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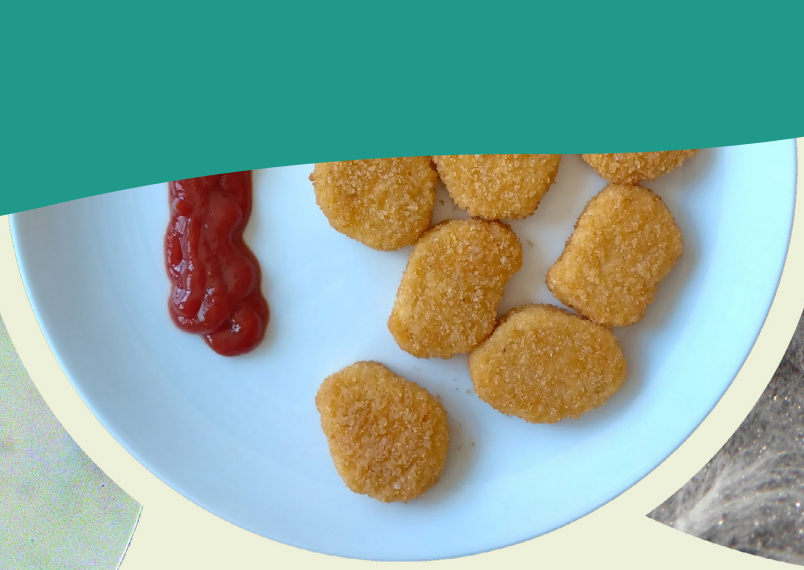

Alternative proteins and better food futures

Moving beyond the binaries

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TABLE helps people navigate the evidence, values and visions shaping global debates about the future of sustainable food systems. Both scientific evidence and our personal biases play roles in these crucial conversations: TABLE provides clarity on where, how and why we disagree in order to support inclusive dialogue and drive much-needed action. Originally founded as a collaboration between the University of Oxford, the Swedish University of Agricultural Sciences (SLU) and Wageningen University & Research (WUR), the TABLE network has since expanded to include la Universidad de los Andes (Colombia) and la Universidad Nacional Autónoma de México.

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1. Table of Contents

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1. Introduction

The global food system faces increasing strain. Climate change, biodiversity loss, health crises, and entrenched poverty and inequity - all of which both contribute to and are impacted by the food system- are driving calls for systemic transformation. A key area of focus is on the problems arising from the production and consumption of animal products. To respond to these challenges, a variety of strategies have been proposed. These include production-side measures, such as changing the way that we farm animals, and consumption-focused approaches aimed at encouraging a dietary shift away from animal products.

The development of novel “alternative proteins” (APs), which, as discussed later, in some ways appears to straddle the division between production and consumption-orientated shifts, is one of the more contentious solutions proposed. Globally, most protein consumed is still in the form of grains and pulses, so in one sense the phrase “alternative proteins” is a misnomer: novel APs are alternatives to animal products and follow in a long history of such foods (consider almond and soy milk, tofu, seitan and tempeh, all of which have been consumed for centuries). In spite of this long history, polarised narratives surrounding novel APs have limited the possibility for constructive, inclusive dialogue in recent years.

Advocates believe that there is potential in the development of new foods which can play similar nutritional and culinary roles to animal foods, but which do not have the same environmental footprint or ethical challenges. Such foods could facilitate a transition away from unsustainable livestock production and consumption practices and thereby reduce our negative impact on the natural world. The same arguments are generally made for a transition to diets low in animal source foods;

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however, a central advantage of developing APs for many advocates is that they might enable some of the benefits of such a shift without placing the onus for change on individuals, which is seen as undemocratic, unjust and/or unlikely to be effective. For most advocates, novel APs would be part of a mix alongside other production-side solutions, rather than representing a singular salve to all food-system ills.

Critics, too, come from a variety of positions. They may cast doubt on the environmental claims of APs. They may see APs as insufficiently ambitious as solutions: a fix that by swapping one food for another tries to avoid the need for deeper transformation of the food system, and perhaps replicates the very problematic relationships with technology and the natural world that have created our current crises; such criticisms are not unique to APs. When APs are framed as "sustainable", "ethical", "clean" these labels, it is argued, present APs as value-neutral products and shift attention away from the systemic problems (e.g. power concentration, inequalities, injustice) that riddle the food system. Problems of corporate power concentration and a system revolving around unhealthy, "ultra-processed" foods might actually be further entrenched by a shift towards APs. Linked to this idea, many critics suggest that a transition to APs could have negative impacts on the agricultural sector, in particular on smallholder farms and livelihoods.

These differing views have led to polarised narratives and contradictory policy decisions surrounding APs, limiting progress towards a just, healthy, and sustainable food system, even though, in broad terms, these end goals are shared by AP advocates and critics alike. The aim of this report is not to adjudicate the technical merits of novel APs, but rather to highlight the diverse perspectives on these foods, identify areas of agreement and disagreement, and examine the conditions under which these products could address health and environmental challenges and facilitate a just transition. This report has been informed by a webinar series discussing APs - details and links to the recording are available in the appendix of this document - and a literature review, as well as helpful additional comments from our reviewers.

The next section provides a brief introduction to what is meant by "alternative proteins" and "novel alternative proteins", while the subsequent sections are structured around three key areas of discussion involving novel APs: 1. investment, power and ownership structures; 2. nutrition, sustainable diets and food security; and 3. ideas about naturalness and what that might imply for how we see our relationship with the natural world.

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What are alternative proteins?

