2023 STATE OF THE INDUSTRY REPORT

Cultivated meat and seafood

Good Food Institute

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Editor's note

In the history of food and agriculture, 2023 was a milestone year—the year that real animal meat made without animals was first approved for sale in the world's largest economy. For the first time, U.S. consumers ordered cultivated meat at two restaurants helmed by world-renowned chefs.

Additionally, cultivated meat broadened into new settings in Singapore, including the first butchery where it was on display and served in the adjoining bistro. And just after 2023 ended, there was more exciting news for cultivated meat: in January 2024 Israel became the third country to advance the approval of cultivated meat sales, and the first to advance the approval of cultivated beef.

Yet the year was not without its challenges. Funding constraints, difficulties with scaling, and the spread of misinformation and disinformation all posed obstacles for cultivated meat. Consumer education, understanding, and adoption are still in the early stages. And the work to secure increased government and private investment continues. Despite these headwinds, the stark realities of our food system remain: Global meat consumption is projected to rise significantly by 2050, and animal agriculture alone accounts for between 11 and 20 percent of greenhouse gas emissions. Taken together, these projections point to the urgent need for the kinds of solutions provided by alternative proteins.

If the world is to achieve our climate, biodiversity, public health, and food security goals, reimagining the way meat is made will be as essential as the global transition to renewable energy. When compared to conventional meat, alternative proteins reduce emissions, feed more people with fewer resources, reduce pandemic and antibiotic-resistance risks, and free up lands and waters around the world for restoration and recovery.

GFI's annual State of the Industry reports equip food system stakeholders with an in-depth understanding of the alternative protein market and its challenges and opportunities. These reports also serve as a global call to action:

Alternative proteins are agricultural innovations that, with proper levels of government and private support, will help ensure planetary and public health, transforming our global food system for the better.

Cultivated meat is a powerful tool for tackling such challenges. It can provide the sensory and nutritional values meat consumers crave without the downsides of conventional animal agriculture. At scale, cultivated meat could enable a shift toward less resource-intensive ways of producing protein. But first, the industry must overcome challenges like disinformation and proposed bans or restrictions on cultivated meat, in the United States and around the world. Despite these obstacles, the next generation of consumers are signaling enthusiasm for cultivated meat as a solution to eating meat made with fewer resources and less harm to the environment.

This report details the innovations and developments that moved the field of cultivated meat forward in 2023. But there is still much to be done.

As a nonprofit and international network of organizations, GFI is accelerating alternative protein innovation and bringing more people into the field. Policymakers and governments, scientists and students, industry leaders and global citizens can all ensure that the sector of nature-positive proteins continues to progress, offering the world a far more sustainable food future.

With gratitude and deep respect to all those on this journey, we invite you to dig deep into this 2023 State of the Industry report.

Best,

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About GFI's State of the Industry Report series

GFI's State of the Industry Report series serves as our annual alternative protein sector deep-dive. The series compiles business developments, key technologies, policy updates, and scientific breakthroughs from around the world that are advancing the entire field. This year's reports include:

Cultivated meat and seafood

Fermentation: Meat, seafood, eggs, and dairy

Plant-based meat, seafood, eggs, and dairy

Global policy: Public support, regulation, and labeling

The *Cultivated meat and seafood* report synthesizes 2023 updates in the global cultivated meat industry—the industry dedicated to making real meat and seafood by growing animal cells. Animal cell culture technology has promising applications beyond meat production, including dairy, eggs, gelatin, drugs and supplements, and materials. This report focuses on cultivated meat and seafood. For a primer on the process of creating cultivated meat, please visit GFI's science of cultivated meat page.

Symbols to look for

Throughout the 2023 State of the Industry Report series, look for symbols highlighting how developments in the past year advanced the alternative protein sector in the areas of health and nutrition, sustainability, and path-to-market progress. Dig deeper and Opportunity icons are calls to action for researchers, investors, and others seeking to learn more and advance the field.

Health

Sustainability

Opportunity

Path-to-market

Dig deeper

Please note that The Good Food Institute is not a licensed investment or financial advisor, and nothing in this report is intended or should be construed as investment advice.

About the Good Food Institute

As a nonprofit think tank and international network of organizations powered by philanthropy, GFI works alongside scientists, businesses, and policymakers to make alternative proteins as delicious, affordable, and accessible as conventional meat. In Asia Pacific, Brazil, Europe, India, Israel, and the United States, our teams are mobilizing the international community to use markets and technology to replace harmful practices with ones that are better for the climate and biodiversity, food security, and global health.

We focus on three programmatic priorities:

1. *Cultivating a strong scientific ecosystem*

GFI's science and technology teams map out the most neglected areas that will allow alternative proteins t compete on taste and price. We produce open-access analyses and resources, educate and connect the ne generation of scientists and entrepreneurs, and fund research that benefits alternative protein developmer across the sector.

2. *Influencing policy and securing government investment*

GFI's policy teams ensure that alternative proteins are a part of the policy discussion around climate chang mitigation and global health. In every region where we have a presence, we advocate for government investment in alternative proteins and educate regulators on novel proteins such as cultivated meat.

3. *Supporting industry to advance alternative proteins*

GFI's corporate teams are replicating past market transformations and partnering with companies and investors across the globe to drive investment, accelerate innovation, and scale the supply chain—all faster than market forces alone would allow.

Stay connected

Newsletters | GFI's suite of expertly curated newsletters puts timely news, insights, and opportunities right in your inbox. Check out gfi.org/newsletters to find the ones most suitable for your interests.

Monthly seminar series | Each month, we host online seminars with leading experts from around the world: The *Business of Alt Protein* series is geared toward a commercially focused audience on topics related to starting and scaling a good food business. The *Science of Alt Protein* series addresses a technical audience and focuses on cutting-edge research developments that enable alternative protein innovation.

This State of the Industry Report series, as well as all of GFI's open-access insights and data, are made possible by gifts and grants from our global community of donors. If you are interested in learning more about giving to GFI, please visit here or contact philanthropy@gfi.org.

Executive summary

Executive summary

In 2023, cultivated meat arrived in U.S. restaurants for the very first time. The year also delivered advances in cultivated meat across science, innovation, talent, and public and private sector support. Yet this still-early-stage industry faced obstacles in 2023, including distorted media coverage questioning the technology. Despite headwinds, cultivated meat has the potential to transform protein production.

More than 170 cultivated meat companies and a rapidly growing number of scientists are hard at work innovating and optimizing cultivated meat products so consumers can enjoy the foods they love without sacrifice. For the first time ever, U.S. restaurants served cultivated chicken, brought to Americans' plates by two world-renowned chefs. Fresh consumer insights and market analysis pointed to growing international interest in cultivated meat. New partnerships and global alliances formed to advance the science and scaling of cultivated meat. In a challenging private funding environment, cultivated meat and seafood companies still raised $225.9 million in 2023. And with the January 2024 milestone of Israel advancing the approval of cultivated beef, the industry took another significant leap forward in reimagining how meat is made.

Cultivated meat and seafood, part of our 2023 State of the Industry Report series, takes a field-wide view of the progress made over the past year.

Commercial landscape

Major path-to-market milestones

- In the United States, cultivated chicken products from **UPSIDE Foods** and **GOOD Meat** debuted at two restaurants.
- The June approval of cultivated meat for sale in the United States sparked major media coverage in outlets like *The New York Times,* NPR*, TIME, CBS Sunday Morning*, and more.
- **Huber's Butchery** in Singapore became the world's first butchery to sell cultivated meat when it began carrying **GOOD Meat**'s cultivated chicken in its bistro.
- In January 2024, Israel became the third country in the world to advance the approval of cultivated meat (**Aleph Farms**' cultivated beef product) and the first country to advance the approval of cultivated beef.

Company landscape

- Around the world, the number of publicly announced cultivated meat companies (focused primarily on cultivated meat inputs or end products) rose to 174 in 2023, up from 166 in 2022.
- An increasing number of companies are focusing on the cultivated meat value chain beyond end-product manufacturing. At least 50 companies identify bioprocess design, cell line development, and cell culture media as focus areas.

Large food company involvement

- **ADM** partnered with **Believer Meats** to refine and expand the cultivated meat production process.
- Large company involvement in cultivated meat deepened, and **Danone** and **Central Bottling Co.**—which owns **Coca-Cola Israel**—both invested in cultivated milk.

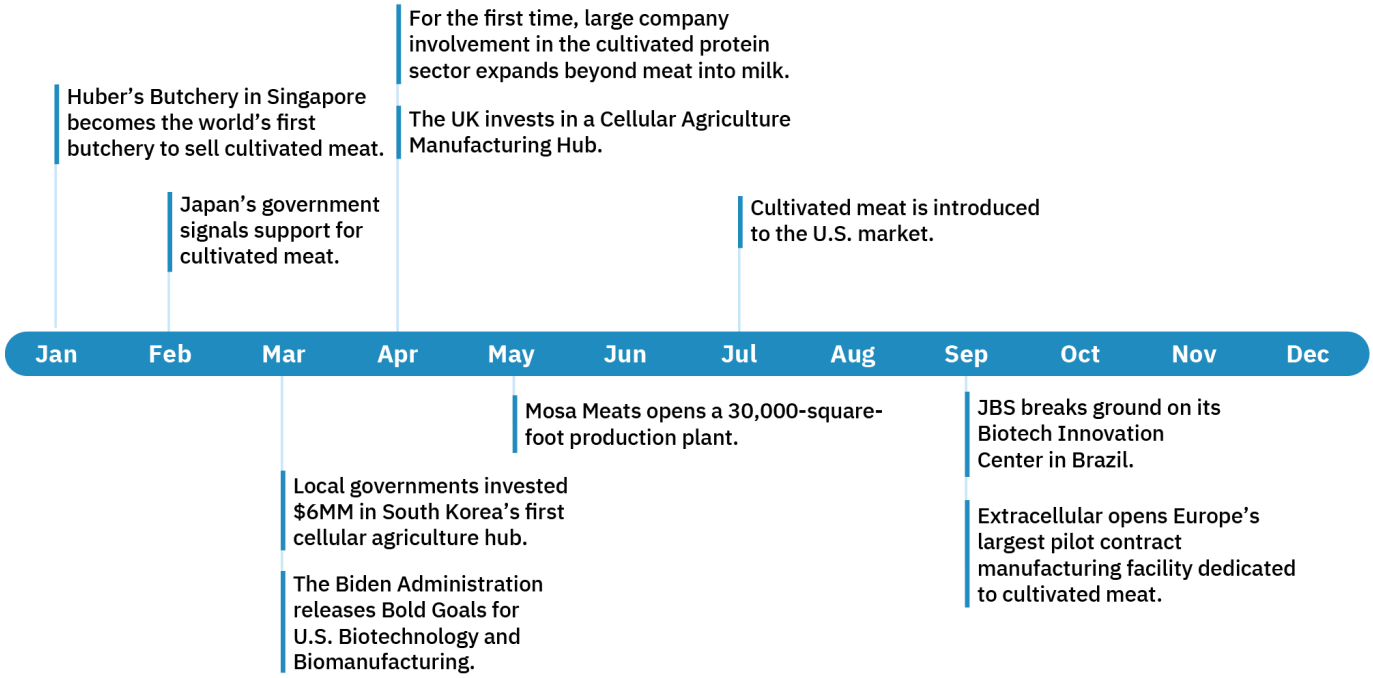
Power of partnerships

- **JBS** partnered with the **Federal University of Santa Catarina** on cultivated meat research and development.
- **Aleph Farms** partnered with chef Marcus Samuelsson to serve the company's Aleph Cuts steaks in the United States once they receive regulatory approval. This follows the trends of other cultivated meat companies, like **UPSIDE Foods** and **GOOD Meat**, partnering with chefs to bring their products to the U.S. market.

Infrastructure momentum

- In 2023, 10 new cultivated meat facilities opened across Asia, Australia, Europe, North America, and the Middle East. Two large-scale plants—**Mosa Meat**'s 30,000-square-foot facility in the Netherlands and **CellX**'s factory in Shanghai—opened in 2023.
- At least seven other cultivated meat facilities were announced in 2023.

Figure 1: Timeline of key cultivated meat updates in 2023



Investments

Cultivated meat and seafood companies raised $225.9 million globally in 2023, bringing the total for the industry (since 2013) to $3.1 billion—a fraction of the investments flowing into other technologies and innovations, like renewable energy, with the potential to reduce emissions and address climate goals. While the 2023 raises represent a sizable decrease from the $922.3 million raised in 2022, this mirrors the broader tepid private funding environment.

In 2023, companies and investors alike faced elevated inflation, rising interest rates, and a mixed economic outlook. As a result, global venture funding fell 42 percent year-over-year (YOY) in 2023 to its lowest levels since 2017 (for context, investments in foodtech startups declined by 61 percent YOY). The largest deal raised in 2023 was **Meatable's** $35 million Series B round. Meanwhile, the number of unique investors in cultivated meat and seafood totaled 111 in 2023 compared to 204 in 2022.

Table 1: Invested capital in cultivated meat

Category	2023	2022	All-time (since 2013)	2023 highlights
Total invested capital	$226MM	$922MM	$3.1B	83% of cultivated meat investment occurred in the last three years alone.
Invested capital deal count	53	72	416	2023's largest investment was $35MM (Meatable).
Unique investors	111	204	590	The number of all-time unique investors grew by 13%.
Growth stage deals (Series B and above)	2	2	13	These included Meatable and BlueNalu.

Source: GFI analysis of data obtained from Net Zero Insights platform

Science and technology

New studies expanded the industry's capacity to reduce costs, increase production scale, and improve the quality of future products, while the research ecosystem continued to expand at universities around the world, bolstering the long-term viability of the cultivated meat sector.

- Breakthrough research showed promising improvements to the taste, texture, and nutritional composition of cultivated meat, bringing it ever closer to product parity with conventional meat.
- The examination of scalability and bioprocess design included one notable study that highlighted several scenarios to bring cultivated meat to mainstream markets at price parity with conventional meat by reducing media costs, improving biomass yields, utilizing significantly larger bioreactors, and exploring hybrid product approaches.
- Multiple studies demonstrated that cell culture media can be produced at a much lower cost and with much less environmental impact using non-animal ingredients and food-grade components. Many of these media can be manufactured using agricultural crop by-products, thereby contributing to a more robust circular bioeconomy.
- There were exciting advancements in the development of plant-, fungal-, and algae-based scaffolds.
- The **Alt Protein Project** (APP) welcomed 24 new chapters (including expansions into countries where APP was not previously represented, such as Brazil, Japan, Malaysia, Portugal, Switzerland, and Turkey) and **Tufts University** became the first in the United States to offer an undergraduate minor in cellular agriculture.

Government and regulation

Governments around the world supported cultivated meat in notable ways, from significant public investment across several regions to the introduction and adoption of public policies favorable to cultivated meat to the U.S. Department of Agriculture's (USDA) approval for cultivated chicken in the United States.

UPSIDE Foods' cultivated chicken. Photo credit: UPSIDE Foods

- For the first time, the COP28 climate conference in Dubai spotlighted food system transformation as a major climate solution.
- China, Israel, Japan, the United Kingdom, the United States, and more supported the creation of new cultivated meat infrastructure and market development.
- A report from the United Nations Environment Programme (UNEP) focused on alternative proteins, including cultivated meat's potential to benefit the environment and public health.
- The United Kingdom led 2023 cultivated meat funding announcements with an allocation of £12 million ($15 million) for a new research hub at the University of Bath followed by an estimated £3.4 million ($4.3 million) for seven research projects on cultivated meat.

Commercial landscape

Commercial landscape

Overview

Advancements across the product, infrastructure, regulatory, and research landscapes made 2023 a historic year for the cultivated meat and seafood industry. By year's end, select cultivated meat products were sold to consumers in two countries, Singapore and the United States, with other countries primed to follow. Further progress was announced in January 2024, when Israel became the third country in the world to advance the approval of cultivated meat with the world's first cultivated beef product approval advancement for **Aleph Farms**.

New commercial developments in 2023 demonstrated the growing depth and breadth of cultivated foods: new facilities opened, representing all stages of the scale-up process; large company involvement in cultivated meat deepened and expanded into cultivated milk; and startups increased their commitments to less-developed segments of the cultivated food value chain. Milestones representing dedicated effort from stakeholders across the cultivated meat ecosystem include:

- Following grants of inspection from USDA in 2023, cultivated chicken products were sold to U.S. consumers for the first time by **UPSIDE Foods** and **GOOD Meat** at two restaurants: **Bar Crenn** in San Francisco and **China Chilcano** in Washington, D.C.
- The number of publicly announced cultivated meat companies focusing primarily on cultivated meat inputs or end products rose to 174 in 2023.
- In 2023, 10 new cultivated meat production facilities opened, and several more were announced or began construction. In the United States, **Believer Meats** broke ground on a 200,000-square-foot commercial cultivated pork facility in North Carolina. This brings the total number of cultivated meat production facilities to approximately 21 across the globe.
- Large food companies continued their involvement in cultivated meat and dairy. **JBS**, the world's largest meat company, began construction on a center for cultivated meat in Brazil, and global food company **Danone** entered the space for the first time with an investment in cultivated milk company **Wilk**.

Company landscape

In 2023, the number of companies primarily dedicated to the development of cultivated meat and seafood inputs or end products exceeded 170, increasing from 166 in 2022. Additionally, at least 88 other companies have been active in the industry through investments, partnerships, or cultivated meat business lines.

An increasing number of companies are shifting focus toward areas of the cultivated meat value chain beyond end-product formulation and manufacturing, like bioprocess design, cell line development, and cell culture media. This advancement of the B2B ecosystem allows companies to focus on their core competencies and, over time, should allow the entire industry to function more efficiently.

These figures may not fully capture the actual count of companies involved in the cultivated meat space, as there likely remain several startups in "stealth mode." Additionally, while GFI's company database is intended to be as comprehensive as possible, it is not exhaustive. Do you know of an alternative protein company that's not on our list? Request to add it here. Likewise, if you see a company in our database that has been acquired, closed, or rebranded, please let us know by requesting an update.

Figure 2: Cultivated meat and seafood companies by year founded

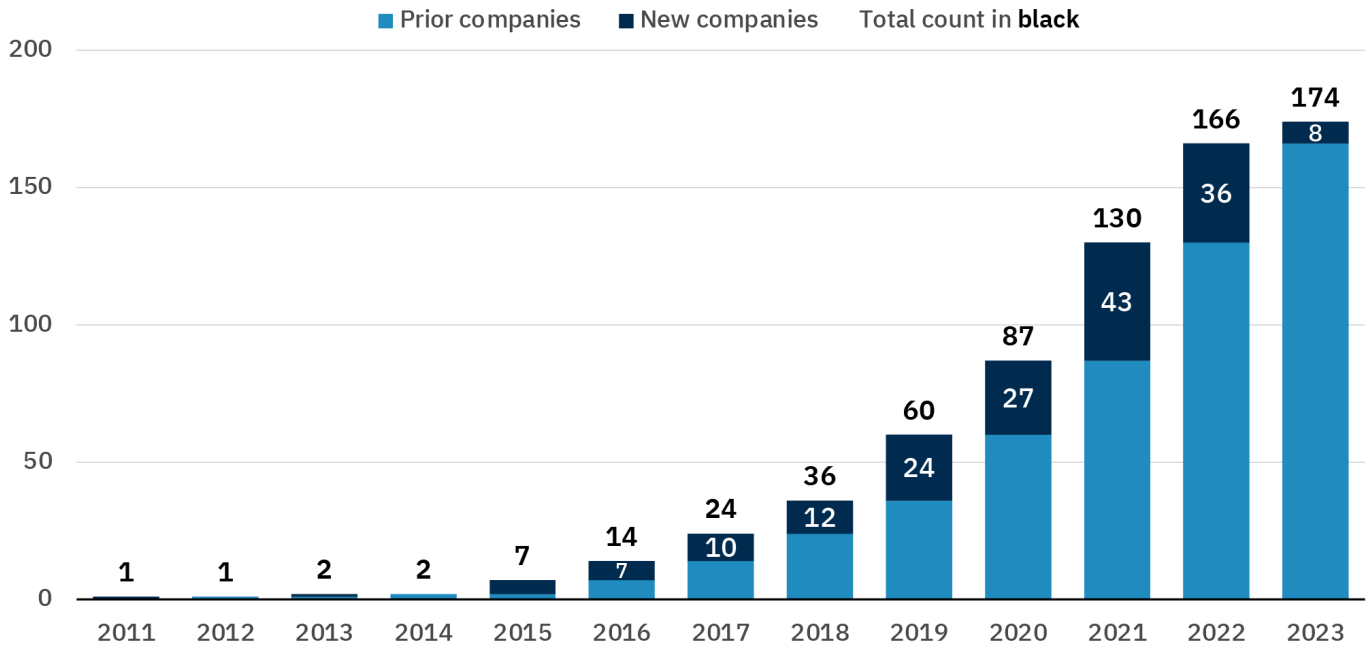
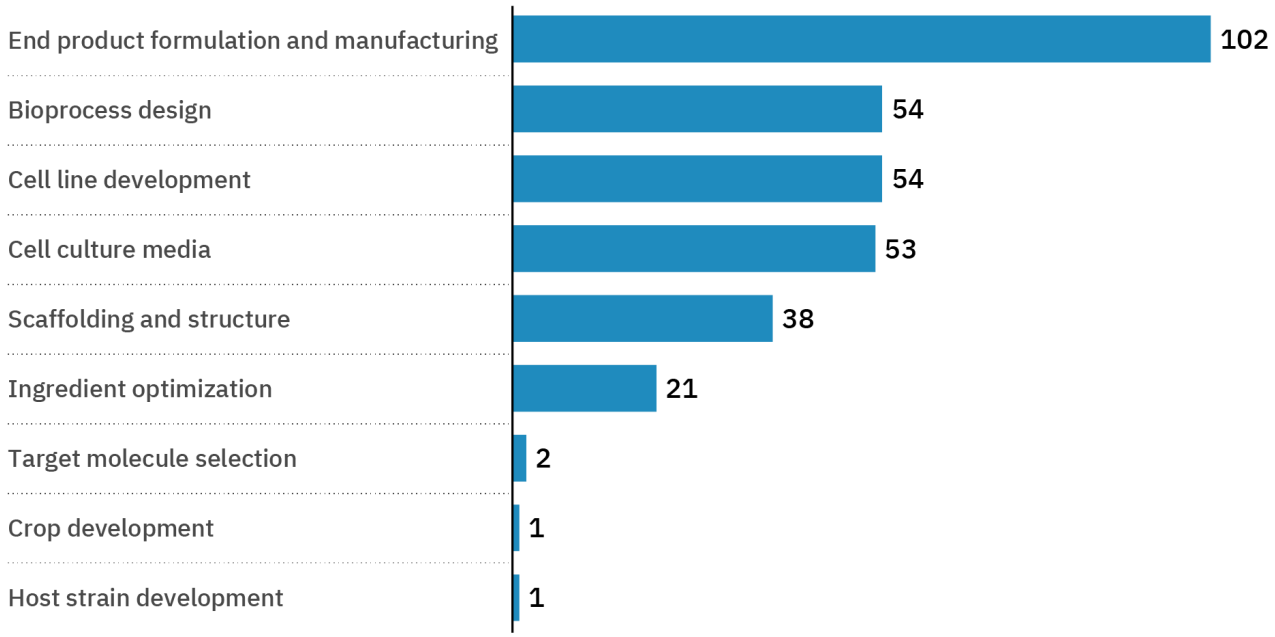


