https://doi.org/10.1038/s43016-022-00609-5

Cellular agriculture will reinforce power asymmetries in food systems

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Industry and governments are increasingly investing in cellular agriculture. However, the trajectory of these technologies is likely to reinforce many current food system problems, particularly power asymmetries.

Proponents of cellular agriculture claim that this nascent technology has the potential to be a 'win–win–win' solution for food system problems facing people, animals and the planet. Yet, cellular agricultural firms that produce meat and fish products are increasingly controlled by the same firms that dominate industrial meat, fish and animal feed processing.

Even if substantial technical barriers are surmounted, patents will create barriers to wide deployment, contributing to trends of centralization and increasing vulnerabilities to disruption, particularly as supply chains will probably continue to rely on input-intensive, monocultural feedstocks. The resulting products will encourage like-for-like substitution and promote centre-of-the-plate dietary patterns, rather than providing solutions to sustainability challenges.

Reinforcing food system problems

Hundreds of millions of people globally lack adequate access to food, but these technologies will not address current inequalities in distribution, which result in high amounts of food waste. This emphasis on speculative technologies is steering attention away from existing, proven approaches to achieving sustainability goals that reduce power asymmetries.

To move closer to commercialization, cellular agriculture requires substantial funding from more powerful institutions—but at the cost of ceding control to these investors. Nearly all the leading global meat and grain/animal feed processors have already acquired ownership stakes in this industry (Fig. 1), including JBS, Tyson, Cargill, BRF, Maple Leaf Foods, Bell Food Group, PHW-Gruppe, Nutreco and Archer-Daniels-Midland (ADM). Many of these firms are also increasingly in control of other protein alternatives, such as plant-based substitutes for meat and fish[1]. Additional firms with ties to cellular meat and fish efforts include the dairy processor Nestlé, the seafood processor Thai Union and the tofu manufacturer Pulmuone[1].

Dominant firms have less incentive to promote the vision of the founders of cellular agriculture firms and will avoid moving in directions that would undermine their core businesses. Founders of these firms frequently suggest that their products will solve ecological problems and eliminate animal suffering associated with conventional meat production. An agribusiness firm representative, however, explained to academic researchers that investments in the industry were both for growth and 'defensive' purposes[2]. Fully replacing industrial livestock and aquaculture production is therefore unlikely, and cellular meat and fish will instead remain expensive niches. A small minority of consumers with ethical objections to conventional animal foods may be willing to pay more for cellular versions, but most consumers will not, even if they have sufficient incomes—especially if they are sceptical of the new technologies behind these products.

Investments in cellular agriculture are focused on business models that implement strong barriers to entry to potential competitors, such as through patents, trade secrets and enacting regulatory barriers, and that promise a high rate of return[2,3]. This will lead to industries that are geographically centralized and controlled by a very small number of decision-makers, and result in greater vulnerability to disruption. This brittleness was illustrated by outbreaks of COVID-19 in workers in a substantial number of meat processing facilities worldwide, and plant shutdowns affecting as much as a quarter of pork processing in the United States[4,5]. Other examples of food system shocks include a loss of nearly one-quarter of the world's pigs due to African swine fever in 2018 and 2019, disruptions from the blockage of the Suez Canal by the ship *Ever Given* in 2021, and the global impacts of the conflict in Ukraine in 2022.

Cellular agriculture will probably continue to rely on feedstocks from conventional supply chains, such as derivatives of soya, maize, potatoes and wheat. Eat Just, for instance, recently entered into a joint development agreement with the grain/oilseed processor ADM for a growth medium for cellular meat[6]. If these products actually do expand beyond a small niche, demand for monocultural crop production will also rise[7,8]. The sustainability impacts of these chemical- and fossil-intensive production systems include resource depletion, pollution, land degradation and loss of biodiversity. The social impacts include taxpayer subsidies to lower the costs of production for these feedstocks in some nations (for example, the United States and Brazil) and negative effects on rural communities, due to industrialization, farm consolidation and a declining number of farmers. Unless current technical challenges are overcome, cellular meat will also rely on products of conventional meat processing firms, such as blood serum taken from foetal calves in dairy slaughterhouses[9,10].