APs are foods designed to imitate some combination of the taste, texture, appearance, culinary function or nutritional content of meat or other animal-source foods. The term "alternative proteins" is subject to critique from several sides: it is argued to reinforce a false idea that protein is the limiting nutrient in the food system; to entrench the idea animal products are the foods that provide protein (when grains are in fact the majority source); to set up an unnecessary binary opposition with animal source foods; to relegate the foods it describes to definitionally secondary status; or to suggest that they are nutritional equivalents of nutritionally superior animal-source foods. What should be included under the term is also contested, but categorisations usually include some of the following:

- Whole plant foods: Plant foods such as grains and legumes which have historically been the main source of dietary protein for most populations and remain the majority source of dietary protein globally.
- Traditional plant-based meat analogues: Traditional foods like tofu, seitan and tempeh which have long histories of serving as replacements for meat (in e.g. Buddhist cuisines) alongside a wide variety of other culinary roles.
- New plant-based meat analogues: Foods created in recent decades based on plant (e.g. rice, peas, soy) proteins, often processed to mimic meat, such as vegan/vegetarian sausages, burgers; this group started with the invention of textured vegetable protein (TVP) in the 1960s.
- Insects and insect proteins: High-protein alternatives to traditional animal proteins. Considered novel for certain cultures but have long been part of the diet in many others.
- New fermentation-derived foods: Proteins derived from microorganisms (e.g. fungi) through fermentation. This includes:
  - Bulk fermentation: the cultivation of edible microorganisms (e.g. mycroprotein derived from *Fusarium venenatum*, which may be most familiar from the brand Quorn); and
  - Precision fermentation: microorganisms are genetically engineered to produce a specific protein of interest which is then extracted; this is an established food technology (e.g. for producing rennet, citric acid, vitamins B12, B2, or C) which in recent years has been expanding to more food uses.
- Cell-cultivated meat: Food produced by cultivating animal cells. This process involves taking a small sample of cells and providing them with the necessary nutrients and conditions to build muscle and/or fat.

The focus of this discussion report is on the debates and developments surrounding these final two categories, new fermentation-derived foods, and cell-cultivated meat. These types of products are the focus of the most contention and polarisation and the area where policy makers need to make most impactful regulatory decisions, even though they are not yet widely available to purchase[1] and have only appeared in a few high-end stores or restaurants[2]. However, since it is the consensus view that these foods will first be used as ingredients to improve the taste and/or nutrition of plant-based foods, and because much current data about APs referred to in the debate actually concerns plant-based meat analogues, this report will also engage extensively with plant-based meat analogues.

1 This is in part due to several technical and commercial barriers that prevent large-scale production and commercial viability. A caveat to this is that many precision fermentation products are currently used in food products (e.g., rennet and flavourings) and that at least one bulk fermentation derived protein, Quorn, has been available since the 1980s, but the focus of this report is on novel types (e.g. animal-free dairy).

2 See, for example, the sale of cell-cultivated meat in Singapore, https://www.bbc.com/news/business-65784505

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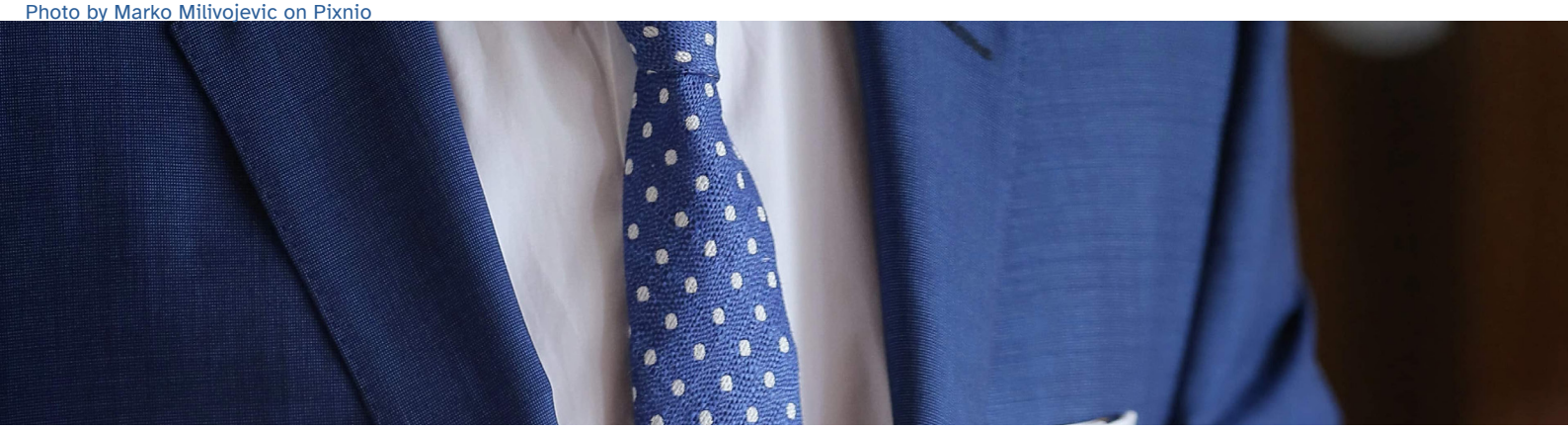


2. Investment, power and ownership structures

Techno-optimism and power critiques

Development of AP technology has predominantly been driven by private investment; this is quite unlike the case of other green technologies such as renewable energy sources and EVs whose development has been spurred by major public funding. The Good Food Institute, a non-profit think tank focused on food system transformation through protein diversification, estimates that $18.7 billion has been committed globally to the AP market since 2016 (GFI, 2025a). However, following an initial "boom" period, which saw significant investment, interest and rapid growth in APs, since 2022, growth and investment in APs has slowed (Mridul, 2025a). In 2024, global investment in APs was only 22% of what it was in 2021, within which investment in fermentation-derived foods was 38% of its 2021 level and cell-cultivated 10% of its 2021 level (Battle et al. 2025a; Battle et al. 2025b; Battle et al. 2025c). These trends are similar but not identical in different regions; in Europe, the drop has been smaller than the global trend: overall investment in APs in 2024 was 50% of its 2021 level, with cultivated meat at 46%, but with fermentation-derived foods actually seeing higher investment than in 2021 (GFI, private communication).

There is a sense among commentators that an initial "boom" in the 2020-2022 period was driven by unrealistic near-term expectations (e.g. profit, time required for these products to come to market, consumer demand) – since then, influenced by rising food prices and perhaps by organised opposition by industry (Carter, 2024), investors have revised expectations, the amount of investment has reduced, and the market is now undergoing a period of consolidation (Mridul, 2025b). It is, however, important context that there were substantial declines in investment across green tech in this period, particularly between 2023 and 2024: global investment in green tech in 2024 was 52% of its value in 2021 (dealroom.co, 2025). Some of the decline in investments in APs is probably a reflection of these broader economic conditions.