Figure 3: Distribution of companies by country and region

1–9 companies | 10–19 companies | 20+ companies

Africa and Middle East *Count 22*					
Israel	19	South Africa	3		
Asia Pacific *Count 45*					
Australia	6	Japan	4	Singapore	11
China	5	New Zealand	1	South Korea	9
India	8	Malaysia	1		
Europe *Count 47*					
Belgium	1	France	3	Spain	3
Croatia	1	Germany	8	Sweden	1
Czech Republic	2	Italy	1	Switzerland	1
Denmark	2	The Netherlands	5	Turkey	1
Estonia	1	Portugal	1	United Kingdom	16
Latin America *Count 6*					
Argentina	1	Brazil	3	Chile	2
Canada & U.S. *Count 54*					
Canada	9	United States	45		

Figure 4: Number of companies involved in each technology focus area



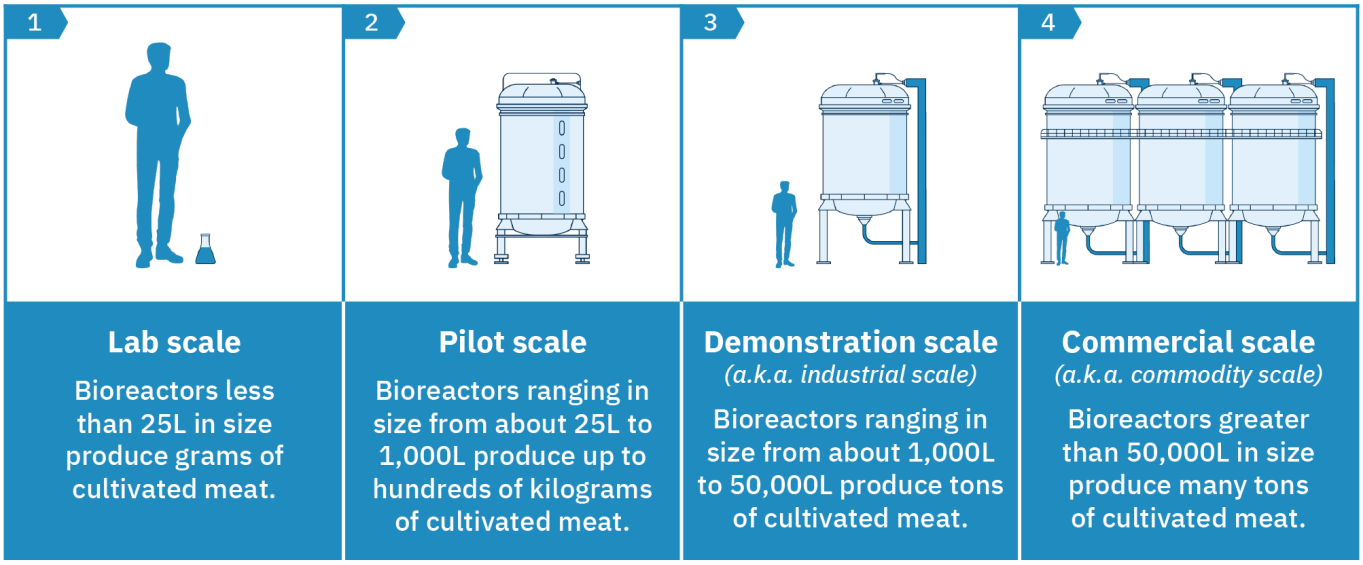
Facilities

The scale-up process for cultivated meat production is frequently divided into four phases: lab scale, pilot scale, demonstration scale (industrial), and commercial (commodity) scale. The pilot scale serves as a crucial proof of concept, allowing companies and investors to assess raw material and production costs, as well as product yield.

Facilities at the demonstration and industrial scales produce hundreds or thousands of kilograms of cultivated product annually. This means that, once a regulatory path to market is established, companies are likely to have the capacity to supply a limited number of restaurants in the following one to three years, while also producing samples for regulators and key industry partners.

In 2023, cultivated meat facilities opened, were announced, or broke ground in several regions, contributing to an expanding global supply chain. **Notably, these new cultivated meat facilities spanned all four phases of the scale-up process. Not only are much larger facilities being built, but the industry also continues to add lab-scale and pilot-scale facilities, meaning the cultivated meat field is both expanding *and* progressing.**

Figure 5: Phases of cultivated meat scale up



Facilities that opened in 2023

- Local governments in South Korea invested $7 million to launch the first cellular agriculture hub in the country. The **North Gyeongsang Cellular Agriculture Industry Support Center** opened in March and houses laboratories, analysis rooms, quality control rooms, a research center, and five companies.
- Cultivated pork company **Fork and Good** opened its 13,000-square-foot pilot facility in Jersey City, NJ, where the company is targeting cost parity with conventional pork products.
- Israel-based cultivated meat company **Aleph Farms** acquired **VBL Therapeutics**' assets and technology from its pilot production facility in Rehovot, Israel, and entered a new manufacturing agreement with **Esco Aster** in Singapore.
- **Mosa Meat**, a cultivated meat company based in the Netherlands, opened a 30,000-square-foot production plant in Maastricht. The plant has the capacity to make tens of thousands of burgers each year from 1,000-liter bioreactors.
- Shanghai-based **CellX** completed the construction of its first large-scale cultivated meat factory, called **Future Food Factory X** (FX). FX will house multiple thousand-liter bioreactors.

Mosa Meat celebrates the opening of their cultivated meat production facility in Maastricht. Photo credit: Mosa Meat

- UK-based cultivated fat startup **Hoxton Farms** opened a 14,000-square-foot pilot facility in London. The facility has the capacity to produce up to 10 tons of cultivated fat per year.
- UK-based cultivated meat company **Extracellular** opened a contract pilot facility dedicated to cultivated meat and seafood production in Bristol. The facility is the largest of its kind in Europe and will provide development, scale-up, and manufacturing services.
- **Meatable**, a cultivated meat company based in the Netherlands, opened a pilot facility to expand the production of its cultivated pork platform. The facility has a bioreactor capacity of 200 liters, with the ability to expand to up to 500 liters.
- Australian cultivated meat company **Magic Valley** expanded operations in a new pilot facility at the **Co-Labs** incubator. The facility has 3,000 liters of bioreactor capacity that can produce 150,000 kilograms of product per year.
- Cultivated meat company **SCiFi Foods** built a pilot plant in California's Bay Area to produce cultivated beef using cells edited with CRISPR technology.

Facilities that broke ground in 2023

- **Believer Meats** broke ground on a 200,000-square-foot cultivated meat production facility in Wilson, North Carolina. The company claims the new facility will be the largest in the world and will be able to produce at least 10,000 metric tons of cultivated meat per year.
- **BioTech Foods**, a subsidiary of **JBS**, broke ground on a commercial-scale cultivated meat facility in Spain, which is set to be completed by mid-2024 and is designed to produce more than 1,000 metric tons of cultivated beef per year.

At least seven other cultivated meat facilities were announced in 2023.

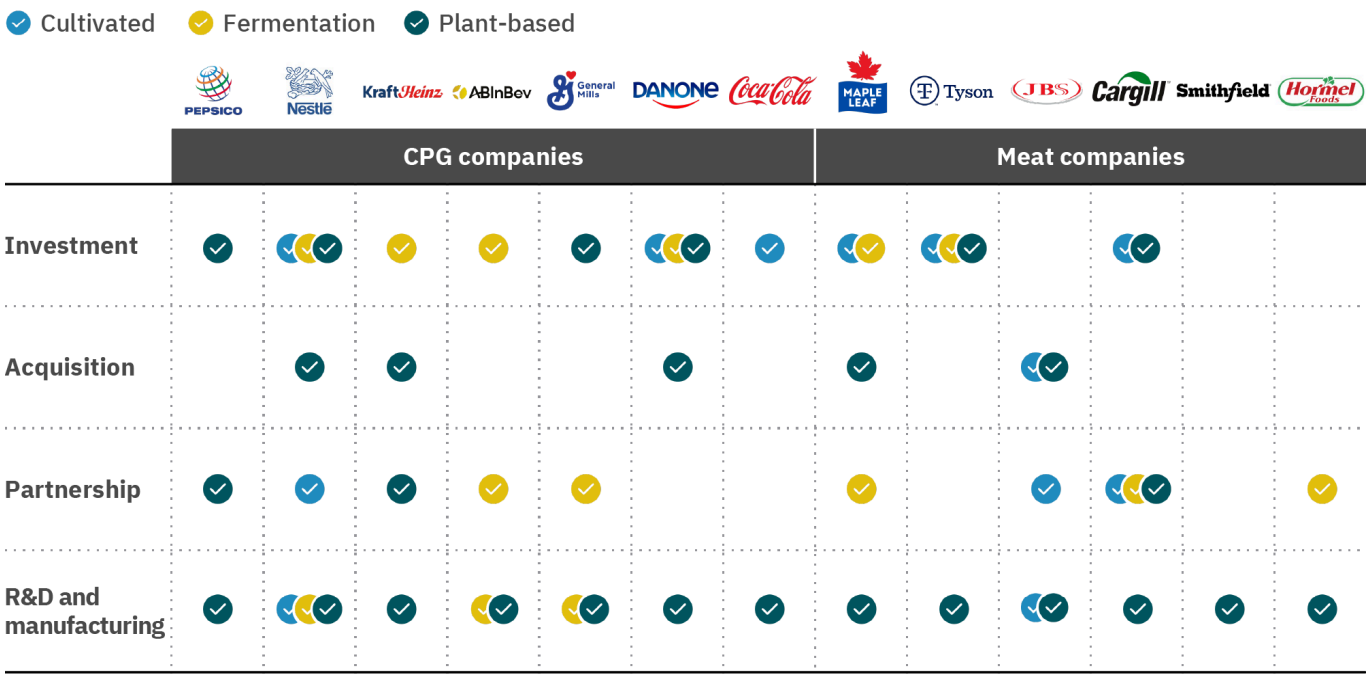
Involvement by diversified companies

Many of the largest meat and consumer packaged goods (CPG) companies around the world–including **JBS**, **Tyson**, **Cargill**, **Nestlé**, and **Danone**–are involved in the cultivated meat industry through investments, acquisitions, partnerships, and/or research, development, and manufacturing. New activity from diversified companies in 2023 indicates a growing commitment to the cultivated meat sector.

Large company involvement in the cultivated food space expanded beyond the meat sector in 2023 and into areas like cultivated milk, as both **Danone** and **Central Bottling Co.** invested in **Wilk**.

- In 2023, French dairy company **Danone** agreed to a $2 million strategic investment deal with Israel-based cultivated milk startup **Wilk** to develop cultivated breast milk components for infant formula. **Central Bottling Co.**, which owns **Coca-Cola Israel**, also participated in the round, which totaled $3.5 million.
- In September 2023, **JBS** began construction on a $62 million research, development, and innovation center for cultivated meat in Brazil.
- In 2022, **Tyson Foods** participated in a $36.5 million Series A funding round for cultivated meat company **Omeat**, which emerged from stealth mode in 2023. Tyson invested in cultivated meat companies **UPSIDE Foods** in 2018 and **Believer Meats** in 2021.

Table 2: Diversified companies with involvement in alternative proteins



Source: GFI analysis of publicly reported industry news and events

Table 3: Diversified companies with involvement in cultivated meat and dairy

	Nestlé	DANONE	Coca-Cola	Maple Leaf	Tyson	JBS	Cargill
	CPG companies			Meat companies			
Investment	✓	✓	✓	✓	✓		✓
Acquisition						✓	
Partnership	✓					✓	✓
R&D and manufacturing	✓					✓	

Source: GFI analysis of publicly reported industry news and events

Partnerships

Collaborations among research, production, and distribution partners are crucial to scale the cultivated meat sector. Here are some of the publicly announced partnerships from 2023:

Table 4: Partnerships table

Research and development partnerships

Companies/ organizations	Details
JBS and the Federal University of Santa Catarina	Cultivated meat research and development; consumer insights studies
The University of Alberta and New Harvest Canada	Formed the Institute of Cellular Agriculture

Product development partnerships

Companies/ organizations	Details
CULT Food Science and Alcheme Bio Inc.	Developing cultivated meat products using AI
CULT Food Science and JellaTech	Developing pet foods using cultivated collagen
Ivy Farm Technologies and Finnebrogue	Developing cultivated Wagyu burgers
New Wave Biotech and Multus	Developing cost-effective growth media
Pulmuone and Simple Planet	Producing cultivated meat and plant-based products
ProFuse and Gelatex	Improving muscle tissue development on plant-based scaffolding
Steakholder Foods and Umami Bioworks	Developing 3D-printed structured eel and grouper products
Umami Bioworks and Triplebar	Developing cell lines for cultivated seafood

Scale-up partnerships

Companies/ organizations	Details
ADM and Believer Meats	Refining and expanding the cultivated meat production process
Aleph Farms and Thermo Fisher Scientific	Building a growth media supply chain
BlueNalu and Nutreco	Building a food-grade supply chain for cultivated seafood
CellX and Tofflon	Building a pilot facility and expanding R&D capacity
Magic Valley and Biocellion	Developing more efficient bioreactors
Mosa Meat and Nutreco	Developing a cell-feed supply chain
Newform Foods and Project Assignments	Building a cultivated meat demonstration facility
Orbillion Bio and Solar Biotech	Scaling Orbillion Bio's cultivated Wagyu beef
ORF Genetics and SeaWith	Advancing cultivated meat commercialization
Re:meat and ICA	Evaluating the market for cultivated meat in Sweden
SeaWith and Esco Aster	Exploring SeaWith's proprietary microalgae technologies for cultivated meat projects
Umami Bioworks and Cell AgriTech	Developing a cultivated seafood production facility
Umami Bioworks and Maruha Nichiro	Building infrastructure for Japan's cultivated seafood industry
Vital Meat and Biowest	Scaling the production of cultivated meat

Distribution partnerships

Companies/ organizations	Details
BlueNalu, Mitsubishi Corporation, Pulmuone Co. Ltd., and Thai Union	Developing a market strategy to launch BlueNalu's products
BlueNalu and NEOM	Advancing the commercialization, marketing, and distribution of BlueNalu's products
Marcus Samuelsson and Aleph Farms	Selling Aleph Farms' cultivated products in the U.S.

Product launches

- **UPSIDE Foods** launched its cultivated chicken at the **Bar Crenn** restaurant in San Francisco following USDA approval in June.
- Also following USDA regulatory approval in June, **GOOD Meat** began selling its cultivated chicken at the **China Chilcano** restaurant in Washington, D.C.
- **Huber's Butchery** in Singapore became the world's first butchery to sell cultivated meat; it carried GOOD Meat's cultivated chicken throughout 2023.

Industry associations

As the cultivated meat industry matures, trade associations and alliances can play important roles in driving regulatory transparency, conducting consumer research, and aligning on nomenclature. In 2023, a group of academic and corporate partners in Japan's cultivated meat space created the **Consortium for Future Innovation by Cultured Meat** to promote cultivated meat manufacturing technology using 3D bioprinting.

Dig deeper: *Check out this blog post for an in-depth discussion on industry collaboration and take a look at a list of alternative protein trade organizations here.*

Consumer insights

Consumer insights

For consumers interested in cultivated meat, 2023 was a pivotal year. Cultivated meat debuted on menus in U.S. restaurants for the first time, although at only two locations. Singaporeans continued to enjoy cultivated meat as it expanded into a new setting, a local butchery.

The number of consumers who have sampled or purchased cultivated meat, however, remains small, and the public's awareness and understanding of cultivated meat remains low. **This means there is immense potential to generate excitement around the launch of the category, earn interest from consumers, and shape perceptions around the advent of cultivated meat in global markets.**

While the consumer insights in GFI's 2022 State of Industry Report, *Cultivated meat and seafood*, are still broadly reflective of consumers' sentiments and beliefs about cultivated meat, new research emerged in 2023 that deepened our understanding and points to emerging opportunities and challenges.

Nomenclature and messaging appeal

While GFI and many industry leaders have continued to use the term "cultivated meat" to describe meat cultivated from animal cells, consumers continue to hear and use other descriptors. Terms such as "cell-cultured" and "lab grown" are still occasionally used in the media. However, consumer research supports "cultivated" as the ideal name in terms of appeal, clarity, comfort seeing it on packaging, and expected personal use for consumers.

- A December 2022 U.S. general population survey that GFI commissioned from Embold Research validated the use of "cultivated meat" over other terms. For a term consumers would like to see on food packaging, twice as many U.S. adults selected cultivated meat over cell-cultured meat. And four times as many people identified "cultivated" compared to "cell-cultured" as a term they could imagine using personally. Overall, the research found that "cultivated meat" was an effective descriptor for the category on differentiation from conventional meat, accuracy and descriptiveness, and appeal.
- A 2023 focus group study of Singaporean consumers who both had and had not eaten cultivated meat suggests that the term "cultivated" is preferred in Singapore as well, by almost twice the number of consumers as "lab-grown meat" (31 percent vs. 18 percent). (Chong et al.)
- Another 2022 study by Malerich & Bryant of U.S. consumers found that "cultivated" prompted the highest appeal and purchase intent of currently used names tested for most meat types including chicken and salmon, though consumers were more able to correctly identify the products when "cell-" was appended.

Together, this research supports the continued use of "cultivated meat." This term offers the strongest combination of accuracy, ability to differentiate, and direct consumer preference. Even with momentum building around "cultivated meat," researchers and companies should continue to test translations across languages, applications of preferred nomenclature, and explanations to the consumer.

Consumer awareness, familiarity, and understanding

Because cultivated meat is still unfamiliar as a term and as a concept to many consumers, and other names remain in use in some contexts, studies find varying levels of awareness, familiarity, and understanding depending on how consumers are asked about it. Results overall suggest that most consumers are unaware and unfamiliar with cultivated meat. It will be crucial for the industry to build consumer awareness in the coming years.

Awareness and familiarity

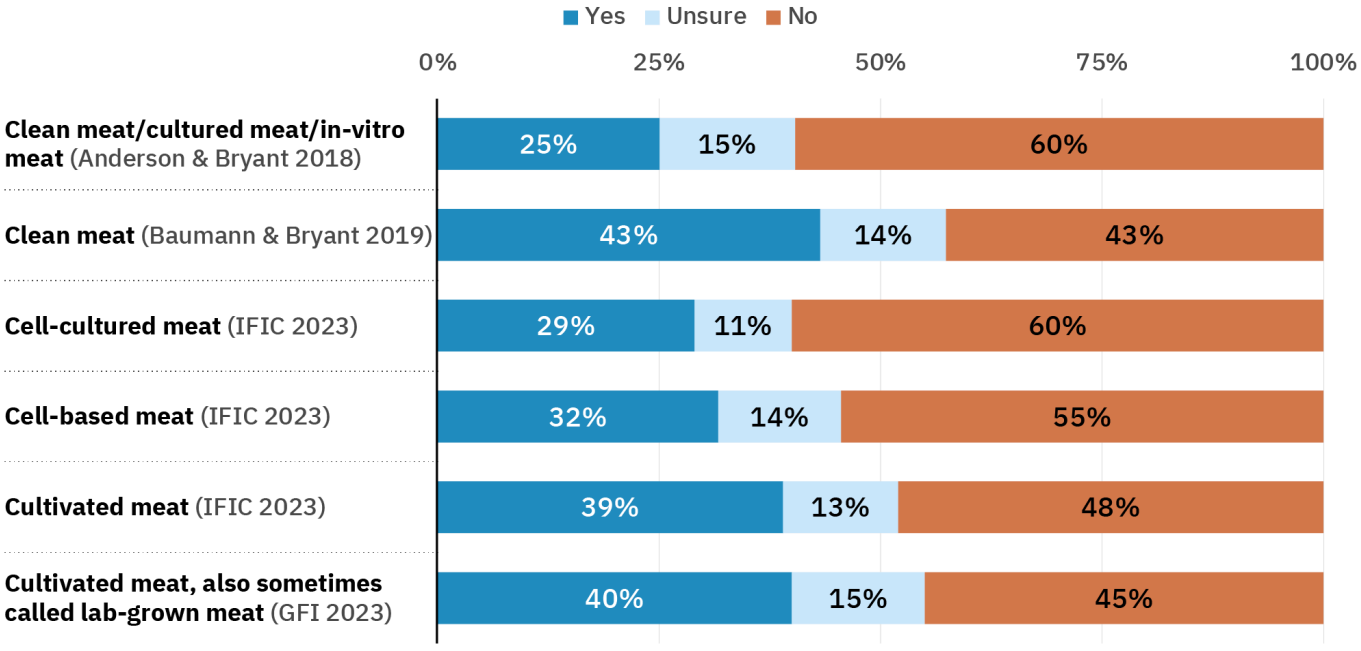
While levels of awareness vary based on how researchers ask the question and which terms are used, comparison across studies suggests that around 30 to 40 percent of the U.S. population has heard of cultivated meat (GFI and Morning Consult found 40 percent in 2023, and IFIC found 39 percent).

