oct06/laveck.html> (accessed May 19, 2022).
- Lee, A. (2018). An ecofeminist perspective on new food technologies. *Can. Food Stud.* 5, 63–89. doi: 10.15353/cfs-rcea.v5i1.226
- Lee, P. Y. (2008). *Meat, Modernity, and the Rise of the Slaughterhouse*. Durham, NH: University of New Hampshire Press.
- Lipnevč, A. (2021). The phenomenon of veganism: from diet and lifestyle to social movement. *Filosofija. Sociologija* 32, 177–185. doi: 10.6001/fil-soc.v32i2.4418
- Lonkila, A., and Kaljonen, M. (2021). Promises of meat and milk alternatives: an integrative literature review on emergent research themes. *Agric. Human Values* 38, 1–15. doi: 10.1007/s10460-020-10184-9
- Lynch, J., and Pierrehumbert, R. (2019). Climate impacts of cultured meat and beef cattle. *Front. in Sustain. Food Syst.* 3, 5. doi: 10.3389/fsufs.2019.00005
- Marder, M. (2016). “Meat without Flesh,” in *The Future of Meat without Animals*, ed. B. Donaldson and C. Carter (Lanham, MD: Rowman and Littlefield), p. 101–109.
- Marouby, C. (2020). *The Question of Limits: A Historical Perspective on the Environmental Crisis*. New York, NY: Routledge.
- Mattick, C. S., Landis, A. E., and Allenby, B. R. (2015). A case for systemic environmental analysis of cultured meat. *J. of Integr. Agric.* 14, 249–254. doi: 10.1016/S2095-3119(14)60885-6
- Melzener, L., Verzijden, K. E., Buijs, A. J., Post, M. J., and Flack, J. E. (2021). Cultured beef: from small biopsy to substantial quantity. *J. Sci. Food Agric.* 101, 7–14. doi: 10.1002/jsfa.10663
- Messmer, T., Klevernic, I., Furquim, C., Ovchinnikova, E., Dogan, A., Cruz, H., et al. (2022). A serum-free media formulation for cultured meat production supports bovine satellite cell differentiation in the absence of serum starvation. *Nature Food* 1, 74–85. doi: 10.1038/s43016-021-00419-1
- Metcalfe, J. (2013). Meet shmeat: food system ethics, biotechnology and re-worlding technoscience. *Parallax* 19:1, 74–87. doi: 10.1080/13534645.2013.743294
- Miller, J. (2012). In vitro meat: power, authenticity and vegetarianism. *J. Critical Animal Stud.* 10, 41–63.
- Mouat, M. J., and Prince, R. (2018). Cultured meat and cowless milk: on making markets for animal-free food. *J. Cult. Econ.* 11:4, 315–329. doi: 10.1080/17530350.2018.1452277
- Neo, H., and Emel, J. (2017). *Geographies of Meat: Politics, Economy, and Culture*. Oxon: Routledge.
- Newton, P., and Blaustein-Rejto, D. (2021). Social and economic opportunities and challenges of plant-based and cultured meat for rural producers in the us. *Front. Sustain. Food Syst.* 5, 1–11. doi: 10.3389/fsufs.2021.624270
- Nimmo, R. (2010). *Milk, Modernity and the Making of the Human: Purifying the Social*. Oxon: Routledge.
- Ong, S., Choudhury, D., and Naing, M. W. (2020). Cell-based meat: current ambiguities with nomenclature. *Trends Food Sci. Technol.* 102, 223–231. doi: 10.1016/j.tifs.2020.02.010
- O’Riordan, K., Fotopoulou, A., and Stephens, N. (2017). The first bite: imaginaries, promotional publics and the laboratory grown burger. *Public Underst. Sci.* 26, 148–163. doi: 10.1177/0963662516639001
- Painter, J., Brennen, J. S., and Kristiansen, S. (2020). The coverage of cultured meat in the us and uk traditional media, 2013–2019: drivers, sources, and competing narratives. *Clim. Change* 162, 2379–2396. doi: 10.1007/s10584-020-02813-3
- Pandurangan, M., and Kim, D. H. (2015). A novel approach for in vitro meat production.” *Appl. Microbiol. Biotechnol.* 99, 5391–5395. doi: 10.1007/s00253-015-6671-5
- Pedersen, H., and Stanescu, V. (2014). “Conclusion: future directions for critical animal studies,” in *The Rise of Critical Animal Studies: From the Margins to the Centre*, ed. N. Taylor and R. Twine (New York, NY: Routledge), p. 264–265.
- Pellow, D. N. (2014). *Total Liberation: The Power and Promise of Animal Rights and Radical Earth Movement*. Minneapolis, MN: University of Minnesota Press.
- Pluhar, E. B. (2010). Meat and morality: alternatives to factory farming. *J. Agric. Environ. Ethics.* 23, 455–468. doi: 10.1007/s10806-009-9226-x
- Poirier, N. (2018a). Technical difficulties: towards a critical, reflexive stance on in vitro meat. *Animalia Anthrozoöl.* J. 3, 1–18.
- Poirier, N. (2018b). The continued devaluation of vegetarianism in light of in vitro meat. *J. Critical Animal Stud.* 15, 3–27.
- Poirier, N. (2021). Alternative animal products: protection rhetoric or protection racket? *J. Critical Animal Stud.* 18, 27–54.