Despite the decline in investment, advocates argue that with a combination of innovation and a supportive policy environment, markets will continue to grow and make a significant contribution to both the global economy and national economies. For example, the German AP market is expected to grow to between €8 and €23 billion by 2045 (depending on the ambition of government investment) (Systemiq 2025). Meanwhile in the UK, the AP market is predicted to grow to between £850 million to £1.7 billion by 2030 (Witten, 2023). As shown in Figure 1 below, the AP market, currently estimated to be worth $21.5 billion (Choudhury, 2025), represents a fraction of the value of the livestock market that APs seek to challenge, which is estimated to be worth $1.39 trillion globally (Pandey, 2025).

Figure 1: Estimated annual revenue of global livestock and meat market ($1.39tn) in comparison to estimated AP industry ($21.5bn) in 2025. Photos by sosiukin on Adobee Stock and Ajay Kumar on Wikimedia Commons.

An area of agreement between many working in the AP field and many of those who are sceptical is that the current reliance on private investment is a major problem. AP advocates are concerned that, as a relatively new research field, the siloed research environment encouraged by private investment may be slowing progress and disincentivising action on important challenges[3], while by contrast open-access publicly funded research could accelerate it (Child 2025). Infrastructure required to scale can be a major cost barrier and leads to the infamous 'valley of death' for startups, leading to more inefficiency. Critics, on the other hand, focus their critiques of private-sector-centric investment on power: they fear that if the private sector continues to dominate the investment landscape, there is a risk of reinforcing existing food system dynamics in which power is concentrated in a handful of major food corporations who are able to exert significant influence over markets, innovation agendas, and policy and governance frameworks (Clapp, 2021; Howard, 2022) as well as cultural norms around food and diets[4]. AP production will be, at least for the foreseeable future, far more capital intensive than livestock production, limiting the role that smaller players can play. Through a wider lens, these concerns from both advocates and critics could all be seen as part of the more general critique that private sector funding incentivises maximisation of profit, not maximisation of the environmental, social and ethical goods promised by AP advocates.

Large multi-national corporations are becoming increasingly active in the novel AP market through the acquisition of existing AP companies, providing venture capital for startups, and in-house development of products, even rebranding themselves as "protein companies"[5]. For some, this confirms fears that development of APs will reinforce existing problematic food system power dynamics. On the other hand, for some AP advocates, the power and scale of these corporations make it all the more crucial to engage with them. They could provide investment to scale production, understanding of complex supply chains and legal considerations, and improve accessibility and affordability through economies of scale, all of which could lead to widespread dietary shifts with subsequent major benefits for the climate and for the reduction of animal suffering.

In addition to this, strategic partnerships between larger companies and smaller innovative start-ups have been suggested as an approach that could diversify the sector and address some of the difficulties facing smaller innovative start-ups trying to access the AP market (e.g. infrastructure costs, capacity to scale). That said, this approach could risk further market consolidation through vertical integration as larger companies take ownership of smaller companies.

3 Such as: development of unprofitable pilot-scale infrastructure necessary for gaining regulatory approval; foundational science a long way from technologies with economic returns (like identifying new raw materials and ingredients or developing novel texturization methods); gathering data on unique food safety issues (Ong et al. 2021; McNamara no date; Child 2025).

4 Advocates respond that such critiques (as well as others) apply more strongly to the production of the animal-source foods which APs seek to replace.

5 For example, Maple Leaf Foods outline their vision to "be the most sustainable protein company on Earth" https://www.mapleleaffoods.com/

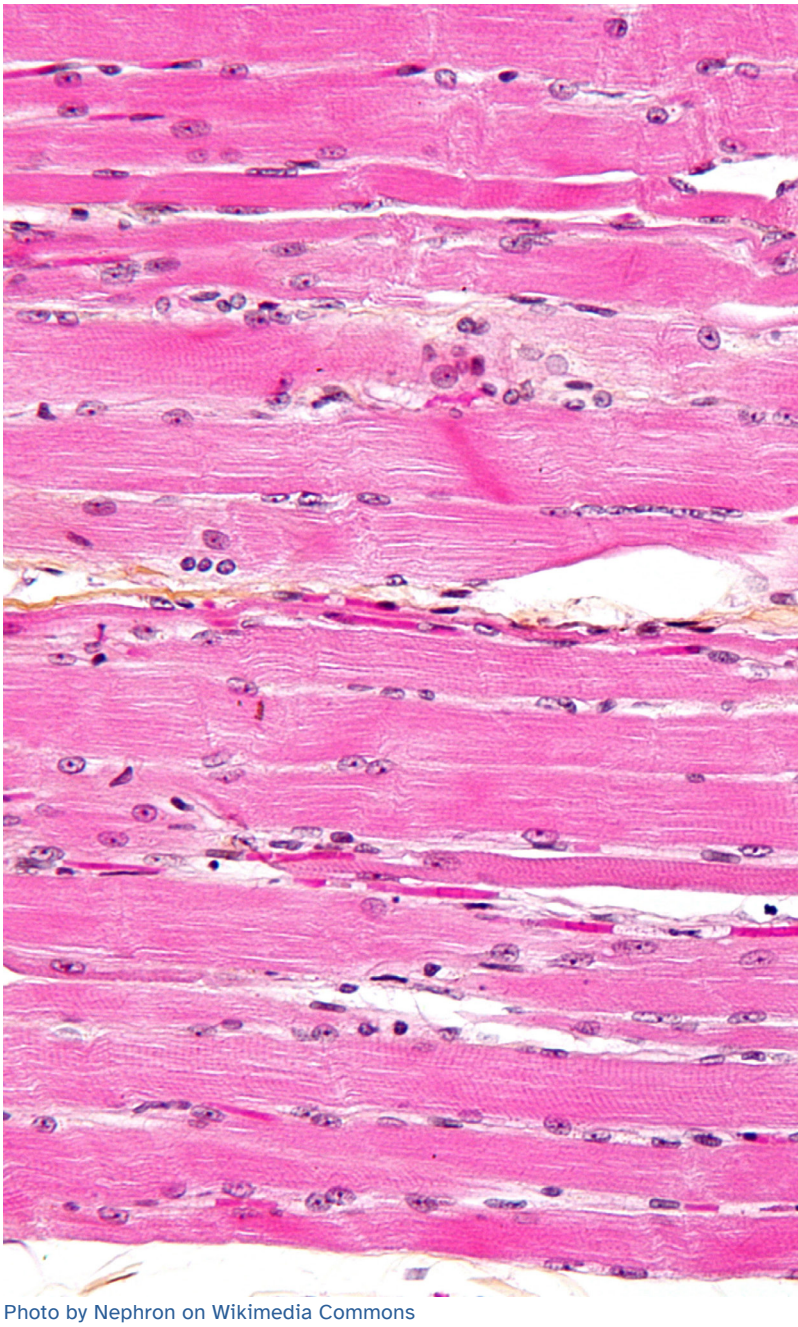
For those who remain optimistic about the potential of APs but share concerns about power imbalances, priorities are:

- efforts towards open-source technologies for use and improvement by all;
- increasing business-to-business collaboration;
- and public or non-profit investment in research and development driven by the logic of public good (see further below).