The data for familiarity reveals that only 10 to 30 percent of consumers feel they are "very" familiar with it (GFI and Morning Consult found eight percent "very" and 19 percent "somewhat" familiar in 2023, while Szejda et al. found 34 percent "somewhat" familiar and seven percent "very" familiar in 2021).

Despite heightened media attention and the limited release of cultivated meat in two U.S. restaurants in 2023, these numbers around consumer awareness and familiarity have not increased significantly in the past five years.

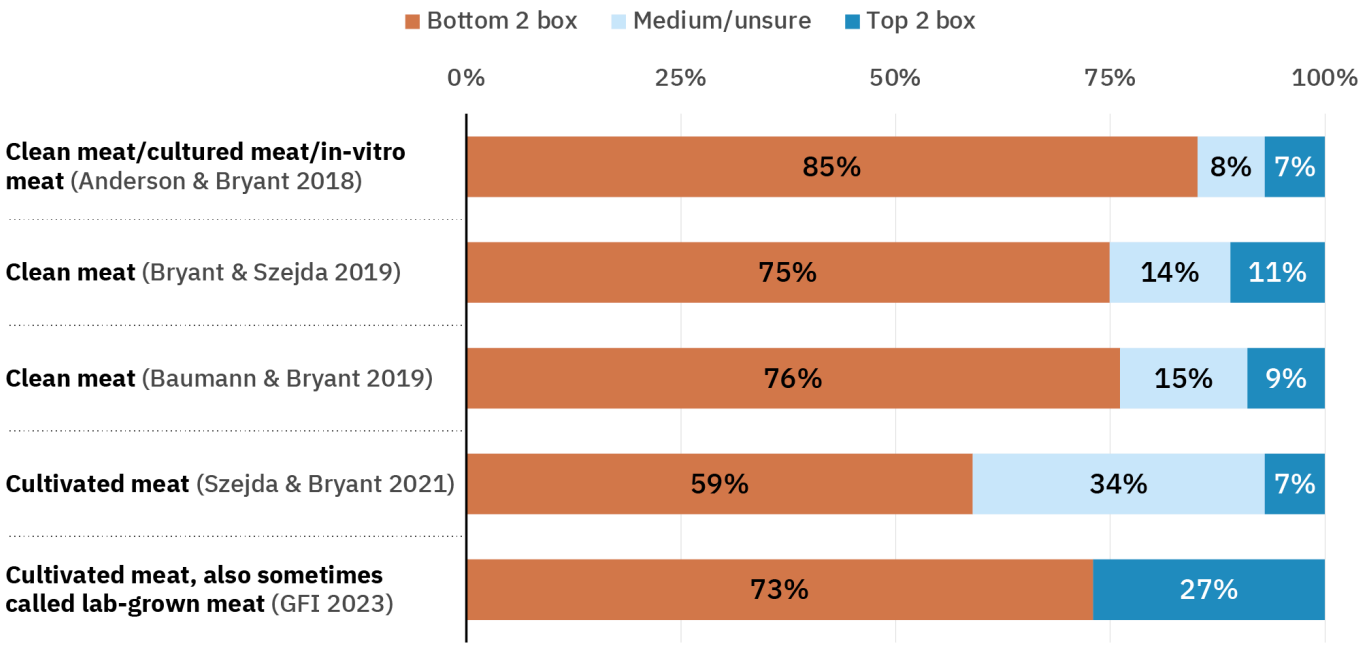
This data suggests companies should consider marketing strategies that increase awareness, and ultimately purchase intent, as they bring products to market.

Figure 6: Cultivated meat awareness across studies



Source: Anderson & Bryant 2018; Baumann & Bryant 2019; IFIC 2023; GFI 2023

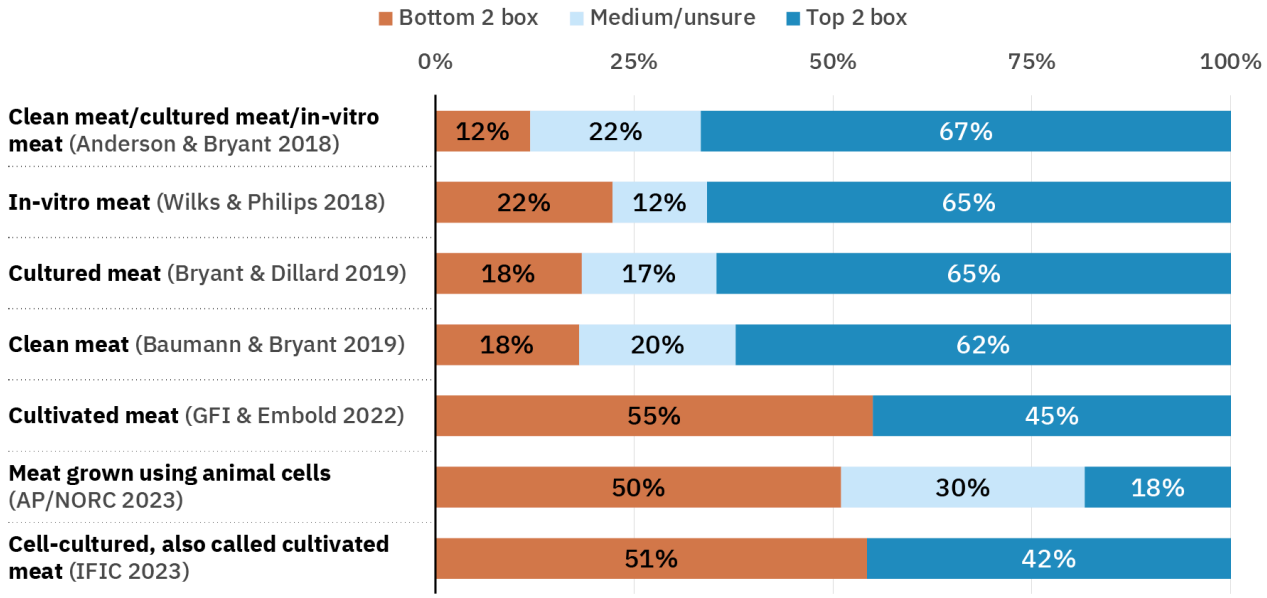
Figure 7: Cultivated meat familiarity across studies



Source: Anderson & Bryant 2018; Bryant & Szejda 2019; Baumann & Bryant 2019; Szejda & Bryant 2021; GFI 2023

Consumer willingness to try

Figure 8: Cultivated meat willingness to try across studies.



Source: Anderson & Bryant 2018; Wilks & Philips 2018; Bryant & Dillard 2019; Baumann & Bryant 2019; GFI & Embold 2022; AP/NORC 2023; IFIC 2023

Recent research suggests that significant numbers of consumers are willing to try cultivated meat and that more are becoming willing as they learn about it.

In a pair of studies conducted by the International Food Information Council in 2021 and 2023, the number of U.S. consumers who reported being "somewhat" or "very" interested in trying cultivated meat almost doubled from 24 percent to 42 percent over the two years between studies. While this is slightly smaller than the number of consumers who are "not too" or "not at all" interested (51 percent), this trend is moving in a positive direction.

When presented with the hypothetical option to try cultivated meat, even more consumers signaled an interest. Research by GFI and Embold Research in 2022 found 45 percent were "willing to try cultivated meat if given a sample." Other researchers in previous years have found that number to be as high as 66 percent percent (Faunalytics 2018). While very few consumers in the United States can currently access cultivated meat (in 2023, it was served in only two restaurants), signals for the potential acceptance of cultivated meat are encouraging.

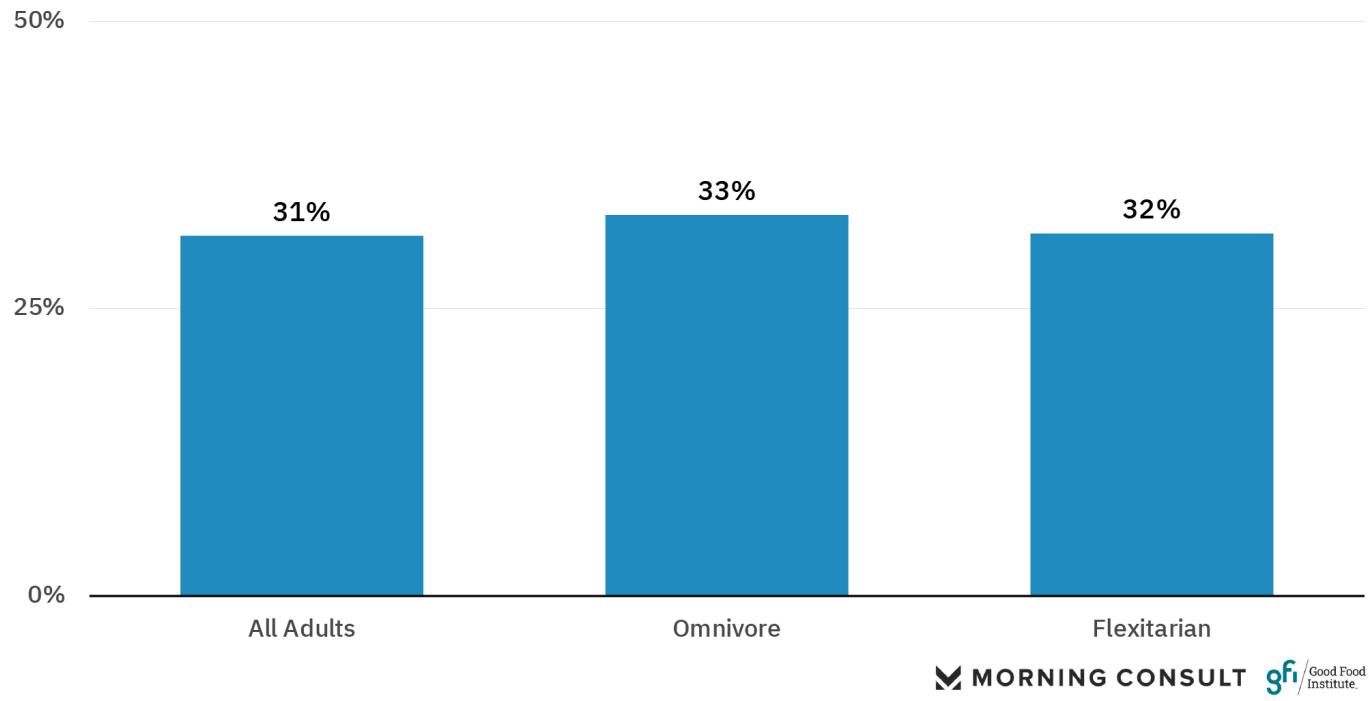
Consumer willingness to try can also be broken down into further categories:

Appeal

A survey by conducted by Morning Consult on behalf of GFI in November 2023 found 32 percent of U.S. consumers rate cultivated meat as "very" or "somewhat" appealing after being given a short neutral explanation of cultivated meat (noting how it's made, its similarity to conventional meat, and that it's available in the United States). Cultivated meat was rated as more appealing by omnivorous and flexitarian (meat-reducing) consumers.

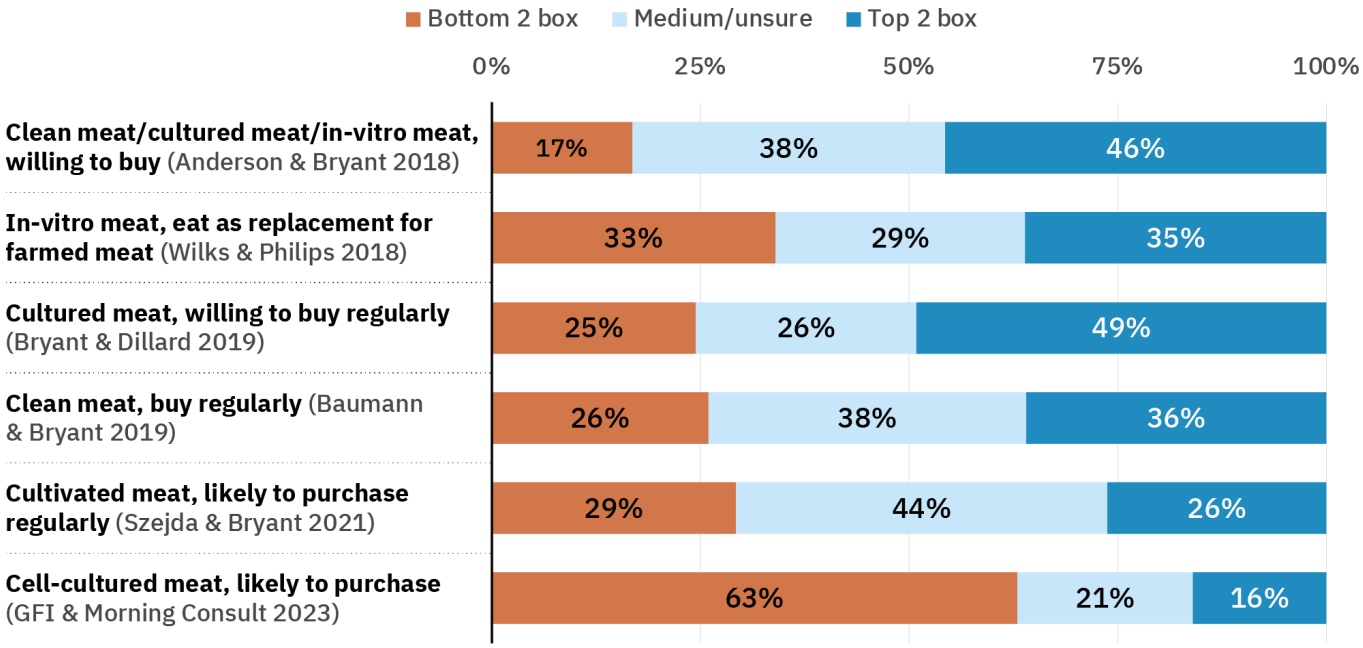
This is comparable to the rated appeal of other types of alternative proteins. A GFI survey commissioned from Embold Research in December 2022 indicates that consumer appeal is higher when consumers are offered an explanation of cultivated meat that focuses on its similarity to conventional meat, compared to explanations that emphasize novelty or technology. **This suggests that highlighting cultivated meat's similarity to conventional meat is the most effective way to build favorability.**

Figure 9: Based on the description provided, how appealing or unappealing do you find cultivated meat?
Percent of respondents who selected "very" or "somewhat" appealing , by diet



Source: Poll by Morning Consult on behalf of GFI, n=2,203 U.S. adults November 2023
Note: Results for pescatarians, vegetarians, and vegans not shown due to small sample size

Figure 10: Likelihood to purchase or eat cultivated meat across studies



Source: Anderson & Bryant 2018; Wilks & Philips 2018; Bryant & Dillard 2019; Baumann & Bryant 2019; Szejda & Bryant 2021; GFI 2023

Purchase likelihood

A review of available research indicates that between 30 and 50 percent of consumers say they would be likely to regularly eat or buy cultivated meat. A November 2023 study conducted by Morning Consult for GFI indicates that 37 percent of U.S. adults report being "somewhat," "very," or "extremely" likely to purchase cultivated meat. This is similar to the purchase likelihood of plant-based meat (46 percent in a poll by Morning Consult on behalf of GFI, December 2023). Comparable levels were seen by Szejda et al. in 2021 for consumers in the United States and the United Kingdom, and research by ProVeg in 2022 for consumers in the United Kingdom saw similar rates at 35 percent likely to try or buy. Research by Aleph Farms on 600 consumers in Singapore in 2022 (85 percent of whom were traditional omnivores and 14 percent of whom were flexitarian) found that 71 percent said they would order cultivated meat "regularly" and 27 percent "occasionally." While it's early in the market launch of these products, these figures demonstrate the need to continue improving interest and purchase intent with consumers, if companies aim for cultivated meat to reach mainstream adoption.

Social motivations

A 2022 survey by Chong et al. comparing Singaporean to American attitudes on cultivated meat found that greater acceptance of cultivated meat in Singapore was driven by stronger social motivations for food choices. While they attribute this to a Singaporean cultural trait of "kiasuism" (which they translate roughly as "FOMO" or fear of missing out), it is likely that consumers in other countries will also become more open to cultivated meat as more people try it and share their experiences in social settings.

Consumer research and demographic insights around the world

Motivators

It is likely too early to tell how well claims and messages about cultivated meat will resonate with consumers. **However, research has consistently shown that consumer interest in cultivated meat is potentially driven by motivators like health, curiosity, environmental benefits, and indulgence without sacrifice.**

- The **International Food Information Council**'s 2023 survey on alternative proteins found that curiosity (32 percent), environmental benefits (28 percent), not requiring animal slaughter (28 percent), and health (26 percent) were the top reasons motivating consumers to try cultivated meat among those interested (with interested consumers selecting up to two reasons).
- Research in 2022 by GFI and Embold Research found that a wide variety of messages about cultivated meat increased consumers' rated appeal, including health (55 percent found health messages made cultivated meat somewhat or much more appealing); climate change and environmental benefits (both 47 percent); and offering the same and potentially better taste, texture, and freshness than conventional meat (also 47 percent). **The health message included both public health messaging around reduced risk of foodborne illness and pandemic, as well as personal health reasons like lack of hormones, antibiotics, and steroids, suggesting that consumers are interested in a variety of personal and public health benefits from cultivated meat.**
- Research published in 2022 by GFI APAC revealed that the lack of mercury and heavy metal contamination in cultivated seafood was a top driver of interest among consumers in Japan, Singapore, South Korea, and Thailand. The top barriers across all four countries were perceptions of taste shortcomings and concerns about "freshness" and "naturalness."

Demographics

- Consumer research conducted by Morning Consult on behalf of GFI suggests that several groups in the United States are more likely to find cultivated meat appealing, including men, Gen Z and Millennial consumers, and liberals.
- Omnivorous and flexitarian consumers are also especially likely to find cultivated meat appealing, echoing results from Singapore that found a majority of early adopters there were omnivores and flexitarians, and suggesting the potential for cultivated meat to appeal to the majority of consumers who are not currently eliminating conventional meat from their diets.
- Some evidence suggests that consumers are likely to be persuaded by certain factors, including the recent USDA/FDA approval of cultivated meat and by seeing others eat it. IFIC's 2023 survey (conducted before the USDA/FDA's approval in June 2023) found that 63 percent of consumers think cultivated meat would be safe if approved by USDA/FDA.

Most effective messages to increase cultivated meat appeal

Based on a December 2022 survey of 1,018 U.S. adults by Embold Research commissioned by GFI

Percentage of respondents who indicated that the message makes cultivated meat much more or somewhat more appealing to them:

55 percent	Cultivated meat can be grown without added hormones, steroids, or antibiotics, in facilities with cleaner conditions than conventional meat processing facilities. This reduces the risk of both foodborne illnesses and future pandemics.
47 percent	Cultivated meat is more environmentally friendly than conventional meat. Producing cultivated meat requires much less water and land than the production of conventional meat. This means less competition for water in times of drought and the slowing of deforestation. Replacing conventional meat with cultivated meat will also reduce the amount of animal waste created, resulting in less air pollution.
47 percent	Animal agriculture is responsible for 20 percent of global greenhouse gas emissions. Replacing conventional meat with cultivated meat produced with renewable energy would result in a massive reduction of greenhouse gas emissions, helping to fight climate change.
47 percent	Cultivated meat will have the same smell, texture, and consistency as the meat you enjoy today. It will also taste the same or better than conventional meat given the production methods, it could have a purer taste and stay fresher longer.