- Poirier, N., and Russell, J. (2019). Does in vitro meat constitute animal liberation? *J. Anim. Ethics* 9, 199–211. doi: 10.5406/janimalethics.9.2.0199
- Poirier, N., and Tomasello, S. (2017). Polar similar: intersections of anthropology and conservation.” *Animalia: Anthrozoöl.* J. 3, 1–20.
- Post, M. J. (2012). Cultured meat from stem cells: challenges and prospects. *Meat Sci.* 92, 297–301. doi: 10.1016/j.meatsci.2012.04.008
- Purdy, C. (2020). *Billion Dollar Burger: Inside Big Tech’s Race for the Future of Food*. London: Penguin Books.
- Sexton, A. E. (2018). “Eating for the post-anthropocene: alternative proteins and the biopolitics of edibility. *Trans. Inst. Br. Geogr.* 43, 586–600. doi: 10.1111/tran.12253
- Sexton, A. E., Garnett, T., and Lorimer, J. (2019). Framing the future of food: the contested promises of alternative proteins. *Environ. Plan. E. Nat. Space.* 2:1, 47–72. doi: 10.1177/2514848619827009
- Shapiro, P. (2018). *Clean Meat: How Growing Meat without Animals Will Revolutionize Dinner and the World*. New York, NY: Simon and Schuster.
- Shriver, A. (2009). Knocking out pain in livestock: can technology succeed where morality has failed? *Neuroethics* 2, 115–124. doi: 10.1007/s12152-009-9048-6
- Simonsen, R. R. (2015). “Eating for the future: veganism and the challenge of in vitro meat,” in *Biopolitics and Utopia: An Interdisciplinary Reader*, ed. P. Stapleton and A. Byers (New York: Palgrave Macmillan), p. 167–190.
- Stephens, M. (2021). *Cultured Meat on the Menu. Conference presentation*. In Vitro Meat: Ethics and Culture [attended virtually February 1, 2021].
- Stephens, N., Di Silvio, L., Dunsford, I., Ellis, M., Glencross, A., and Sexton, A. (2018). Bringing cultured meat to market: technical, socio-political, and regulatory challenges in cellular agriculture. *Trends Food Sci. Technol.* 78, 155–166. doi: 10.1016/j.tifs.2018.04.010
- Stephens, N., Sexton, A. E., and Driessen, C. (2019). Making sense of making meat: key moments in the first 20 years of tissue engineering muscle to make food. *Front. Sustain. Food Syst.* 3:45, 1–16. doi: 10.3389/fsufs.2019.00045
- Stephens, N. (2013). Growing meat in laboratories: the promise, ontology, and ethical boundary-work of using muscle cells to make food. *Configurations.* 21, 159–181. doi: 10.1353/con.2013.0013
- Terhaar, T. (2012). The animal in the age of its technological reducibility. *J. Critical Animal Stud.* 10, 64–77.
- Tuomisto, H. L., Ellis, M. J., and Haastrup, P. (2014). “Environmental impacts of cultured meat: alternative production scenarios,” in *Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food Sector*.
- Tuomisto, H. L., and Teixeira de Mattos, M. J. (2011). Environmental impacts of cultured meat production. *Environ. Sci. Technol.* 45, 6117–6123. doi: 10.1021/es200130u

- Twine, R. (2013). Is biotechnology deconstructing animal domestication? movements toward liberation. *Configurations* 21, 135–158. doi: 10.1353/con.2013.0011
- United Poultry Concerns (2019). *2019 Conscious Eating Conference - Cell-Based Meat Debate*. Available online at: https://www.youtube.com/watch?v=BUWUy%200K03_w&t=%201943s (accessed November 22, 2021).
- Vialles, N. (1994). *Animal to Edible*. Cambridge: Cambridge University Press.
- Volden, J., and Wethal, U. (2021). “What Happens When Cultured Meat Meets Meat Culture? (Un)naturalness and (Un)familiarity in the Meat of Today and Tomorrow,” in *Changing Meat Cultures: Food Practices, Global Capitalism, and the Consumption of Animals*, ed. A. Hansen and K. L. Syse. (Lanham, MD: Rowman and Littlefield), pp. 185–206.
- Welin, S., and Van der Weele, C. (2012). “Cultured Meat: Will it Separate Us from Nature?,” in *Climate Change and Sustainable Development: Ethical Perspectives on Land Use and Food Production*, ed. T. Potthast and S. Meisch. (Wageningen, Germany: Wageningen Academic Publishers), pp. 348–351.
- Wood, L. (2014). “Mo” meat, mo problems: an assessment of cultured meat and food system transitions. *Maastricht Univ. J. Sustain. Stud.* 2, 41–48.
- York, R. (2012). Alternative energy sources displace fossil fuels? *Nat. Clim. Change* 2, 441–443. doi: 10.1038/NCLIMATE1451
- York, R. (2017). Why petroleum did not save the whales. *Socius* 3, 2378023117739217. doi: 10.1177/2378023117739217
- York, R. (2021). Poultry and fish and aquatic invertebrates have not displaced other meat sources *Nature Sustain.* 4, 766–768. doi: 10.1038/s41893-021-00714-6
- York, R., and Bell, S. E. (2019). Energy transitions or additions?: why a transition from fossil fuels requires more than the growth of renewable energy. *Energy Res. Soc. Sci.* 51, 40–43. doi: 10.1016/j.erss.2019.01.008

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