The role of the public sector

These concerns lead naturally to questions about the role of the public sector and the consequences of action or inaction by states. Although there has been some public investment in novel technologies, the amount of R&D funding pales in comparison to that allocated to other green technologies[6] and to that spent on livestock production[7]. As a result, public investment overall works to maintain the status quo of animal-based production and consumption (Vallone & Lambin, 2023).

Globally, political and policy support for novel APs varies widely. Some countries, such as Singapore and the Netherlands, have invested heavily in novel APs and view their development as a means to ensure food security and reduce dependence on imports. At the other end of the spectrum, Italy has pre-emptively banned cultivated meat on the grounds that it is protecting its farmers and food traditions[8]. An attempt was made by Hungary to pass a similar bill, although it was rejected by the EU Commission; five US states also followed suit, successfully passing bans, and two others passed two-year bans. Many countries, including the UK, are still assessing their pathways forward (although the acknowledgement of the benefits of APs in the newly launched food strategy implies a positive view) (DEFRA, 2025). In the UK context, post-Brexit regulatory autonomy and movement away from EU market



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6 The Good Food Institute estimated all-time cumulative government investment in AP development at $2.1bn by the end of 2024 (Battle et al. 2025d); by comparison, annual government spending on green energy R&D was between $40bn and $50bn in 2021-3 (Gould et al. 2024). For another comparison, in 2022, annual global government spend on agricultural R&D was around $32bn (van Dijk et al. 2025).

7 Vallone & Lambin (2023) estimate that the EU public expenditure on R&D for livestock systems was around $26m per year compared with around $1m on novel analogues; the same study finds EU public sector spending on conventional livestock production of $34bn per year. However, the figures for R&D vary hugely between studies, depending on definitions and data sources, creating a degree of uncertainty.

8 This bill was the result of campaigning by Coldiretti, an agricultural industry lobby group (Boren 2024).

standards has led some to suggest that the UK has an opportunity to support innovation on novel food processes; however, this hinges on the ability of regulators to keep pace with changing AP development processes to ensure consumer safety and public transparency (UKRI, 2022).

In TABLE's webinar series on the topic (see appendix), most panellists agreed that active public sector engagement in the development of APs could help to support innovation, limit risks of a concentration of power among a few corporate actors and shape the direction of novel APs as a public good. Engagement could take the form of public-private partnerships that help to ensure a more diverse and competitive eco-system[9]. However, those most critical of novel APs argued that public investment risks reinforcing unequal power dynamics by subsidising large multinational corporations and would be better spent on different structural approaches (e.g. different approaches to dietary shift patterns).

3. Nutrition, sustainable diets and food security

The nutritional perspective

There is a growing body of research on nutritional questions about APs. For *novel* foods like cultivated meat, while rigorous safety reviews have been undertaken as part of approvals, very little research on health endpoints has thus far been possible. There is more research, however, on plant-based and fermentation (see for example Nájera Espinosa et al. 2025, Fernández-Rodríguez et al. 2025). Given the likelihood that in the immediate term the primary applications for newer APs will be as enhancements to plant-based products, such research is very relevant.

Photo by Towfiqu barbhuiya on Pexels

With reference to these products, proponents argue that replacing processed meat, which is known to be harmful when eaten to excess, with APs would be a nutritional positive. Existing plant-based meat analogues (e.g. Quorn or THIS burgers) contain more fibre and less saturated fat and dietary cholesterol than their meat equivalents. Salt levels are a focus of some contention, and the conclusion drawn depends on what comparison is made: compared to plain uncooked meat (which contains no salt as sold) plant-based meat is higher in salt, but it has a lower salt content than the processed meat products that it typically replaces (De Bie et al., 2025; GFI, 2025b; Sultan et al. 2024). Technological innovations

9 See, for example, the National Industrial Biotechnology Facility in the UK (https://www.uk-cpi.com/about/national-centres/national-industrial-biotechnology-facility), Bio Base Europe in Belgium (https://www.bbeu.org/), and Biotech Heights in Sweden (https://www.biotechheights.com/).

in conventional and novel AP development may enable producers to optimise their nutritional composition in a variety of ways, such as lowering saturated fat or salt or adding more fibre or micronutrients.

Critics of APs question what they see as narrow, nutritionist logic in such comparisons. They argue that a holistic, systems-aware approach to health suggests we need more fundamental changes in the food system, which a binary, "nutrients-in, nutrients-out" analysis of the role APs misses. For healthful and sustainable choices to become the norm, more is needed than simply swapping animal-source foods for APs in otherwise unhealthy diets (Tso et al., 2020)[10]. In turn, proponents point out that the health arguments in favour of APs go beyond the nutritionist frame. Common benefits claimed include their ability to make plant-rich diets more accessible without demanding dramatic changes in tastes and culinary skills of those without resources to pursue them; their potential to alleviate demand pressure on animal source foods which are disproportionately relied on for key nutrients and susceptible to price inflation, thus lessening nutrient security risks; and their potential to lessen the food security threats of antibiotic resistance and zoonotic disease by reducing dependence on intensive livestock farming (Witten, 2023).