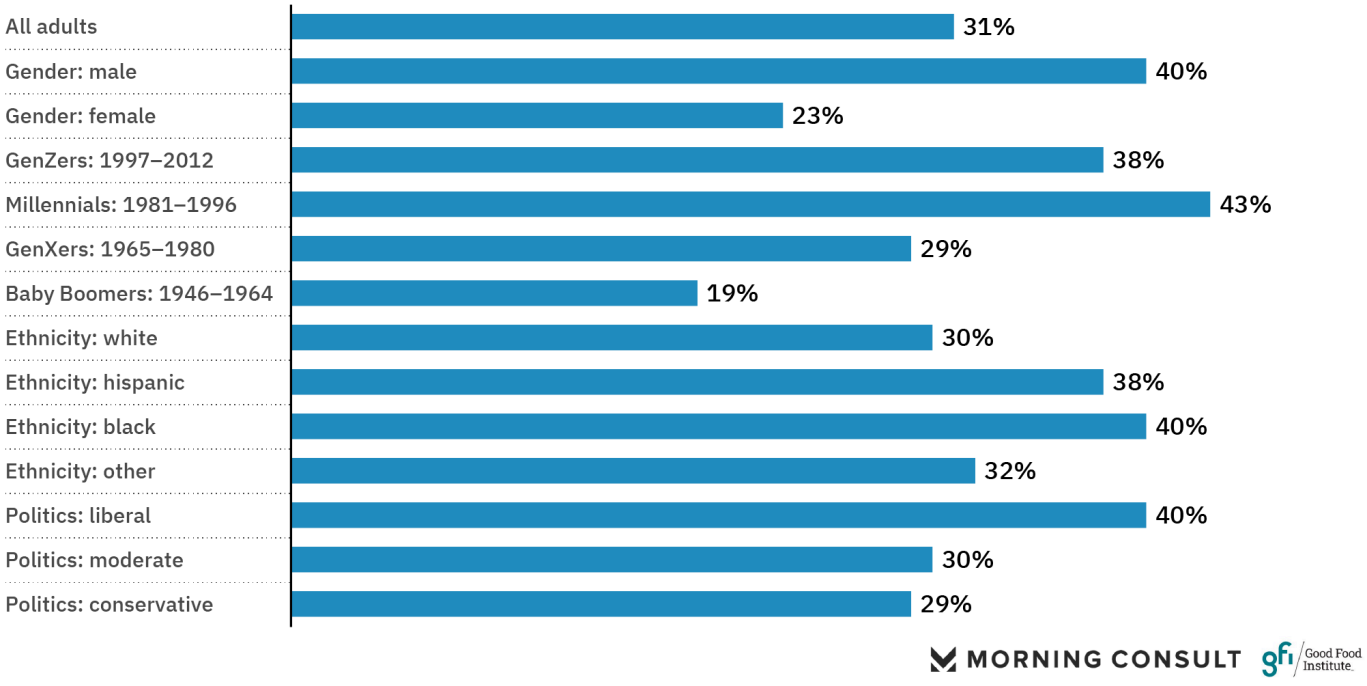
Finless Food's cultivated sushi rolls.
Photo credit: Finless Foods.

Global perspective

- In 2023, additional insights from around the world provided further context for how cultivated meat is currently viewed by consumers and how its potential resonates.
- Studies from the United Kingdom (including by ProVeg in 2022 and by Fidder and Graça in 2023) explored the power of imagery. These studies found that images of cultivated meat that showcased its similarity to conventional meat led to a higher willingness to try and higher appeal ratings. The ProVeg study also found that consumers who were more familiar with cultivated meat reported seeing it more frequently associated with lab imagery, suggesting that there is enormous potential to improve associations between appetizing imagery and cultivated meat.
- A 2022 survey in France of mostly young consumers (67 percent of the sample were aged 18 to 30) found that 80 percent of consumers are open to trying cultivated meat and believe it will become widespread.
- A total of 49 percent of consumers in Italy, Portugal, and Spain perceived meat as "promising and/or acceptable," according to a June 2023 study from Liu et al. The study revealed that 66 percent would be willing to try cultivated meat.

In Poland, 63 percent of adults "had heard of cultivated meat" and 54 percent said "they would purchase it when available," according to a November 2023 study from Sikora and Rzymski.

Figure 11: Based on the description provided, how appealing or unappealing do you find cultivated meat?
Percent of respondents who selected "very" or "somewhat" appealing by demographic group



Source: Poll by Morning Consult on behalf of GFI, n=2,203 U.S. adults November 2023

Gourmey's cultivated and pan-fried foie gras.
Photo credit: Gourmey and Romain Buisson

The rise in misinformation and disinformation about cultivated meat online

Based on a November 2023 social media analysis by Changing Markets Foundation and Ripple Research

A large social media analysis by Changing Markets Foundation and Ripple Insights in 2023 documented and categorized the spread of misinformation on X (formerly Twitter) about meat and meat alternatives. They identify a small number of accounts (50) spreading misinformation about meat or meat alternatives, primarily focused on disparaging meat abstention or alternatives (78 percent of content disparaged meat alternatives or abstention while 22 percent promoted meat). While the net percentage of engagement is small in terms of the population (two million interactions, measured in views, retweets, likes, shares, and comments), the content is misrepresentative and raises unfounded concerns about meat alternatives that probably negatively affected consumer perceptions, especially among those with less familiarity with the category.

Investments

Investments

Overview

Following the first disclosed investment in cultivated meat and seafood in 2013, companies involved primarily in the cultivated meat sector have raised $3.1 billion, with more than 80 percent of investments coming in the last three years alone. While 2023 fundraising totals marked a decline from 2022 levels, other primarily venture-backed sectors like fintech also experienced funding declines of around 50 percent year-over-year (YOY).

A GFI analysis of data from Net Zero Insights shows that Cultivated meat companies raised $225.9 million in 2023, representing a sizable decrease from the $922.3 million raised in 2022. Cultivated meat and seafood remain a nascent sector with fewer than 200 companies worldwide, approximately half of which were founded in the last three years. As a result, a small number of deals can significantly impact annual investment totals for the sector. For example, in 2022, nearly half of the year's total investment dollars were raised in **UPSIDE Foods**' $400-million Series C round. Since advanced companies generally do not raise large rounds two years in a row, there is a degree of randomness in any single year's funding totals.

The cultivated meat and seafood sector lacked similar funding mega-rounds in 2023. The largest deal raised in 2023 was **Meatable**'s $35 million Series B round, and the three largest investments for the year totaled less than $100 million collectively. These are impressive totals for early-stage, pre-revenue companies, but without any mega-rounds raised, a much larger number of similarly sized deals would have been required to keep pace with recent years' industry-wide investment totals.

The wider alternative protein industry also saw private funding fall in 2023. While alternative protein companies raised $15.7 billion from 2014 to 2023—over half of which was raised in 2020 and 2021—investments dipped from $2.9 billion in 2022 to $1.6 billion in 2023. That said, these totals—and those for cultivated meat companies—are likely underestimated. Some companies raised funds that were not publicly reported under simple agreements for future equity (SAFE) or bridge rounds to increase financial runway. While certain deals, in general, are not publicly disclosed, we suspect an increased frequency of under-reporting this year based on the larger number of SAFE and bridge rounds and on our conversations with market participants. Some of these investments may eventually be reported as investments in 2024.

Various industries contended with a tepid private funding environment in 2023 driven by rising interest rates, elevated inflation, and a mixed economic outlook. As a result, global venture funding across all sectors fell 42 percent YOY in 2023 to its lowest level since 2017. Climate tech equity investments decreased by as much as 40 percent YOY, despite the sector receiving significant government support through the Inflation Reduction Act and other policies that helped to de-risk and fuel investment. Investments in food tech startups declined by 61 percent YOY.

Even in the face of these challenges, the cultivated meat industry continued to advance in 2023. Consumers purchased cultivated meat products in the United States for the first time, and several countries reviewed cultivated meat products for regulatory approval. Companies also continued to innovate their processes and products.

The challenging private funding environment for cultivated meat and alternative proteins may continue in the year ahead, especially as interest rates in the United States, Europe, and elsewhere are likely to remain elevated in 2024. At the same time, alternative proteins and cultivated meat continue to be among the most promising solutions for reducing the negative impacts of conventional meat production. **This also makes cultivated meat an important ESG opportunity, providing potential upside for investors and the industry.**

With this backdrop, we expect alternative protein and cultivated meat investments to evolve in the coming years. Since 2023 was a year of major transition, the industry is likely to settle on an adjusted, more realistic path in 2024. In light of the tighter private funding environment that is expected to persist into 2024, we expect the alternative protein companies best-positioned to attract equity investment will be those that can demonstrate clear pathways to revenue and profitability. At the same time, long-term debt, grants, and government incentives are essential for companies to lower their production costs and achieve price parity as they scale production. To enable alternative protein companies to access such funding, they will need creative solutions in areas such as product off-take and leveraging government and philanthropic funding. **Fortunately, there are replicable solutions already being implemented (e.g., school districts procuring alternative proteins for lunch menus) as well as those that have been successfully used in other industries (e.g., government loan guarantees and blended philanthropic financing for renewable energy). Through multi-stakeholder collaboration, these solutions can facilitate the flow of capital into alternative proteins.**

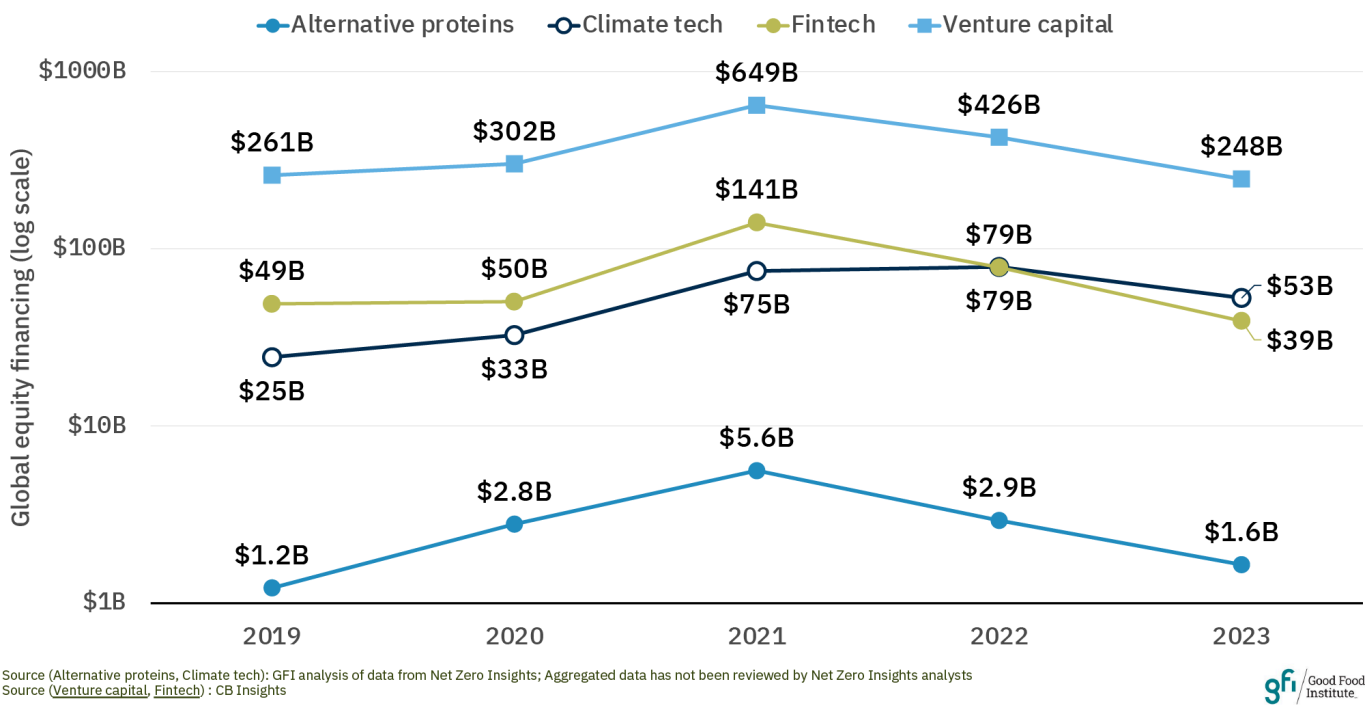
Regardless of external market forces, if governments and companies are serious about improving food security, reducing emissions, and achieving their climate goals, more alternative protein funding is needed to help companies scale, improve their products, and reduce their costs. On that front, public funding for cultivated meat grew more robust in 2023, with governments investing in research centers of excellence, commercialization and infrastructure programs, and targeted support for producers.

Source: Unless otherwise cited, the investment data reported above was derived from GFI's analysis of data from Net Zero Insights.

Note: Aggregated data has not been reviewed by Net Zero Insights analysts. The total deal count includes deals with undisclosed amounts.

> *When things are easy, everyone can look brilliant, but when times are hard, you need to really look at what sets you out from the other areas. I, personally, and Barclays are very invested in the long-term of [alt protein], and I think now is the time for us to take a long-term perspective.*
>
> *I'm excited about how far we've come and just because the capital markets overall are at a rough time, we should not lose faith. The critical part is what this sector does for the planet and I think there it has some real longer-term returns.*
>
> **Matt Spence**
> *Managing Director and Global Head of Venture Capital Banking at Barclays*

Figure 12: Cumulative and annual alternative protein invested capital, by pillar

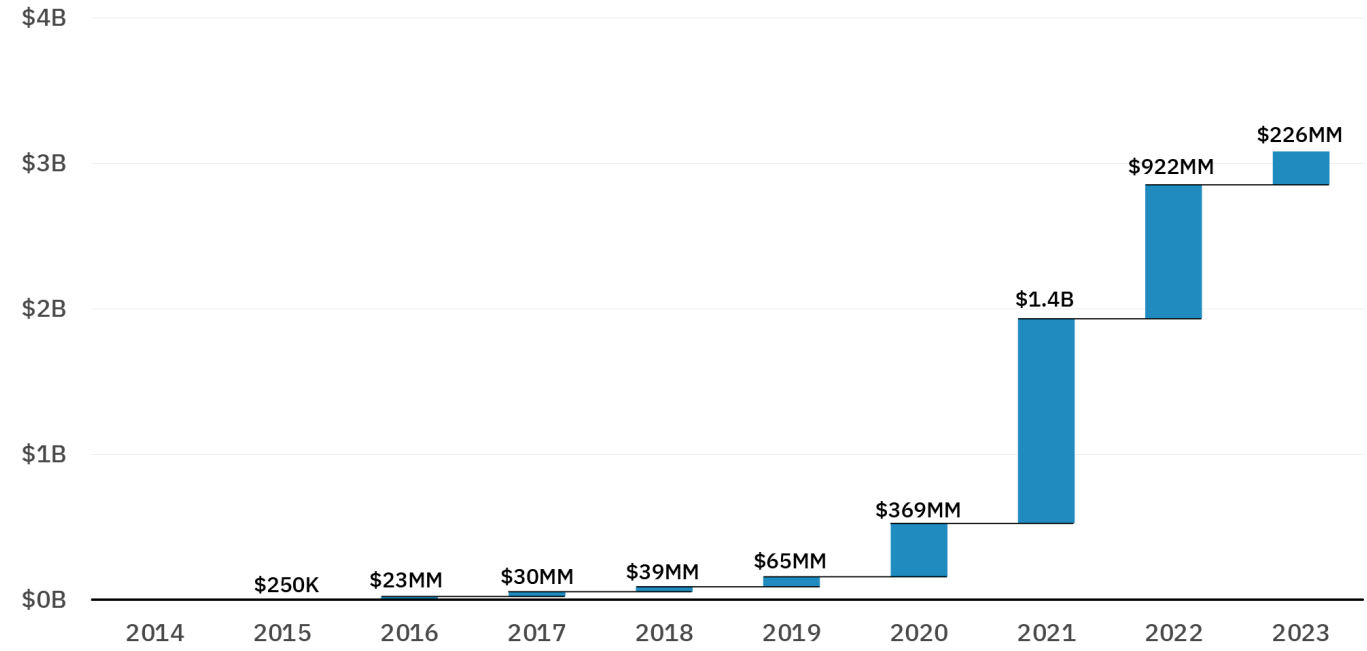


Source: GFI analysis of data from Net Zero Insights.
Note: Aggregated data has not been reviewed by Net Zero Insights analysts.

Figure 13: Global equity financing across sectors

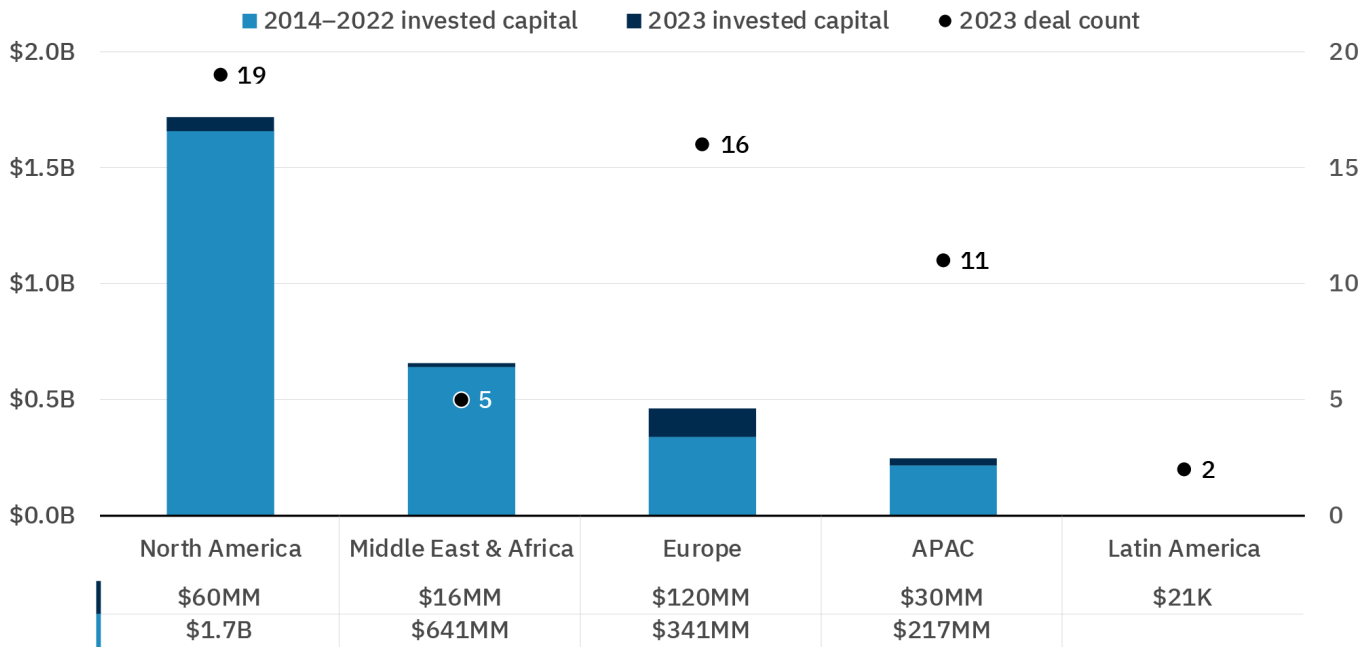
Source: (Alternative proteins, Climate tech): GFI Analysis of data from Net Zero Insights; Aggregated data has not been reviewed by Net Zero Insights analysts.
Source: (Venture capital, Fintech) : CB Insights

Figure 14: Cumulative and annual investment in cultivated meat and seafood (2014-2023)



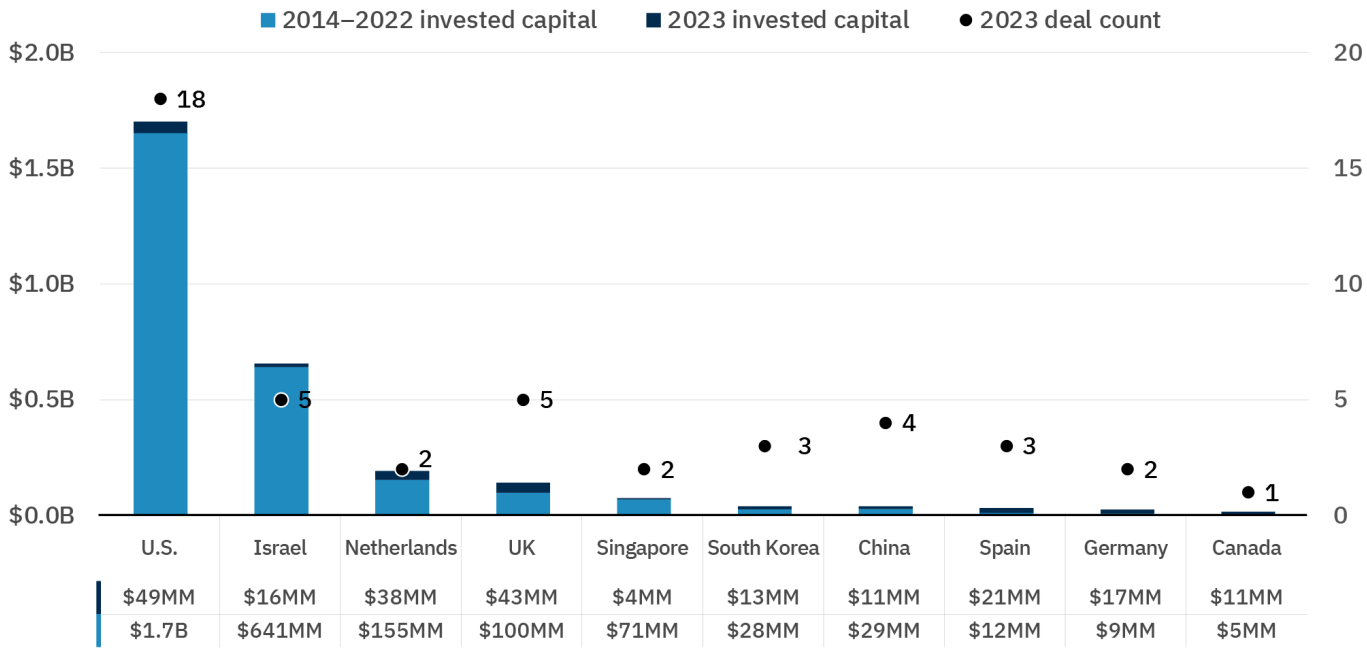
Source: GFI analysis of data from Net Zero Insights.
Note: Aggregated data has not been reviewed by Net Zero Insights analysts.

Figure 15: Investments in cultivated meat and seafood by region (2014-2023)



Source: GFI analysis of data from Net Zero Insights.
Note: Aggregated data has not been reviewed by Net Zero Insights analysts. The total deal count includes deals with undisclosed amounts.