Products arising from the cellular agriculture industry will continue to promote centre-of-plate dietary patterns[11,12]. It will not shift eating behaviours towards more diverse and less processed foods, but instead encourage the substitution of conventional meat and fish products, particularly when cellular versions are widely available and/or less expensive. In many markets, even as sales of plant-based meat substitutes increase, meat consumption is not declining[13]. This is an illustration of the 'displacement paradox', which results in little suppression of demand for the initial product when a substitute product is available, and is especially likely when the political economic context remains unchanged[14]. One potential outcome, for example, is that cellular agricultural products will be sold as highly processed products (for example, burgers, sausages and nuggets), but not as more technically complex and more expensive full cuts of meat, which would

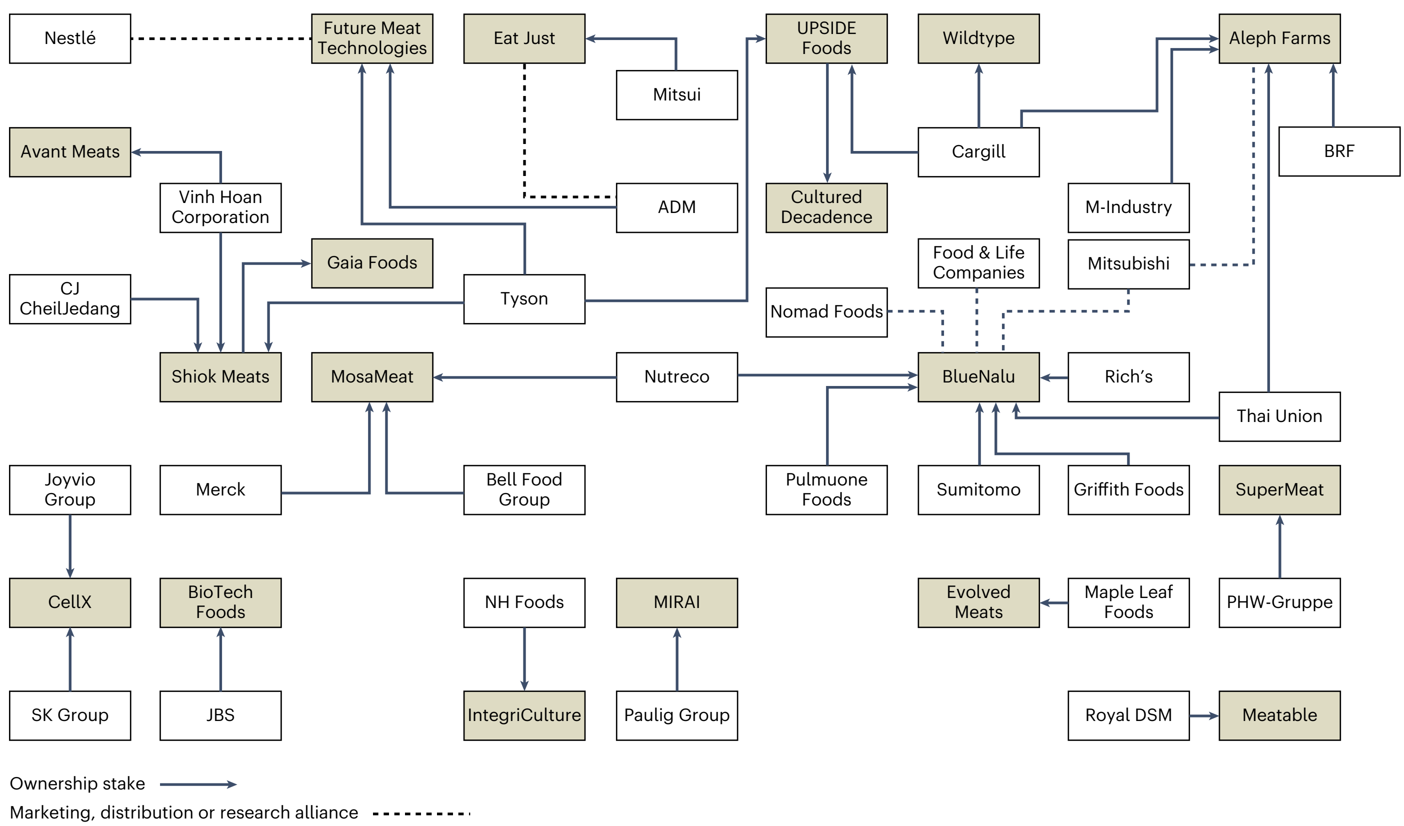

Fig. 1 | Firm relationships in the cellular meat and fish industry. The relationships between cellular agriculture start-ups that focus on meat and fish (grey boxes) and more established firms (white boxes). Data sources: www.crunchbase.com and firm press releases.

instead continue to be produced primarily by concentrated animal feeding operations[7].