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"Ultra-processed" foods and naturalness

Another consideration is where APs fit into the debates surrounding "ultra-processed foods" (UPFs) and questions of "naturalness". UPFs, as defined in the NOVA classification system, are "formulations of ingredients, mostly of exclusive industrial use, typically created by a series of industrial techniques and processes" (Monteiro et al., 2019). UPFs are typically, but not definitionally, characterised by high quantities of salt, sugar and fat; lack of dietary fibre and micronutrients; high energy density; and are argued to encapsulate an extractive and exploitative food system that seeks to maximise corporate profit and control, rather than promote

10 An important question here is what effect increasing consumption of APs has on overall dietary patterns. This is not well answered by the existing research literature. Various studies compare dietary patterns by dietary identities (omnivore, flexitarian, vegetarian, vegan, etc.), often focusing on the issue of ultra-processed foods (see further below). All of these find that vegans and vegetarians have higher consumption of plant-based meat and dairy analogues. Some find that these groups have higher overall UPF consumption driven by consumption of analogues (Gehring et al., 2021; Chang et al., 2024); others find lower UPF consumption (Ohlau et al., 2022). They tend also to find higher consumption of fruit, vegetables, nuts and legumes. This might be suggestive that consumption of APs is associated with higher consumption of whole plant foods. However, this class of study design precludes drawing direct conclusions on this question. Ideally, this question would be examined not with synchronic but diachronic data. The closest example known to the authors is Carr et al. (2025), which looks at households whose food GHG footprint has dropped over a seven-year period, finding that such households marginally increase their purchasing of APs, nuts and pulses, and more dramatically so their purchasing of dairy, vegetables and fruit. Again, this is suggestive of positive dietary correlates of increased consumption of APs, but, again, the study design precludes drawing any direct conclusions.

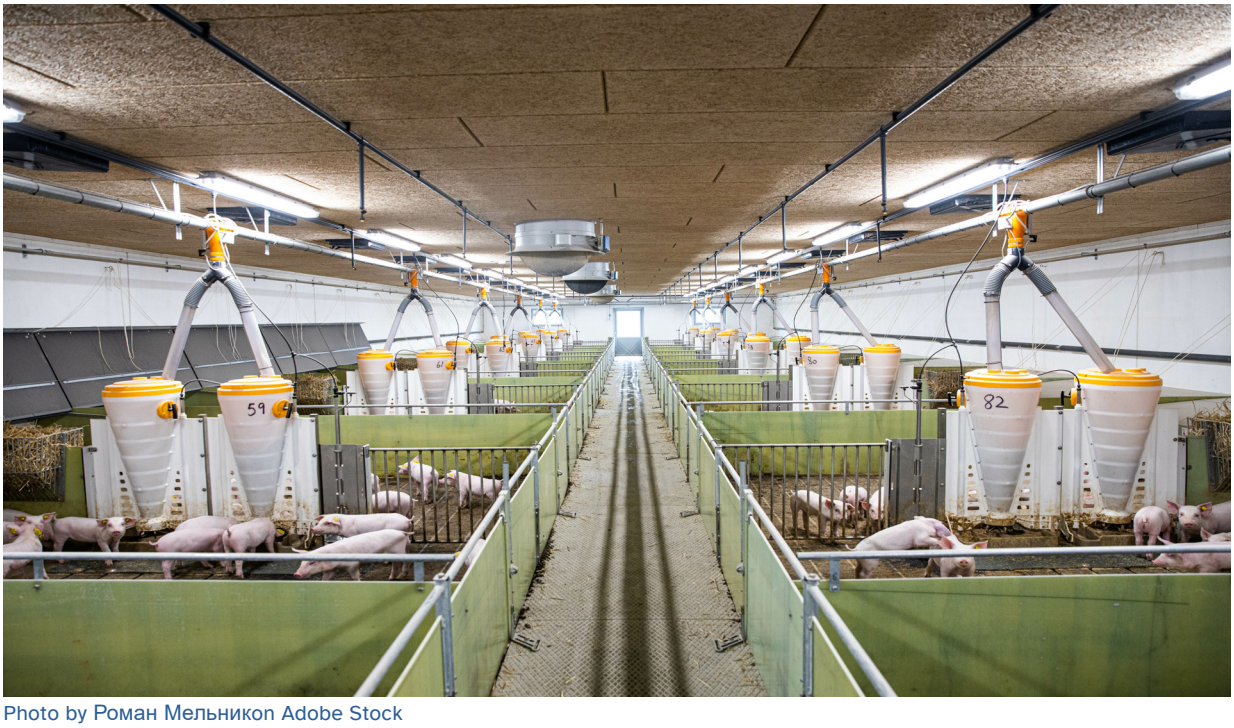
health (Fisher, 2022; see also van Hensbergen 2024; Fraanje et al. 2019). It is well established that high consumption of ultra-processed foods is associated with poor health outcomes, though it is not universally agreed why this is.

Studies of plant-based meat analogues generally judge them to fit the formal definition of UPFs (e.g. Sultan et al. 2024; Melville et al. 2023), and a growing literature focuses on critiquing these foods (or diets low in animal foods more generally) on this basis. For more novel APs, particularly cell-cultivated meat, the ultra-processed food appellation becomes more complex as they are grown and nutritionally enhanced using industrial processes, yet – at the cellular level – are almost identical to "natural" unprocessed animal-derived products. Nevertheless, assuming that in the immediate future novel APs come to market integrated into plant-based products, this difficulty is moot.

For those who assume that the health risks of UPFs are due to the nature of processing, replacing "less-processed" animal-source products with "ultra-processed" APs will heighten exposure to these health risks. Both sceptics[11] and some supporters of the NOVA classification question the logic that processing per se has a causal relationship with negative health outcomes. They may argue that the health risks associated with UPFs are less to do with degree of processing and more to do with the *typical* nutritional content of these products, or simply that what it is within the UPF category which results in poor health outcomes is unknown; therefore, to talk about *individual* foods, including APs, as UPFs (rather than overall dietary patterns) risks demonising healthy foods (Greger, 2025). In the particular case of APs, since they are nutritionally atypical within the UPF category and make up only a minute proportion of UPFs consumed in studies which have established the relationship between UPF and poor health outcomes, these arguments are particularly strong. Even if concerns about UPFs are accepted, to the extent that APs generally substitute for UPF animal products, AP advocates argue that they add no additional health risk while bringing potential health and environmental benefits. This can be set in the larger context of arguments that the increase of ultra-processed and of animal-based foods are interlinked outcomes of the same systems (Sievert et al. 2025).