Figure 16: Investments in cultivated meat and seafood: Top 10 countries (2014-2023)



Source: GFI analysis of data from Net Zero Insights.
Note: Aggregated data has not been reviewed by Net Zero Insights analysts. The top 10 countries were selected based on 2023 invested capital. The total deal count includes deals with undisclosed amounts.

Table 5: Deal type summary statistics

Deal type	Median (2023)	Median (2022)	Median (all years)	Maximum (all years)	Deal count (all years)
Accelerator/incubator	$0.02MM	$0.20MM	$0.13MM	$0.51MM	94
Bridge			$10.00MM	$10.00MM	2
Convertible note	$0.16MM		$1.25MM	$60.00MM	7
Corporate	$3.50MM		$3.5MM	$3.50MM	1
Debt	$0.10MM		$0.59MM	$4.00MM	5
Early VC	$2.50MM	$4.18MM	$2.43MM	$18.5MM	110
Late VC		$7.00MM	$97.00MM	$170.00MM	5
Pre-seed	$2.94MM	$1.00MM	$1.00MM	$3.00MM	27
Product crowdfunding			$20.47MM	$20.47MM	1
Seed	$3.50MM	$2.45MM	$2.50MM	$22.60MM	108
Series A	$10.22MM	$13.59MM	$13.18MM	$70.00MM	41
Series B	$34.25MM	$100.00MM	$67.50MM	$347.00MM	11
Series C		$400.00MM	$400.00MM	$400.00MM	1
Series F			$200.00MM	$200.00MM	1

Source: GFI analysis of data from Net Zero Insights.
Note: Aggregated data has not been reviewed by Net Zero Insights analysts. These figures represent summary statistics of invested capital rounds with disclosed deal amounts. Deal count includes rounds with undisclosed amounts. Due to their limited number and size, this table excludes angel, general crowdfunding, debt crowdfunding, growth equity, private equity, private placement, and series D, E, G, and H rounds. It also excludes uncategorized rounds. The total deal count includes deals with undisclosed amounts.

Figure 17: 2023 key funding rounds

Source: GFI analysis of data from Net Zero Insights.
Note: "2023 key funding rounds" includes investments in the 75th percentile or higher by dollar amount for each funding round category that includes more than three deals. For funding round categories that include three deals or fewer, all deals are included.

For a list of investors who have expressed interest in funding cultivated meat and seafood, companies can request access to GFI's investor directory.

Methodology

GFI conducted a global analysis of cultivated meat investments using data from Net Zero Insights. Our analysis uses a list we built in Net Zero Insights' platform of companies that focus primarily on cultivated products or on providing services to those who produce them.

Types of companies included and excluded

- We excluded the many companies that are involved in animal cell culture but not as their core business, such as **Merck KGaA, Darmstadt, Germany**, as the funding these companies devote to cultivated meat is undisclosed.
- We also exclude companies that are *more* focused on plant-based or fermentation than on cultivated meat—we instead include those companies in the area they are most involved in (e.g., plant-based, fermentation).
- Some companies included in our list may also offer products or services that apply to another protein category. The $200 million that **Eat Just** raised in March 2021 for use across their product lines and the $267 million raised for their **GOOD Meat** division in the funding round completed in September 2021 are categorized under cultivated meat. All other Eat Just funds raised are categorized under plant-based (the company was founded as a plant-based egg company, and their business is focused on both plant-based eggs and cultivated meat today).
- Some companies use a different alternative protein production platform to produce inputs for cultivated meat, for example using precision fermentation to produce growth factors. Those companies are categorized as fermentation companies and are excluded from our cultivated meat dataset.
- We included cultivated milk and egg companies as well as cultivated meat pet food companies, though they are not the primary focus of this report.

The Net Zero Insights platform contained 173 companies involved primarily in the cultivated meat industry, 125 of which had disclosed deals. Of these, 101 had deals with publicly disclosed amounts. Net Zero Insights primarily tracks deals from publicly disclosed sources unless companies claim their profiles on the platform and provide their own investment information. Because our aggregate calculations include only companies with deals and deal sizes available to Net Zero Insights, they are conservative estimates.

Types of funding included

For this report, invested capital/investment comprises accelerator and incubator funding, angel funding, bridge funding, convertible debt, corporate venture, equity and product crowdfunding, general debt completed deals, debt crowdfunding, seed funding, early-stage venture capital, late-stage venture capital, private equity growth/expansion, capitalization, joint venture, and private placements. Liquidity events comprise completed mergers, acquisitions, reverse mergers, buyouts, leveraged buyouts, spinoffs, and IPOs, while other financing comprises completed subsequent public share offerings and private investment in public equity. We do not include capital raised through a SPAC IPO until the entity has merged with or acquired a target company.

Data provider

Please note that the figures published in this report may differ from prior figures published by GFI, as we are now using Net Zero Insights as our investment data provider and are continually working to improve our dataset. To verify your company's data on the Net Zero Insights platform, claim your company's profile here and help us ensure we have access to the fullest, most up-to-date information.

Liquidity events

Liquidity events represent the sale of an equity owner's interest in a company, typically through a merger, acquisition, buyout, or IPO. In a relatively nascent category like the cultivated meat sector where the vast majority of companies remain in pre-revenue stages, certain liquidity events such as mergers and acquisitions (M&A) are more common components of industry development, while others, such as IPOs, are less common at this stage. Mergers and acquisitions allow companies with stronger financial footing to acquire firms with valuable technologies, manufacturing processes, and talent. That said, liquidity event activity is also highly dependent on the broader economic context.

No liquidity events, also known as exits, took place in the cultivated meat sector in 2023.

In a year when global M&A activity fell to its lowest level in over a decade, the relative lack of cultivated meat liquidity events was representative of the larger funding and M&A environment. The same conditions that led to fundraising difficulties—like economic concerns and a tight financing environment—also contributed to limited M&A activity.

While we expect cultivated meat liquidity event activity to accelerate in the coming years, as seen in the trajectories of other transformative innovations like electric vehicles, the rate at which it does so will also hinge on conditions like interest rates, economic sentiment, and views of the cultivated meat sector.

Other financing

Some public companies pursue financing paths such as subsequent public share offerings and private investment in public equity (PIPE) deals.

The only cultivated meat and seafood company to have raised such financing in 2023 is **Steakholder Foods** (previously MeaTech, which is traded publicly on the NASDAQ stock exchange). According to Net Zero Insights, the company raised $6.5 million in post-IPO equity financing in January 2023. Once more cultivated meat and seafood companies begin trading publicly, we expect to see a higher number of other financing rounds.

The Good Food Institute is not a licensed investment or financial advisor, and nothing in the State of the Industry Report series is intended or should be construed as investment advice.

Science and technology

Science and technology

Overview

As many companies march toward market readiness, a growing number of scientists in industry and academia are exploring new lines of inquiry that will help reduce costs, increase the scale, and improve the quality of future products. As the rate of newly published research accelerates, the entire sector benefits from the growing foundation of open-access information and discoveries that can be translated into the commercial realm.

For a comprehensive view into the current state of the science in cultivated meat, visit GFI's science of cultivated meat page.

Research across the sector

As results for new cell lines and culture conditions are published each year, more research groups have expanded their focus into scaling up production with small bioreactors, using scaffolding to culture cells in 3D, and creating prototype products that can be analyzed for taste, texture, and nutrition. With these advances, a growing number of scientists are focused on product safety and quality, while others are exploring the potential environmental and societal effects of a future with a growing market share of cultivated meat.

This section provides a snapshot of notable scientific advancements from 2023.

Cell lines

Definition: For cultivated meat and seafood to match the variety of conventional products on the market, high-quality cell lines from many species will be required. A variety of cell types may be applicable to cultivated meat, from pluripotent stem cells to adult stem cells capable of becoming fat, muscle, or connective tissues. Researchers are working to develop and characterize new cell lines and to better understand the properties of different cell types—growth potential, metabolism, media requirements, and effects on the properties of the final product—that will determine how suitable each cell type is for cultivated meat.

2023 research highlights

The cultivated meat research community continued to expand the availability of high-quality cell lines for research and commercialization. To better understand cultivated meat companies' needs when it comes to cell lines, GFI APAC conducted an industry-wide survey and developed a report with key insights into: the species and cell types of highest priority; the methods currently used for cell line development, characterization, and growth; and regulatory documentation and testing.

A new muscle cell line from the freshwater carp *Labeo rohita* was described by a team that included GFI grantees Dr. Mukunda Goswami and Dr. Reza Ovissipour. Another muscle cell line from olive flounder was described by researchers at **Pukyong National University**. Besides muscle, producing a whole cut of meat like a steak or a chicken breast requires producing different cell types—including fat cells—and a 3D structure for their growth. Researchers from **Nanjing Agricultural University** reported the derivation of a new immortalized porcine (pork) fat cell line, including the co-differentiation of muscle and fat cells on the

same scaffolds. If such processes can be scaled effectively, they have the potential to increase the resemblance of cultivated products to their conventional counterparts and substantially simplify the production process.

Additionally, researchers from **Aleph Farms** described their approach to bovine embryonic stem cell line development and characterization. Embryonic cells such as these could be used as the starting point for muscle, fat, and any other cell type desired by cultivated meat producers. Collectively, these studies fill many of the knowledge gaps about the cells being used in cultivated meat production and expand the repertoire of cell lines available for research.

It was also an exciting year for B2B cell line development. GFI has identified 65 lines (up from 41 in 2022) relevant for cultivated meat that can be ordered from public repositories or directly from the cell line owner, many of which are owned by B2B providers such as **OpoBio**, **QuestMeat**, **Roslin Technologies**, and **PluriCells**. In addition, the contract manufacturer **Extracellular** announced the creation of a new, license-free cell bank for the cultivated meat industry in partnership with **Multus Media**.

Beginning with primary muscle and fat cells from cows, pigs, and lambs, Extracellular plans to expand to additional species and tissues. Cultivated meat company **Ohayo Valley** also indicated their intention to pursue a partial B2B model as a supplier of custom cell lines. Finally, a partnership between biotechnology company **Triplebar** and cultivated seafood company **Umami Bioworks** was also announced this year to accelerate cultivated fish cell line development. Triplebar presented their technology at GFI's Cultivated Meat Collaborative Seminar in late 2022.

Cell Culture Media

Definition: Cell culture media contains the nutrients and growth factors needed to cultivate cells outside the body. As the primary input into the cultivated meat process, it is currently the largest cost and environmental impact driver of cultivated meat production. Additional research is needed to derive animal-free formulations that match the metabolic requirements of each cell line, in addition to creating a supply chain of more affordable, animal-free, and food-grade ingredients.

2023 research highlights

Approaches to research in cell culture media have included removing animal components and replacing high-cost ingredients with more affordable alternatives, optimizing the efficiency of media use within the production process, and enabling the use of fewer overall media ingredients. In 2023, companies made progress along various points of this research pipeline.

One promising approach uses waste streams from one industry as feedstock into another, which can improve both cost and sustainability metrics. GFI and collaborating researchers explored the potential use of sidestreams from commodity crops in North America for cultivated meat production, finding that soybean meal, corn distillers dried grain, canola meal, brewer's spent grain, and corn gluten meal could all be good candidate sources for hydrolysates to supply amino acids for cell culture media.

The ultimate goal in using crop sidestreams is to replace serum and to more affordably and sustainably supply nutrients to cultivated cells. Researchers have already begun to investigate this

concept, with groups in South Korea and Singapore finding that fermented soybean meal and okara, a waste stream from tofu and soy milk production, could potentially be used as a serum alternative. Several studies also explored using compounds extracted from cyanobacteria and extracts from different species of microalgae, finding that these could be a beneficial supplement to cell cultures.

However, challenges remain, including optimizing the protocols for obtaining hydrolysates or extracts. In one study, researchers at the University of Campinas in Brazil tested various enzymes and conditions to discover how to maximize the yield of peptides and amino acids from soybean and peanut protein meals. Future studies that optimize protocols for raw material extracts and hydrolysates will be crucial for the cultivated meat industry, and the research into reducing the cost and environmental impact of cell culture media using available alternatives remains promising.

Other notable research focuses on optimizing the overall media formulation and ensuring that it is used efficiently. Recent research on this topic used mathematical techniques and algorithms to optimize media costs and reduce environmental impact, as well as to derive serum-free media that outperforms serum-containing media.

Media formulation discovery can also be enhanced through systems biology and metabolic modeling techniques, which are increasingly important as the cultivated meat industry matures. Collectively, these efforts can accelerate the development of culture conditions across a variety of species and cell types used to cultivate meat, enabling an easier starting point for new labs and companies entering the field. However, to date, most media research has focused on mammalian and avian cells, and **media optimization for seafood continues to be a major bottleneck.**

Finally, the field saw progress in 2023 on another known challenge: preventing the buildup of toxic metabolites such as ammonia. Potential methods for addressing this issue range from adsorption to genetic engineering to altering the media composition. Researchers at Mosa Meat demonstrated the latter approach, showing that ammonia production can be kept at a minimum by changing what cells are fed, a simple solution that could potentially have a large impact if adopted throughout the industry.

Scaffolding

Many approaches to producing cultivated meat use some form of 3D scaffolding to provide structure to the final product; facilitate nutrient, oxygen, and waste transport; and provide cues that can help the cells differentiate and mature as desired. Research into scaffolding for cultivated meat focuses on identifying the best materials (or combinations of materials) and developing innovative manufacturing technologies for scalable and cost-effective scaffolds.

2023 research highlights

Research into scaffolding for cultivated meat focuses on identifying the best materials (or combinations of materials) and developing innovative manufacturing technologies for scalable and cost-effective scaffolds.

One key theme for 2023 was the use of biomaterials derived from plants, fungi, and other sustainable sources as cultivated meat scaffolds. Traditionally, tissue engineering has relied heavily on animal-derived proteins such as collagen or on synthetic polymers as scaffolds. **Today's cultivated meat researchers are proving that there is plenty of useful scaffolding functionality to be found in the plant and fungi kingdoms if we know where to look.**

Researchers at **Boston College** and **Worcester Polytechnic Institute** used decellularized plant material from existing waste streams—specifically corn husks and jackfruit rinds—as microcarriers. With an eye toward improving the applicability of decellularization-based techniques to cultivated meat, the same team also tested methods for replacing the traditional solvents and detergents and identifying conditions where effective decellularization could be achieved using food-safe compounds. Researchers from the **Sanjay Gandhi Post-Graduate Institute of Medical Sciences** (India) demonstrated that decellularized mushrooms could be successfully used as scaffolds for myoblasts (muscle precursor cells).

Similarly, researchers from **A*STAR** performed a bioinformatics analysis that found that the RGD motif, an amino acid sequence known to be important for the adhesion of animal cells to the extracellular matrix, was common among both plants and fungi. They also demonstrated that RGD-rich protein extracts from fungi compared favorably to the animal-derived matrix proteins collagen and fibronectin, thereby adding further evidence that plants and fungi show promise as scaffold sources for cultivated meat production.

Researchers from the **National University of Singapore** determined that pumpkin seed protein supported cell adhesion and proliferation to a similar extent as animal gelatin and could support long-term proliferation of mouse muscle and fat cells, adhesion of chicken and pig muscle cells, and muscle cell differentiation. They also confirmed that pumpkin seed proteins are rich in RGD sequences, which presumably explains their results. A second paper by the same group found that chickpea protein, despite performing poorly when untreated, was highly effective at supporting adhesion, proliferation, and differentiation when used as a hydrolysate. And whereas alginate is usually observed to have poor cell adhesion properties, a study by researchers from **Konkuk University, NoAH Biotech**, and **Seoul National University** demonstrated that these properties could be modified by altering the crosslinking conditions.

A great deal of diversity exists within plant-, fungal-, and algal-derived biomaterials, including properties that are beneficial for cultivated meat scaffolds. Through a combination of bioinformatic and empirical screening for desirable properties and careful testing of the conditions by which scaffolds are created, researchers in 2023 identified food-safe scaffold

materials that support cell adhesion and proliferation with positive or neutral effects on flavor, texture, and nutritional properties of the final product.

These findings collectively validate the hypothesis that animal-derived materials will not be necessary to create cultivated meat products in the future.

Bioprocess design

Definition: The bioprocess for cultivated meat encompasses production lines of bioreactors outfitted with sensor equipment, integrated with cell-harvesting and food-processing equipment, and designed with automation in mind. Production lines can be constructed in various ways, and research is needed to determine the best-suited bioreactors and technologies required to create and scale a spectrum of cultivated meat product types.

2023 research highlights

Companies are actively employing a variety of cell lines to cultivate muscle and fat for many products, ranging from fish and shrimp to beef, chicken, and pork. However, there are still challenges in closing the knowledge gaps, optimizing cell culture protocols, and developing and selecting suitable bioreactors.

To achieve price and taste parity, there are several areas in the field of bioprocessing that researchers, suppliers, and investors can tackle, including addressing the high costs and limited availability of media components, raw materials, and bioreactors. **Key areas requiring further research and development include improving the cost and accessibility of bioreactors, using food-grade materials, and developing other fit-for-purpose equipment such as for cell harvesting.** Additional areas include training professionals in bioprocessing, modeling, simulation, and automation.

Cultivated meat bioprocessing saw several notable advancements in 2023. **Ark Biotech** published a techno-economic analysis highlighting the potential of *current* biomanufacturing technologies to produce cultivated meat at scale at an estimated price of $29.50 per pound. The report outlines four strategies to further lower the cost of goods sold: reducing media costs, improving biomass yields, optimizing the bioprocess, and utilizing larger bioreactors. According to the report, media is the main contributor to costs, and lowering its cost to around $1 per liter is essential for cultivated meat to reach price parity. Another insight from the report is the importance of scaled production, which enables a lower cost burden of depreciation and labor.

The analysis also compares scenarios using different bioprocess methods, favoring fed-batch or continuous processing for cost-effectiveness. While fed-batch processing was found to be superior in most cases of scaled production, continuous processing requires less overall capital expenditure and space. In conclusion, Ark Biotech emphasizes the need for integrated advancements across media, bioreactors, cells, and bioprocesses to achieve price parity with conventional meat.

Researchers from Norway and the Netherlands enhanced the cost-effectiveness and efficiency of cultivated meat production by focusing on tuning and optimizing media components and cell culture parameters. The group was able to expand skeletal muscle satellite cells for up to 38 days under serum-free conditions in a bench-scale bioreactor. This approach highlights the potential for optimizing various parameters specific to each cell line and bioprocess, thereby reducing costs and increasing yields while removing the reliance on fetal bovine serum (FBS).

Cultivated meat production shares some challenges and opportunities with fields like regenerative medicine, highlighting the potential for collaborative efforts and resource allocation.

Regenerative medicine can contribute insights into areas such as developing scaffolds for tissue generation, stem cell biology, or media development. Bioreactors—pivotal in both healthcare and cultivated meat manufacturing—enable efficiency and scalability by expanding cell culture and providing controlled conditions for cell growth. This review explores and assesses bioreactor technology in cell therapy and cultured meat production.

To address the challenges associated with 3D culture for cultivated meat production, a team of scientists in France has developed an innovative solution. Traditional 3D culture methods often rely on scaffolds that are not easily scalable. In response, the researchers created an in vitro culture system that combines the benefits of biomimetic 3D culture with scalable bioreactor-based production. The study successfully scaled up the production of stem cells and demonstrated scale-independent expansion yields, reaching an impressive 277-fold expansion in just 6.5 days in a 10-liter stirred-tank bioreactor. While these results were demonstrated in human cells, this concept could rationally be translated for the cultivated meat industry.

Finally, using computer models and simulations is crucial for optimizing cultivated meat processing and achieving cost parity, particularly at large scales. One major challenge in this process is the disruptive shear stress caused by high rotor speeds in bioreactors. In a recent study, researchers developed a computational model integrating agent-based modeling and computational fluid dynamics to examine biomass growth in stirred-tank bioreactors. Their focus was to understand how mechanical stress induced by rotor speed impacts cell growth on spherical microcarriers. The simulation results aligned with physical experiments, demonstrating that elevated rotor speeds reduce cell growth rates and increase cell death due to high mechanical stresses. This simulation was the first step in building comprehensive models that can improve biomass production and reduce costs by informing bioreaction design and culture condition optimization.

End-product formulation and characterization

Commercial success for cultivated meat will require both the development of efficient and reliable bioprocesses and a clear understanding of what goes into making a tasty and nutritious product. To that end, with every passing year, the inclusion of flavor, texture, and nutritional characterization in academic papers on cultivated meat is becoming more routine, specifically for: fat profiles (Yuen Jr. et al. 2023; Louis et al. 2023); texture profiles (Xu et al. 2023; Yen et al. 2023; Guan et al. 2023; Liu et al. 2023; Zhu et al. 2023); and changes to the product in response to cooking (Yen et al. 2023; Kawecki et al. 2023; Guan et al. 2023).

Methods for the characterization of cultivated meat products are expected to borrow heavily from those used for conventional meat. For example, a review by Mariano et al. (2023) discusses the use of characterization methods for the authentication and traceability of cultivated meat to validate and differentiate it from conventional meat.

A key question that the cultivated meat field is beginning to grapple with is how can cultivated muscle and fat be most effectively combined into a cohesive tissue? Co-culture of myogenic (muscle) and adipogenic (fat) cells may be complicated due to their different media requirements and their tendency to influence one another's activity. However, it appears that this is not an insurmountable obstacle and successful co-differentiation of pork fat and mouse muscle cells has been demonstrated.

Alternative approaches that do not require co-differentiation have also been validated. For example, one study showed that pre-differentiated fat and muscle constructs could be combined to form a cohesive tissue, and another created a prototype by combining differentiated muscle constructs with a plant-based oleogel. Further research is needed to identify and ensure the most efficient approaches for bioprocess efficiency and product quality.