Cellular meat and fish do not challenge the inequities in global food systems, which produce enough to feed everyone in the world but fail to deliver food where it is most needed. The number of malnourished people has increased in recent years, and an estimated 720 million to 811 million people globally faced hunger in 2020[15]. At the same time, substantial amounts of food are wasted—often deliberately when the practice leads to higher profits[16]. This has not prevented proponents of cellular agriculture from advancing 'feed the world' narratives to justify their products as a technological fix[17], despite doing little to address poverty, social exclusion or other drivers of inequalities of food access[18]. A techno-fix can be self-fulfilling as it "naturalizes a specific development pathway, while pre-empting alternatives, regardless of whether or not its original expectations are fulfilled"[19].

Diverting attention from existing solutions

Policymakers and investors are increasing funding for cellular agriculture based on the promises of its proponents, while more proven approaches to increasing the sustainability of food systems receive little support. Governments that are directly funding cellular agriculture firms include Israel, Singapore, China, Japan, the European Union and New South Wales (Australia)[1], while indirect research subsidies have been allocated by nations including the United States (US$10 million) and the Netherlands (€60 million).

Most of the purported and yet-to-be-realized benefits of cellular agriculture could instead be achieved by increasing support for more demonstrated and less centralized strategies, such as agroecology, integrated multi-trophic aquaculture, increasing diversity in food systems and greater self-sufficiency. Agroecology, for example, is based on principles that apply the science of ecology to the design and management of food systems. It has resulted in positive outcomes in a vast majority of studies, including improved food security and nutrition, and better soil and animal health[20]. Although approximately 30% of farms globally employ agroecological principles, funding for agroecology makes up just a small fraction of research and development budgets[21].

Integrated multi-trophic aquaculture also applies ecological principles to food production, but with a focus on aquatic systems. It involves culturing multiple species at different trophic levels in close proximity, to capture as much waste as possible and reduce input costs. An example is a system that includes sablefish (a finfish), shellfish, kelp, sea urchin and sea cucumber. This approach receives far less funding compared with industrial aquaculture, while more broadly, fish and other aquatic foods are underrepresented in food aid budgets[22].

Promoting diversity is a key component of the above approaches. Some initiatives, however, place more emphasis on the importance of increasing diversity in production systems and other components of food systems at multiple spatial and temporal scales. Diversification of crops, livestock and fish is urgently needed, as many breeds/

varieties adapted to local contexts and better suited for multiple uses are at risk of extinction. Enhancing biodiversity and social diversity—including economic, epistemic and organizational diversity—is likely to improve resilience to shocks and stressors[23]. Efforts to implement these transitions currently face numerous policy barriers, such as food safety regulations, intellectual property protections, and substantially fewer subsidies compared with monocultural and industrial systems[18].

Greater self-sufficiency is another strategy for addressing food system problems. Recent political conflicts and extreme weather events have dramatically illustrated the risks of an overreliance on imports, particularly for food and agricultural inputs. These disruptions have substantially contributed to rising prices, and in some cases shortages, for products that include fertilizers, wheat and sunflower oil. Most local food provision networks are supplied by small-scale food producers, but just 2% of published agricultural research offers solutions that are appropriate for this scale[24]. In addition, government payments tend to disproportionately flow to the largest producers, such as the top 20% of farmers typically receiving more than 80% of funds in agricultural subsidy programmes in the United States[25].

Moving beyond speculative technologies

Capital-intensive technologies that are still in development make bold and even dubious claims in their efforts to attract investors and public subsidies. Part of their appeal is the possibility of avoiding engagement with more fundamental political and economic power asymmetries. Another factor is that they are promoted by a small number of politically influential actors who stand to gain the most if they are effective in achieving wide commercialization. These groups are often more effective than limited resource organizations in influencing media coverage and policymakers, such as the overwhelmingly positive portrayals of cellular agriculture in prominent media outlets so far[7].

Failure to recognize and counter these biases is likely to lock-in current trends that exacerbate food system problems, particularly by increasing concentrations of power. Although it will certainly be politically challenging to implement, public funding for efforts that primarily benefit dominant firms should be dismantled. Where possible, these funds should be redirected towards more democratic initiatives, including for technologies that have the potential to be more widely distributed and deployed immediately, such as agroecology and integrated multi-trophic aquaculture. Research and policy changes in the future should devote more attention to better established approaches to transforming food systems, particularly those that benefit diverse constituencies, rather than those that are more speculative, opaque and easily monopolized.

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Published online: 18 October 2022

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Competing interests

The author declares no competing interests.

Additional information

Peer review information *Nature Food* thanks the anonymous reviewers for their contribution to the peer review of this work.