Those critical of novel APs may also invoke ideas of "naturalness" from both a moral and cultural standpoint, arguing that foods created using industrialised processes cannot possibly reclaim the

11 Including government agencies and professional bodies (e.g. ANSES 2024; Government Office for Science 2024; Scientific Advisory Committee on Nutrition 2023).



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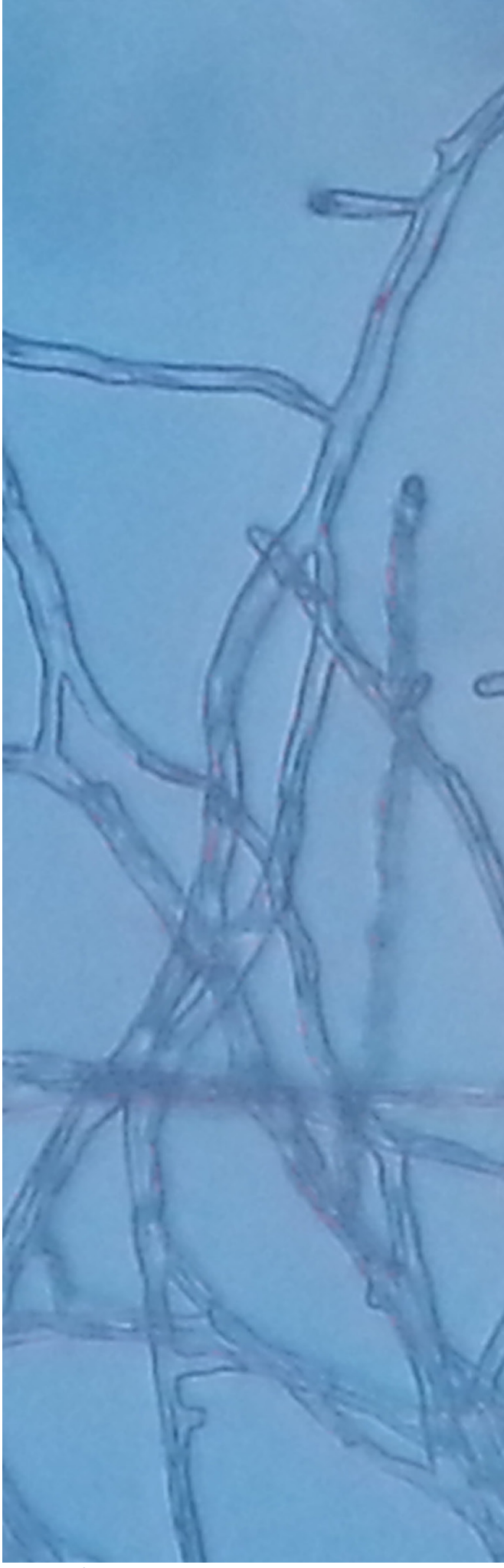
authenticity and meanings associated with “natural foods”. They fear that the development of novel APs may further erode our awareness and knowledge of where foods come from and the intricate relationship they have to the land and our natural environment. On the other hand, proponents point out that animal products that are considered “natural” are already the outcomes of industrialised processes. The fortification of animal feeds (typically heat-treated and extruded mixtures of fractionated ingredients which would largely meet the definition of UPFs themselves), use of antibacterial agents or antiparasitics as growth promoters, indoor livestock systems, or use of advanced meat recovery are all examples of technological innovation within livestock production processes and range from very common to near universal. With the naturalness critique thus turned upon some of its proponents, one might reject it in principle and consider novel APs no more than the next step in a long line of technological innovations in food production and consumption. Alternatively, one might accept the naturalness critique but expand it to most foods produced by the modern food system. In this light, APs might be seen as playing the more limited role of less impactful substitutes for existing “unnatural” and ultra-processed animal foods—and by reducing the environmental impacts of those foods, lowering pressure on nature.

How might they fit into dietary considerations?

An important consideration for these products is how might they fit into our existing understanding of what constitutes a healthy and sustainable diet. On the one hand, these products may offer a convenient way for people to swap out animal-source foods. This process may not even require a huge amount of conscious choice for consumers, as APs offer an opportunity to replace “hidden” ingredients found in processed foods. Although it moves beyond the framing of APs as an alternative to *protein*, an example of this would be the development of a lab-grown, cellular-based alternative to solid fats like butter, lard and palm oil in processed foods, which could help to reduce the detrimental environmental impact of palm oil production (Lathman, 2023). However, whether APs can be scaled fast enough and costs reduced far enough for them to play this role in the near future remains to be seen.

A shift away from the consumption of animal products and towards novel APs would also heavily depend on whether or not people would be willing to eat them. Despite some initial research, there is still a limited understanding of people's perceptions of novel APs, due in part to the fact that most novel APs remain largely at the proof-of-



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concept stage. As a result people's views are based on very little - they are predominantly informed by how these products are presented and described rather than their having tasted or purchased them. For example, the "unnatural" imagery of production processes (e.g. a collection of cells surrounded by laboratory equipment) compared to "natural" images showing the preparation or presentation of novel APs (e.g. showing the products being cooked, prepared, and presented as if they were conventional animal-based products) elicits different - positive or negative - reactions from people. Similarly, terminology has a significant influence on people's perceptions of novel APs: terms that include the word "cell" were viewed to be less appealing than the terms "cultured" or "cultivated" (FSA, 2025a).

The fluid nature of opinions means that it is difficult to predict how attitudes will change over time and, if they become commercially available, how opinions will be shaped by marketing and the opportunity to actually taste these foods. Currently, consumer perceptions and acceptance of novel APs in surveys are mixed; willingness to accept, or consider, these products is driven by a range of factors and values including product characteristics (e.g. taste, texture), economics (e.g. product costs), ethical dimensions (e.g. exploitation and harm of non-human animals), environmental concerns (e.g. the environmental impact of conventional agriculture), or questions of "naturalness" and fears about high-tech food production methods[12]. The UK Food Standards Agency conducted an evidence review to examine consumer responses to novel APs. The research noted that when presented with information on these products, people generally tend to agree that novel APs have the potential to provide benefits (e.g. animal welfare, environment, and global food availability); however, on balance they felt that concerns around safety, unnaturalness, and impact on farmers were more significant than the perceived benefits (FSA, 2025a & 2025b). To navigate the uncertainty surrounding these products, proponents suggested that presentation of these products should be coupled with the provision of background information to offer insight into the technical/scientific process without overwhelming consumers.