Nutrition and taste parity

In 2023, **GOOD Meat** received clearance from FDA and USDA, setting the stage for greater scalability, reduced manufacturing costs, and a more eco-friendly product. In GOOD Meat's dossier submitted to support the safety of their cultivated chicken, they compared the nutritional value of their cultivated chicken with that of conventional chicken. **This report demonstrated that 100 grams of cultivated chicken had a similar nutritional profile, including total protein, fat, and carbohydrate levels, to conventional chicken.**

GOOD Meat's cultivated chicken has a lower caloric value than conventional chicken breast, as the cultured cells have a higher moisture content. The cultivated chicken had similar monounsaturated fat, saturated fat, and cholesterol levels as the conventional chicken breast.

Adipose (fat) tissue is crucial to the flavor of meat products. Recent research showed that adipose-derived stem cells can differentiate into fat cells, and that by adjusting the fatty acid composition of the culture medium, the cells could create the qualities of real muscle fat.

Although cultured fat has the potential to significantly enhance the quality of alternative protein products, the production of macroscale tissues continues to be constrained due to the delivery of oxygen and nutrients to larger tissues. One team has developed a method to produce macroscale fat tissue suitable for food applications. The team resolved the challenges of macroscale tissue engineering and 3D cell culture by first growing adipocytes on 2D surfaces and then forming 3D tissues after the cells underwent adipogenesis. Unlike regenerative medicine, cultivated meat doesn't require ongoing cell viability once the final macroscale fat tissue is created, thus opening up more options for developing the final tissue structure.

Also in 2023, **Vow** applied to **Food Standards Australia New Zealand** (FSANZ) to secure approval for cultivated quail cells made from Japanese quail embryonic fibroblasts as a novel food. FSANZ conducted a comprehensive hazard and risk assessment covering microbiology, biotechnology, toxicology, nutrition, and dietary intake. Their published report in December 2023 concluded that the cell line is genetically stable, microbiological hazards are low, and there are no safety concerns regarding exposure to production process substances or food allergenicity. There was no detected gluten, and there were no identified nutritional risks. Overall, FSANZ's assessment supports the safety and approval of Vow's cultured quail cells as a novel food.

Food safety and public health

New safety dossiers from **GOOD Meat** in the United States and **Vow** in Australia and New Zealand became publicly available in 2023. Encouragingly, both products are made without antibiotics, contain no detectable heavy metals, and are free from common foodborne pathogens such as *E. coli* and *Salmonella*. Overall, these documents are also a rich resource for understanding how quality control of cell lines and media is performed and the key considerations for regulators when evaluating safety.

GFI Brazil and collaborating scientists at the **University of Campinas** released a report that outlines a food safety plan for a hypothetical cultivated burger production process based on Hazard Analysis and Critical Control Points (HACCP) principles. This report, together with the aforementioned safety dossiers, provides an excellent overview of the safety considerations and hazard mitigation strategies for the production of cultivated meat.

At the multinational level, the FAO published a summary report from a stakeholder meeting convened in Israel in 2022 and hosted another meeting in China in 2023. At these meetings, cultivated meat companies presented to local regulators, providing a deeper understanding of production processes and safety considerations.

The Singapore Food Agency convened a roundtable meeting with more than 250 participants to discuss

how to approach risk assessment for novel foods such as cultivated meat, as well as how to harmonize regulatory frameworks and increase information sharing around the globe. Following the meeting, the APAC regulatory coordination forum was announced with the aim of contributing toward the same goal on a regional level.

Finally, with H5N1 avian flu crossing into several mammalian species in 2023, some experts began to highlight the potential for cultivated meat to help mitigate these zoonotic disease threats. If cultivated meat can substitute for conventional meat in future diets, it could substantially mitigate risks of antibiotic resistance and zoonotic disease associated with industrial animal farming.

Environmental and social impact

The UN Environment Programme (UNEP) released a landmark report in 2023 that assessed the potential impacts of alternative proteins on public health and environmental harms compared to animal agriculture (summarized here). **The report cites numerous life cycle assessments (LCAs) of cultivated meat, which collectively show how cultivated meat requires significantly less land, results in less nitrogen-related impact such as less air pollution and less eutrophication, and could produce fewer greenhouse gas emissions than conventional meat, especially if renewable energy is used.**

In 2023, headlines were briefly dominated by a preprint study from **University of California, Davis** scientists which claimed cultivated meat could have a carbon footprint many times higher than that of conventional beef, significantly diverging from the existing literature. GFI and other scientists refuted findings from a preprint study from UC Davis scientists that diverged from existing literature. GFI found that the study's assumptions (which resulted in claims that cultivated meat could have a carbon footprint many times higher than that of conventional beef) do not accurately reflect practices in the industry. GFI asserts that more realistic estimates of the carbon footprint of cultivated meat can be found in existing peer-reviewed studies.

A new study from researchers at **Iowa State University** showed that cultivated meat has higher [caloric] energy and protein productivity per unit area of land compared to conventional meat. But since treating wastewater is costlier than manure application, media recycling will become important in managing nitrogen as the industry scales up. Another study led by researchers at **Tufts University** assessed the impacts of recombinant growth factors used in cell culture media, aligning with other studies that suggest their contribution to overall impacts can be high despite being used in small quantities.

Given the importance of LCA studies, GFI published an LCA guide that provides a standardized approach for commissioning and conducting studies, as well as interpreting and leveraging their results.

Understanding the potential impacts of cultivated meat on society will become increasingly important as cultivated meat matures. A study from Asia Research & Engagement described how the adoption of alternative proteins in Asia is critical for meeting its sustainability goals. It describes how this transition will require a concerted effort between the public and private sectors, with ramifications that could drastically change the landscape of agriculture across numerous countries. Further to this concern, a summary report from a 2022 workshop was published. The workshop hosted cultivated meat companies, research labs, dairy farms, animal rights organizations, and indigenous communities, and the report contains numerous insights on how a just and equitable transition can be reached among diverse communities.

A similar study summarized discussions with focus groups with farmers in the United Kingdom. Some farmers perceived opportunities, such as growing inputs for the cell culture media, but many farmers perceived cultivated meat as a threat to farming traditions and livelihoods. Overall, the study highlights the importance of including farmers' perspectives in discussions related to cultivated meat.

Scientific ecosystem

Increasing the number of people involved in cultivated meat projects around the world is critical to solving R&D challenges and ensuring that enough talented professionals are entering the workforce as the industry grows. An assessment of the number of publications and public research funding dollars, combined with other signals, reveals that the scientific ecosystem continued to grow steadily.

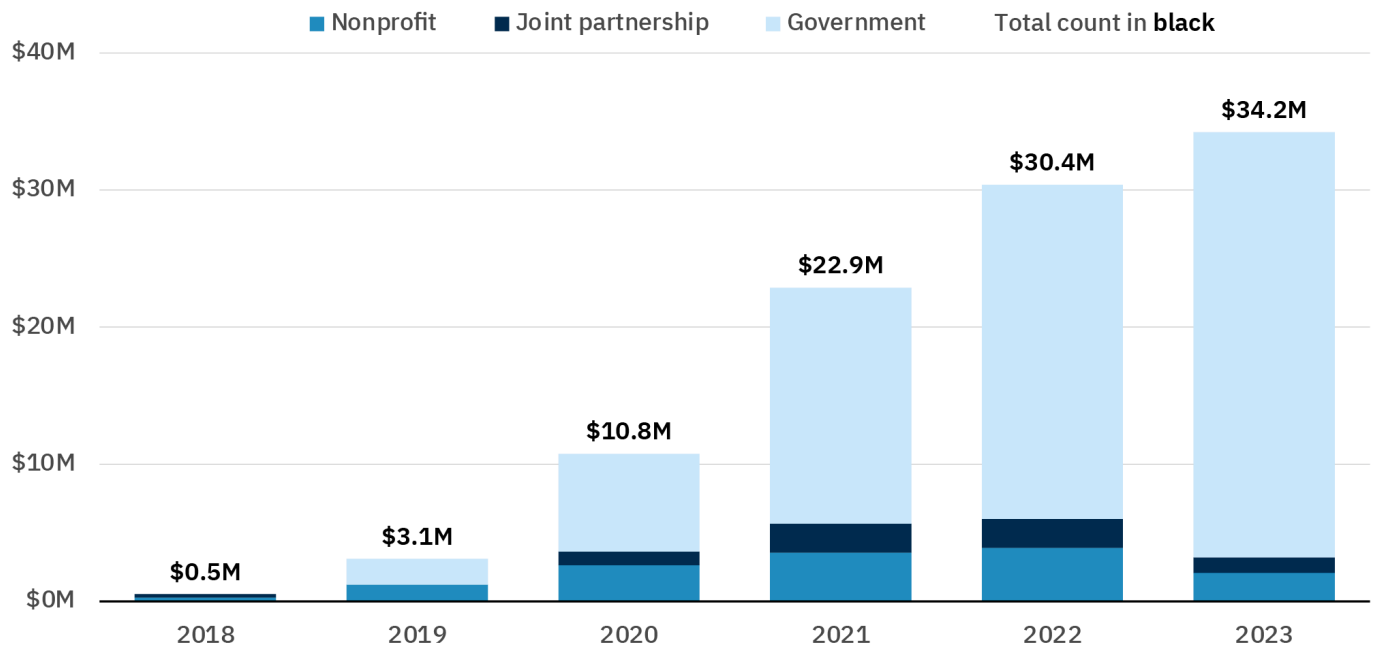
- The upward trajectory of the number of cultivated meat-focused scientific publications continued in 2023 (see figure 19). Notably, several of the recent papers have come from cultivated meat companies, including **Mosa Meat** (Hubalek et al. 2023, Melzener et al. 2023a, Melzener et al. 2023b, Martins et al, Messmer et al, Caponi et al), **Aleph Farms** (Zehorai et al. 2023, David et al), **OpoBio** (Jin et al.), and **Cultimate Foods** (Kirsch et al). Publications by companies, or by academic–industry collaborative teams, are an important ingredient in the success of the cultivated meat field because they signal the realization that success comes not from knowledge silos within individual companies but from an open and collaborative effort to solve shared problems.

- **Public sector funding is critical for building the scientific foundation to grow new ideas, spawn new technology, and train new scientists and engineers. Although significantly more funding is needed, more government funding agencies are realizing the potential of cultivated meat to address critical challenges, and public funding dollar totals have been steadily increasing YOY.** Additionally, many of these awards, such as the Cellular Agriculture Manufacturing Hub in the United Kingdom, represent multimillion dollar commitments involving universities and companies alike.

- A new program at **Tufts University** now enables students to earn an undergraduate minor in cellular agriculture—a first for the field. The program consists of six classes, including a research-based course, and is yet another example of how cellular agriculture is maturing as a field.

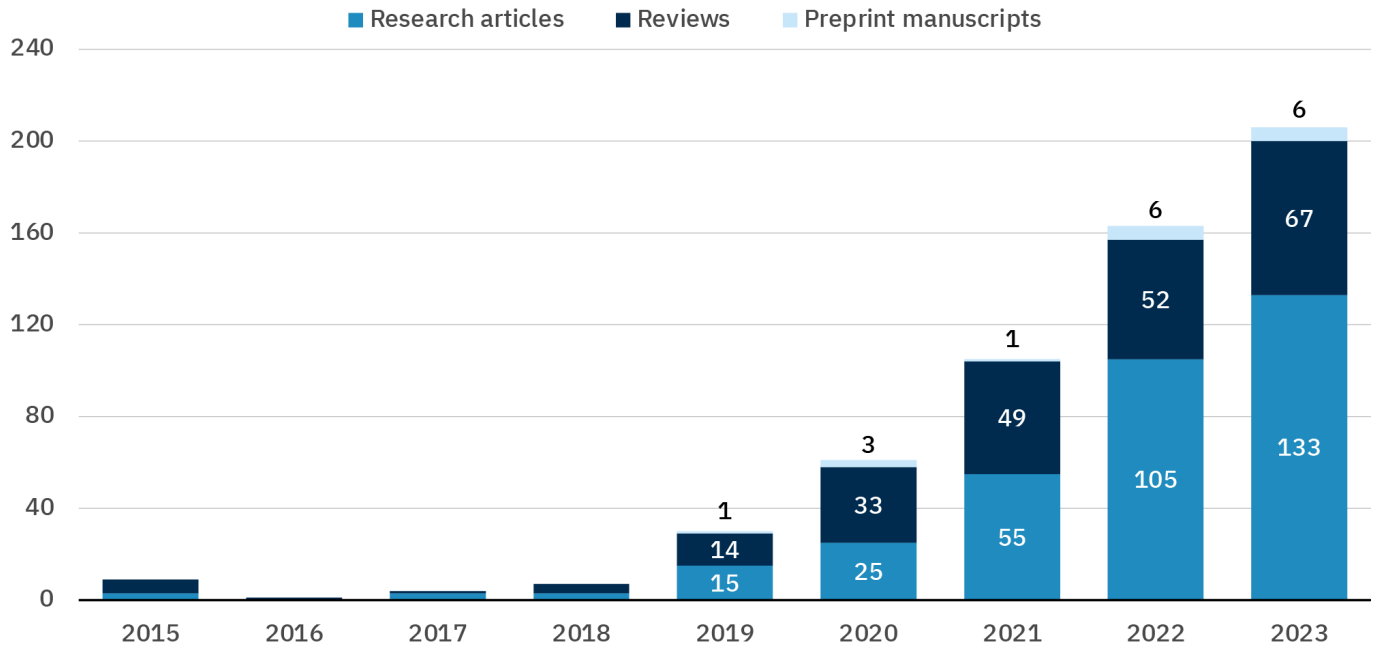
- The **Alt Protein Project** welcomed 24 new student groups from across the globe in 2023. Student leaders from the Alt Protein Project continue to drive change at their universities—from developing courses to organizing community events to conducting original research. After graduation, the skills developed in the Alt Protein Project help to set students up for meaningful careers in alternative proteins.

Figure 18: Cultivated meat research funding by year and source



Source: GFI Research Grants Tracker

Figure 19: Papers about cultivated meat



Source: GFI's alternative protein literature library.
Note: Reviews refer to analyses of previously published work, whereas research articles refer to newly conducted experimental work. Preprints refer to manuscripts that are released online prior to peer review. Preprints that have been subsequently published are not included in this figure.

Resources for scientists

GFI supports the cultivated meat industry by creating open-access tools and resources that make scientists' jobs easier. Free tools and resources launched or substantially updated in 2023 include:

- **Solutions database**. GFI continued to build a solutions database this year, including new entries on synergistic climate and biodiversity benefits of alternative proteins, fit-for-purpose bioreactors, naturally adhesive scaffolding materials, seafood cell lines, and alternative surimi written by research fellow Dr. Matt McNulty. This database captures ideas for research projects, commercial ventures, or ecosystem solutions that have the potential to accelerate the development and commercialization of alternative proteins. Those looking to get involved or looking for a new project can find ideas and inspiration there.

- **Literature library**. GFI maintains an alternative protein literature library tracking publications about or relevant to cultivated meat and other alternative proteins. In addition to keeping the library up to date with this year's most influential papers, GFI added a new feature in 2023: the end product tracker. This resource makes it easy to find details on experiments characterizing the flavor, texture, nutrition, and more for cultivated meat prototypes described in academic literature or documentation submitted by companies to regulators.

- **Trends in cultivated meat scale-up and bioprocessing.** An upcoming GFI report will summarize a survey conducted in early 2023 on 30 cultivated meat companies and suppliers, aimed at understanding the current bioprocessing, production capacities, and challenges faced by cultivated meat manufacturers worldwide. It collected information on infrastructure, production capacities, food safety practices, and bioprocessing details at various stages of production. This report provides an overview of the current and future needs of the cultivated meat industry. It identifies key insights for investors, highlights essential research and development opportunities, and outlines critical considerations for suppliers in this evolving sector.

- **Cell line survey**. GFI APAC published a report summarizing a survey they conducted to better understand what cell types cultivated meat companies are using, where the biggest cell line-related pain points are, and how GFI and others can better support this growing industry.

- **Seafood differentiation pathways review**. Together with several collaborators, GFI published a review paper in *Marine Biotechnology* exploring what is known about the pathways involved in the differentiation and maturation of meat-relevant cell types in fish and aquatic invertebrates, and the implications for cultivated seafood's next steps.

- **Cultivated seafood white space workshop**. In January 2023, GFI held a workshop with experts from academia and industry that explored the challenges associated with culturing fish cells and how the field of cultivated seafood can more effectively move forward. The report describes key takeaways from those discussions, which helped us refine our topic selection for the Research Grants Program RFP later in the year.

- **Fish & CHIPS**. In response to participant feedback from the white space workshop, GFI piloted a new cultivated seafood event series called the Collaborative Huddle for Ideation & Problem Solving, or Fish & CHIPS. These online, discussion-based workshops bring the cultivated seafood community together, foster potential new collaborations, and offer an opportunity for collaborative problem solving and knowledge sharing. Upcoming huddles can be found on our events page, and are tentatively scheduled for March, July, and November 2024.

- **Science of cultivated meat**. GFI continued refreshing our series of cultivated meat technical explainers, focusing on a technical deep dive into cultivated meat cell lines.

GFI Brazil's massive open online course (MOOC)

- **MOOC**. We recorded updated videos in our free massive open online course (MOOC) to package the lectures into shorter, more accessible segments. This resource is a digestible starting point for learning about alternative proteins, including cultivated meat and seafood.
- **Researcher directory**. If you're a researcher in the field, find collaborators and increase the visibility of your work by joining the recently revamped alternative protein researcher directory.
- **Cultivated meat collaborative seminars**. GFI hosts an invitation-only monthly seminar for scientists in the cultivated meat industry. Solutions providers present their technology, with the goal of establishing new collaborations throughout the industry. While some presenters only make their material available to live attendees, many of these recordings are now available on GFI's YouTube channel.
- **LCA guide**. Our new LCA guide provides an overview of best practices for conducting life cycle assessments, which are increasingly important tools for understanding and communicating environmental impacts and for identifying key levers for continued sustainability improvement.
- **TEA review**. GFI collaborated with Next Rung Technology to write a chapter on performing techno-economic analyses for cultivated meat for the new textbook *Advances in Cultured Meat Technology*, which includes comparative analyses of the cultivated meat TEAs published to date.
- **Assuring the safety of cultivated meat**. In this report, GFI Brazil and collaborators outline the first steps of a food safety plan for a cultivated burger production process based on Hazard Analysis and Critical Control Points principles.
- **Sidestreams analysis**. This new analysis explores how sidestreams from the cultivation of commodity crops can be used in alternative protein production, including as sources of hydrolysates for cultivated meat cell culture media.

Government and regulation

Government and regulation

Overview

In 2023, a handful of governments made significant progress in supporting the development of cultivated meat. This progress included allocating new funding to the sector through research and development programs, infrastructure development, tax incentives, and more.

As the planet experienced record high temperatures in 2023—potentially breaking a 125,000-year-old record—governments allocated funds from climate and sustainability programs to develop cultivated meat, including in the United Kingdom and Spain. Cultivated meat's potential to benefit the environment and the climate was confirmed in a report from the United Nations Environment Program (UNEP) in December. And notably, the COP28 climate conference in Dubai focused on food system transformation as essential for meeting global climate goals for the first time.

Policymakers considered not only cultivated meat's global benefits but also the economic and technological benefits it could bring within national and sub-national borders. **The United States, the European Union, China, the United Kingdom, Japan, Israel, and more supported cultivated meat infrastructure and development for the new markets and jobs they are expected to bring.**

These governments also supported researchers and companies by establishing new institutions, grants, and incentives. As bioeconomies increasingly emerged as priorities in national development plans, cultivated meat and its cross-benefits are increasingly considered not just an environmental solution but also a strategic and economic investment for meeting country-level food security, public health, and economic goals.

Global public funding

Americas

Public investment in cultivated meat research and development accelerated in the Americas in 2023. New research projects were announced in Brazil and the United States, including a project to develop a hybrid plant-based and cultivated sausage at Brazilian state research agency Embrapa and a project to 3D print cultivated meat and fat at the United States National Science Foundation (NSF). The United States, in addition to funding several new research projects through the NSF and the USDA's National Institute of Food and Agriculture (NIFA), also allocated a number of small business grants to cultivated meat companies.

In March 2023, the Biden Administration released a report titled "Bold Goals for U.S. Biotechnology and Biomanufacturing" that proposed supportive policies for the domestic biotechnology sector. Alternative proteins were included in chapters from the Department of Agriculture and the Department of Energy, both of which attested to the potential benefits of alternative protein production through biotechnology and the need for government support.

At the sub-national level, the state government of Paraná in Brazil continued an initiative called "New Research and Innovation Arrangement in Alternative Proteins" (NAPI-PA), which will assist several universities in developing cellular agriculture capabilities, including acquiring bioreactors at bench and demonstration scales. In the United States, the government of North Carolina awarded a grant to **Atlantic Fish Co.** through the North Carolina Biotechnology Center, an initiative of the state's Department of Commerce. Similarly, the Maryland Stem Cell Research Fund awarded a grant to a local company, **Phycin**, making cell culture media from algae.

Asia Pacific

After cultivated meat was included in China's five-year plan for agriculture in 2022, local governments started to act, per reports, including taking steps to ensure the cost of crucial equipment like bioreactors stays low. The exact value and nature of this support is not public, but China's cultivated meat industry has grown amid an environment that is lower-cost than in Europe and the United States.

In February 2023, Japan's Prime Minister Fumio Kishida announced his support for cultivated meat: "Food tech, including cellular foods, is an important technology from the perspective of realizing a sustainable food supply. We have to support efforts that contribute to solving the world's food problems." The government has subsequently pursued policies that support cultivated meat development, including a $13.1 million grant to a Japanese cultivated meat company at the end of 2023.

Research on cultivated meat continued in Singapore through previously announced work packages, including A*STAR's Singapore Food Story's second phase on Future Foods. Singapore also collaborated with the government of Israel on a research project to develop 3D-printed cultivated seafood, which was announced in 2022 and completed in 2023.

In February 2023, South Korea's North Gyeongsang Province led a 28-member Memorandum of Understanding calling for the advancement of the cellular agriculture ecosystem in South Korea and informally creating a cellular agriculture cluster comprising companies, universities, and city governments. The province also established a regulation-free zone in which companies can showcase proof-of-concept prototypes, as well as a nine billion won ($6.7 million) North Gyeongsang Cellular Agriculture Industry Support Center, which opened in March 2023 in a ceremony at which the world's largest cultivated meat prototype, weighing in at 10 kilograms (22 pounds), was unveiled by **Tissen Biofarm**, a cluster member.

Europe

After taking the global lead in alternative protein public funding in 2022, Europe maintained a steady pace of support for alternative proteins, including cultivated meat, in 2023. The European Union's 2023/24 Horizon Europe work package included €7 million ($7.5 million) for a research project to provide open-access information about how to maximize the environmental, social, and economic benefits of cultivated meat, including sustainability assessments, ethical and regulatory aspects, business models, and social impact studies.

The United Kingdom led 2023's cultivated meat funding announcements, with an allocation of £12 million ($15 million) for a new Cellular Agriculture Research Hub at the University of Bath, followed by an estimated £3.4 million ($4.3 million) for seven research projects on cultivated meat through a program supporting low-emission food production systems. The country additionally supported its domestic cultivated meat industry through business grants, including a $2.5 million grant to growth media startup **Multus Biotechnology** through Innovate UK's EIC Accelerator program, helping the company begin construction on a production facility.

Later in the year, Germany announced €38 million ($41 million) in federal funding for 2024 toward a sustainable protein transition, including funding for innovating in alternative protein production, promoting the nutritional value of alternative proteins, and aiding farmers and companies in transitioning from animal agriculture to plant-based, cultivated, or fermented protein production.

Previously announced publicly funded cultivated meat research continued in several European countries, including Norway, the Netherlands, Belgium, Spain, and Germany, as well as through multiple European Union initiatives. **A new research project in Germany, announced in October 2023, will not only research ways of creating cultivated fish products but also study their potential uptake and acceptance among consumers.**

The Middle East

Israel maintained strong leadership in supporting the cultivated meat sector, funding more research and commercialization efforts domestically and internationally. Among other investments, a new human capital program will foster expertise in alternative proteins and food technology, fueling the country's research ecosystem and developing a workforce for a future food system.

Additionally, Israel has championed international alternative protein collaborations, embarking on multiple bilateral and multilateral efforts to co-develop new products and technologies with other nations. The first, a joint initiative titled the **Singapore-Israel Industrial R&D program** (SIIRD), provided funds from both Israel and Singapore to one company from each country to work together on a 3D-printed cultivated grouper prototype, which was unveiled in 2023. Israel announced other joint initiatives through BIRD (with the United States), KORIL-RDF (South Korea), and a multilateral effort with Sweden, Switzerland, and Singapore in 2023. All follow similar models, providing joint funding for initiatives that develop not only specific products but also research and business ties between participants and their governments.

Regulation by country

The sale of cultivated meat and seafood depends on a clear and efficient regulatory path to market, and companies and governments are continuing to work together to develop the appropriate processes to ensure safety.

In 2023, the United States became the second country in the world after Singapore to allow the sale of cultivated meat products to consumers. After completing FDA's pre-market evaluation in 2022, **UPSIDE Foods** obtained a grant of inspection and label approval from the U.S. Department of Agriculture (USDA) in June 2023. **GOOD Meat** also completed the FDA's pre-market evaluation in March 2023 and obtained the necessary approvals from USDA in June. Other nations and regions are also continuing to make progress toward approving cultivated meat products, as described below.

Australia/New Zealand

In Australia and New Zealand, new foods, including cultivated meat, are jointly regulated by the two nations under their existing Novel Foods Standard. To gain pre-market approval for a cultivated meat product, a company must submit an application to **Food Standards Australia New Zealand** (FSANZ). FSANZ evaluates each novel food product independently. To obtain approval, cultivated meat companies are required to petition FSANZ to amend the Australia and New Zealand Food Standards Code. Based on the composition of the cultivated meat product in question, FSANZ will determine whether to amend certain sections of the Code such as novel foods, foods produced using gene technology, and food safety requirements.

In early 2023, **Vow Food** became the first Australian cultivated meat company to apply for regulatory approval. In December 2023, FSANZ concluded its scientific risk assessment of Vow's application and moved on to conduct the first of two rounds of public consultation. In its first call for public input, FSANZ proposed that cultivated meat products be labeled as "cell-cultured." The first public consultation process allows the public six weeks to provide input on Vow's cultivated quail product, and all non-confidential comments will be posted on FSANZ's website. Following this, FSANZ may propose an amendment to the Code and prepare a draft regulation for the cultivated quail, at which point there will be another opportunity for public comment. Finally, the FSANZ board will need to approve the application. The Food Minister's Meeting will be notified of such approval (if given) and the approval may then be finalized. While the regulatory approval process for Vow Food's cultivated quail is ongoing, the completion of FSANZ's application review is an encouraging step forward for cultivated meat approval in Australia and New Zealand.

Brazil

In Brazil, the General Food Office at the National Health Agency (Anvisa) and the Animal Products Inspection Department within the Ministry of Agriculture have jurisdiction over cultivated meat. Brazil has yet to implement a regulatory framework for cultivated meat products, but the Ministry of Agriculture and Livestock is developing a National Plan for Alternative Proteins. The plan will include foods and protein-based ingredients from a variety of alternative protein sources, including animal cell culture.

Anvisa's publication was a prerequisite for the next stages of the regulatory process, which defines the product registration regulations, comprising the labeling rules, the identity and quality standards to be met, and the rules for inspecting manufacturing units, all of which are the responsibility of the Ministry of Agriculture (MAPA). GFI Brazil has already started working with the Ministry so all the regulations can be debated and published by 2024.

The government plans to conduct a pre-market authorization process for cultivated meat products. Cultivated meat companies will need to apply for authorization, and then government agencies will conduct a safety evaluation. The safety evaluation will occur under the country's current novel foods framework, which was updated in December 2023.

Canada

Health Canada's Food Directorate has jurisdiction over cultivated meat. The Canadian government has stated that it intends to regulate cultivated meat under its existing novel foods regulation, rather than considering a new regulatory approach. This authorization will require companies to submit a pre-market proposal with detailed information about the product. After that point, Health Canada will aim to conduct a safety assessment of the product within 410 calendar days of receiving notification of the novel food pre-market proposal.

All ingredients used in novel food proposals must comply with the Food and Drugs Act and the Safe Food for Canadians Act, and their associated regulations. In addition to Health Canada, the Canadian Food Inspection Agency (CFIA) and Environment and Climate Change Canada (ECCC) will conduct pre-market safety assessments of cultivated meat products before they may be sold in Canada. Cultivated meat products will be subject to the labeling rules that apply to all foods in Canada, and the agencies may require these products to comply with additional labeling rules related to product composition and common names. CFIA will verify that products comply with these requirements. More information about the regulation of cultivated meat in Canada may be found here. Canadian regulators are continuing to develop the framework for cultivated meat.

China

The Chinese government has a history of investing in emerging technologies such as solar panels, lithium batteries, and electric vehicles, and alternative proteins are proving to be on a positive track for development.

In 2021, the Chinese government announced a three-year R&D project that included sub-projects in cultivated meat research under the Green Biological Manufacturing National Key R&D Program, which also supports projects in a number of other sectors. Also in 2021, China's Ministry of Agriculture and Rural Affairs released a highly anticipated five-year blueprint for strengthening innovation in emerging technologies, including the manufacturing of alternative proteins. These multiyear plans continue to fuel positive developments for the alternative protein industry in China.

In late 2022, government officials from the United States and China's National Center for Food Safety Assessment (CFSA) met to discuss cultivated meat regulation at a virtual event hosted by the AgFood Future Center of Excellence and the Agriculture Food Partnership. At this event, CFSA indicated that it would promote the safety assessment of cultivated meat. CFSA also indicated its intent to establish a special group to focus on the regulatory framework for cultivated meat in China, although that framework has not yet been established.

European Union (EU)

The European Commission has stated that it will regulate cultivated meat as a novel food. Before a cultivated meat product can be sold in the European Union, it must be approved by regulators in a process governed by the Novel Foods Regulation. To begin this approval process, companies must apply to the European Commission for pre-market authorization of their products. The pre-market authorization process includes a safety evaluation by the European Food Safety Authority (EFSA), which entails a thorough, evidence-based assessment of the safety and nutritional value of the cultivated meat product, estimated to take at least 18 months. The European Commission and representatives from the EU member states have the authority to grant final approval of a product after EFSA's evaluation. If granted, the approval would apply across all 27 EU member states.

Cultivated meat products developed using genetic engineering may fall under the EU regulation on genetically modified (GM) food and feed, which includes a similar food safety assessment.

Throughout the EU member states, attitudes toward cultivated meat vary, and a range of developments reflected those varying attitudes in 2023.

- In **Romania**, the Senate voted to ban the sale of cultivated meat. That proposal still requires final approval from the country's Chamber of Deputies.
- **France**'s Republican party submitted a ban on cultivated meat to the lower house of their legislature in December.
- In **Italy**, the government drafted a law to ban cultivated meat which its Senate voted to approve in July. Italy submitted a Technical Regulations Information System (TRIS) notification to the European Union after that vote, which is the procedural mechanism through which Italy would get EU approval for the ban. In October, the Italian government withdrew the TRIS, only to pass a law banning the production and marketing of cultivated meat in November.

At the time of this report, the Italian law remains in place, and the Romanian legislation remains pending.

These bans are being proposed or implemented despite broad consumer support for cultivated meat in Europe, as noted in studies by the Smart Protein Project in 2023 and GFI Europe in 2022. A 2019 survey found that more than 50 percent of Italian consumers are open to cultivated meat, and a 2021 survey by the Smart Protein Project showed Italy as a leader within Europe for public acceptance and use of alternative proteins and individual meat reduction. Still, a campaign in favor of the ban was driven by a large farming association that attracted millions of signatures and the support of several local and regional governments. While the Italian ban on cultivated meat remains in effect, it has not been approved by the EU. If the EU approves cultivated meat products in the future, Italy's ban could be challenged by the European Commission.

Israel

Israel continues to be a leader in supporting cultivated meat. The National Food Service (FCS) within the Ministry of Health has regulatory authority over cultivated meat that is produced and marketed within Israel. While Israel is home to multiple cultivated meat companies, as of the end of 2023, it had not yet granted regulatory approval to those companies, or issued information about the regulatory process for cultivated meat. However, Israel has indicated that cultivated meat products fit into their novel foods regulatory framework and will require pre-market authorization. The FCS has a dedicated team of experts who will be tasked with evaluating what the regulatory process will look like for Israel's safety assessments of cultivated meat. In January 2024, Israel became the third country to advance the approval of cultivated meat sales, and the first to advance the approval of cultivated beef.

Japan

In 2022, Japan announced that it would establish a team of experts to study food safety and regulatory pathways for cultivated meat. In February 2023, the Ministry of Agriculture, Forestry, and Fisheries announced a "Vision of promoting food-tech" with an associated roadmap that includes cultivated food products. Japan's Prime Minister Fumio Kishida has been vocal about his plans to develop a cellular agriculture industry in Japan, and stated that ensuring the safety of future food products and establishing labeling rules are priorities for this development.

The Japanese Association for Cellular Agriculture (JACA), an industry trade association, submitted suggestions for cultivated food product regulations such as product definitions, food labels, and food safety procedures in November 2022. JACA established a legal entity at that same time to accelerate activity toward consensus on cellular agriculture in Japan. JACA also leads a Cellular Agriculture Working Team under a public-private partnership for food tech, hosted by the Ministry of Agriculture, Forestry, and Fisheries.

In 2023, JACA and the Asia-Pacific Society for Cellular Agriculture (APAC-SCA) collaborated on a Memorandum of Understanding to advance the field of cellular agriculture across Japan and the Asia Pacific region. Through this agreement, JACA will have access to the global cellular agriculture network, and APAC-SCA will have an increased role in guiding regulatory processes in Japan.

> *Multilateral discussions on food safety and import/export issues are essential for the growth of [the cultivated protein] field. JACA and GFI will continue to collaborate in encouraging the Japanese government and the authorities of other trade partner countries to proceed with bilateral communications, which eventually make it possible for international players to explore opportunities in Japan.*
>
> **Megumi Avigail Yoshitomi**
> *Representative Director, Japanese Association of Cellular Agriculture*

South Korea

South Korea's current regulatory structure allows for cultivated meat R&D and tasting events, but until recently it did not allow for commercial production and sale of cultivated meat products. South Korea's Ministry of Food and Drug Safety (MFDS) and the Ministry of Agriculture Food and Rural Affairs (MAFRA) are primarily responsible for granting regulatory approvals for cultivated meat products. MAFRA regulates the upstream supply chain (such as cell collection) while MFDS regulates the final product. In July of 2023, MFDS made significant progress in enabling novel foods to enter the Korean market through amendments to the Enforcement Rule of Food Sanitation Act. The Act brought ingredients such as cultivated meat and seafood within the scope of pre-market authorization under the category "Temporary Standards and Specifications." In February 2024, MFDS also established procedures for recognizing food ingredients produced with cellular agriculture and began accepting applications from companies for the regulatory approval of cultivated meat products. This marks the first time that cultivated meat has had the opportunity to get commercial approval in South Korea.

Singapore

The Singapore Food Agency (SFA) became the first national regulator to approve the sale of cultivated meat in 2020, approving **GOOD Meat**'s (formerly **Eat Just**) cultivated chicken for use as the main ingredient in the company's chicken bites. Since then, SFA has approved other cultivated meat products from GOOD Meat as well, and in early 2023 Singapore approved the use of serum-free media in the production of GOOD Meat's products. This could allow the company to further scale up production and reduce costs.

Singapore treats cultivated meat as a novel food requiring pre-market authorization. SFA publishes its guidelines for the types of data and safety tests that cultivated meat companies must include in their safety dossier during their submission for authorization. Singapore has also developed a Novel Food Safety Expert Working Group made up of food safety experts, scientists, public policy experts, and others to help SFA ascertain whether food safety issues have been adequately addressed by the companies. The approval process typically takes between nine and 12 months.

As of 2023, Singapore is continuing to work on a Food Safety and Security Bill that will offer even greater clarity about regulatory frameworks for novel foods such as cultivated meat. The bill has been in the works since 2021, and while there has been progress on its status, it is not certain when the bill's language will be finalized.

Switzerland

In 2023, Israel-based company **Aleph Farms** submitted to Swiss regulators the first-ever application to sell cultivated meat in Europe, specifically its cultivated beef in Switzerland. At the time of this report, the application is being reviewed by the Federal Food Safety and Veterinary Office (FSVO). Aleph Farms' submission was part of their collaboration with Migros, Switzerland's largest food enterprise. Switzerland has historically been amenable to innovation, and according to research conducted jointly by Aleph Farms and Migros, 74 percent of Swiss consumers have indicated an openness to trying cultivated meat.

The Swiss regulatory process is similar to that of the European Union in that it includes a robust, evidence-based process for determining novel food safety. Companies must apply for authorization from FSVO by submitting a safety dossier. The process includes a safety assessment and extensive toxicological studies and is expected to take at least 12 months. The Swiss FSVO provides a template for applications to help companies navigate the process and to make applying straightforward.

United Kingdom

In August 2023, the Israel-based company Aleph Farms became the first cultivated meat company to file for product approval in the United Kingdom. While the United Kingdom had thus far retained the EU novel food regulation (despite its exit from the EU), in 2023, the United Kingdom Food Standards Agency (FSA) issued new guidance for businesses directed at England and Wales on cultivated meat products, which it refers to as "cell-cultivated products."

In the United Kingdom, cultivated meat products will require pre-market authorization from the FSA using its regulated product application service, and cultivated meat product applications are likely to be assessed under the novel food regulations or the genetically modified organism (GMO) regulations, depending on the product. Either of these regulatory processes would require the cultivated meat producer to ensure traceability of the food product, present the food appropriately, provide suitable food information, withdraw or recall unsafe food, and ensure that food imported into and exported from the United Kingdom complies with UK food law.

The UK guidance indicated that cultivated meat product labels, like other food product labels in the United Kingdom, must include ingredients, allergens, and a "use by" or "best before" date. The United Kingdom has indicated it may require additional specific labeling requirements for novel foods such as cultivated meat in the future.

United States

Federal regulation

In early 2023, **UPSIDE Foods** and **GOOD Meat** became the first and second companies, respectively, to complete the FDA pre-market consultation process. In June 2023, both UPSIDE Foods and GOOD Meat obtained landmark grants of inspection and label approvals from USDA. Having completed both FDA and USDA regulatory approval processes, the companies are permitted to sell their cultivated chicken products in the United States, marking a pivotal moment in the history of food and agriculture.

To complete FDA's pre-market consultation process, the companies submitted data and information to the agency documenting the product's safety and production process. FDA informed the companies that it had no questions or concerns about the safety of their products via a "no questions" letter. FDA's responses and additional information regarding their consultations with GOOD Meat and UPSIDE Foods are available on the agency's website.

After completing FDA's pre-market consultation process, the companies each applied for a grant of inspection (GOI) from the USDA Food Safety and Inspection Service. Before granting each GOI, USDA performed a comprehensive review of the facility where each product was being created to verify that cultivated meat products are "safe, wholesome, and unadulterated." USDA also reviewed proposed product labels. UPSIDE Foods' and GOOD Meat's successful completion of both the FDA and USDA regulatory processes made the United States the second country in the world, after Singapore, to authorize the production and sale of cultivated meat.

As of the end of 2023, neither FDA nor USDA has published labeling requirements for cultivated meat products, but both agencies have solicited public comments on labeling and nomenclature. While the rulemaking process for cultivated meat labeling is underway, USDA has reviewed and pre-approved labels on a case-by-case basis. For now, USDA has approved the term "cell-cultivated chicken" to label cultivated chicken products from UPSIDE Foods and GOOD Meat. FDA does not pre-approve labels but will exercise enforcement authority if regulators become aware of false or misleading food labels.

The regulatory processes for cultivated meat companies to obtain approvals to sell products in the United States draw on and overlap with those applicable to conventionally produced foods. Both FDA and USDA have developed, or are currently developing, processes specific to cultivated meat companies, as detailed above. Additional regulatory developments from FDA and USDA are expected in the coming months and years, and the United States appears well-positioned to continue handling the regulatory approval of cultivated meat products in the interim.

State legislation and litigation

Since 2022, a handful of new states have proposed or enacted label censorship laws that restrict cultivated meat from being labeled as "meat." Label censorship laws either ban various terms such as "burger" or "sausage" on products that are not made from an animal carcass or compel language on cultivated meat labels to include terms such as "lab-grown" or "lab-created" in a specific font size. GFI and other groups continue to challenge these types of laws in court on the grounds that they violate the First Amendment and other constitutional provisions. While cultivated meat companies have not yet challenged these types of laws directly, the outcomes of these challenges are important for all alternative protein producers:

- In **Louisiana**, GFI and co-counsel Animal Legal Defense Fund (ALDF) sued the state on behalf of **Tofurky**, arguing that the state's label censorship law violates the First Amendment right to freedom of speech and the Fourteenth Amendment right to due process. In April 2023, a federal appeals court upheld the law but narrowly interpreted it to find that the law only applies to companies that intentionally mislead consumers about the nature of a product.

- In **Missouri**, a federal district court declined to grant Tofurky and GFI a preliminary injunction (a halt on enforcing the law while the case is pending) on the grounds that Missouri's label censorship law was not likely to apply to Tofurky's product labels. In 2021, a federal appeals court upheld this ruling. The case returned to the district court where it is currently pending with an amended complaint.
- In **Oklahoma**, ALDF brought a new challenge to the state's label censorship law in 2021 on behalf of plaintiffs Tofurky and the Plant Based Foods Association after a district court had denied a motion to prevent enforcement of the law. The new complaint argues that Oklahoma's law is vague, overly burdensome, unconstitutional, and is preempted by federal law. At the time of this report, the case remains pending in federal court.
- In **Texas**, GFI and co-counsel ALDF challenged the state's label censorship law in 2023 on behalf of plaintiff Tofurky. The complaint argues that Texas's law is vague, unreasonably burdensome, preempted by federal law, and unconstitutional under the First Amendment right to freedom of speech. This litigation is continuing in the federal district court.
- In 2023, **Florida** and **Texas** proposed laws that would ban the production, sale, and distribution of cultivated meat products altogether. The Texas ban bill did not pass and GFI and other groups are actively working to oppose the Florida bill as of the time of this report.

Global cooperation and coordination

As mentioned above, 2023 began a new trend of governments conducting joint research projects, in service of not only advancing alternative protein science but also developing a global, interconnected research and business ecosystem.

COP28

The year also brought new ideas on how governments might collaborate on alternative protein development, not only for their mutual gain but also to advance the common good.

A report from the United Nations Environment Programme, released at COP28 in Dubai and focused 100 percent on alternative proteins, assembled a strong list of potential actions governments could take individually and in concert. In a section on multilateral cooperation, the report suggests that governments embark on bilateral and multilateral research efforts, evaluate and revise trade policy to be more supportive, develop international food safety standards, and collaborate with development finance institutions to build capabilities worldwide.