Food security and feeding the world

Driven by a combination of economic and population growth, it is estimated that (under a business-as-usual set of assumptions) total global demand for food will increase by between 35-56% in the period between 2010 to 2050 as a result of increasing population and wealth (van Dijk et al., 2021; though see also Breewood et al. 2018). Many proponents of APs argue that the development of novel APs can improve global food availability and food security because AP production would be more resilient to shocks (e.g. climate change, extreme weather, disease outbreaks), would be less land use intensive, and less seasonal. Under this frame the inclusion of novel APs in a diverse food system can shield it from shocks and enhance stability and resilience (Tubb & Seba, 2019). The present dynamics

12 Though it is worth noting that in practice these concerns haven't been a major stumbling block for existing products that use the same techniques, such as rennet.

of the global food system result in food insecurity and micronutrient deficits in low-income countries, while at the same time low- and middle-income countries export animal feed to supply the Global North. Proponents argue that APs could help to disrupt these dynamics, partly by reducing the global burden of supplying agricultural inputs to high-consuming countries, and potentially by supplying micronutrient-rich foods in low-consuming countries, if affordable, scalable and culturally appropriate approaches can be co-developed with local partners.

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Yet critics argue against framing food and nutrition insecurity through what they see as a narrow supply-side lens. This frame assumes that this is a problem of availability, an assumption that critics counter is misleading - there is enough food produced in the world; it is just not distributed equitably. They warn that since the Green Revolution, a focus on volume of output has created a system that favours technological solutionism and ignores deep-rooted inequalities; APs, if understood as a technological, production-side solution, risk perpetuating this. Similarly, the present system is geared to export technological fixes designed for the Global North to the Global South without considering local contexts, needs, or cultures, with disastrous results; this, too, is a pattern which could play out with APs. Moreover, although novel APs and the infrastructure used to create them are presented as resilient to shocks, they themselves could be subject to new vulnerabilities. Concerns have been raised over the high energy demands of AP production processes, which come at the same time that electrification and decarbonisation already put heavy demands on electricity grids and with increased susceptibility to outages or disruption from geopolitical shocks, as seen in the Russia-Ukraine conflict.

4. Relationship with the natural world

Land use reconfiguration

The food system is identified as a major driver of environmental degradation, exceeding safe planetary boundaries in GHG emissions, nitrogen/phosphorus use, and biodiversity loss. Currently almost half of the world's habitable land is used for agriculture, of which two thirds are used for grazing, while a significant proportion of the land put to crop production is used to produce food to feed livestock (Ritchie & Roser, 2024). APs have been presented as a potential solution to the land use problem, the argument being that they present opportunities for “land-sparing” (see Fraanje et al. 2018), enabling us to move away from land demanding conventional agriculture, while also avoiding the use of harmful inputs, in doing so mitigating these environmental concerns and nurturing more sustainable food systems.

This view sees a need for us to minimise our footprint on landscapes and restore nature, even if by doing so we use “less natural” forms of food production. Under optimistic high innovation scenarios, proponents claim that alternative proteins could displace two thirds of the meat and dairy consumed in Europe by 2050, creating space for nature recovery and carbon storage (Collas & Benton, 2024). A global modelling study based on lifecycle assessment supports this view, suggesting that, in comparison to current agriculture emissions, replacing livestock products with cellular agriculture by 2050 could reduce greenhouse gas emissions by 54%, phosphorus use by 53%, and land use by 83% (El Wali et al., 2024).

A transition to APs could potentially also facilitate a structural shift in the livestock sector, by taking the pressure off the system to produce high volumes of meat, thereby enabling a greater focus on rearing fewer animals, less intensively and in ways that prioritise higher welfare. This “less and better” approach could not only, it is argued, support management regimes that lead to positive biodiversity outcomes on grazing land, but, because far fewer animals are reared, could also free up considerable areas of land for nature restoration. Land that is currently used for feed crop production could be repurposed to grow feed stock for novel APs and, as the feed conversion ratio is significantly lower than that of traditional livestock, simultaneously free up additional land.

Critics counter that reduction of livestock - and associated feed production - does not guarantee nature restoration, or that nature-friendly practices will necessarily be applied to freed-up land. They argue that alternative land management practices (e.g. organic, agroecology, regenerative agriculture) already exist and seek to reconfigure approaches to livestock farming and develop more sustainable food. Such arguments must still contend with the need for dietary change, however. There is longstanding debate about whether alternative agricultural systems can be sufficiently productive to supply global food needs, but all models which find that they can do so only by assuming substantial reductions in animal-source food consumption of all types.

Going beyond such arguments, critics push back against using lifecycle assessments to justify a transition to novel APs at all. These assessments often frame the environmental impacts of APs vs. livestock in terms of quantifiable metrics (e.g. emissions, land use, water usage) but are limited in their ability to assess and capture the wider and longer-term consequences of introducing transformative new technologies.

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Photo “Funtington” by grassrootsgroundswell on flickr CC BY 2.0

Impact on the agricultural sector

There are fears that the development of these novel foods will come at the expense of farmers and others currently working in the agricultural sector, a sector which is already facing challenges from climate induced weather fluctuations, soaring production costs, and economic uncertainty. Critics point out that if a transition to novel APs occurs, which sees APs compete with livestock farming and leads to a reduction in livestock production, then livestock farmers stand to be negatively affected (Morais-da-Silva et al., 2022). Research conducted by the Royal Agricultural University explored farmer perceptions of cultured meat in the UK and identified that although there were fears and hopes about long-term direct effects on their businesses, their main concerns were about broader social implications of the types discussed above (MacMillan et al., 2024).

However, it has also been suggested that the development of these products could lead to the creation of new jobs in production, research, or development. The UK NGO Green Alliance estimates that, with the right combination of investment and regulation, the UK AP industry could grow to be worth £6.8 billion annually by 2035 and this growth would bring about new job opportunities (Witten, 2023). They argue that this will catalyse the creation of new agricultural jobs (e.g. producing agricultural inputs for APs), thereby helping to alleviate fears that a transition away from livestock products would lead to significant job losses. In addition to this, while these products are often thought of as “taking away” from smallholder farmers, the reality is that smallholders are already at the hands of an existing system which is dominated by large companies producing “low quality” animal-source products destined for unhealthy processed meat products. Proponents posit that APs could disrupt the activities of big, industrial meat producers and, situated within a democratic policy environment that supports farmers to transition their practices, could provide new economic opportunities for farmers to rear “premium” livestock in higher welfare systems while diversifying their businesses by valorising waste streams for use in AP feedstocks, leading to improved pay and farm viability.