Also at COP28, 159 countries, including the United States, China, the EU27, and Brazil, signed the Emirates Declaration on Sustainable Agriculture and Food Systems, committing to addressing emissions from food systems in their 2025 Nationally Determined Contributions (NDCs). While the declaration does not mention alternative proteins outright, supporting alternatives to animal agriculture will be necessary to keep global temperatures from rising by 1.5°C.

CAC46

The Codex Alimentarius Commission is an international body jointly run by the United Nations Food and Agriculture Organization (FAO) and the World Health Organization (WHO). It includes 188 member countries and the European Union as well as many official observer organizations, including GFI. The Commission promulgates voluntary standards and guidelines for food safety and trade in a publication called the *Codex Alimentarius*.

In April 2023, the Codex Secretariat issued a circular letter seeking comments from member countries and observers on specific topics that would require the development of a Codex standard related to new food sources and production systems (NFPS), which

includes alternative proteins. The circular letter also sought comments about the appropriate procedural methods within Codex to address NFPS. Members and observers, including GFI, commented on whether the current Codex procedural mechanisms were appropriate to address NFPS issues and raised aspects relevant to NFPS standard-setting that had not yet been considered by the Commission. The topic of NFPS was discussed at the 46th convening of the entire Commission (CAC46) in December 2023, and it was decided that current Codex procedural mechanisms were sufficient to address any future NFPS issues that may arise. Several Codex members indicated an interest in submitting specific proposals for new work related to NFPS in the future.

FAO/WHO

The FAO and WHO released a publication titled "Food Safety Aspects of Cell-Based Foods" in April 2023. The publication describes relevant issues related to the terminology, development, safety, and sustainability of alternative proteins. It also describes available resources and activities concerning alternative proteins at the global level and tips for authorities to consider to align on regulatory requirements. The publication includes the results of an FAO-led expert consultation held in Singapore in November 2022. Along with the report, FAO released a fact sheet summarizing its findings.

Outlook

Outlook

Overview

Innovation often occurs in fits and starts. Breakthroughs follow roadblocks, and roadblocks follow breakthroughs. The cultivated meat industry experienced its share of both in 2023.

Two companies, **GOOD Meat** and **UPSIDE Foods**, lawfully brought cultivated chicken products to sale in the world's largest economy, a monumental achievement for the sector. At the same time, those companies and others continued to wrestle with the difficulties of scaling production beyond limited quantities, and sectors of the media took a more skeptical view of cultivated meat's market viability.

The cultivated meat industry was defined by these two realities in 2023. Growing public investments in cultivated meat research corresponded with declines in private fundraising as capital markets tightened. Regulatory approvals in the United States and progress toward approvals in several other countries occurred, while elsewhere, governments attempted to ban cultivated meat's production and sale (with challenges in a few U.S. states as well). Around the world, at least 10 new cultivated meat facilities opened, yet most companies continued to measure their production volumes in kilograms rather than tons.

Cultivated meat remains a nascent industry where individual developments and setbacks garner outsized reactions. Take any of the above examples alone, and cultivated meat may seem either world-changing or overly ambitious. Significant advancements must occur for companies in the space to deliver large quantities of cultivated meat at reasonable prices, but alternative proteins remain one of the most promising approaches to allow consumers to satisfy their growing appetite for meat while limiting the negative impacts of its production.

Consumer appetites for meat are certainly growing. The FAO expects meat consumption worldwide to rise by at least 50 percent by 2050 (from 2012 levels). Cultivated meat can help address the growing global demand for meat while improving environmental and public health outcomes. To do so, the category needs to continue to innovate and attract public investments in the face of technological challenges and a subdued private funding environment.

What does the future hold for the cultivated meat industry? The remainder of this section will explore the category's near- and long-term outlooks, along with expert insights and external forecasts.

2024 outlook

Regulatory approvals, increased public funding, and process scale-up characterized the cultivated meat sector in 2023, and those factors will continue to drive the direction of the industry in 2024.

One company in Singapore and two companies in the United States are currently approved to sell cultivated chicken products. Those approvals lay the groundwork for other countries worldwide, and regulatory advancements are expected in several regions in 2024. In early 2024, Israel became the third country in the world to advance approval of cultivated meat with the world's first cultivated beef product approval from **Aleph Farms**. The United Kingdom, Switzerland, and Australia and New Zealand are all currently reviewing cultivated meat approval applications, and some of those products will likely be approved within the year.

The products under review represent a diversity in production processes and end products. In a first, a cultivated product other than chicken will be available to customers in 2024, as will the first cultivated product made with serum-free growth media. Plus, more products entering the market means more companies generating revenue. While product volumes will remain limited enough to keep revenue totals relatively small, it will nevertheless mark a new stage for the sector.

The fact that only a small handful of companies will be generating revenues in 2024 means that fundraising will continue to be important in the cultivated meat industry. The vast majority of cultivated food companies remain in the pre-revenue stage of operations. As a result, the fundraising environment plays a significant role in the health of the category. Startups rely on fundraising to provide a financial runway during research and development, and for companies with products approved for sale, funding is key to crossing the "valley of death" when scaling from pilot to commercial production.

Some cultivated meat companies will access the financing they need to grow their businesses, but they'll do so in a less conducive environment than in years past. As a result, it will be increasingly important for governments around the world to step up to support the growing cultivated foods sector through investments in R&D, grants, loans and loan guarantees, and other forms of financing. On that front, the progress made in 2023 with governments recognizing cultivated meat as a climate, bioeconomy, and food security solution bodes well for the future of the sector. However, more work needs to be done to close the gap between investments in alternative proteins and other climate solutions, which have received many multiples more funding.

While only a few cultivated meat products will be available to customers in 2024, companies in the sector will continue to refine and scale their production processes. In the coming years, new industrial-scale facilities—including Believer Meats' 200,000-square-foot plant in North Carolina—are expected to open, significantly increasing the total production capacity of the cultivated meat industry. According to GFI's 2023 cultivated meat bioprocessing survey (to be published in 2024), global cultivated meat production volume could potentially reach 125,000 tons by the end of 2026 (see report for a discussion of the limitations of this projection). While this would only comprise a small portion of global meat production, it would represent sizable growth from today's volumes and would provide thousands of consumers around the world a chance to taste cultivated meat.

The cultivated foods sector will continue to progress in 2024. Additional products are poised to achieve regulatory approval, and production capacity will expand. While companies will be tasked with scaling their processes amid a subdued funding environment, more cultivated meat products will likely be sold in 2024 than any other year to date. To help make this progress a reality, governments, investors, and companies around the world need to firm up their commitments to cultivated foods by continuing to invest in research, product development, and infrastructure.

Long-term outlook

Scaling a sector from virtually nonexistent to commercial volumes is a monumental task. Tissue engineering, a sector with technologies that overlap with cultivated meat production, has been iterating and improving for over four decades and remains short of many of its long-term goals. The cultivated meat industry has a long path to price, taste, and convenience parity with conventional meat. Even once cultivated meat is more widely available, companies will need to continue to navigate regulatory challenges while communicating their products' value to consumers.

Meeting the challenge of producing affordable, accessible, and tasty cultivated meat will require continued innovation and funding from companies, governments, and investors. Advancements in growth media optimization, equipment, and feedstock sourcing are poised to both increase manufacturing capacity and lower operational costs. This will serve to make the entire industry more competitive within the broader food sector.

But progress is not linear, and is not guaranteed. The cultivated meat industry still faces hurdles on the path to robust, long-term growth. Companies must continue to refine their processes to achieve maximum efficiencies, and governments need to foster supportive funding and regulatory environments for cultivated foods. In the near term, companies will likely continue to face a tighter private capital funding environment than in previous

years. They'll also need to contend with global regulatory obstacles and limited consumer understanding of cultivated meat.

Considering these factors, plus the size of the $1 trillion global meat market, the opportunity for the cultivated meat sector remains immense. The category is still in its earliest stages, and there exists a sizable runway for expansion as products enter the market and companies innovate. In the coming years, more companies will have the opportunity to sell their products to consumers and, over time, to capture meat market share. Doing so will require investment, collaboration, and commitment. Given the challenges facing our planet and global food systems, progress is not only possible—it is necessary to meet international goals.

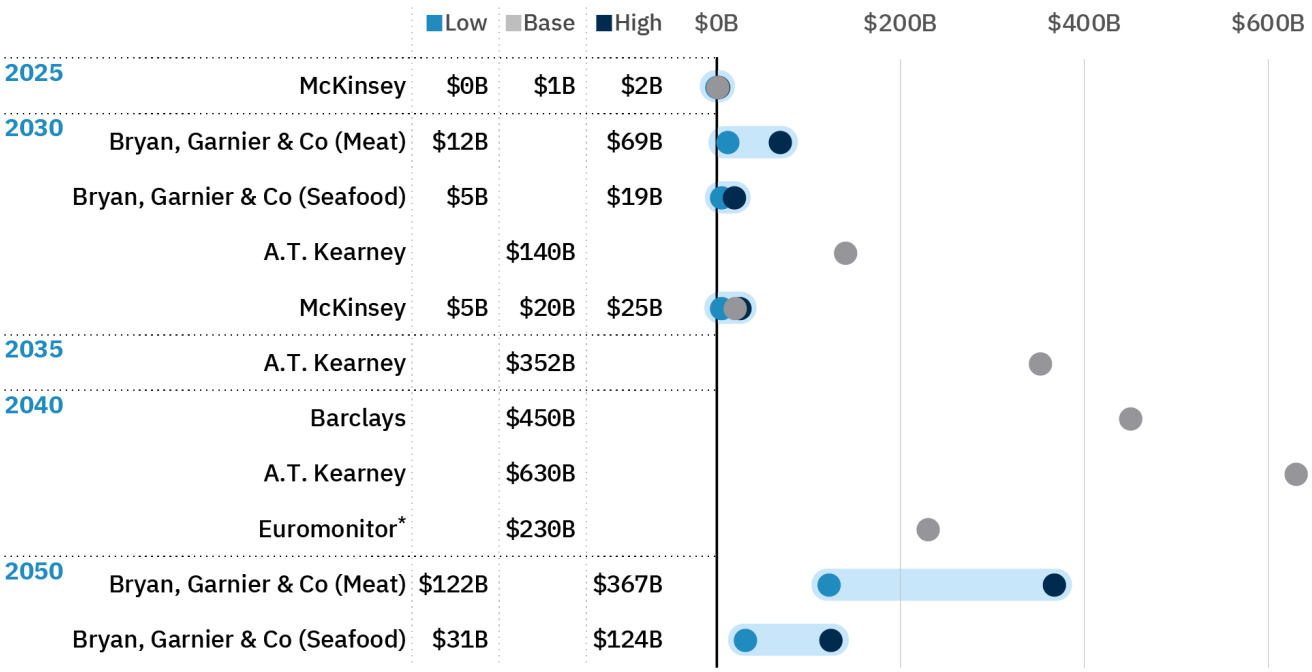
External projections

External forecasts of the alternative protein and cultivated food markets from consulting firms, think tanks, and research organizations vary widely in their estimates of the industry's future size, but they all project robust growth from today. Forecasts for 2030 range from estimates of $5 billion to $140 billion for the cultivated meat market, though some of these forecasts were published several years ago and no longer reflect probable outcomes for 2030. Any of these outcomes would represent a massive increase from 2023's market size, which is composed of a handful of cultivated product sales in two countries, though many cultivated meat companies are seeking near-term revenue from technology licensing in parallel with their continued drive toward making consumer products. Combined alternative protein (plant-based, fermentation, and cultivated) market forecasts for 2030 range from $58 billion to $570 billion. Such market growth would demand unprecedented investment and innovation in the sector.

Will the cultivated meat market grow to reach this size by 2030? Meeting even the low-end estimate requires notable advancements in production efficiency, costs, and capacity. Several countries would need to approve a large number of cultivated meat products, and the products would need to be affordable and accessible to consumers. Given the current environment, significant growth from today's market size is possible, but it necessitates levels of public and private investment many times higher than today's norms.

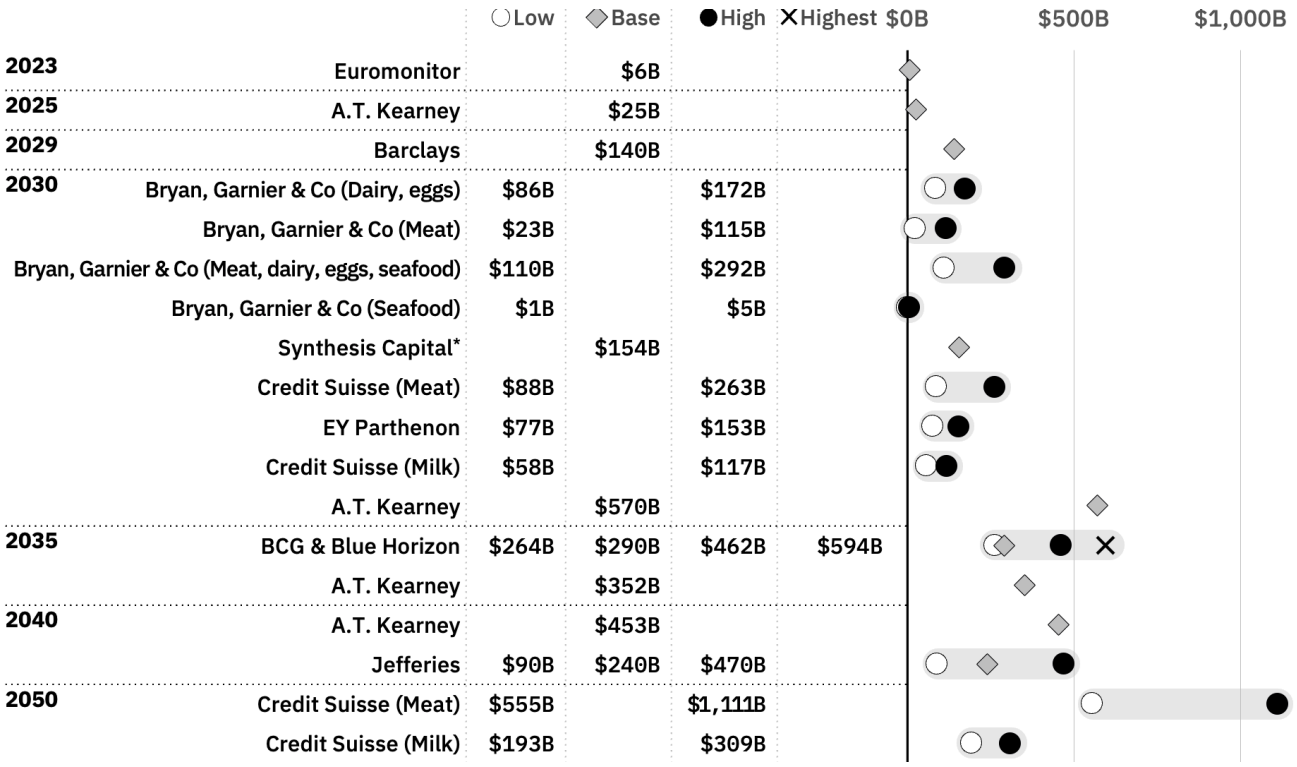
Vast increases in support for alternative proteins are justified by their potential climate, public health, and food security benefits. Cultivated meat companies need to innovate to scale production, bring costs down, and ensure a fair regulatory landscape. While the private funding environment, the health of individual alternative protein companies, and the media's sentiment regarding alternative proteins are constantly changing, the challenge before us is not. Animal agriculture alone, including the crops and pastures to feed those animals, accounts for between 11 and 20 percent of all emissions (FAO, Nature Food). If governments and investors around the world are serious about meeting key climate benchmarks, they must step up investment to position the sector for long-term success.

Figure 20: Forecasts for global cultivated industry market size



*Some forecasts projected the share of the total market rather than the industry size in dollars. For those forecasts, we estimated the dollar size of the cultivated meat sector using Barclays' forecast for the total 2040 meat market.
Source: A.T. Kearney, Barclays, Bryan, Garnier & Co, Euromonitor, McKinsey

Figure 21: Forecasts for global alternative protein industry market size



*Some forecasts projected the share of the total meat market rather than the industry in dollars. For those forecasts, we estimated the dollar size of the alternative protein sector using EY's forecast for the total 2030 meat market.
Source: A.T. Kearney, Barclays, BCG & Blue Horizon, Bryan, Garnier & Co, Credit Suisse, Euromonitor International Limited 2023 © All rights reserved., EY Parthenon, Jefferies, Synthesis Capital

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Conclusion

Without question, 2023 was a milestone year for cultivated meat. The United States joined Singapore as the second country to permit the commercial production and sale of cultivated meat. Government investment in cultivated meat research and development accelerated globally. And scores of impactful scientific breakthroughs brought cultivated meat closer to market than ever before.

Nevertheless, like other industries, cultivated meat faced economic headwinds in 2023 as the global economy continued to slow and private investments tailed off previous highs. Despite the sobering economic landscape, we remain optimistic about the future of cultivated meat as a promising agricultural innovation with far-reaching implications for planetary and public health, strong bioeconomies, and more resilient global security. In that spirit, we offer these reflections and calls to action for the year ahead:

A global protein transformation will require strong, system-wide participation.

Where do you see yourself?

By delivering delicious, affordable alternative protein products to mainstream consumers, companies can realize a significant market opportunity to satisfy a growing consumer interest in healthy, sustainable protein sources that meet their foundational needs on taste and price. The research community can lean in by encouraging more scientists, from varied disciplines and at different points in their careers, to jump into the alternative protein field. The world's policymakers can invest in critical R&D to advance alternative protein science, manufacturing incentives to help scale up, and policies that level the playing field to allow alternatives to compete on taste, price, and convenience. And philanthropy can advance the alternative protein ecosystem by unlocking early breakthroughs and greater investment from governments and the private sector. System-wide participation can address the industry's biggest technical challenges, inspire research, create growth opportunities, and ensure these sustainable foods can benefit everyone.

We always keep the long view in sight.

What steps can you take toward a long-term goal?

This industry is still under development, and yet we see the growing recognition that cultivated meat and other alternative proteins are a solution for reducing greenhouse gas emissions from food systems and feeding more people with fewer resources. Advances in cultivated meat technologies are escalating, and the policy and regulatory landscape is looking brighter as more governments and agencies look to alternative proteins to offer solutions to serious global issues like food safety and security and environmental degradation. Consumers want sustainable options, but they don't want to compromise on taste, price, or convenience. Navigating and building the path to scale and adoption will take years. Staying on this path while overcoming obstacles and headwinds will be critical to success.

Believe change is possible.

What inspires your vision?

At GFI, we bring determination and informed optimism to our work because we know a better food future is achievable. We see these same traits in those who pushed the field forward this year, many of them highlighted in this report. Across sectors and regions, there is a growing understanding of the importance of finding viable alternatives to industrial animal agriculture, and huge opportunities for companies who get involved in this space. Just as the world is changing how energy is produced, we need to change how meat is made. Alternative proteins can satisfy growing demand, reduce pressure on the planet, and create jobs. Alongside other advances and innovations, alternative proteins—including cultivated meat and seafood—can help write the next chapter for food and agriculture around the world.

To those who are in this work already, we hope GFI's 2023 State of the Industry Report: *Cultivated meat and seafood* provides a detailed look at this rapidly evolving sector. For those new to the field, welcome. Stay a while, grow with us, and change the world.

Expert predictions

Dr. Wonnop Visessanguan

Executive Director, National Center for Genetic Engineering and Biotechnology, National Science and Technology Development Agency, Ministry of Higher Education, Science, Research and Innovation Thailand

In the short term, the cultivated meat industry will focus on overcoming technical challenges, expanding market presence, and enhancing consumer acceptance. Research and development efforts will continue to drive innovation, making cultivated meat a more viable and accessible protein source.

In the long term, the cultivated meat industry is poised to play a significant role in global food production. Continued advancements in technology, increased efficiency, and broader consumer acceptance will likely position cultivated meat as a mainstream protein source, contributing to a more sustainable and resilient food system.

Jason Ng

Manufacturing Vice President, Cell AgriTech

To tackle the challenges of high production costs, strategic partnerships and risk-sharing mechanisms are likely to become more prevalent. We'll see collaborations forming between cultivated meat and seafood companies with bioreactor companies, media suppliers, and food producers, all working in tandem to bring these innovative products to market more efficiently.

Carlos Rodrigues

Research Associate, Institute for Bioengineering and Biosciences, Instituto Superior Técnico

The academic ecosystem will be essential to advance the field, providing open knowledge and creating a solid basic science foundation for the field as a whole. It will be essential to have strong cooperation between academia and industry so that research can be oriented towards overcoming the still substantial challenges that prevent cultivated meat from being available in everyone's home. Academia will also have the crucial role, already started in 2023, of creating new graduate and undergraduate programs to educate the future leaders of the field.

Jo Anne Shatkin, PhD

President, Vireo Advisors, LLC

In the next decade, we anticipate a significant increase in the authorization of cultured meat and seafood products globally, as more regions establish guidance and programs to review and approve these sustainable protein sources. As the development and acceptance of safety demonstration methods and publicly available data expands, it will contribute to a positive effect on consumer acceptance.

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Cover image is courtesy of BlueNalu. The image features BlueNalu's bluefin tuna toro nigiri, topped with wasabi.

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About GFI

The Good Food Institute is a nonprofit think tank working to make the global food system better for the planet, people, and animals. Alongside scientists, businesses, and policymakers, GFI's teams focus on making plant-based and cultivated meat delicious, affordable, and accessible. Powered by philanthropy, GFI is an international network of organizations advancing alternative proteins as an essential solution needed to meet the world's climate, global health, food security, and biodiversity goals. To learn more, please visit gfi.org.

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