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Whilst these changes *could* bring about positives for farmers it was noted that, in the UK context, those working in the agricultural sector already feel let down by policy makers and excluded from discussions that directly impact them. Before any significant changes take place, it would be imperative to involve farmers in discussions around APs, to explore how changes to the livestock sector

and the development of APs could be designed to be more inclusive and supportive of smallholder farmers. Although inclusive communication is an important first step, additional efforts are required to build on common ground between the agricultural sector and novel AP industry to explore how farmers could have a substantive shared stake in future technologies. It has been suggested that a possible starting point could be joint research and innovation, to explore the synergies between emerging technology and sustainable farming systems; efforts to support farmers who want to engage novel AP business; and the introduction of criteria for those investing in APs to require the companies they invest in to commit to a "just transition" within their ESG frameworks.

5. Reflections and considerations

At the surface, we find tensions between technological solutions and systemic reform, the relationship between novel technologies and corporate power, the balance between "feeding the world" and a holistic approach to global health, and whether to favour land sparing through technological innovation or land sharing through nature-friendly farming practices. Deeper interrogation of these fault lines reveals more nuance. Where does technological innovation enable structural shifts, and where does it entrench the status quo? Where does holism lead to paralysis or conservatism? What forms of evidence and knowing should we trust, and how should we balance our moral responsibilities towards the human and non-human worlds?

While there are certainly tensions between stakeholder perspectives, exploration has also revealed significant commonalities and shared ways forward. Although the reasons they emphasise differ, both proponents and critics oppose private-only investment in APs; this alignment points to the possibility of policies that would address some concerns of both sides, such as public funding for development structured to ensure a focus on public goods. More generally, critics and proponents are concerned with many of the same goods: a fair deal for eaters and producers; reducing environmental impacts; and transforming a status-quo food system in which power, priorities and values seem out of balance.

Novel APs do not embody a single, coherent and universal vision of food systems transformation, and among the various plausible AP visions we can find further, promising possibilities for compromise and forward movement. It is possible to conceive of a future in which affordable novel foods substitute for some lower quality animal products, and in doing so take pressure off land-based livestock systems to maximise yields at all costs. Reductions in the number of animals in intensive systems will lead to lower levels of animal suffering and death. Traditional animal products continue to occupy the premium end of the market, yielding livestock producers a price premium and enabling a shift to "less and better" meat production. In this scenario, then, by disrupting the dynamics of the current system, novel APs are beneficial both for farm businesses and environmental impacts, even acting as an enabler for shifts to agroecological or other low-intensity forms of farming. Questions about a 'two-tiered food system' are likely to arise, requiring careful and imaginative policy approaches to reduce inequitable outcomes.

In a different imagined future we could instead focus on the role of APs in dietary transitions. Rather than propping up a UPF- and meat-centric status quo, they could act as behavioural entry points, catalysing a curiosity and willingness to explore new (as well as traditional, neglected, plant based) foods and dietary habits. In that future they represent one tool in a varied toolbox for achieving a broader shift to more diverse, healthier and sustainable diets.

Of course, it is also possible to envisage negative futures and black and white futures: these are the normal stuff of pro- and anti-AP discourse. However, as we have seen both in the case of arguments around naturalness and UPFs, and around LCA, holism, and forms of evidence, these futures are often based on overly simplified arguments: there are more complex realities to be explored beneath them. Any real future food system will be pluralistic, containing contradictory trends, competing stories, and both positives and negatives side by side. To steer toward 'better', we must think in more imaginative, less binary ways. In this spirit, we call for further explorations of this complexity, visions of the future which engage both with the potential and the limits of technological innovations. This approach could involve an analysis of the strengths, weaknesses, opportunities, and threats of different kinds and applications of novel APs (and different financial and organisational models for their development) from a range of ethical, health, environmental, social, and economic perspectives. It would consider how to involve these perspectives in the development of "guardrails" within policies, institutions, and technologies to enhance the positive - and mitigate the negative - impact of these products. Such an approach also requires us to consider how novel APs could be integrated into (rather than compete with) more socio-political approaches to addressing our problems, such as those associated with the agroecology and food sovereignty movements.

Whether these products serve as tools for meaningful change or entrench existing inequalities will depend on the decisions made by policymakers, investors, producers, and civil society actors. The evidence and debates discussed here highlight the value in creating space for multi-sector engagement and dialogue that can explore the competing views, narratives and assumptions that surround food systems change.

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7. Appendix

The Webinar Series

Between June and July 2025, TABLE - in collaboration with the UN Foundation and Food Standards Agency - organised a series of three webinars to explore the debates surrounding novel alternative proteins (APs). This series was an opportunity for both advocates and critics to come together to engage in a meaningful and nuanced discussion on novel APs (e.g. cell-cultivated meat and new fermentation-derived proteins). Each webinar included at least three expert speakers from a range of backgrounds and were structured around three themes:

Drivers, Investments, Trends, and Regulation of APs (access the recording here)

1. Helen Breewood, Good Food Institute
2. Dr. Yadira Tejeda-Saldana, Director of Responsible Research & Innovation, New Harvest
3. Dr Thomas Vincent, Deputy Director, Innovation Policy, Food Standards Agency

Health Dimensions of APs (access the recording here)

1. Rob Percival, Head of Food Policy, Soil Association
2. Dr. Sarah Nájera Espinosa, Research Fellow, London School of Hygiene and Tropical Medicine
3. Amy Williams, Senior Digital Communications Manager & Nutrition Lead, Good Food Institute

The Environmental Dimensions of APs (access the recording here)

1. Prof. Hanna Tuomisto, University of Helsinki and Natural Resources Institute Finland
2. Dr Philip Howard, Michigan State University
3. Joel Scott-Halkes, Wild Card/WePlanet
4. Jennifer Dodsworth, University of Oxford

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